7TH INTERNATIONAL MEETING
ON RETOUCHING OF CULTURAL HERITAGE,
RECH7

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FOREWORD

Ana Bailão, RECH Group Chair

Between 12th and 14th October 2023, the RECH Group organised the seventh international conference in Lisbon, in collaboration with the Faculty of Fine Arts of the University of Lisbon. Specialists from various fields of conservation gathered to discuss issues surrounding chromatic reintegration.

The event took place over three days, featuring thirty-one presentations, demonstrations and two workshops. Experts from Croatia, Spain, Portugal, Turkey, Austria, Poland, Israel, Canada, Monaco, Belgium, Italy, Taiwan and Brazil participated.

Interests and concerns regarding chromatic reintegration practices were shared, both from the perspective of decision-making and materials and execution techniques. A trend towards seeking more sustainable and less toxic approaches was observed throughout the event.

We express our gratitude to all speakers and participants of the conference, to the sponsors and to the entire team at the Faculty of Fine Arts who hosted us.

Special thanks to the Committee members for their support and contributions during the conference and to this publication.

This publication represents a truly collaborative effort that we hope will assist the conservation and restoration community in developing their chromatic reintegration work.

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ÍNDICE

COMMUNICATIONS

FINDING COHERENT SOLUTIONS FOR RESTORING POLITICAL AND AESTHETIC VALUES OF THE FRESCOED LUNETTES IN THE HERCULES GALLERY OF THE PRINCE'S PALACE OF MONACO

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Abstract

In 2015, Prince Albert II of Monaco launched a wall painting conservation and restoration project in the Prince's Palace, this included the restoration of thirteen lunettes in the Hercules Gallery. Preliminary studies on seven of the thirteen lunettes concluded that a substantial percentage of original, 16th- century frescoes lay underneath the visible layer. These fragments occurred in the upper sections whereas the lower sections consisted of later interventions (19th and 20th centuries). Maintaining aesthetically and historically incompatible painting styles, in various states of conservation, on the same lunette, posed a dilemma. The objective was to determine a restoration protocol that would reconstitute the political associations of power of the 16th-century iconography within the current context of a living and working palace. Debates on cultural values led to the application of removable panels which concealed the lower sections. Iconographical and anatomical studies led to them being painted in completion of the 16th-century fragments.

Keywords:

Wall paintings,

16th-century,

frescoes,

removable panels,

cultural values,

iconography

Introduction

The foundations of the Prince's Palace of Monaco, as a military fortress, date back to the end of the 12th century A.D. In the 13th century, the fortress was occupied by the Genoese-based, Grimaldi family. Today, the Palace remains under Grimaldi's rule, inhabited by His Serene Highness Prince Albert II.

Today's architecture owes much of its appearance to its 16th-century transformation from military fortress to Renaissance *palazzo*. A major feature is the *Cour d'Honneur* (Honorary Courtyard) - a 1300 square meters courtyard, framed by four majestic painted facades and bordered along its south-western perimeter by the *Galerie d'Hercule* (Hercules Gallery). The impressive Hercules Gallery, viewed from the Honorary Courtyard, can be considered as the hub of palace life, a venue for diplomatic meetings and international or local public events (**Fig. 1** and **2**). The Gallery is an integral feature of the guided tour of the state apartments, open to the public for several months of the year. The space plays an undeniable ceremonial role, echoed in the Renaissance iconography featured on the *lunettes*: Hercules, the hero of Antiquity, embodying connotations of courage and physical strength and through association acts as a metaphor through time; of the patron who commissioned the artwork and the entire sovereign rule of Monaco.

Wall paintings are depicted on a total of thirteen, semi-circular *lunettes*, situated between the vaulted ceilings and the walls of the Gallery. Each lunette depicts a scene from either the life cycle or the twelve labors of Hercules. The original wall paintings of the *lunettes*, painted in the fresco technique, presumably date from the 16th century

Fig. 1. Summer concerts with the Monte Carlo Philharmonic Orchestra (2023 ©Alesi/APM).

Fig. 2. Wedding of Prince Rainier III and Princess Grace Kelly (1956 ©APM).

and were commissioned under the reign of Lord Honorato I (1540-1581) and his regent, Stefano Grimaldi.

Between 1863 and 1866, under the patronage of Prince Charles III, the *lunettes* underwent an extensive restoration campaign. The most notable of these interventions was carried out by Jean-Baptiste Prudent Carbillet. Eleven, originally frescoed *lunettes* were filled and overpainted, whereas two *lunettes*, *The Birth and The Death of Hercules*, were added onto the portals of the main doors which lead to the entrance and exit of the Gallery. From the 20th century onwards, numerous restoration campaigns ensued, including an intervention in 1955 by Ten Kate and Bourgoin from the Ateliers Malesset in Paris. These interventions were focused on retouching and embellishing the deteriorated 19th-century overpainting; restoring the original 16th-century frescoes was not a priority.

Today, seven *lunettes* retain a substantial amount of original, presumed 16th-century frescoes situated mainly in

the upper sections. The lower sections of six of these seven *lunettes*, with no underlying fragments of original fresco, were filled and overpainted.

This paper attempts to outline the solutions which were adopted in the restoration of the general iconographic program of the Hercules fresco cycle. The major challenge was obtaining an overall, aesthetic coherence between the various pictorial interventions of the *lunettes* (16th, 19th and 20th centuries) whilst considering the past and current political context of the artwork and the associative cultural values.

Preliminary studies

Analyses

Historic photographs, obtained from the Prince's Palace of Monaco Archives, were essential starting points in terms of understanding the evolution of the wall paintings. An example can be seen below (**Fig. 3**) which depicts the first wet-plate collodion photograph of the Hercules Gallery. Dating from ca. 1856, this photo provides important information with regards to the state of conservation and the architectural transformations that occurred. The large window bays cutting into the lower half of the *lunettes* are discernable (**Fig. 3**); however, there is no further information as to whether these bays were a part of the original construction of the Gallery (second half of the 16th century) or date from a later transformation. This photo explains the absence of original decor today in the lower sections of the *lunettes*.

Fig. 3. Wet-plate collodion photograph of the Hercules gallery and the Honorary staircase before the renovation project under the patronage of Prince Charles III (ca. 1856 ©APM).

Preliminary investigations and analyses of all thirteen lunettes determined that the 19th-century pictorial layer was nonhomogeneous and incomplete. Few traces of pigments, presumably dating from this intervention, were still present on the 19th-century plaster. Post 16th-century pictorial interventions had fused and agglomerated and could no longer be analyzed in separate layers. Fillings and retouching dating to the 19th, 20th and 21st century were dominant on all thirteen *lunettes*, only identifiable through multispectral imagery (**Fig. 4** and **5**).

Fig. 4. Natural light photograph of the lunette depicting Hercules fighting the mares of Diomede (2017 ©Moufflet/APM).

Fig. 5. Composite UV false colors photograph with stratigraphic windows (2018 ©Moufflet/APM).

The imagery enabled conservators to determine the exact location where samples could be taken for pigment analyses using scanning electron microscopy (SEM) and energy dispersive X-ray (EDX) analysis. Once the pigments were identified, it was possible to classify certain pigments according to their dates of manufacture (Eastaugh, Walsh, Chaplin, & Siddall, 2013).

Furthermore, stratigraphic surveys confirmed the presence of fresco painting on seven of the thirteen lunettes. Original 16th-century pigments included: green earth, red hematite, yellow ochre, blue smalt, carbon black, and green malachite.

After analyses, it was estimated that between 40% to 75% of the presumed 16th-century, original material was present on seven of the thirteen lunettes. Two more lunettes contained approximately 10% of original fresco, situated along the lower and upper perimeters of the scenes.

Discussion

The Prince's Palace of Monaco is not entrusted to a governing, cultural body that determines conservation and restoration protocols. The team involved in the decision-making processes regarding the conservation and restoration of the *lunettes* consisted of the project manager, the senior conservator, the artistic coordinator, the art historian, and the scientific committee (Prof. Lauro Magnani, Mr. François Goven, Dr. Jean-Marc Vallet and Mr. Pierre Curie). This panel of decision-makers strived for what Staniforth calls 'negotiative conservation' (Staniforth, 2000). A collective consciousness towards decision-making that aims to be inclusive and non-elitist, whereby "conservation is done for the sake of the subjects: its users. The user of the object is any person for whom the object performs any function, be it tangible or intangible" (Munoz-Vinaz, 2012). The user, in this case, being first and foremost His Serene Highness Prince Albert II, family and honored guests, and secondly, the general public.

As indicated above, the 19th-century layer and subsequent overpainting were highly degraded. The underlying 16th-century fresco layer was deemed as satisfactory in terms of conservation status. A joint decision was made to remove the overpainting covering the 16th-century fragments on seven of the thirteen lunettes. Once the original fragments were visible, art historical research and the artistic and technical value of the fresco cycle became central themes whereby iconographic studies were initiated.

After removal and cleaning, large 19th and 20th-century, plaster fillings, along the lower half of five lunettes, were found to be co-existing with the 16th-century plaster. The decision was made to conserve these later fragments due to their historical value. A solution was needed in balancing historical and aesthetic values between the 16th-century frescoed fragments and the adjacent interventions. As Brajer states, "Aesthetic treatment, in fact is like an act of juggling- we are dealing with several issues at the same time: respect for material authenticity; improving comprehension; achieving potential oneness; ensuring removability; maintaining discernibility of the retouching." (Brajer, 2015).

Questions regarding removability or retractability, legibility, readability, cultural and environmental sustainability, objectivity vs. subjectivity, and the technical challenges involved, were debated during two scientific committee meetings in May 2019 and again in February 2020. The most tangible functions of the Hercules Gallery, political and aesthetical, were defining factors in choosing an intervention protocol.

The following proposals were put forward (**Fig. 6**):

- Cut-to-size, removable panels would be placed over the later interventions. These panels allow for an aesthetic completion of the original fresco;
- With regards to the seven lunettes displaying both original 16th-century and later interventions: concealment would only occur if a historically researched proposal was validated. Otherwise, the various interventions would co-exist on the same lunette.
- The remaining six lunettes which contained little or no 16th-century fragments would not be concealed. They were to be conserved and restored.
- Concealment using the removable panels was considered a viable solution due to their protective, removable, and identifiable characteristics.
- The panels would be painted in a *mimetic* style, based on historical and iconographical research, to restore the readability of the narrative and highlight the artistic value of the original frescoes.

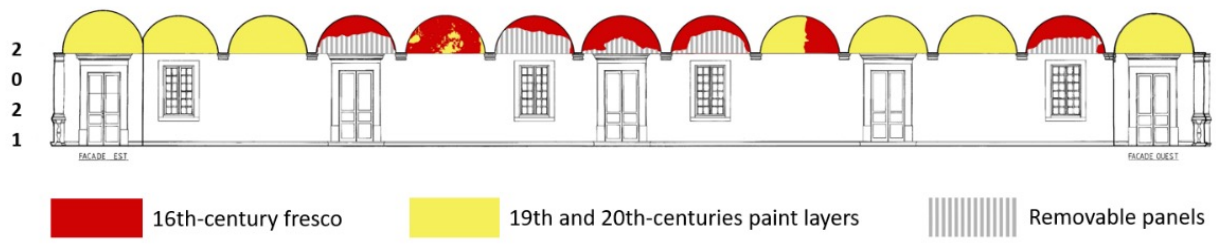

Fig. 6. Location of the original 16th-century fresco after paint removal. Location of the five removable panels (2021 ©Jaulin/PPM).

Method and results

Preparation

On each of the five *lunettes* concerned by the panel project, the large lacunae were photographed, vectorised (**Fig. 7**), and exported as a DraWinG (DWG) file in order to obtain a 1:1 scale plan of the intervention area that could be read by Computer Numerical Control (CNC) software (**Fig. 8**). All the models and research work were carried out on this true-to-scale template.

Fig. 7. Diagram of the vectorised lacuna on the uncovered lunette (2019 ©Voyer Gadin, Jaulin/PPM)

Fig. 8. DWG file of the lacuna (2019 ©Voyer Gadin/PPM)

Iconographic and morphological study

An art historical and iconographic study was commissioned to assist the painter-illustrator in his proposals for the reconstruction of the lacunae. Studio research was also carried out, based on:

- Detailed mappings of the in situ fresco, to-scale location of the lacunae (**Fig. 9**);
- Selected iconographic documents depicting related scenes and the Renaissance painting style (**Fig. 10** and **11**);
- Posing sessions with live models for anatomical understanding.

Fig. 9. Mapping of the existing fresco Hercules and the Hydra of Lerna (2019 ©Girard, Patard/PPM).

Fig. 10. and Fig 11. Iconographic research on the morphology of Hercules depicted in Mannerist works of art, specifically by 16th-century Genoese artists. (©Rijksmuseum)

Photographs were taken to document muscular tensions (**Fig. 12** and **13**). Graphic research included: the reconstruction of the morphology, physical postures and iconographic attributes. Backgrounds and landscapes were deliberately left undefined to avoid misinterpretations.

Several mock-ups were presented for the lower, incomplete sections of the lunettes. The validated versions were enlarged to real-scale representations for further discussion with the scientific committee.

Fig. 12. Studio photo shoot with live models (2020 ©Voyer Gadin/PPM).

Fig. 13. Illustration of a drawing session and graphic research in the studio (2020 ©Patard/PPM).

Materials: the panels

Replicas of the lacunae were laser-cut from a 'sandwich' panel (**Fig. 14**, **15**, and **16**) with a core in aluminum honeycomb (4 mm thick) bonded to two skins of aluminum (0.5 mm each). This material, used in the aeronautical industry, proved to meet many of the expectations in our specifications: it is light and thin but mechanically resistant, easy to cut and to drill for installation, durable and stable over time, and compatible with a wide range of paint formulas. Furthermore, the panel is recyclable as it is composed of 95% aluminum, which can be melted and reused multiple times [1].

1 The panels were obtained and prepared with the collaboration of CEL Components S.r.l-Via Bruno Buozzi, 25, 40057 Cadriano BO, Italy- https://www.celcomponents.com/

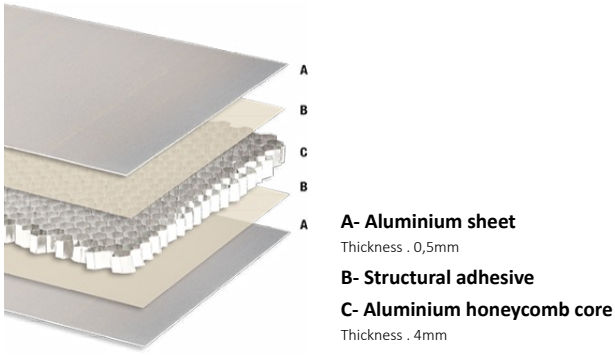

Fig. 14. Close-up and Fig. 15. detail of the constituent layers (2020 ©CEL Components)

Fig. 16. General appearance of the cut-to-size panel before priming and painting (2020 ©Voyer Gadin/PPM)

The panel was fixed into the filling which lined the border between the 16th and 19th-century interventions (**Fig. 17**).

Fig. 17. The filled gap defining the various interventions; the upper section of 16th-century fresco painting and the lower section of 19th and 20th-century filling and overpainting (2020 ©Voyer Gadin/PPM).

Screws and hammer-drive anchors were used which allowed for a 2 mm air gap which insured that the intervention was identifiable from below (**Fig. 18** and **19**).

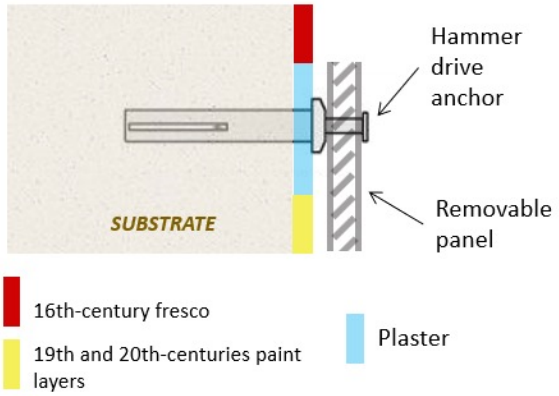

Fig. 18. Cross-section of the installation in the substrate (2023 ©Jaulin/PPM).

Fig. 19. General appearance of the panel on the original 16th-century fresco, seen from a low angle (2023 ©Vie/PPM).

The panel was then primed with an adapted metal paint. The painter-illustrator reproduced the validated mock-up using pigments bound with a transparent acrylic binder, suitable for use on metal. This technique guaranteed the brilliance of the pure colors and a transparency resembling the characteristics of the original fresco (**Fig. 20** and **21**).

The result was submitted one last time to the scientific committee for approval, and the final validation was made by His Serene Highness before the panel was finally varnished for UV protection.

Fig. 20. Work in progress: preparatory drawing executed on the panel (2020 ©Voyer Gadin/PPM).

Fig. 21. View of the completed work: co-visibility of the 16th-century restored fresco and the 2020 painted removable panel (2021 ©Voyer Gadin/PPM).

Conclusion

The conservation and restoration of more than 600 square meters of 16th-century frescoes in the Prince's Palace of Monaco has motivated innovative thinking in terms of the aesthetic harmonization of the wall paintings. Methodology concerning project conception, the decision-making process and the resources deployed for intervention were reviewed. The removable panels project of the lunettes in the Hercules Gallery is an excellent example whereby the political context of the work of art is a dominant and decisive factor in choosing a restoration protocol. This project demonstrates that decisions about intervention cannot be taken in isolation from the spatial context in which they exist and the function they fulfill, whether material or immaterial. As Brajer states, "[…] it is the local point of view on the object's function and impact on cultural history that dictates how wall paintings will be treated." (Brajer, 2015). The Prince's Palace of Monaco is first and foremost a working and living historical monument, a strategic location for diplomatic meetings and international cultural events. The Palace is central to Monegasque identity and history, and plays an essential role in highlighting Monaco's cultural heritage. The removable panel project of the Hercules fresco cycle is an important example of that cultural heritage striving to retain its relevance within its current context.

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WOODEN SCULPTURE AND RETOUCHING OF GILDING: SOURCES, CASE STUDIES AND LABORATORY PRACTICE FROM THE POINT OF VIEW OF CONSERVATION STUDENTS. THE CHALLENGE TOWARDS A HOPEFUL HANDBOOK?

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Abstract

This study explores the retouching of gilding on wooden sculptures from the perspective of conservation students at the School of Conservation and Restoration, Urbino University. As part of their 2021-2022 coursework, fourth-year students undertook an investigation into the methodological and practical aspects of gilding retouching. Their research encompassed a wide range of sources, including historical-artistic literature, case studies published by Italian restoration institutes such as the Opificio delle Pietre Dure in Florence and the Istituto Centrale del Restauro in Rome, as well as international conference proceedings.

Despite the structured and multidisciplinary nature of their academic background, students found that no comprehensive handbook exists to guide the study and practice of gilding retouching, particularly in relation to wooden sculpture. While other technical conservation matters, such as cleaning and structural restoration, benefit from established educational resources, gilding retouching is largely informed by individual experience and case studies. In Italy, this issue is further complicated by adherence to Cesare Brandi's influential restoration theory, which emphasises the visibility of interventions and the importance of recognisability in retouching. The students' contribution aims to lay the groundwork for a future handbook on gilding retouching, supplemented by an interactive and evolving online bibliography. This resource would address the need for a systematic educational tool, offering both methodological principles and practical applications in line with contemporary restoration ethics. Ultimately, this study seeks to aid in the standardisation of teaching methods for gilding retouching, promoting a balance between theory and practice and enhancing the quality of conservation education.

Keywords

Inpainting,

gilding,

wooden sculpture,

technical art history,

case studies,

methodology,

handbook,

conservation-restoration schools

Introduction

From the first year, the practical laboratory activities of the School of Conservation and Restoration at the University of Urbino include a focus on the study and practice of retouching. Initially, the training is carried out on models, before progressing to actual artworks, predominantly sourced from the museums and collections of the Marche region, which holds a significant heritage of painting and wood sculpture (Cuzzolin 2012).

To date, there is no specific manual dedicated to teaching the retouching of gilded surfaces on wooden sculptures or panel paintings. The theoretical and practical instruction on this subject is usually conveyed by professors, who rely on their personal experience. Consequently, this study aims to approach the subject of gilding retouching comprehensively and begins to systematise its teaching.

This research followed three key steps, corresponding to the teaching methodology at Urbino University. The first involved a theoretical study, building upon the work of figures such as Cesare Brandi, Umberto Baldini, Ornella Casazza, and international scholars like Paul Philippot, whose studies focus on sculpture (Philippot 1970). The second step involved collecting various practical solutions for retouching gilding, published in both national and international literature. Finally, different retouching methods were implemented, always chosen with consideration of the aesthetic purpose and the intended use of the artefact.

In the case of wooden sculptures, these recommendations could be enhanced by considering the intended use of the work, whether it is now a museum piece or continues to serve as a devotional object in sacred spaces, as a focus of popular piety through processions or religious performances (Tonini 2021; Kopania 2010; Kopania 2017).

Integration of Gilding in Italy. Historical Overview

The issue of integrating gaps in gilding has been a crucial matter in Italy since the 16th century. However, the subsequent debate primarily focused on paintings on canvas and wood, with little attention given to wooden sculptures. Due to their devotional nature, these sculptures were frequently altered and repainted, distorting their original carving, colouring, and gilding. As a result, they were often considered artefacts of little artistic value, despite the work of renowned artists such as Giovanni Pisano, Brunelleschi, Donatello, and Michelangelo.

Until the late 19th century, the restoration of gilded surfaces on sculptures was typically handled through 're-gilding,' a craft practice that prioritised restoring functionality over preserving the original materials (Ciatti 2009). Such interventions varied in scope, from small repairs to the complete replacement of the original gilding. This approach was largely justified by the need to present the sculptures in a visually appealing manner for religious veneration.

Before the advent of modern restoration principles, another common method for integrating gilded surfaces involved using 'mosaic gold' or 'porporin.' This compound, made from tin sulphide (SnS_2), was popular from the 13th century onwards, particularly in the 14th century. However, due to its chemical composition, porporin oxidised quickly, losing its lustre and developing an unpleasant greenish hue (Matteini and Moles 1989).

By the late 19th century, restoration methods began to shift, influenced by Cesare Brandi's reflections at the Istituto Centrale del Restauro, which he founded with Giulio Carlo Argan. Brandi's ideas on distinguishing between the restorer's work and the original had a significant impact on approaches to gilded surfaces, with the principles later developed further by Umberto Baldini at the Opificio delle Pietre Dure in Florence.

Although Brandi does not explicitly refer to works made

of carved, gilded, and polychrome wood, the principles he outlines for the aesthetic presentation phase of paintings can be applied to three-dimensional works as well. Starting from the premise that any pictorial integration must be strictly confined to the lacuna, the theoretical approach advocates the use of distinct painting techniques and materials to enhance the visibility and appreciation of the original. Brandi firmly rejects the so-called '*mimetic*' or 'cosmetic' retouching, which he views as both a historical falsification and an aesthetic offence (Severini, 2017). According to Brandi's theory, integration must always be easily recognisable without the need for special aids. Disregarding these constraints would undermine the entire system, which balances various considerations (Bonsanti, 1998). The objective is to ensure that retouching minimises the restorer's subjectivity, thus enabling a fuller appreciation and validation of the artwork's intrinsic qualities.

In Italy today, retouching differentiation is achieved primarily through two methods: "*tratteggio*" (or "rigatino"), used predominantly by the Roman school at the Istituto Centrale del Restauro (Mora, Philippot, 1984), and the "selezione" and "abstraction" techniques developed at the Opificio delle Pietre Dure in Florence, particularly after the 1966 flood (Casazza, 1981). Additionally, the "puntinato" (or dotted) technique, dating back to the 19th century and pioneered by Pietro Palmaroli, is employed. This method, particularly suited to three-dimensional surfaces, involves reproducing the effect of gold through the juxtaposition of three colours—yellow, red, and green—applied as dots rather than brushstrokes (Rinaldi, 2004; Mercier, 2017).

While Brandi's text largely prioritises two-dimensional paintings, the restoration of polychrome wooden sculptures has been more extensively addressed outside Italy, particularly in Germany and the Netherlands, where interest in these works is greater. Key publications include those by Johannes Taubert (Tauberg, 1978), Agnes Ballestrem (Ballestrem, 1970), and Paul Philippot (Philippot, 1970). Philippot's contribution is especially significant, establishing key theoretical foundations for the restoration of wooden sculptures by stressing that the three-dimensionality of these artefacts plays an active role in their aesthetic presentation. The wooden substrate, far from being a mere support, contributes both structurally and aesthetically to a balanced interpretation of the work, particularly due to its chromatic harmony with the gilding.

In Italy, the painterly intervention on wooden sculptures was addressed during the 1970s at the Opificio delle Pietre Dure (Baldini, 1981). Following Brandi's theoretical framework, the Florentine school maintains that retouching should only concern the 'whole' parts, excluding abrasions. Respect for the work's original characteristics and the signs of ageing is paramount.

For didactics of retouching

As part of the didactic activities at the School of Conservation and Restoration of the University of Urbino, the first phase of study focuses on restoration theory and its practical application. Brandi's and Baldini's theories underline the necessity of a strong theoretical foundation, which becomes manifest in the retouching phase through techniques such as "*tratteggio*" or "selezione cromatica". Paul Philippot, a student of Brandi who specialised in the restoration of wooden sculptures, emphasised the importance of "listening" to each sculpture and appreciating its individuality, with its three-dimensional qualities contributing actively to its aesthetic presentation. Philippot posits that the work's three-dimensionality can serve to highlight any colour deficiencies without needing additional colour. Similarly, the exposed wood can compensate for gaps in the gilding due to the tonal harmony between the two materials.

Agnes Ballestrem, a pioneer in this field since the 1950s, asserts that the restorer holds a significant responsibility in preserving both the tangible and intangible values (artistic, religious, spiritual, social, etc.) of these artefacts (Ballestrem, 1970).

The contemporary perspectives on restoration ethics, particularly those proposed by Salvador Muñoz Viñas, increasingly recognise that restoration decisions should be agreed upon by all stakeholders rather than being imposed unilaterally (Muñoz Viñas, 2004).

The second phase of the teaching process involves analysing case studies published in books, conference proceedings, or specialised journals. When studying different retouching techniques for gilded surfaces on wooden sculptures, the first step is to differentiate the methods: either the "*tratteggio*" used by the Istituto Centrale del

Restauro in Rome, or the "selezione effetto oro" used by the Opificio delle Pietre Dure in Florence.

Following various experiments in the 1990s, the Istituto Centrale del Restauro concluded that "*tratteggio*" was not suitable for three-dimensional objects. Therefore, restorers have sought to standardise the technique for three-dimensional works by applying "puntinato" instead (Pannuzi, Valenzuela, 2017).

The third phase of the course involves applying these techniques, first on models, and later on actual works. This phase takes place during the final-year workshop, where students combine their theoretical knowledge with practical skills. The fifth-year students (2021-2022) have conducted personal studies on gilding integration and produced reports detailing their acquired knowledge, which form the basis of this article. After analysing the degradation and execution techniques for wooden sculptures, it becomes clear that integrating gold presents distinct challenges compared to polychrome surfaces. The metal's ability to reflect and scatter light results in surfaces characterised by great luminosity, whose appearance varies depending on the light source. Additionally, the chromatic effect of a metal leaf depends on the colour of the underlying bole, which plays a significant role in determining the final hue due to its transparency.

During the integration stage, it is crucial to respect the characteristics of the metal leaf and preserve the lustre of the gilded surfaces. Over time, this has led to the development of different operational solutions, described in the following case studies that the students deemed particularly significant in their research.

Case Studies - Istituto Centrale del Restauro

Restorer Marisol Valenzuela of the Istituto Centrale del Restauro in Rome reports in a recent article that gold leaf losses at the ICR were previously treated as follows:

- Initially, with bare watercolours, which could not match the lustre of the gold;
- Shell gold was then introduced, applied to a watercolour base using a hatching technique, although the result remained unsatisfactory as the vertical lines appeared heavy;
- Next, gold leaf was applied using the gouache technique, followed by watercolour hatching, yielding more acceptable results;
- Finally, an even layer of gold and mica paint was applied, followed by "*tratteggio*" or stippling with watercolours, which produced effective and economical results.

The "puntinato" technique was used, for instance, in the integration of gilding for the Nativity by Saturnino Gatti, damaged during the 2009 L'Aquila earthquake. In this case, mica gold watercolour was applied evenly over the damaged areas, and the "puntinato" method was then used to achieve a perfect colour match and recognisability (Huber, 2015; Pannuti, Valenzuela, 2017; Bailão, Šustić, 2013).

Case Studies - Opificio delle Pietre Dure

In the 1970s, the Opificio delle Pietre Dure developed the "selezione effetto oro" technique, based on Umberto Baldini's theory and Ornella Casazza's practical applications. This technique was designed for repairing gilding defects (but not abrasions) on wooden sculptures and other three-dimensional works.

One of the earliest experiments involved filling gaps in the gilding of a sculpture of a Holy Bishop, housed at the Bargello Museum in Florence (Rasario, 1995). The intervention was performed on a plaster and glue stucco, impregnated with light shellac and lightly patinated with varnish lake colours, applied in overlapping strokes of yellow, red, and green (Casazza, 1981).

After assessing the issue of differing reflectivity between the original gilding and the integration, the Opificio employed a method that involved polishing the stucco surface before retouching. However, in difficult lighting conditions, the integration appeared darker. To address this, subsequent methods were developed to imitate the gold's colour and reflectivity more effectively.

Some examples include: a) Small brushstrokes of shell gold inserted into chromatic traces, as used in the Redeemer by Mariotto di Nardo (Ciatti, Senesi, 1991); b) Application of a homogeneous shell gold layer, burnished in relation to the original, as in the case of the Maestà of the Master of Città di Castello (Cianfanelli, 1989; Ciatti, 2009); c) Overlaying gold leaf using the gouache technique, then applying the "selezione effetto oro" without yellow, as seen in the triptych by Ambrogio Lorenzetti at Badia a

Rofeno, Siena (Ciatti, Gismeroli, 2012), and the frame of the San Zeno Altarpiece in Verona by Andrea Mantegna (Ciatti, Marini, 2009).

Case study – University of Urbino Carlo Bo

The theoretical and technical skills acquired by students at the School of Conservation and Restoration, University of Urbino, were put into practice in their final thesis projects.

The Wooden frame of the altar of San Michele Arcangelo della Chiesa di San Francesco in Ostra (AN)

The intervention carried out by student Linda Soldani, as part of her thesis, illustrates the restoration of the monumental wooden frame of the altar of San Michele Arcangelo in the Church of San Francesco di Ostra (**Fig. 1**). The project considers the complexity of the altarpiece, which is intricately articulated in its decorative elements and closely linked to the four canvas paintings housed within it. The structure, featuring rich carvings with symmetrical elements and overhanging volutes, is adorned with areas of gold leaf contrasted against brown lacquered parts and light faux-marble backgrounds.

In the intricate organisation of the frame, the primary disruptions are found in the decorative gold-leaf sections, which emphasise the sense of loss that abruptly interrupts the sinuous flow of the carving. To restore a sense of symmetry fundamental to this structure, it was decided to reconstruct the missing parts as closely as possible to the existing elements. This choice was further justified by the continued devotional function of the altar for the local community.

The gilded surfaces of the frame were generally in good condition, except for some missing elements. For these areas, it was decided to carry out a *mimetic* retouching treatment using mica pigments.

Mica pigments consist of metal oxides deposited on the natural mineral mica, making them highly stable since mica does not oxidise. These materials reflect and scatter light, closely mimicking the properties of metals, though their presence is detectable when light strikes the surface. By adjusting the oxides and their proportions in the mixtures, different shades can be achieved to closely match the original metal leaf. Mixing mica pigments with a consistent geometric structure is essential for maintaining optical stability at different light angles (Bailão, Šustić, 2013).

The pigments used for the integration of the Ostra frame included Kremer® products in variants such as royal gold, sun pearl, light gold, and pearl gold. Their ease of application and transparency allowed for precise calibration of the colour tone through layering glazes. In the case of the Ostra frame, the areas to be integrated were grouted following several tests and then covered with multiple layers of bole. These layers were polished to create a smooth, compact surface to facilitate reflection, as mica pigments cannot be polished (**Fig. 2**).

The mica pigments were prepared with gum Arabic in three different shades: a mixture of light gold pearl and sun pearl (1:1), with the addition of some Sungold.

The application was designed to be sufficiently translucent, allowing the warm tone of the bole, characteristic of gold leaf, to shine through. Finally, the surface was coated with a Retoucher Surfin varnish (Lefranc & Burgeois) in 50% White Spirit, applied with a brush to enhance the contrast between light and dark areas (**Fig. 3**).

Fig. 1. Wooden frame of the altar of San Michele Arcangelo, Church of San Francesco in Ostra. General view before the restoration treatment (picture of University of Urbino Carlo Bo).

Fig. 2. Detail of a reconstructed leaf with polished bolo layer and the first passage of mica pigment (picture of University of Urbino Carlo Bo).

Fig. 3. Detail of a reconstructed leaf with polished bolo layer and the first passage of mica pigment (picture of University of Urbino Carlo Bo).

Madonna del Rosario from the St. John the Evangelist parish church of Stacciola (PU)

The intervention undertaken by student Rachele Greco, as part of her thesis, illustrates the restoration of the Madonna of the Rosary sculpture, located in the niche above the high altar of the parish church of Stacciola, dedicated to St. John the Evangelist. The aesthetic presentation of the sculpture was approached in a "purely reconstructive" manner to re-establish a balance between its conservation history, iconographic significance, and devotional function (**Fig. 4**).

The retouching of the metal leaf

The state of conservation of any material, and consequently the choice of the most appropriate intervention for its preservation, is determined by two "physical states": the nature of the material and the execution technique with which it was used in the context of the work. In this case, the two factors are the metallic nature of the materials - usually the characteristic shiny appearance - and the method used to apply them. Thanks to for the transparency of the leaf, which is due to its extremely thin thickness, the metallic leaf can take on warmer or colder shades depending on the underlying bole. The aesthetic presentation of materials of this type must therefore consider the problems involved, i.e. the difficulty of reproducing not only the specific hue of the metal but also above all its shine due to its ability to reflect light.

The aesthetic representation of the golden areas of the Madonna of the Rosary was developed in two different phases.

Gaps in the gilding

As with pictorial layers, the widespread abrasions and gaps, which had exposed the underlying preparation, were covered with paint. However, the wear on the leaves was left untouched so that the original bole remained visible. For the grouted areas, a different intervention was implemented. In consultation with the site management, it was decided to reproduce the gilding to preserve the material's characteristic metallic sheen. A bole layer, matching the original in colour, was applied to the gilded areas and polished with an agate stone.

After this initial phase, the gilded surface was restored with a camouflage retouching technique using mica colours to distinguish the intervention areas based on the type of material. Completely redoing the gilding was avoided due to concerns of recognisability and cost. In the case of the Madonna of the Rosary, mica pigments were used in gum Arabic, applied in a way that revealed the restoration bole, thus creating a surface akin to worn gold leaf (**Fig. 5**).

The reproduction of the decorations of the Virgin Mary's mantle

The most delicate phase of the retouching involved reattaching the flowers and stars that originally adorned the Virgin Mary's mantle. The decision to proceed with this intervention was supported by the devotional context of the artefact. The legitimacy of the intervention was justified by analysing both the individual decorations and the overall decorative scheme. Historically, the flowers and stars had been mechanically removed across most of the mantle, except on the right-hand side, where they re-

mained largely intact but were affected by some abrasion of the gold leaf. Observation of the silhouettes revealed that the two motifs were repeated consistently, adapted to the folds of the mantle.

The evaluation of the entire decorative scheme indicated a row of stars alternating with a row of flowers. Following these observations, the new proposal was deemed plausible for both the individual motifs and their placement. Where the decorations were not recognisable from the gilding fragments and engraved profiles, comparisons were made with other decorations from the same series.

First, the intact motifs affected by leaf abrasion were treated by veiling the surface with mica pigments to restore the chromatic integrity of the stars and flowers. A precise method for restoring each decoration was then established to avoid misinterpretation. A monosiliconised Melinex® film was applied to a star and flower on the right-hand side, and the shapes were traced onto the film with an indelible marker. These templates were then used as guides for reconstructing the missing motifs. The Melinex sheet allowed for gradual adaptation to the folds of the mantle, while a metal point was used to engrave the missing features. The profiles of the stars and flowers were then chromatically reconstructed using mica pigments (**Fig. 6**).

To distinguish the original gilding from the restored areas, the latter were highlighted with overlapping brown dots, applied with colour pigments, to interrupt the mica coating and align it with the worn leaf. This process produced a "vibrant" retouching effect (**Fig. 7**-**8**).

Fig. 4. General view of the Madonna before retouching treatment with all the lacunas filled (picture of the University of Urbino Carlo Bo).

Fig. 5. Detail of the golden decoration retouching of the mantle with Mica pigment bound with Arabic gum. (picture of the University of Urbino Carlo Bo).

Fig. 6. Detail of the steps for the reconstruction of the missing golden decoration (picture of University of Urbino Carlo Bo).

Fig. 7. Detail of the reconstructed part of the golden decoration after the retouching with overlapping brown dots for recognizability (picture of University of Urbino Carlo Bo).

Fig. 8. General view after retouching treatment (picture of the University of Urbino Carlo Bo).

Conclusions

The examples presented illustrate how contemporary methods for retouching gilding share a common methodological foundation: recognisability. This approach is exemplified in techniques such as “selezione effetto oro” and “puntinato,” which make retouching visible without concealing it, in line with Cesare Brandi’s theoretical framework. While the foundational theories of Brandi and Baldini remain solid, the approach to gilding restoration has evolved over time to better align with perceptual needs. This evolution reflects a gradual adaptation, aiming to bridge the gap between theory and practice and to harmonise the appearance of restored and original sections.

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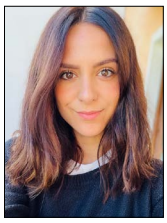

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THE RESTORATION OF ST. ANTHONY ALTARPIECE FROM SERMONETA: IDENTIFICATION OF SUITABLE INFILLING MATERIALS FOR LOSSES TREATMENT IN AN OIL PAINTING ON SLATE

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Abstract

The altarpiece of St. Anthony, painted by Girolamo and Tullio Siciolante in 1572, is an oil on slate, made of thin slabs (1.5-2 cm) of considerable dimensions (3,5x1,8 m), preserved in the Sermoneta Castel (Italy), in an environment characterized by significant thermo-hygrometric fluctuations. The pictorial layer shows several gaps and abrasions that largely compromise the original aesthetic features of the painting. Due to the particular technique of the artwork, the oil paint film is very thin, nevertheless, the gaps in the paint film create many areas of unevenness that alter the original smoothness of the surface. Usually, when dealing with oil on slate, the chromatic reintegration of lacunas is carried out by applying the colour directly on the stone support, but this approach does not consider the correct interpretation of the artwork's stratigraphy and does not eliminate the unevenness caused by the gaps, which alter the correct visual perception and aesthetic features of the image. This work aims is to identify suitable materials for the filling and reintegration of oil paintings on slate, considering the lack of specific studies on this topic, and testing different new infilling materials in comparison with traditional ones.

Our experimental results allow us to find a suitable infilling material to be applied in very thin layers without cracking, with a good adhesive power to the slate surface and good properties as a retouching substrate.

Keywords:

Oil on slate,

Infilling Material,

Retouching

Introduction

This study aimed to identify suitable materials for gaps filling of an oil painting on slate. The research starts from the restoration of the altarpiece of Saint Anthony, an oil on a slate painting by Girolamo and Tullio Siciolante from Sermoneta. The altarpiece had considerable dimensions (3,5 x 1,8 m) and was made up of different slates, of which only five remain to this day. The painting represents the Virgin and Child with angels and, below them, Saint Anthony the Abbot and Saint Francis. In the missing plates, Saint Anthony from Padua and Saint Paul the Hermit were depicted, but only a single fragment remains, showing two feet, a portion of drapery and the end of a staff (Pennacchi, 2014).

Fig. 1. Saint Anthony altarpiece, before restoration.

The altarpiece is now preserved in the Sermoneta Castle (Italy), but it was originally located in the church of Sant'Antonio Abate in Cisterna di Latina from where, between 1864 and 1880, the plates have been removed.

The pictorial layers, whose average thickness is about 200 microns, are very thin and they consist of a paint film on a ground layer of ochre and white lead. The pictorial layers are compromised by several gaps of both the paint film and the ground layer, which create slight unevenness of the surface so that a filling was required to regive the original smoothness to the surface. However, when reintegrating gaps in pictorial films on slate, some critical issues related to the specific technique of slate painting must be addressed:

- very thin pictorial and ground layers that make difficult the filling procedure and the selection of suitable materials
- minimal porosity of the slate substrate and its low absorbency, which makes it problematic to ensure adequate adhesion of the filling material to the surface.

Probably due to these reasons, a bibliographic survey revealed that the most common gap treatment of oil on slate consists of the application of the colour directly on the stone without any filling. This procedure has some relevant drawbacks from a perceptive standpoint, because it implies maintaining the gap at a different level than that of the painted image, not re-establishing the original smoothness of the painted surface. It also has some significant implications from a technical point of view: it doesn't allow to realize a reintegration with watercolours and *tratteggio* technique, as usual in the Italian tradition, because of the transparency of watercolours, particularly evident on a black surface, and their scarce spread ability on a smooth and low absorbent surface. In addition, from a theoretical point of view, this reintegration method generates some methodological errors in the interpretation of the original painting's stratigraphy. According to Brandi's theory, indeed, the chromatic and figurative reintegration of the lacuna cannot be executed at the same level of the support, but must be at the same level of the paint layer.

As the literature review did not reveal any specific study for the identification of a suitable material for filling on a slate, it was deemed necessary to develop a comparative study that took into consideration various materials, to identify a suitable filling material on which to perform the

pictorial reintegration with *tratteggio*, to ensure that the integration could be clearly distinguished from the original, and watercolour technique, to ensure its reversibility.

Experimental

Materials

The experimental testing consists of investigating different mixtures selected according to workability and aesthetic parameters, comparing them with the traditional filling used for easel paintings made of animal glue and gypsum (Bologna chalk).

The materials tested during the study had to meet the following requirements:

- minimal application thicknesses while still ensuring adequate coverage of the black slate substrate
- good internal cohesion and good adhesion to slate
- adequate absorption capacity of watercolour retouching
- good workability in the fluid phase and after drying to give the desired texture
- stability to thermo-hygrometric changes
- low bio receptivity
- reversibility in solvents that are not harmful to the original paint film

The study started with a preliminary phase of empirical evaluation of 52 mixtures aimed at identifying materials for experimental tests.

Different categories of binders, two types of aggregates, and some products used as additives were compared.

The additives used, especially acrylic products, had the dual purpose of increasing the cohesive and adhesive properties of the filler on a smooth and compact stone substrate such as slate. The components shown in Table 1 were mixed to test different possible combinations:

Table 1. Binder-aggregate-additive combinations tested in the preliminary phase of the experiment.

BINDERS	AGGREGATES	ADDITIVES
PREMIXED PRODUCTS		
Red Devil One Time [1]		
Aguaplast [2]		Microacril CV 40
Polyfilla [3]		
ANIMAL GLUES		
Lapin glue		Microacril CV 40
Sturgeon glue		E 411
		Primal B 60
CELLULOSE ETHERS		
		Microacril CV 40
Tylose MH 300 P [4]	Gypsum (Bologna chalk)	E 411
Klucel G [5]	Calcium Carbonate	Primal® B 60
		Aquazol® 500
		Plextol B 500
POLYSACCHARIDES		
Funori		
SYNTHETICS		
Aquazol 500 [6]		
Regalrez 1094 [7]		Microacril CV 40
Regalrez 1126		Titanium oxide
Laropal A 81 [8]		

In each mixture, the components were proportioned to obtain an easily workable mixture suitable for both trowel and brush application.

In the preliminary phase, the 52 mixtures were empirically evaluated according to the following requirements:

- workability of the mixture in the fluid phase and after drying
- spread ability in minimum thickness and adequate coverage
- cohesive capacity

During the preliminary testing, it was observed that gypsum, when added to synthetic resins, (i.e. Laropal

1 Ready-to-use filler, made up of vinyl acetate and acrylic polymers and hollow glass microspheres.
2 Ready-to-use water-based filler, based on acrylic copolymers and hollow glass microspheres.
3 White powdered filler composed of hemihydrated gypsum and cellulose to be mixed in a 2:1 ratio with water.
4 Non-ionic polymer derived from cellulose (methylhydroxyethylcellulose) which appears as a fine white powder soluble in cold water.
5 Hydroxypropyl cellulose is soluble in water below 38°C and in various polar solvents.
6 Water-soluble Poly (2-ethyl-2oxazoline) polymer free of additives or other compounds. Highly stable to ageing.
7 Low molecular weight aliphatic resin.
8 Urea aldehyde resin is used as a final varnish for paintings and as a binder for pigments.

and Regalrez) exhibited an evident brown colour, both during the mixing phase and once dried (**Fig. 2**), making it unsuitable for reintegration purposes. In light of this behavior, it was decided not to select it as an aggregate. Calcium carbonate was, therefore, chosen because it demonstrated good compatibility with all the binders tested.

Fig. 2. Brown colour of mixtures containing gypsum and synthetic resins, compared with the same mixtures containing calcium carbonate.

According to the results of the preliminary phase, 10 mixtures were selected to undergo the experimental phase, and these are shown in Table 2:

Table 2. Mixtures selected to undergo the experimental phase.

Binders name (binder : water ratio)	Aggregates	Binder-to-aggregate proportions	Additives	Mixtures-to-additive proportions	Abbreviation
Polyfilla 2:1	CaCO³	-	-	-	PF_1
Polyfilla 2:1		-	Microacril CV 40	1,5:1	PF_2
Lapin glue 7:1		1:2	-	-	LG_$CaCO_3$_1
Lapin glue 7:1		1:2	Microacril CV 40	5:1	LG_$CaCO_3$_2
Lapin glue 7:1		1:2	E411 20% in H_2O	1,5:1	LG_$CaCO_3$_3
Tylose MH 300 P 5%		1:1,5	Microacril CV 40	5:1	Ty_$CaCO_3$_1
Tylose MH 300 P 5% + Plextol B 500 (80:20)		2:3	-	-	Ty_$CaCO_3$_2
Sturgeon glue 7:1		1:1	-	-	SG_$CaCO_3$
Laropal A 81 50% in ethyl alcohol		2:3	Titanium oxide	100:2	Lar_$CaCO_3$
Lapin glue 7:1	Gypsum (Bologna chalk)	1:2,8		-	LG_Gy

Methods

The 10 selected mixtures underwent several tests to analyze the following properties, as shown in Table 3, some of them before and after artificial ageing:

Table 3. Experimental setting properties investigated and types of tests.

EXPERIMENTAL SETTING		ARTIFICIAL AGEING
Property to be investigated	Type of test	
Stability to thermo-higrometric stress	pH measurement Digital microscope observations	Before and After
Optical and colorimetric stability	Colorimetric measurement	Before and After
Adhesion to the slate substrate	Peeling test	Before and After
Bioreceptivity	Biological contamination	Before
Watercolour absorption capacity	Observations of the diffusion of drops of watercolour onto the surface	Before

Appropriate specimens were set up on polished slate slabs (**Fig. 3**) on which the 10 selected mixtures were applied with a uniform thickness of 250 microns[1].

Before spreading the filler onto the slate, the surface of the slate was primed with a solution of 5% Regalrez® 1094 in white spirit, to simulate the procedure of applying a thin varnish layer on the artwork as protection before filling, thus testing whether the interposed varnish layer would interfere with the adhesive power of the filler.

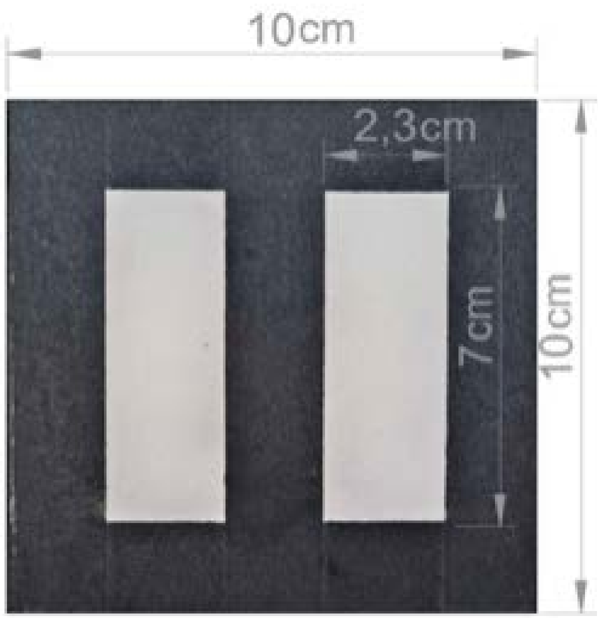

Fig. 3. Sample of fillers on a slate slab.

For each mixture, three different samples were prepared and then tested.

Artificial ageing was conducted in a climatic chamber[2] by setting cold-humid and hot-dry cycles according to the following parameters[3]:

1 The thickness was obtained by applying scotch tape strips on the slate, to obtain a mould of proper thickness.

2 Climates CH 250 climatic chamber produced by ARGOLab.

3 The ageing parameters and cycles were set according to the microclimatic parameters registered in the exhibition room in Sermoneta Castle during one-year microclimatic survey.

Table 4. Parameters of artificial

Typology		Tempera-ture	Relative Humidity	Dura-tion	Transition Interval Between Cycles	Ageing Period
CYCLE 1	Cold wet	10°C	95%	11 hours	1 hour	49 days
CYCLE 2	Dry hot	50°C	40%	11 hours		

Results and discussion

Digital microscope observations

The surface of each sample was observed with a digital microscope during 7-week artificial ageing, to detect any changes that occurred, due to thermoigrometric stress, and their rate of appearance. Degradation morphology was analyzed by digital microscope observations in raking light at 50x.

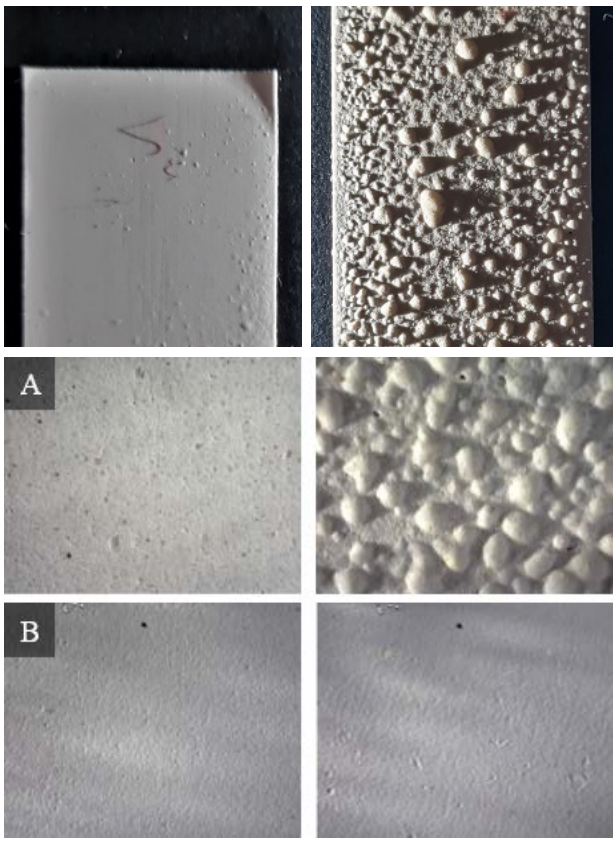

Fig. 5. A) Before and after artificial ageing, animal glues, 50x. B) Before and after artificial ageing, Tylose + calcium carbonate + Microacril CV 40, 50x.

During artificial ageing, from the first days, mixtures with animal glues showed significant morphological alteration, consisting of globular swellings of the filling layer (**Fig. 4**). This particular alteration was caused by the formation of drops of water derived from condensation phenomena on the slate surface.

Conversely, the samples based on Polyfilla, Tylose and Laropal A 81 did not undergo morphological alteration.

pH measurement

The surface pH of each sample was measured[4] before and after artificial ageing, to evaluate fillers and binders' stability to thermoigrometric stress. As a result of ageing, the animal glues showed an increase in pH values, while other binders showed a decrease in values, as shown in **Fig. 6**. However, pH values within the range of values considered acceptable were always recorded.

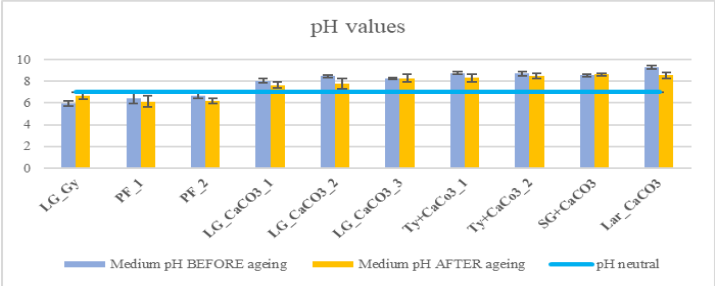

Fig. 6. Surface pH values of fillings before and after artificial ageing.

Colorimetric measurements

Colorimetric measurements[5] were conducted before and after ageing to evaluate the colour changes of the fillers. The colorimetric variations detected are also indicative of the chemical and physical alterations that occurred in each specimen. The chromatic change of the surface, ΔE, was obtained by comparing the average *Lab* values for each kind of specimen before and after ageing (Tab. 5).

Table 5. Colorimetric coordinate variations.

MIXTURES	Δ L* (D65) (average values)	ΔE (average values)
Lapin glue + gypsum	-3,68	4,82
Polyfilla	0,55	1,17
Polyfilla + Microacril CV 40	-0,18	0,70
Lapin glue + $CaCO_3$	-1,73	1,86
Lapin glue + $CaCO_3$ + Microacril CV 40	-2,38	2,55
Lapin glue + $CaCO_3$ + E 411 20% in H_2O	-0,17	1,62
Tylose MH P 300 5% + + $CaCO_3$ + Microacril CV 40	0,35	0,37
Tylose MH P 300 5% + + $CaCO_3$ + Plextol B 500 (80:20)	-2,36	2,36
Sturgeon glue + $CaCO_3$	-5,07	5,08
Laropal® A 81 + $CaCO_3$ + Oxid titaniun	1,46	1,75

4 The instrument used is a benchtop pH meter, the XS 8 Instruments with an articulated probe from LabProcess, with an integrated thermometer.

5 The instrument used is the Minolta® CM700d portable spectrophotometer. The measurement parameters are as follows: SCE (Specular Component Excluded), Lab Color Space, measurement spot 3 mm, standard illuminant D65, observation angle 8°, auto average 3.

Animal glues showed the most pronounced colour modification, with ΔE greater than 3[6] and with loss of brightness; the mixtures based on lapin glue + $CaCO_3$ + Microacril and Tylose + Plextol+ CaCO3 showed ΔE close to the threshold limit with values of 2.55 and 2.36, while the best outcomes were recorded on the series of fillers based on Polyfilla + Microacril and Tylose + Microacril.

Peeling test:

Evaluation of the cohesion and adhesiveness of the fillers to the slate substrate, before and after artificial ageing, was conducted by Scotch Tape Test[7].

The Scotch Tape Test quantify the amount of material removed by the peeling action of an adhesive tape on a surface, by weighting the tape before and after the procedure. The procedure was repeated three times on the same area of each of the five specimens prepared for each mixture. **Fig. 8** displays the average of five measurements for each mixture.

The series of samples with animal glues maintained good adhesiveness, although they showed swelling and surface morphological changes after thermohygrometric aging. The same behaviour was observed for cellulose derivatives and the series with Laropal, which exhibited minimal changes in adhesiveness. The worst outcomes were recorded for Polyfilla, with complete detachment of the filler from the substrate (**Fig. 7**).

Fig. 7. Peeling test, filler detachment, an example of a specimen with Polyfilla only.

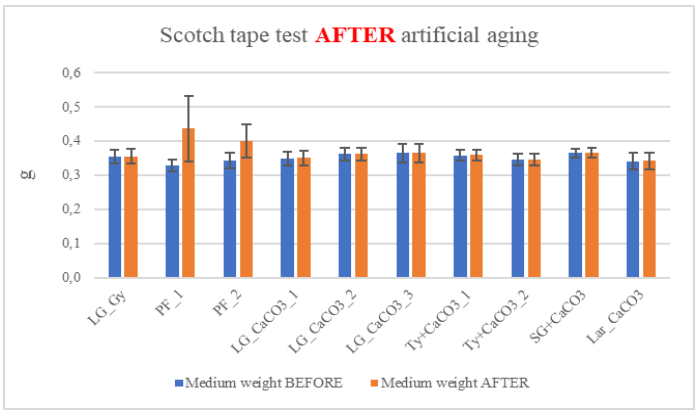

Fig. 8. Changes in Scotch Tape Weight After Aging with Standard Deviation.

Watercolour absorption test:

Watercolour absorption test was conducted on unaged samples. The test was carried out by preparing a solution of watercolour[8] diluted in water at a known concentration (1 gram of colour in 3 grams of water); using a graduated pipette, a drop of the solution was applied to the surface of each of the 10 different kinds of fillers. After about 5 minutes, the diameter size of the circular stain produced by the migration of water and colour through the filler layer was documented and measured.

The two samples containing Polyfilla showed the most evident diffusion of water, so that a wide circular stain formed around the watercolour, showing the unsuitability of this material for watercolour retouching, if used in this thickness (**Fig. 9**). All the other series, instead, retained colour optimally.

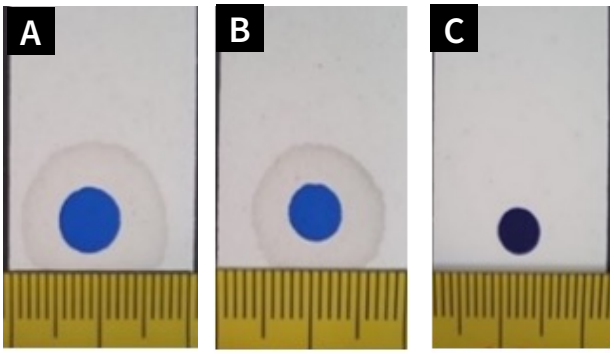

Fig. 9. Watercolour absorption test: A) Polyfilla, B) Polyfilla + Microacril, C) lapin glue + CaCO3.

6 ΔE=3 is considered the minimum chromatic variation detectable by the human eye.

7 "Method B" described in ASTM D3359 – 09 Standard Test Methods for Measuring Adhesion by Tape Test has been used.

8 Winsor and Newton watercolour tubes.

Resistance to biological contamination:

The fillers' bioreceptivity was investigated by visual evaluation of the resistance of each filler to biological contamination. This test was particularly necessary, considering that the painting's conservation site is characterized by thermoigrometric parameters sometimes close to dew temperatures.

The samples made in triplicate with the selected mixtures were contaminated with an aqueous solution containing a suspension of spores of 5 different strains of fungi isolated from wall paintings or generally present in airborne biological particulate (*Cladosporium cladosporioides, Aspergillus japonicus Fusarium sp., Alternaria sp., Penicillium sp.*). The samples were contaminated by spraying the spore suspension and then placed inside containers with water to create a humid environment. The containers were covered and sealed with cling film to prevent water evaporation and maintain constant humidity. The samples were then placed in a thermostat at a stable temperature of 27°C for 25 days. Fungal development was assessed weekly by visual and stereomicroscope observation of the sample surface and documented photographically.

The samples made with lapin glue showed rapid growth of fungal contaminants with the appearance of dark spots produced by the development of Cladosporium already during the first week. The colonization was particularly intense in the case of the samples made with lapin glue and E411 (**Fig. 10-A**), probably due to the surfactants and water-retaining agents contained within the acrylic product, useful for stabilizing the formulation but usable as an additional nutritional source by microorganisms.

The mixtures prepared with the binders Tylose + Microacril and Laropal A 81 (**Fig. 10-B**), however, showed the best performance, being resistant to colonization.

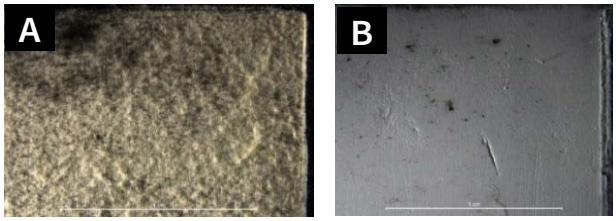

Fig. 10. After biological contamination: A) Lapin glue + $CaCO_3$ + E411; B) Laropal A 81 + CaCO3.

Data interpretation

The results obtained from analytical tests performed during the present study (Tab. 6) made it possible to select the most suitable filler according to the requirements sought.

Tests have shown that mixtures with animal glues are not durable and stable enough to be used on a slate substrate in a non-controlled environment. In fact, they proved to be the most vulnerable to the artificial ageing cycle with the formation of substantial swelling, morphological alteration and colour variation. They have also been shown to be the most bio receptive.

Specimens made with Polyfilla did not maintain adequate adhesion to the substrate after artificial ageing, as made evident by the results of the peeling test. In addition, this material did not show good watercolour absorption capacity.

The mixtures prepared with Tylose MH 300 P and Laropal A 81 binders gave the best results in the tests performed: good stability under thermohygrometric stress, adequate colour absorption capacity and resistance to biological contamination. In particular, among the formulations containing Tylose, the one consisting of a mixture of Tylose MH300P, calcium carbonate and Microacril CV40, gave the best performance in colorimetric stability test.

Although also Laropal A81 + calcium carbonate + Titanium oxide mixture gave good results, the one made up of Tylose MH300P + calcium carbonate + Microacril CV40 was preferred, because of its better workability (in the fluid phase and after drying), a necessary requirement to achieve the desired texture during the grouting procedure.

The selected filler was then applied to some sample areas of the painting to observe the filler directly on the original painting, before applying the tested grout extensively (**Fig.11**). The monitoring is still ongoing to observe the filler behaviour over time directly on the original painting.

Table 6. Evaluation table of the 10 fillers according to experimental results (O= positive; X= negative).

	Thermo-hi-grometric stability	Variation pH	Colorimetric stability	Bioreceptivity	Adhe-sion	Absorption capacity of watercolour	Workability
Lapin glue + gypsum	X	O	X	X	O	O	O
Polyfilla	X	O	O	O	X	X	O
Polyfilla + Microacril	X	O	O	X	X	X	O
Lapin glue + $CaCO_3$	X	O	O	X	O	O	O
Lapin glue + $CaCO_3$+ Microacril	X	O	X	X	O	O	O
Lapin glue + $CaCO_3$ + E411	X	O	O	X	O	O	O
Tylose + $CaCO_3$+ Microacril	O	O	O	O	O	O	O
Tylose + $CaCO_3$+ Plextol B500	O	O	X	O	O	O	O
Sturgeon glue+ $CaCO_3$	X	O	X	X	O	O	O
Laropal + $CaCO_3$+ Titanium oxide	O	O	O	O	O	O	X

Fig. 11. St. Anthony altarpiece's detail: A) before the infilling procedure; B) after the application of the filler; C) after the reintegration using watercolour *tratteggio* technique.

Conclusions

In conclusion, this research makes an important contribution to the solutions to some problems concerning the reintegration of gaps in the paint film of oil paintings on slate. The identification of a material suitable for filling gaps of minimum thickness, but sufficiently opaque and adhesive to smooth and compact surfaces, made it possible to overcome the technical obstacles that prevented the execution of a recognizable reintegration using watercolour *tratteggio* technique and respecting the stratigraphy of the painting, also when restoring an oil on slate.

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SOUND REINTEGRATION: AUDIO PROCESSING TO LIVE THE EXPERIENCE OF PRIMITIVE RECORDINGS

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Abstract

This paper approach a similar concept to chromatic reintegration in art conservation, describing the development and use of an online tool to allow sound reintegration of any digitized audio to make it sound like a primitive recording. Instead of visually reconstructing missing or damaged sections of an artwork, the main goal is to filter and process the audio files to emulate recordings made with different audio recording, thus reproducing devices, such as a phonograph, a gramophone, and a wire magnetophone. In addition, the sound reception with an old Galena radio (the first radio receivers), a bakelite telephone or a morse code radiotelegraph is emulated, bringing the intangible and technological cultural heritage closer to new generations through this experience.

This application, developed by the Museum of Telecommunications History Vicente Miralles Segarra of the Polytechnic University of Valencia, is currently accessible online at https://museotelecomvlc.webs.upv.es/demostradores-tecnologicos/.

Keywords:

sound reintegration,

audio recording,

digital audio processing,

intangible cultural heritage,

technological cultural heritage,

museum experience

Introduction

The Museum of Telecommunications Vicente Miralles Segarra of Universitat Politècnica de València is a small university museum. The museum is located in the School of Telecommunications Engineering of the university, and it is devoted to technological heritage, since it preserves all kind of artifacts related to telecommunications.

The objects of telecommunications are a clear example of technological and intangible heritage, which share some common characteristics. These objects are destinated for social and cultural usage, since distance communication has been a human need for a long time, and it conforms a set of trends in the social and cultural life of a community. They are appreciated beyond their functionality, as their aesthetic value or their historic value. Likewise, they present a diversity of materials, which made their conservation a challenging task. Moreover, they are considered complex objects and sometimes ephemeral, furthermore, sometimes they are very fragile, and their regular use would damage them. Furthermore, these objects are linked to human emotional experiences, people remember speaking to their relatives with a dial phone, watching TV, listening to an old radio transistor, or the first mobile phone they have used. Last but not least, these objects act as support for intangible heritage, likewise wax cylinders or celluloid films that contain recorded sound or images (Rion, 2010).

The objects of technological heritage have a particular feature that made them different from other artifacts, it is their functionality. These objects cannot be read without their function, it is critical for understanding them, but when an object is exhibited in a museum, this function is usually lost. Furthermore, sometimes, the object is very fragile and operating it may damage it or sometimes it needs to be restored, i.e. substituting broken, malfunctioning or missing parts by new ones. This is a delicate process from the point of view of restoration, since not always the parts are available (especially in the case of electronic components) and they must be substituted by modern ones. Eventually, the restoration process can result in an anachronic reintegration of parts, which jeopardizes the historical integrity of the artifact. In other cases, small museums do not have specialists in the specific technology of each artefact, making it impossible for them to provide adequate restoration. (Ullate Estanyol, 2015).

In the Museum of Telecommunications, we faced these same problems with many of our artifacts. But we understood that with the audiovisual objects the issue could even be more problematic. Audiovisual artifacts (such as videocameras, TV receptors, radio receptors, gramophones, tape recorders, etc.) are used to be objects of common use, very linked to personal experiences and with a strong emotional load. The specific way a music fragment sounded on a gramophone could give a bunch of memories to a whole generation of people (Giménez & Cibrián, 2015). So that, recovering those feelings and preserving them for future generations was the object of this work. Therefore, the work was focused on the development and use of an online tool that allows the sound reintegration of any digitized audio to make it sound like a primitive recording.

The reintegration of old audio recordings through digital processing, to minimize noise, the effects of the degradation of the support or restore lost parts is a common technique among professionals in the audiovisual world and has been widely studied.

However, professionals in scientific, technological or ethnographic heritage museums face additional problems. When one takes a historical tour at audio recording techniques, equipment and media, it is difficult to understand what those old recordings were like. Some museums have few primitive recordings, in other cases they do have many, but these remain on their physical supports because the equipment to reproduce them is not available due to their wear out, and, even in the cases in which both the supports and the equipment are available, their

fragility discourages reproducing them continuously (Indiana University, 2021).

There are libraries with primitive audio recordings, but they have both catalogue and technological limitations. (National Film and Sound Archive of Australia, 2016). So, it is not an easy task for a museum to offer the experience of listening to an old audio recording for its visitors, even less to create new recordings with primitive techniques to compare, study or simply understand what the audio recordings sounded like.

Since it was difficult to make this audio recordings available in the physical world, the natural path is to provide the experience in the virtual world (AMETIC, 2018).

Experimental

The objective of the sound reintegration project is to develop an online tool that allows sound reintegration of any digitized audio to make it sound like a primitive recording. To achieve this aim, the audio files are filtered and processed to emulate recordings made with different audio recording technology or received through ancient audio receivers. The tool is available in the Museum of Telecommunications web and the users can interact with them uploading the desired audio and getting the processed output. The end result of the work it to bring the intangible and technological cultural heritage closer to new generations through this experience.

Materials

The devices which are emulated can be divided into playing devices (i.e. devices to play recorded audios on a physical support) and sound reception devices (i.e. devices used to receive an audio signal).

- Playing devices:
  - Phonograph
  - Gramophone
  - Wire magnetophone.
- Sound reception devices:
  - Old Galena radio (the first radio receivers)
  - Bakelite telephone
  - Morse code radiotelegraph

Concerning the sound effects applied to the digital audios, it has to be said that, although each device has different sound characteristics, the effects applied have a common base (changing certain parameters for each case). Below are the main effects used in the algorithms (Cases Molés, 2015):

- **Header:** when each of the devices was operated to receive and/or reproduce audio, these devices presented a series of characteristic sounds produced by the movement of the clockwise wind, the gears, the winding of the tape, the ringing bell or the vacuum tube tuning sound. These sounds have been taken from original fragments and are introduced at the beginning of the corresponding audio.
- **Stereo-mono conversion:** most digital recordings today consist of 2 channels (stereo), but this has not always been the case. At the beginning of the analogue audio recording and reproduction (late 19th century) only one channel (mono) was used. It was not until 1930 that stereo recording and playback was patented. Therefore, to achieve a realistic sound effect through our algorithms we have to do a stereo to mono conversion of the audio digital input. Thus, we average the two digital channels (stereo) to obtain a single channel (mono).
- **Digital filtering:** in current recording and playback equipment we can have a very large recording and playback bandwidth (they can reach a bandwidth greater than 20 kHz). On old analogue equipment (like the ones we are dealing with) this was not possible. In them, the bandwidth limitation was given by the recording method, but also due to the reproduction media that were used (normally magnetic together with horns). Each of the chosen devices has a frequency response characteristic. Therefore, recordings from the different devices were analyzed to obtain its frequency response and be able to design digital filters that achieve a suitable response for the output audio from the algorithm.
- **Amplitude distortion:** distortion is one of the typical effects introduced by analogue recordings. In our case, we have used a distortion in amplitude that makes the reproduction more similar to what would be obtained with the museum devices. To obtain the said distortion, a mathematical formula is applied

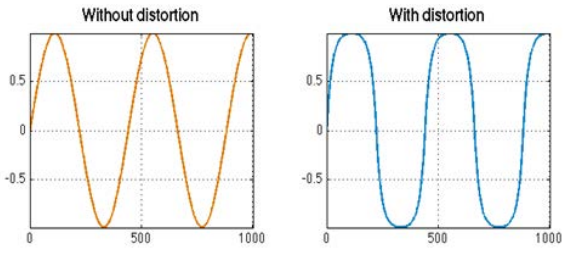


Fig 1. Effect of amplitude distortion on a 100 Hz sinus signal.

that causes the input amplitude values to have values closer together, thus having a lower richness of amplitudes in the distorted output. **Fig. 1** shows the amplitude distortion applied to a sinus signal.

- **Wow and Flutter:** the cyclical variations in the playback speed of physical media cause the wow and flutter effects in analogue devices. This phenomenon causes a frequency modulation, which causes, in wow, a slight variation in the sampling frequency with which the audio is reproduced. As for the flutter effect, this is caused by frequency deviations higher than those of wow, reaching the order of 100 Hz – 500 Hz, as a consequence of faster playback speed variations (Zölzer, 2011).
- **Noise:** to obtain the characteristic noise of each device, the Additive White Gaussian Noise (AWGN) is filtered predictively to obtain a spectral distribution very similar to that of the audio that you want to emulate. Thus, if we have a fragment of noise from an old device, we can use it to develop the filtering that will be applied to the input audio, thereby obtaining an output audio with a noise spectral distribution very similar to that of the original fragment. With this tool we can simulate the characteristic noises of each one of the devices. Likewise, subsampling has been carried out with a rate of 44100 Hz for the processing of the audio tracks, so that the quality is more similar to that of an original playback/reception.

Methods

Playing devices:

Phonograph (**Fig. 2**). The first phonograph prototype was stated by Thomas Alva Edison in 1877. From the first moment, it constituted a true technological revolution, given that it was the first device capable of recording and reproducing the human voice. It consists of a receiver, a recorder and a player. The receiver is nothing more than a conical horn at the apex of which there is a metal membrane. The sound waves entered through the horn, which concentrated them on the membrane, which serves as a diaphragm, and is attached to the center through a needle. The movements perceived by the membrane were transmitted to the needle, which recorded the sound pressure detected on the surface of a cylinder that was initially made of paper, but over time evolved towards wax and, later, celluloid.

For sound reproduction the system worked the opposite. A previously engraved cylinder was introduced into the system and the needle was made to follow these grooves. In this way, the oscillations were transmitted to the diaphragm membrane in the form of vibrations, and then converted into sound waves and amplified by the horn.

Fig 2. **Phonograph and wax cylinders. ©Museo Telecom UPV**

Characteristic effects:

1. Header. The header applied to the digital audio corresponds to the sound made by the wind of the clockwise mechanism.
2. Stereo-mono conversión.
3. Flutter. Since the speed of rotation of the cylinder on the stylus of the phonograph is not perfectly constant, causing a small frequency modulation that gives rise to flutter. In the algorithms, 100 Hz has been established as the repetition frequency for this effect. This effect causes a certain randomness and a slight metallization of the sound.
4. Amplitude distortion. The aforementioned amplitude distortion is applied to try to reduce the number of amplitudes (the richness of amplitudes in the interval). The compression parameter used varies randomly at each instant of time, its maximum value being 30.

Bandpass filtering (**Fig. 3**). The limitation in the main bandwidth of the phonograph is given by the recording medium, but also by the response of the speakers that were used together with the phonograph. In this way, the response used to be good in the range of 400 to 2000 Hz. Therefore, we have applied the filter whose frequency response we can see in **Fig. 4** to the input aud

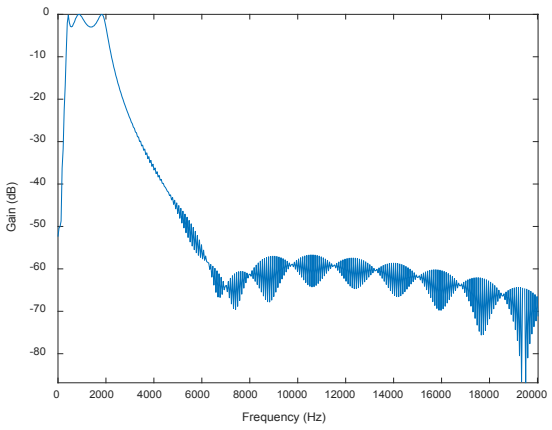


Fig 3. Frequency response of the band pass filtering for phonograph.

5. Periodic noise. The mechanism that the phonograph has to rotate the cylinder (thus causing the stylus to move across its surface) is made up of gears and ribbons. This mechanism produces a periodic noise that is very difficult to simulate using digital signal processing procedures, which is why it was determined that the best solution was to extract a complete period of the said noise from one of the recordings available and repeat it periodically throughout the entire reproduction, multiplying by a random amplitude for each period.

Gramophone. The differential characteristic of this new instrument was its ability to record and reproduce sound on a flat disc, which distinguished it from other previous systems such as, for example, the phonograph, which used a cylinder as a physical medium. The gramophone reproduced sound with higher quality, although it had the serious disadvantage that users could not make their own recordings with music or voices, as was the case with the phonograph cylinders.

The gramophone mainly consists of a turntable, a movable arm that holds the reading stylus at the end, and an amplifier (**Fig. 4**). The disc on which the sound is recorded is made of Bakelite which, unfortunately, caused it to break easily. The turntable is a flat, circular support on which the disc rests and which rotates at a constant speed.

Regarding the disc recording system, it is an analogue procedure according to which sound waves are transformed into mechanical vibrations that are transmitted to a plectrum, causing spiral-shaped grooves to be drawn on the surface of a metal disc or waxy. These discs have to be subsequently treated by chemical means. Thousands of copies could be made with a single original mold. During playback, the stylus arm is dropped onto the record and runs along the grooves, producing mechanical vibrations that are transmitted to a diaphragm located in the playback head of the arm. In the playback head, the vibrations are finally transformed into sound, emitted and amplified through a speaker.

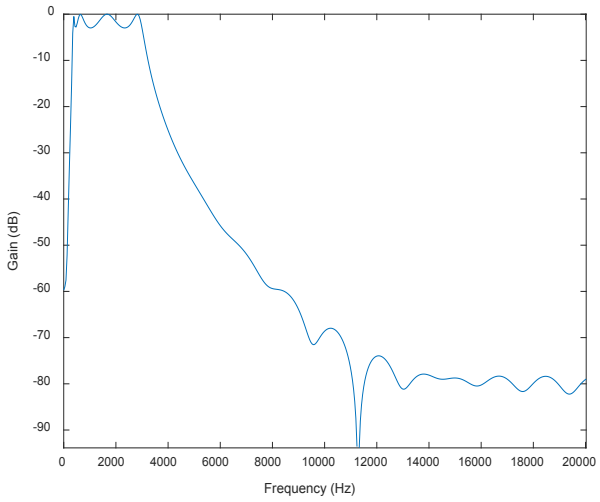
Fig 4. Gramophone with shellac disc. ©Museo Telecom UPV

Characteristic effects:

1. Header The header applied to the digital audio corresponds to the sound made by the wind of the clockwise mechanism.
2. Stereo-mono conversión.
3. Wow. This effect usually occurs because the needle is not completely centered in the groove of the record and therefore the speed with which the needle passes through the groove is not constant within a single revolution. As gramophones usually had a rotation speed of 33 rpm, to make the effect more realistic we have made the repetition period of the wow coincide with said speed. Thus, we will have a repetition frequency of 0.55 Hz.
4. Amplitude distorsion. In this case, we have used amplitude distortion to reduce the dynamic range of the input audio, seeking that the relationship between the peak power and the average power of the processed audio is not greater than a factor of 25.
5. Band pass filtering. The bandwidth of the gramophone goes from 350 Hz to 2900 Hz. Thus, we have applied the filter whose frequency response we can

see in **Fig. 5.(a)** to the input audio.

6. Noise. To simulate the noise introduced by the gramophone we analyzed the noise of the real device and obtained the filter response in **Fig. 5.(b)**. This filter applied to AWGN noise provides a noise with the same spectral distribution as the original. To obtain the most realistic noise possible, it was decided to fragment the noise into 100 ms frames by applying a random amplitude to each of these frames.



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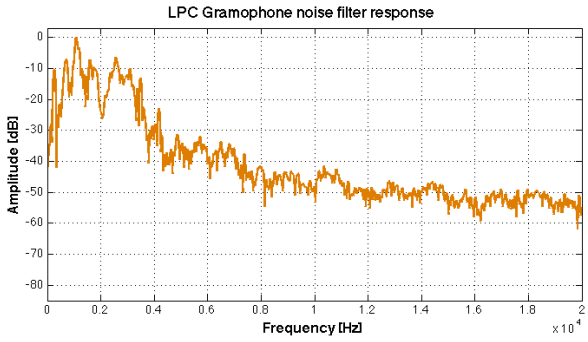


(b)

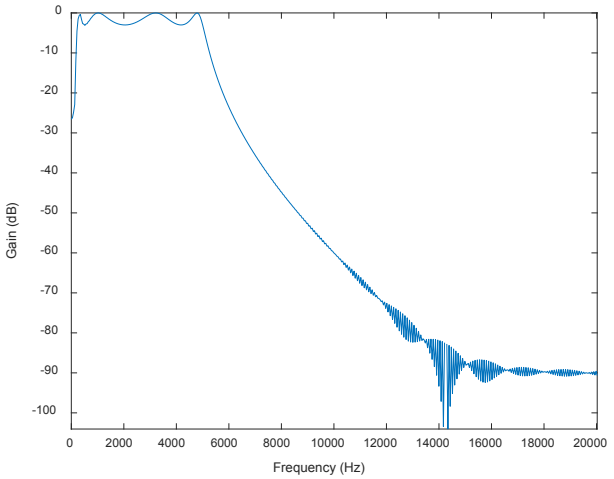
Fig 5. (a)Frequency response of band pass filtering for gramophone. (b) Noise filter response for gramophone.

Wire magnetophone. The wire magnetophone was the first magnetic sound recording device to be commercialized (**Fig. 6**). The operation of the device is based on a metal wire that is magnetized through an electric magnetophone with a circular head. The acoustic wave is transformed by a microphone into an electrical signal, this signal is amplified and its variation induces a magnetic field that, crossing a gap in the vacuum in the magnetized material, creates patterns that are recorded through the orientation of the magnetic dipoles. For playback, the magnetism stored in the wire is converted into electrical current, which powers a speaker.

Fig 6. Miniaturized wire magnetophone. ©Museo Telecom UPV

Characteristic effects:

1. Heather. The header applied to the digital audio corresponds to the sound made by the tab that fixes the wire to the coil.
2. Stereo-mono conversion
3. Flutter. Since the rotation speed of the wire tape recorder motor is not constant, producing small speed variations, we have to consider the Flutter effect for the simulation of this device. In this case, a repetition rate of 80 Hz has been selected.
4. Amplitude distortion. Magnetic recording on a wire had many limitations. One of them is precision in the amplitude of the recorded audio, which is why we use the amplitude distortion effect with a limitation of 8.
5. Band-pass filtering. The response of the wire tape recorder has been approximated with a band-pass filter whose lower cut-off frequency is 200 Hz and the upper cut-off frequency is 5 kHz. In **Fig. 7.(a)** you can see the aforementioned frequency response.
6. Noise. To simulate the noise of the wire magnetophone, the noise has been analyzed, obtaining the filter whose response we can see in **Fig. 7.(b)**.



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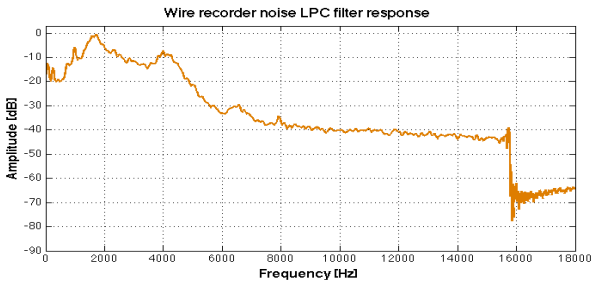


(b)

Fig 7. (a)Frequency response of band pass filtering for magnetophone. (b) Noise filter response for magnetophone.

Sound reception devices

Bakelite telephone. When the Ericsson Bakelite telephone [**fig. 8**] was first distributed around the world in the 1930s, it was called the Swedish-type telephone and set the standard for what a modern plastic telephone should look like. Bakelite was the perfect material for telephones of the time. Basically, they can be molded into any shape possible, even soft, ergonomic shapes are preferred. The material is homogeneous, uniformly coloured and hard, with a beautiful shine. The change from metal to Bakelite has allowed manufacturing times to be reduced, from one week to seven minutes, the time it took for the hot molding compound to cure and then the components were ready for assembly. The response of these devices (both their speaker and microphone) is designed only for voice and not for music, thus, the band eliminated from their response begins at 3000 Hz approximately (Ericsson, 2022).

Fig 8. Ericsson Bakelite telephone ©Museo Telecom UPV

Characteristic effects:

1. Header. The header applied to the digital audio corresponds to the sound made by the ring of the telephone bell.
2. Stereo-mono conversión.
3. Band pass filtering and noise. Since the audio generated by the Bakelite phone was available when the input audio was AWGN noise, we were able to obtain the filter that models the behavior of the phone, whose response we can see in **Fig. 9**. Once the response is known from the phone, we just have to add the input mono signal with AWGN noise (with the appropriate Signal to Noire Range, in our case 60 dB) and filter said sum with the filter obtained, obtaining the desired signal. As can be seen the bandwidth of the filter goes from 200 to 3400 Hz.

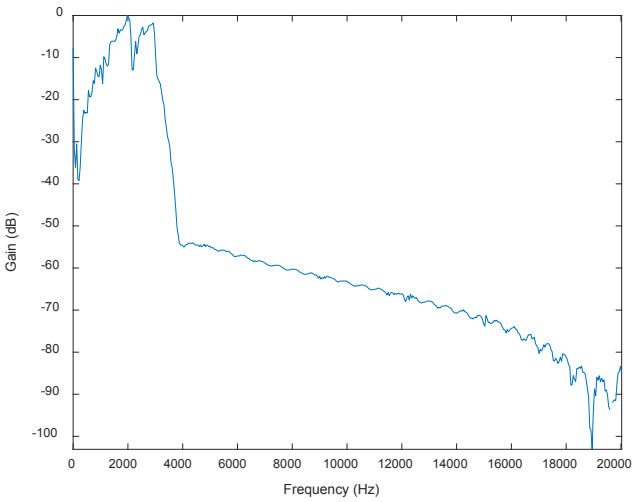


Fig 9. Frequency response of band pass filtering and noise for Bakelite telephone.

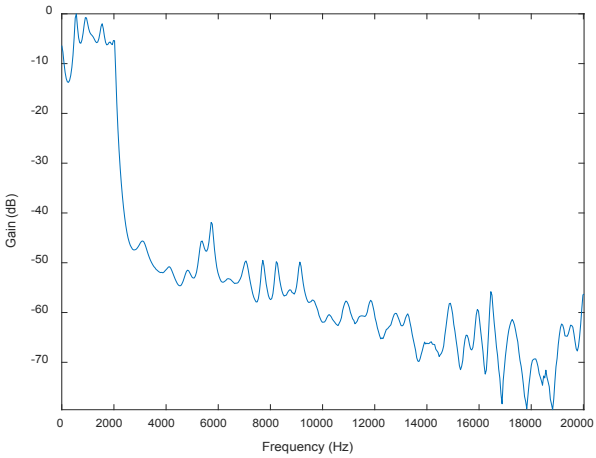
Radio receptor. Radio receivers worked with vacuum tubes or valves commonly known as lamps [**fig. 10**]. In its beginnings, in the 1920s, this was a very rudimentary technology capable of generating little signal volume. Radios used to feature a gradual centesimal dial for tuning, which made the tuning with regard to selectivity and sensitivity very difficult.

In the following decade, radio devices improved, both in the quality of the sound received and in their tuning. In addition, they were connected to the electrical grid and did not need batteries. They were perceived as just another piece of furniture in the house.

Fig 10. Galena radio receptor. @Museo Telecom UPV

Characteristic effects:

1. Header
2. Stereo-mono conversion
3. Band pass filtering. The response of the radio receiver has been approximated with a band pass filter whose lower cut-off frequency is 200 Hz and the upper cut-off frequency is 2 kHz. **Fig. 11.(a)** shows the aforementioned frequency response.
4. Noise. The noise introduced by the radio receiver has very specific characteristics. Therefore, it was decided to filter the AWGN noise directly with a representative noise sample, thus achieving the desired noise. **Fig. 11.(b)** shows the frequency response of the samples used to perform the filtering (in this case a sample by a Marconi Transceptor was used since it was the one available).



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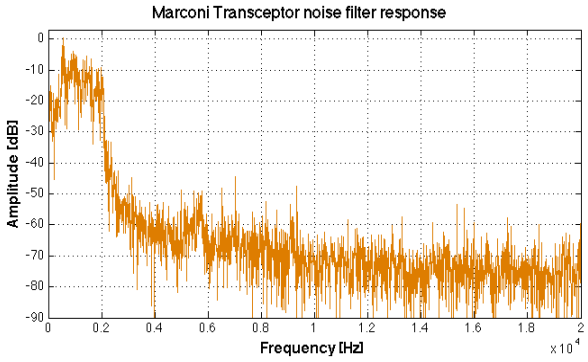


(b)

Fig 11. (a)Frequency response of band pass filtering for radio receptor. (b) Noise filter response for radio receptor.

Morse radio receptor. The electric telegraph was the oldest way of modern telecommunications. Among the different telegraphs developed during the XIX century, Morse telegraph was the most widely adopted (**Fig. 12**). Morse code, also known as the Morse alphabet, is a system of representing letters and numbers using signals emitted intermittently. A Morse message could be received by wire, usually with equipment that printed it on a strip of paper, or by radio, with an acoustic receiver.

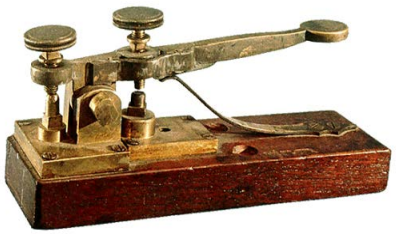
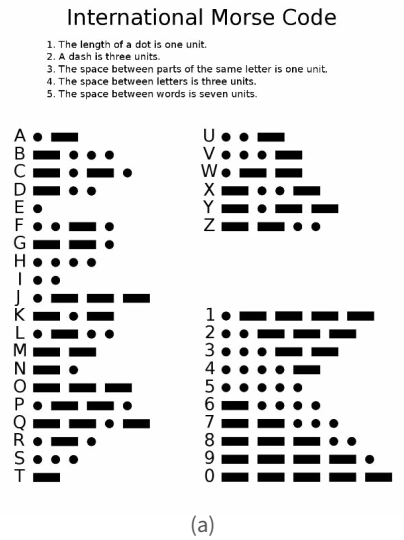


Fig. 12. Morse telegraph key. ©Museo Telecom UPV

Characteristic effects:

Morse coding. To encode text messages, the Morse coding table (**Fig. 13.(a)**) has been used, a standard supported by ITU-R and that has been in use since 1844 (International Telecommunication Union, 2009). **Fig. 13.(b)** shows the temporal response of the long and short interval that has been used for transmission simulation. As can be seen, the duration of the short interval is 140 ms, while the duration of the long interval is 375 ms.



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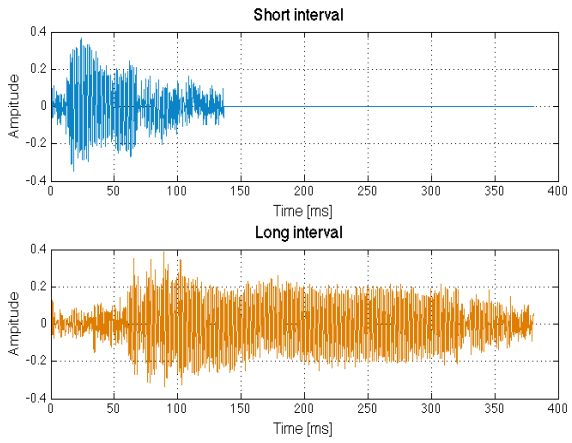

(b)

Fig 13. (a) International Morse Code. (b) Temporal response of a dot (blue) and a slash (orange).

Results and discussion

Following the development of the application, it was integrated into the museum's website and made accessible to the general public. (Voronov, 2022).

Fig. 14. The application of online audio processing on the museum website https://museotelecomvlc.webs.upv.es/demostradores-tecnologicos/

In addition, a short satisfaction survey was carried out to check whether the application worked well on different platforms and whether users found it interesting. Only 10 answers were received, but some results are valuable.

Concerning the type of device used to access the application, 70% used a mobile phone and 30% used a PC. Concerning the web browser: 60% used Google Chrome, 20% used Microsoft Edge, 10% used Mozilla Firefox and 10% used Safari. Regarding the Smartphone model: Oppo A74, Huawei p30 pro, Xiaomi POCO F3, Xiaomi Mi A2, IPhone 11, Xiaomi 11pro and Samsung A70 were used.

The users reported that none of the options have failed during the operation. Concerning more subjective aspects, the users reported the following (**Fig.15**):

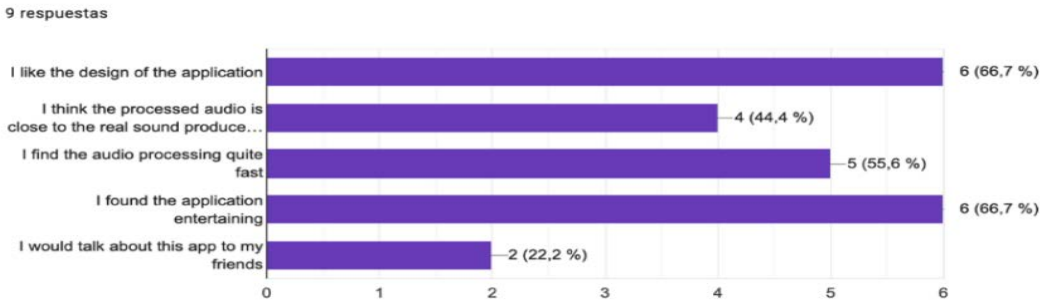

Fig. 15. Subjective views of the application users

Conclusions

This approach parallels the concept of chromatic reintegration in art conservation, where missing or damaged areas are visually reconstructed to restore the overall aesthetic integrity of an artwork. The use of online applications to emulate the functioning of technological heritage artefacts can be a solution for museums that want to offer such an experience to their visitors. In this way the objects recover, even virtually their functionality, thus making possible an integral understanding of the heritage.

The logical extension of this work would be to develop dedicated software to emulate old video recordings. The reception and/or playback technologies may be virtually simulated, so that any fragment of a digital video file would look it has been filmed with a cinematographic format "Super -8", "35 mm film", etc. or would have been received on a black and white or colour analogue television. This digital reintegration of visual characteristics mirrors the principles of chromatic reintegration in conservation, where the goal is to restore the visual coherence of an object while respecting its historical integrity.

Just as conservators-restorers carefully choose techniques and materials for chromatic reintegration to ensure reversibility and distinguishability, when developing these emulation technologies it is necessary to strive for accuracy and transparency in their digital reconstructions. This approach ensures that while the heritage object's functionality is virtually restored, its historical authenticity is maintained, aligning with core principles of conservation and restoration.

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THE SYMBOLISM OF THE CHROMATICISM IN FLORAL ORNAMENTATION OF THE "ROCAS" AND OTHER ALLGORICAL ELEMENTS OF THE CORPUS CHRISTI FEAST IN VALENCIA

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Abstract

The feast of Corpus Christi is nourished by numerous allegorical elements that help to exalt the devotional worship of the Eucharistic sacrament. Among them all, the processional carriages, known as "las Rocas" (the Rocks), appear as distinctive components of the city of Valencia. Traditionally, these rolling platforms have been decorated with floral arrangements that have strictly resorted to a two-colour solution, consisting of white and yellow. However, in some cases this solution distorts the symbolic meaning of many elements.

This contribution reviews this symbology to design a floral proposal in accordance with the meanings of each representation, assimilating the emblematic sense of colour with the motifs of the allegorical elements. In this context, floral decoration is an act of chromatic reintegration, as it improves the understanding of the images from an iconographic point of view, where the colour of the flowers helps to enhance the associated meanings and symbolism.

Keywords:

colour symbology,

floral ornamentation,

Corpus Christi,

las Rocas,

festive culture

Introduction

The Corpus Christi Museum-House of the Rocas in Valencia conserves the most outstanding elements of the festive heritage of what is known as the festa grossa valenciana (Valencian festival). Among other symbolic representations, the eleven Rocas del Corpus, allegorical triumphal carriages (**Fig. 1**), are the most significant pieces. However, figures from the collective imagination, such as the giants and big-heads and the diverse repertoire that makes up the bestiary of the processional parade, although of more recent origin, also deserve attention as an integral part of our festive culture.

It is especially worth mentioning the useful or functional nature of the Rocas and the rest of the heritage elements of the Corpus Christi which, far from remaining immobile and lifeless in the building that houses them, take on their maximum significance as participants in the processional parade. And it is then when they have to display their greatest load of scenographic suggestion, as each year they undergo a maintenance and conservation review that guarantees the legibility of all the allegories, symbols and allusive attributes that accompany them.

The process of patrimonialisation of the festivity, linked to the musealisation of the tangible elements that make up the Corpus Christi processions and parades, must undoubtedly be associated with actions that request the valorisation of this type of festive representations, due to their condition of representative testimony of human activity (González-Varas, 1999: 43). Certainly, the adequate argumentation of each image, with conservation, mediation and dissemination strategies that ensure the assimilation and symbolic understanding of all the characters, objects and attributes of the parade, will guarantee an adequate contextualisation through the identification of their meanings.

This is where the typification of the different elements of the Valencian Corpus Christi, in accordance with the chromatic correspondence attributed to each one of them, will help to complete its symbolic and representative efficacy. The images, beyond their ornamental function, have always emerged with a clear catechetical objective, where the correct use of colour in the iconography will enhance the pedagogical attitude of the message to awaken the empathetic emotions of the spectator, whose mood is stirred more by sensitivity than by intelligence (Sánchez, 2001: 135).

Fig. 1. The Corpus *Rocas*, placed in the Plaza de la Virgen in the city of Valencia.

For this reason, during the conservation interventions that the Instituto de Restauración del Patrimonio (IRP) of the Universitat Politècnica de València carried out on the Corpus Rocas and other unique elements of the festivity during 2016, an ornamental programme was designed to accompany the various representations, paying special attention to the chromatic correspondence of the floral arrangements with the symbolism of each image. In this way, the message is encoded through the strong power of communication and suggestion of colour, whose powerful expressive charge stimulates the viewer and helps to clearly identify, as an effective mnemonic resource, ideas and concepts.

In short, it is necessary to stress the importance of the specific attributes of the figures that form part of the narrative discourse of the Corpus Christi, where colour also plays a transcendental role in the identification and differentiation of individuals, subjects and objects. As a communicative channel and bearer of a message, it has historically served to favour the recognition of the images, as an element of hagiographic reference or to establish

synergies that refer to the qualities and virtues of the soul of the character represented (Sánchez, 2001: 326).

Solemnity of Corpus Christi

A feast for the senses

The feast of Corpus Christi has medieval origins, but it was not until the 17th and 18th centuries that it reached its maximum magnificence, exhibiting the most outstanding manifestations that define the ephemeral Baroque. During the 14th century, the appearance of biblical characters in the procession and the participation of carriages incorporating sculptures and other decorations proliferated; later, especially from the 16th century onwards, theatrical representations flourished, as well as the bigheads and giants (**Fig. 2**), to which were added other dancing characters, hieroglyphs and symbolic elements of religious connotation from which allegorical referential readings linked to the dogmas and creeds of Christianity were derived (Narbona, 1993: 373-374).

Fig. 2. Corpus Christi Giants in front of the Apostles' Gate of Valencia Cathedral.

The ostentation that the solemnity reached was thanks to the impressive processional apparatus that was deployed, with a latent theatricality throughout the celebration and the obvious grandeur of the ephemeral architectures that, in a fleeting and artificial way, aroused the admiration of the spectators (Bonet, 1993). All this pompous display not only served as a pious ritual but was also a focus of socialisation that reaffirmed the identity of the citizens, while the dominant entities and authorities subjected the festival to turn it into a powerful instrument of propaganda and legitimisation of power. All the social strata of the city would have a reserved space in the procession, where the highest ecclesiastical and military authorities would show off their authority and preponderance, while the representatives of the guilds and trades would display their ensigns.

All the neighbours were called upon to participate, encouraged to cover the streets with aromatic herbs and decorate balconies and windows with tapestries and other hangings (Aldea, 2003: 756-757). The processional parade was accompanied by a whole host of ephemeral architecture, such as triumphal arches, altars, fictitious façades and aedicule, whose opulence rivalled the splendour displayed by other manifestations such as arbours and floral tapestries, luminaries and artificial gardens, with rocks and fountains. The city in celebration was filled with numerous ingredients of suggestion for the senses, where all these creations of a provisional nature merged with an infinity of dictions such as music, theatre, dance or poetry, to form a unique universe that could be coined with the Wagnerian term of total work of art (Colomina, 2006: 17; Pöltner, 2003).

The Corpus Christi in the city of Valencia and its heritage elements

For centuries, the Corpus Christi festival was the main festival of the city of Valencia. For this reason, it has an extraordinary immaterial richness as a representative manifestation of the culture and tradition of the Valencian people. The first news of its celebration date back to the second half of the 14th century, more specifically since the first proclamation was made public in 1355 to encourage citizens to participate in the solemn procession in honour of the Body of Jesus Christ (Alejos, 2003: 670), almost a century after Pope Urban IV officially instituted the solemnity. For Valencia, from that time onwards, it was a festive expression of an integral character, where all the spiritual, patrimonial and identity aspects of the city and its inhabitants converged. The notoriety of its ritual, due to the splendour of which it could boast, meant that it was even reproduced and adapted for extraordinary occasions, such as the entry of kings and emperors into the city.

In the 20th century the procession began to languish, but thanks to the efforts of ecclesiastical and municipal agents, together with the popular initiative expressed through associations, it recovered its splendour. In terms

of its most representative characteristics and beyond its spiritual and catechetical elements, it is a complex display of total celebration, where diverse symbols are used and, with a marked baroque style, as has been pointed out, all the senses are stimulated.

It is unquestionable that many of the elements that make up the feast can be found in other celebrations. Figures such as the giants and big-heads, the dances or the triumphal carriages have historically paraded as protagonist representations in festivities all over Europe as a plastic expression of the festival (Soto 1991: 4). However, what makes the Solemnity of Corpus Christi in Valencia unique is the particular harmonisation of all these different components, as well as their special survival to the present day. For this reason, the Consell, as the executive entity of the Generalitat Valenciana, considered it appropriate in 2010 to declare the Solemnity of Corpus Christi in the city of Valencia as a Wealth of Intangible Cultural Interest, due to its singularity and special relevance, by means of DECREE 92/2010, of 28th May.

In this context, the events programmed during the days dedicated to the celebration include numerous tangible heritage elements which, in the same way as the immaterial and ephemeral rituals with which they are associated, deserve attention in order to preserve their structure, appearance and significance. Specifically, the triumphal carriages or Corpus Rocas, together with other figurative representations, make up a set of festive culture wealth that require specific attention.

Precisely, it can be affirmed that the Rocas are the most singular elements of the Solemnity. Some sources connect their origin with other civic celebrations and commemorations (Bueno, 2015: 149; Alejos, 2003: 686), such as the visit to Valencia of members of royalty and the tributes paid to them since the end of the 14th century. These allegorical carriages, richly decorated and pulled by stables, adapted their use to the city's festa grossa and served as travelling stages on which the misteris, amusements or interludes in the form of an auto sacramental, of a festive type, but which essentially served didactic intentions, were performed.

The most revealing problem in terms of their significance, lies in the fact that the Rocas are dynamic components of the feast and take on their full meaning when they are carried through the streets of the historic centre of Valencia. In this sense, they are ephemeral ingredients, insofar as they assume their reason for being in correspondence with the days of celebration to which they are linked and with the ritual acts in which they participate.

This dynamic property means that its material conservation also requires the revision and maintenance of the mechanisms that form part of its movement, as well as the aesthetic restoration that guarantees the symbolic legibility of each allegorical and representative element. It is precisely this allusive charge that must be maintained and exposed by making use of all possible symbolic resources. And this is where, taking advantage of the dried flower decoration that accompanies the Rocas every year (**Fig. 3**), the suggestive power of colour is proposed.

Fig. 3. Floral decoration in red and green on the Eagle of Patmos, a representation associated with St John the Evangelist.

Structural changes, anthropogenic action and atmospheric phenomena

The Corpus Rocas of the city of Valencia have undergone many changes over the centuries. Practically none

of these works remain in their original state, with the exception of those incorporated into the procession at the end of the last century. Unfortunately, the historical triumphal carriages were amputated in height in 1912 as a result of the installation of the tram lines and the city's electric lighting (Mateu, 1969: 45), considerably reducing the size of the figures or groups on each carriage. It was at this time that the seats and thrones disappeared, with ornamental panels and clusters of clouds and seraphs, and the sculptures were practically flush with the architectural body of the central support, with the consequent reduction of the original composition and size.

In some of the Rocas, in the area of the so-called boat, its transformations are documented through dates and chronological data that testify to its age and vicissitudes, as well as the change in its ownership and meaning. Undoubtedly, this monumental set of triumphal chariots is today the result of its material life, evolved over time, and its transformations, the consequence of changes in religious sentiment and devotion at different times.

Other situations that have seriously compromised the conservation and stability of the ensemble have been the floods caused by the overflowing of the River Turia, especially the last one documented in 1957, when the carriages were extraordinarily affected by the action of water and mud and which was followed by a major restoration process (Bosch, 2012: 174-190). This catastrophic disaster caused the loss of countless original elements whose constituent material made of cardboard, fabric, plaster and glue was practically disintegrated by the action of complete immersion in water.

In addition to these drastic events, there are also those that have constantly transformed the groups over time due to wear and tear, accidents, repairs, breakage or other deteriorating factors. It should be pointed out that, as the carriages are drawn by stables, they undergo continuous movement and mechanical action every year due to the movement of their structure. Likewise, the permanence and exhibition of the carriages for two days and nights outdoors in the Plaza de la Virgen, subjected to sudden fluctuations in temperature and relative humidity, has dramatic consequences for the stability of the works.

On more than a few occasions they have had to withstand attacks against the trees of the urban fabric, days and nights of strong wind, rain, high temperatures and a long etcetera of atmospheric phenomena. The annual and constant use of the Rocas has led to the restitution and change of many of their elements, especially in those groups or figurations of structures made of perishable materials, basically made of cardboard. The figures of the mythological animals that accompany Saint Martha with the Tarasca, Saint Michael with the Dragon and Saint Margaret with the Cuca-fera have been restored relatively recently. The same kind of reconstruction has been carried out on the group of eagles that prefigure St John the Evangelist and the power of Rome. In this way, it is clear that the patrimonial ensemble that constitutes and makes up the different floats and the other figurative and allegorical elements that form part of the parade have, as a product of the passage of time, been adapted, exchanged and reconstructed at the mercy of new fashions and imperatives derived from their deterioration and state of conservation.

In addition to the aforementioned agents, there are those causes that are inherent to its use within the festivity and which form part of its anthropological, social and religious legacy. The Rocas have a large area in the form of a platform where the figures accompanying the procession have traditionally been seated or accommodated. Originally, these platforms were used for the performance of small theatrical pieces or misteris (Bueno, 2015: 50), fables, entremeses or performances of a pious nature, which over time lost their function to become, definitively, places for seating (**Fig. 4**). Another circumstance related to the Rocas parade was the two slopes they had to overcome on their route, one near the convent of Saint Francis, known as the pujada de sant Francesc; and a second, right next to the Episcopal Palace, known as the pujada del Palau. The latter, which still exists as a sufficiently steep slope, is still used in recent times to carry out exercises and bets in the traditional Valencian sport known as tir i arrossegament, when many amateurs, holding on to the structures of the lower body of the Rocas, add weight to the exercise of pulling the horses up. This use and exercise of strength, added to the spontaneity of gripping the carriage's carcass, has led over the years to countless accidents, deterioration and all kinds of damage of a mechanical nature.

In conclusion, we must emphasise the constant updating of the festive heritage which, as a cultural heritage, in accordance with the vicissitudes, changes and alterations it has undergone, is not only passed down through the generations, but also manifests itself as a living element, con-

stantly renewed and enriched, in agreement with the sensibility of present-day society. For this reason, the evident transformation of the festival is undeniable, which, while maintaining the essence of its origin, continues to evolve and incorporate new elements and resources that offer new, multi-faceted readings. In this line of readjustment, true to modernity, the incorporation of the symbolism of colour aims to enhance the significance and provide a new approach to the legibility and understanding of the festive culture of the Valencian Corpus Christi.

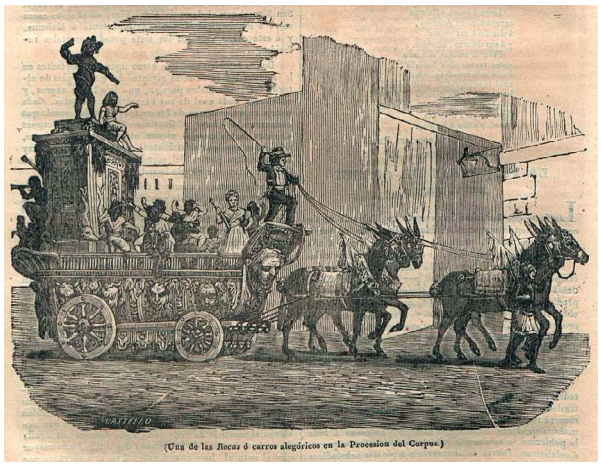

Fig. 4. *Roca Diablera*, according to an engraving that appeared in the Semanario Pintoresco Español on 26 May 1839, which shows its use as a mobile stage for the performance of the Moma dance.

A PROPOSAL FOR SYMBOLIC FLORAL ORNAMENTATION THROUGH COLOUR

In the structural configuration of the Rocas and around the stage where the dramatized performances took place, there is usually a perimeter balustrade as a parapet to protect the occupants in what could be considered a kind of guardrail. In other cases, this protection system is solved, only with iron handrails and made up of perimeter braces, as in the case of the Roca de la Trinidad. In the delineation of this area, vases usually appear as pots on pilasters, delimiting angles and halves all around. The floral arrangements in these vases are usually based on an equal solution for all the Rocas, consisting of dried flowers in a combination of yellow and white. On other occasions, it should be said, the alternative to this solution was to mix an infinite number of colours in the same floral arrangement.

In 2016, as a result of the maintenance, cleaning and restoration work on the groups that make up the Rocas, the IRP team proposed to Valencia City Council, as custodian of the ownership and of the Museum itself where they are kept, as well as to the association Amics del Corpus, to carry out a symbolic adaptation through the chromaticism with which to decorate the vases, crowns of eagles and other elements present in the parade.

Undoubtedly, the ornamentation used to date each year did not take into account the symbolic meaning of each carriage or element and was limited to filling the vases with the same floral arrangement. This design has been made since ancient times with a type of dried flower, later dyed, using a system adopted so that its appearance would remain unalterable and long-lasting from the time it was made for the Corpus Christi festivity and during its storage and exhibition in the Casa de las Rocas until the following festive calendar.

For the Roca of the Holy Chalice, whose main body is a large-scale representation of the Chalice of the Chapter House of Valencia Cathedral, a floral configuration was proposed using the liturgical colours of the Eucharist: yellow and white. The colour yellow personifies the Faith revealed and is especially related to the Sacred Form because it is the colour of the ears of wheat and bread. White symbolises light and eternity; it is the colour of the Dove of the Holy Spirit and, by extension, of God, the angels and the Sacred Form. Yellow is the mantle of two saints of great religious significance: St. Joseph and St. Peter. In both cases, this symbolism of colour is granted by the revealed Faith, in the case of Saint Joseph, by accepting the message of the angel announcing Mary's maternity; and in the case of Saint Peter, through his response to his master by recognising him as the son of God. Yellow and white are the sgraffito on many of the tabernacles, evoking through their two-colour chromaticism the Eucharistic nature of the sacred precinct. Yellow and white is also the flag of the Vatican.

We cannot go into all the allegories presented in the Roca of the Immaculate Conception, although, as its name indicates, in the main body there is an image of the Immaculate Conception. For its floral and chromatic arrangement, we proposed the colours blue and white (**Fig. 5**). Light blue is a chromatism given to the Virgin Mary's mantle, as it is the colour that represents the celestial

and alludes to purity and virginity. This tonality takes over from the ancient symbolism where it signified the knowledge of the spiritual. White, in addition to the meanings described above, symbolises the Virgin tota pulcra, that is to say, without stain, hence its emblematic meaning as the colour of virginal purity. Traditionally, Marian representations of the mystery of the Immaculate Conception have been depicted with a white tunic and blue cloak, so that, extrapolating from this condition, the combination of both colours coincides with the proposal for the vases of the Roca, which symbolically integrate the emblematic meaning of its title.

The Roca de la Mare de Déu dels Desemparats is chromatically divided into two registers (**Fig. 6**). For the vases in the upper area, just to the sides of the Virgin, the colour red was proposed, in reference to the beheaded innocent saints who accompany the image. Its title as Santa María de los Santos Inocentes, Mártires y Desamparados (Saint Mary of the Holy Innocents, Martyrs and Forsaken) imbues the Valencian Marian devotion par excellence with a sense of martyrdom. Red is the colour of blood, of mystical love taken to the extreme by the martyr saints. In the area of the balusters of the platform, the colours blue and white, typical of the Virgin, are combined with the pink flower, which is the symbolic colour of the brotherhood attributed to the ancient Brotherhood of the Virgin and to human love and fraternal communion. The colour pink, moreover, is usually associated with the perizoma or tunic of the representations of the Child Jesus and, as such, its presence in the Virgin's hands led us to reflect on the appropriateness of the appearance of this chromaticism in the floral ornamentation of the Roca. Ultimately, the pink tonality is also associated with the representation of Christ's robe at the moment of his resurrection. And in this connection, it should not be forgotten that the primitive image of the Virgin of the Forsaken was used by the old brotherhood in a recumbent form on the shrouds of the executed in order to give Christian burial to those condemned to capital punishment.

Fig. 5. *Roca* of the Immaculate Conception, with blue and white floral ornamentation.

For the two eagles symbolising the union of the Churches of Rome and Spain, in their respective crowns in the form of floral plumes, the symbolic colours of their own flags were proposed: yellow, white and red. Yellow and white for the Vatican flag; and yellow and red for the Spanish flag. A chromatic symbiosis where the colour yellow accompanies both emblems.

The eagle of St. John the Evangelist is presented with red and green flowers as the colours that symbolically accompany the garments of Christ's beloved disciple. Green signifies hope and is given to the youngest of the disciples who represents a renewed generation, but also personifies the new and eternal life after death, hence its meaning of hope. Red, as noted above, represents blood, but also the life-giving fire of faith, the fire of the Holy Spirit transmitted in flaming tongues at Pentecost, and thus God's love for mankind. Saint John as Evangelist has been depicted in countless compositions alongside the apostolic college or in self-descriptive scenes and passages, always mostly distinguishable as a beardless young man with long hair and wearing a green habit and a red cloak.

Given its characteristics and connotations associated with the evil one, the Diablera Roca was decorated with black flowers, as this colour signifies the idea of death and mourning. Together with the floral design, the inclusion of thistle flowers was suggested because their thorny structure and purple appearance evoke a sense of penitence. Hell associated with the idea of fire was also allegorically related to red and yellow floral centres.

Finally, it is only worth mentioning the small bouquets that appear in the hands of the female figures of the so-called gegants (giants), which represent the nations and races of the world with polychrome arrangements in order to convey a multicultural and ethnic sense.

Fig. 6. *Roca de la Mare de Déu dels Desemparats*, with two different registers of flower arrangements

The question of the floral and symbolic ornamentation of the Valencia Corpus Christi Rocas, which it was proposed to maintain for successive years, should also be implemented with those floats that do not have the aforementioned vases for their decoration in their structure. Thus, the Roca de la Trinidad, the Roca de la Fama or the Roca de la Ciudad de Valencia, to give some examples, should also be presented with their respective flower boxes, carefully studying their symbology or searching in archive photographs and other documentary references for graphic or textual information that would help to adapt their floral ornamentation, without underestimating the incorporation of other plant or fruit elements. In this sense, the addition of ears of corn and bunches of grapes is planned for the Roca of San Juan de Ribera; and vine leaves, fig leaves and apples in that of the Trinity, where the first parents Adam and Eve are represented. Further research into the suitability of the management of the symbolism of colour in the ornamentation of the Rocas will continue to be our objective in the short term.

Conclusions

The feast of Corpus Christi, rooted in the splendour of the Baroque period, is distinguished by an abundance of allegorical symbolism designed to enhance the veneration of the Eucharistic sacrament. The plastic expression of the celebration, particularly through the processional carriages known as las Rocas, reveals a distinctive tradition in the city of Valencia. These carriages, adorned with paintings, sculptures and scenographies, have undergone transformations over the centuries, maintaining a strong symbolic charge linked to testamentary passages and hagiographic narratives.

The floral decoration, rooted in the bicolour tradition of white and yellow associated with Eucharistic worship, has undergone a significant overhaul following the maintenance work carried out in 2016. The conservation intervention, supported by the Heritage Restoration Institute of the Universitat Politècnica de València, sought a chromatic adaptation with dried flowers that respected and enhanced the symbolic meanings of each element in the parade. This action not only improved the legibility of the images, but also enriched the iconographic understanding by aligning the colour of the flowers with the meanings and symbolisms associated with the figures, floats and other allegorical elements. Consequently, the floral decoration emerges as an essential component that enhances the cultural and spiritual richness of the festivity, adding an additional layer of meaning through the careful chromatic selection that accurately reflects the motifs depicted.

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CHROMATIC REINTEGRATION AS A MEANS OF DIALOGUE BETWEEN ARTIST AND CONSERVATOR. THE CONTEMPORARY ART SCULPTURE "MURMURS OF THE FOREST"

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Abstract

This text presents the intervention of the contemporary art sculpture "Murmurs of the forest" by Miguel Molina, belonging to the Museu Campus Escultòric (MUCAES) of the Universitat Politècnica de València (UPV) (Spain). This sculpture, in the shape of a branched axe and made in bronze with a vine plant growing from its base, has suffered some vandalism actions in recent years that have caused it to break in several parts, as well as the total loss of the vine. To preserve it, in constant dialogue with the artist, a transformation of the piece is proposed through welding and chromatic reintegration work that integrates the welded areas. Miguel Molina conceives this transformation of his artwork by extending the re-integration to other intact areas of the sculpture so that they form part of the evolution of the sculpture and of the new meaning that emerges from this new creative act. Consequently, in this particular case, the process of chromatic reintegration is at the service of the artist's intention, serving as a means of capturing the transformation of the artwork under the new criteria of artistic creation proposed by Miguel Molina.

Keywords:

chromatic reintegration,

contemporary art,

conservation and restoration,

conservation and restoration of contemporary sculpture,

chromatic reintegration of contemporary sculpture,

chromatic reintegration methodology

Introduction

The conservation and restoration of contemporary art often involves conflict resolution and difficult decision-making that is determined by the complexity of both the material and conceptual levels, both differentiated mainly by the tangible and intangible aspects of the works of art themselves (Hummelen, 2005; Llamas-Pacheco, 2020).

Thus, the material level encompasses the physical and visible elements of the work, such as the materials and the technique used, the shape, the size, the colour or the texture. While the conceptual level refers to the concepts and ideas that the artist himself seeks to express and transmit through his work. Likewise, in this sense, the conceptual level is intimately related to the symbolic load, the historical-social-cultural context of the artist, the piece and its location, as well as the philosophical or critical reflections that may be present in the work. On this last level, the artist's intention stands out, a fact that requires, as far as possible, that the conservator-restorer must undertake his intervention by establishing a continuous dialogue with the author (Wharton, 2015).

It should be noted that the two levels are intrinsically related and complement each other. The way in which the artist chooses materials and employs techniques can influence the conceptual interpretation of the work to a certain extent, and the conceptual message or original idea can also guide and determine the artist's material and aesthetic choices (Llamas-Pacheco, 2023

The Museu Campus Escultòric (MUCAES) of the UPV

The Universitat Politècnica de València (UPV) (Spain) has a considerable historical, artistic, scientific, technological and industrial heritage, spread over the campuses of Vera (Valencia), Alcoi and Gandia. This cultural heritage serves different purposes, mainly related to the study, teaching, research and dissemination of science, technology, art and culture in general. The main objective of the structures in charge of its custody is to ensure its conservation, management and dissemination, considering its diversity, dispersion and the particular characteristics of the UPV Museums and Collections.

In particular, the Museu Campus Escultòric (MUCAES) of the Universitat Politècnica de València (**Fig. 1**) brings together a collection of around 80 monumental or large sculptural works, mostly exhibited outdoors, which coexist with the urban, landscape and human environment of the campuses that comprise the UPV. The MUCAES exhibition space is spread over the three UPV campuses, although it is the Vera Campus in Valencia where most of the collection is on display (Universitat Politècnica de València, 2017).

Fig. 1. **Panoramic view of MUCAES at the Vera Campus (Valencia, Spain). Photo: ©UPV**

The collection of artworks by prestigious national and international artists (Jorge Oteiza, Manolo Valdés, Susanne Bayer, Ramón de Soto, Nassio Bayarri, Fernanda Fragateiro, Néstor Basterretxea, Eusebio Sempre, Nati Navalón, Javier Mariscal, among many others) is considered one of the largest and best Spanish collections of outdoor sculpture. The diversity is evident in terms of artistic styles, plastic languages, techniques and materials so that visitors can follow highly variable thematic itineraries, with sculptures that dialogue with the spaces and which have been created in different materials, such as steel, bronze, iron, stone or even clay, ceramic, glass, polyester, wood and fibreglass.

For all these reasons, the open-air sculpture collection of the MUCAES, uniquely combining art and habitat, allows direct contact with the works, giving the spectator access to multiple parameters of artistic language and sensory impressions. Visiting the Museu Campus Escultòric is to enter a sensory circle where the sculpture-spectator interaction allows the generation of unique dialogues with the works, ideas, concepts, form and materials of which they are composed.

Murmurs of the forest

This sculpture (**Fig. 2**), located on the Vera Campus (Valencia, Spain) of the UPV, was created in wax bronze and vine vines by the artist Miguel Molina (1960, Teatinos, Cuenca, Spain) in 2000.

Fig. 2. Murmurs of the forest, 2000. Waxed bronze and vine vines, 200 x 300 x 150 cm. Photo: ©UPV

Murmurs of the forest was initially conceived in 1989, in the artist's first solo exhibition, by devising an axe made of iron and holm oak wood in which the handle had become a branch. With it, Miguel Molina sought to represent a metaphor for the concept of transformation in which power and culture become elements that impose themselves. In this way, the sculpture symbolises a hymn to life in which the axe is a destructive component, while the vine symbolises the power of nature and its ability to always break through and make life sprout again, regardless of the difficulties. Thus, the sculpture is intended to be a continuous renewal (Navarro-Montón et al., 2018).

At the end of the 1990s, with the proposal to include *Murmurs from the Forest* in the MUCAES collection, the artist reconsidered the configuration of the sculpture itself, as the original materials (iron and wood) would end up being destroyed over time in the open air, thus requiring something less perishable. All its constituent elements had to be permanent, so he conceived this new version of the sculpture in wax bronze, both the trunk and the axe and handle. However, to complete his initial idea, he lacked a living element so that the work would not be static, which is why he included a vine, which would embody the sense of renewal of nature. This vine grows from the base through the sculpture itself, reflecting the four seasons, so that the artwork changes with the seasonal cycles. Thus, the axe is hidden in the spring and summer seasons, giving nature greater prominence, and remains in view during the autumn and winter seasons (**Fig. 3**).

Fig. 3. *Murmurs of the forest* through the seasons. Photos: Rosario Llamas

The title of the work comes from a passage from Siegfried in Richard Wagner's epic opera, part of The Ring of the Nibelung cycle. In it, Siegfried, the protagonist, goes into the forest following the murmur of a bird that leads him to the dragon that can make him immortal. Once he finds it, Siegfried kills it and bathes in its blood to achieve immortality, although a leaf from a tree falls on his back, which will be his weak point and from which he will later die (Wagner, 1986). Similarly, the head of the axe in the sculpture has a leaf that Miguel Molina has depicted to symbolise the weak point of the axe itself.

Vandalism

The sculpture has been the object of various acts of vandalism, apparently by the university community itself. In an interview given by the artist in 2011 (UPV Radiotelevisió, 2011), he mentions that the work had suffered damage that had resulted in the breaking of some of the branches of the bronze handle, which had ended up scattered on the ground or lost.

In the years following this interview, *Murmurs of the Forest* suffered another vandalism with more serious results, as the sculpture was mainly broken into three parts, separating the handle of the axe and also detaching it from the base trunk (**Fig. 4**), resulting in the complete loss of the vine at the same time. As a precautionary measure, it was decided to store all the fragments of the sculpture in the

Art and Heritage Department's storerooms of the UPV until further intervention.

Fig. 4. State of conservation of the sculpture after the vandalism it has suffered. Photos: Beatriz Doménech

Recovery of the sculpture

For the intervention of the sculpture, it has been essential to work closely with the artist, who is also currently a professor and lecturer at the UPV and who has been enthusiastic and very involved in this project. Establishing contact with Miguel Molina, getting to know his point of view and his current perception of both the artwork and the damage suffered, has been fundamental to recovering *Murmurs of the forest*, maintaining its meaning and preserving the artistic intention. After conversations with the artist, it was decided to restore the sculpture to its initial state prior to all the vandalism it had suffered, that is, with the branches of the handle upwards as a synonym of the transformation and evolution of life through nature.

The restoration work consisted of a first phase of intervention at the structural level and a second phase focused on chromatic reintegration. The first of these was carried out in two stages:

Stage 1: A company external to the UPV with workers specialised in bronze welding was contacted and the fragments of the axe were transported to their workshop. This company was in charge of welding the handle to the head and the small fragments of broken branches according to Miguel Molina's instructions. The artist was present during this process and actively participated in indicating the directionality that each of the elements should follow, as well as in determining an irregular finish in the welds (**Fig. 5**).

Fig. 5. Welding process by specialised workers, Miguel Molina can be seen giving instructions. Photos: Beatriz Doménech

Stage 2: This was carried out in situ at the site of the sculpture on the Vera Campus in Valencia. Once the welding of the axe to the handle had been completed, the piece was transported back to the university campus to weld the edge of the head to the bronze stump that serves as the base of the sculpture. In this second stage, the piece was restored to its original state with the position of the branches of the handle facing upwards (**Fig. 6**).

Fig. 6. General view of the sculpture after the first welding work in situ. Photo: Beatriz Doménech

However, after a short time, the sculpture was again fragmented, possibly as a result of another hypothetical vandalism. In this case, after conversations with the artist, the possibility of transforming the sculpture was considered and it was finally decided to weld it back together again, but with the branches of the handle facing downwards, towards the earth for security reasons (**Fig. 7**). For Miguel

Molina this meant a new stage in the life of Murmurs of the forest, an artwork which, after the intervention, not only symbolises the transformation, but the sculpture itself is transformed, returning to the earth and, therefore, to the nature from which it originates or comes.

Fig. 7. General view of the sculpture in its new position after the collaborative welding work with the artist. Photo: Beatriz Domènech

Chromatic reintegration

The second phase of restoration was determined by the need to integrate the welding unions, as they were golden and shiny (**Fig. 8, left**) and the artist did not like them. Furthermore, these unions also lacked the bluish tones of the natural patina of the bronze of the rest of the sculpture. It is worth mentioning that the welding work had caused, uniquely, reddish tones at the junction of the axe edge with the base stump (**Fig. 8, right**), mainly due to the high temperatures of the welding process.

Miguel Molina was in favour not only of preserving these new reddish tones, but also of reproducing them in other areas of the sculpture during the process of chromatic reintegration. He stated that the welded areas should also be integrated in the same way as the bluish patina of the bronze, invading some parts of the original, as he conceived this intervention as part of the creative process of the second stage of the sculpture's life in which it is transformed. Likewise, he indicated that the reintegrations made should not be invisible, but that he wanted something evident that would form part of the new conception of the sculpture.

Fig. 8. Detail of welded unions. Photos: Beatriz Domènech

For the chromatic reintegration, we opted for the preparation and use of pigments agglutinated with the acrylic resin Paraloid® B-44 (Carnazza *et al.*, 2020), due to the excellent results obtained from the use of this resin in the curative conservation of other outdoor sculptures at MUCAES. Thus, the preparation of the varnish paints was carried out, in the first instance, by grinding the pigments and then adding Paraloid® B44 diluted 7% in ethyl acetate, making circular movements to properly encompass the pigment particles.

Following Miguel Molina's instructions, the chromatic reintegrations were carried out in the welded areas, applying the paint made with a brush and paper stumps to give the finish conceived by the artist. Similarly, some of these actions were extended to original parts of the sculpture that had not been damaged, once again following the artist's criteria (**Fig. 9** and **Fig. 10**).

Fig. 9. Sequence of the chromatic reintegration process. Photos: Beatriz Domènech

Fig. 10. Detail of chromatic reintegration. Photo: Beatriz Doménech

Conclusions

This project shows that, in the intervention of contemporary art, the decisions of the conservator-restorer are subject not only to the characteristics and nature of the artwork but also to the opinion of the artist when he or she is still alive.

The intervention undertaken to recover *Murmurs of the forest* is currently conceived as an act of conservation-restoration, as well as a process of artistic creation thanks to the collaborative work carried out with the artist. In this way, the sculpture is transformed and has a new representation conceived by Miguel Molina himself.

Chromatic reintegrations made with pigments bonded with Paraloid® B-44 serve a triple function: protective, as they protect the welded areas, which are mainly weak points against environmental deterioration factors; integrative, as they aesthetically integrate the colour and finish of the welds into the original patinated bronze surface of the rest of the sculpture; and finally, artistic, as they are not limited to the affected areas, but go beyond them, invading the original according to the artist›s indications, thus becoming conceived as part of the artistic-creative process of the work itself.

Finally, it is worth mentioning that, to prevent future acts of vandalism both in *Murmurs of the forest* and in any other sculpture of the Museu Campus Escultòric, dissemination and awareness-raising work is currently being carried out among the university community. These activities, such as guided tours of the MUCAES and photography workshops, among others, help to publicise part of the university heritage and enhance the value of the sculptures in the collection.

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ESSAYS ON RETOUCHING WITH DRY TECHNIQUES. INVERTED DRAWING

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Abstract

This paper presents the results of a dry retouching exercise carried out with the students of the Paper Restoration course of the Conservation-Restoration of Cultural Heritage course at the University of La Laguna. To this end, we will take as a starting point the studies carried out by Betty Edwards on learning to draw with the right side of the brain. We will use the resource of inverted drawing as a method of retouching.

The exercise is developed in three parts on a mock-up with different losses of support material. In one of the mock-ups, the work is worked on upside down, so that the students correct the missing parts of the drawing line by line, focusing on the shapes and isolating them from the whole. The first results of this experiment suggest that the fact of retouching with the work upside down makes it possible to see details that are different from those made in the reading direction.

Keywords:

Dry techniques,

inverted drawing,

works on paper,

right brain

Introduction

In general, the subject of retouching is treated from the point of view of the use or validation of materials and the differentiation criteria used in practice. However, there is less emphasis on analysing the most effective tools for achieving successful retouching on paper. (Poulsson, 2010)

Paper is a very sensitive material and any marks made are difficult to remove. Therefore, it is necessary to learn different methods to improve this practice without the need for correction. It seems logical that some drawing skills are needed to retouch different works on paper, whether they are drawings or intaglio prints.

We have therefore investigated how drawing skills can be practised and transferred to the field of heritage conservation and restoration. The starting point is Betty Edwards' work on learning to draw with the right side of the brain.

Betty Edwards is an American art teacher and researcher, best known for her book *Drawing with the Right Side of the Brain: A Course in Creativity and Artistic Confidence*.

She taught and researched at California State University until her retirement in the late 1990s.

There she founded the Centre for the Educational Applications of Brain Hemisphere Research. Edwards' method of drawing and teaching was revolutionary when it was published in 1979 (Edwards, 2008).

It received an immediate positive response and is now widely used by artists, teachers and researchers around the world. It is based on the idea that the brain has two ways of perceiving and processing reality: one verbal and analytical, the other visual and perceptual.

The verbal model, or Mode D, is a right hemisphere dominant state characterised by simultaneous, global, spatial information processing and an understanding of the relationships between parts. On the other hand, the analytical model or Mode I is a state in which the left hemisphere predominates and is characterised by linear, verbal, analytical and logical processing of information. (Edwards, 2022)

Edwards' method focuses on ignoring preconceived notions of what the drawn object should look like and 'seeing' it individually. For Edwards, drawing has five components of perception and drawing ability-skills:

- Borders and lines (including copy drawing and contour drawing exercises)
- Negative space (i.e. space between elements)
- Relationships (i.e. perspective and proportion between things)
- Light and shadow (shading)
- The whole: shape emerges as the first four are taught

It proposes a series of exercises to work on, with the aim of providing effective guidance in the practice of the five basic skills of drawing. On the perception of boundaries and lines, she suggests a series of preliminary drawings based on a self-portrait, in one's hand, in a corner of the room, of a flower, of a composition of a background, and so on. Exercise number 6 is the so-called inverted drawing, an exercise that we have transferred to the practice of reintegration in works on paper.

Exercise no. 6, the inverted drawing, aims to reduce the conflict between the brain modalities by getting the verbal modality to abandon the task. It is possible that the verbal modality, confused and blocked by the strange, inverted picture you are about to draw, will not be able to name or symbolise as usual. In her workbook, Edwards provides a series of instructions to follow for each exercise:

1. "The drawing you have chosen is Front view of a horse... printed upside down. Copy it as it is. Start copying the chosen drawing from wherever you like, some people start from the top left corner. Note: I advise against drawing the whole outline first; if there is a mistake in the outline, the parts will not fit together and this frustrates the D modality, which specialises in perceiving how the parts fit together.
2. Fit the pieces together by moving from line to line, from space to space. Do not try to name the pieces as you draw them. Draw the lines as you see them,

without trying to imagine what you are drawing. When you come to parts that seem to force you to name them, such as the hands and the face, try to concentrate on them as if they were unnamed shapes.

3. When you have finished, place the drawing on the right. I think you will be surprised and pleased with what you see. But don't turn it right side up until you've finished.
4. Sign and date the drawing and add the note that is always added to a copied drawing. Copy by Anonymous" (Edwards, 2003)

In this type of exercise, the author suggests that, when copying the drawing, you start copying wherever you want and advises against drawing the whole outline first. The idea is to go from line to line, from space to space, trying to concentrate on them as if they were nameless shapes. He also advises not to draw it straight until it is finished.

The adaptation of this exercise to improve the retouching ability of works on paper consisted in carrying out tests before the final retouching, with the work reversed, in order to know and identify the lines and shapes well and to be able to carry out the final retouching in a more confident way, avoiding the tedious corrections on paper.

Experimental

This experiment is put into practice in the restoration workshops with second-year students of the Conservation-Restoration of Cultural Heritage course at the University of La Laguna. The exercise was carried out by 40 students.

Materials

The materials needed to carry out this activity are as follows:

- A digitised black and white image, either printed on a drawing or as an intaglio print, emphasising the use of drawing lines. Each student will be given three copies of the image to facilitate the exercise.
- Graphite pencil, coloured pencil and crayon. The methods used are based on dry techniques. The three types of pencil are combined according to the intensity of the lines in the copies. No special markers are used. Each student will work with the ones they have. This exercise is about imitating shapes, not about measuring the quality of the materials used.

Methods

An image is chosen from a drawing or an intaglio, basically based on lines, which is digitised and printed in black and white. In this image, several losses with different degrees of difficulty are applied, depending on the selection of the areas of the drawing (**Fig. 1**):

- 2 losses of curved lines (**fig. 1**, marked 1 and 2 in the image)
- 1 loss of straight lines (**fig.1** marked as 4 in the picture)
- 2 losses with shading (**fig.1** marked as 6 and 7 in the picture)
- 2 losses with shape interpretation (**fig.1** marked in the image as 3 and 5)

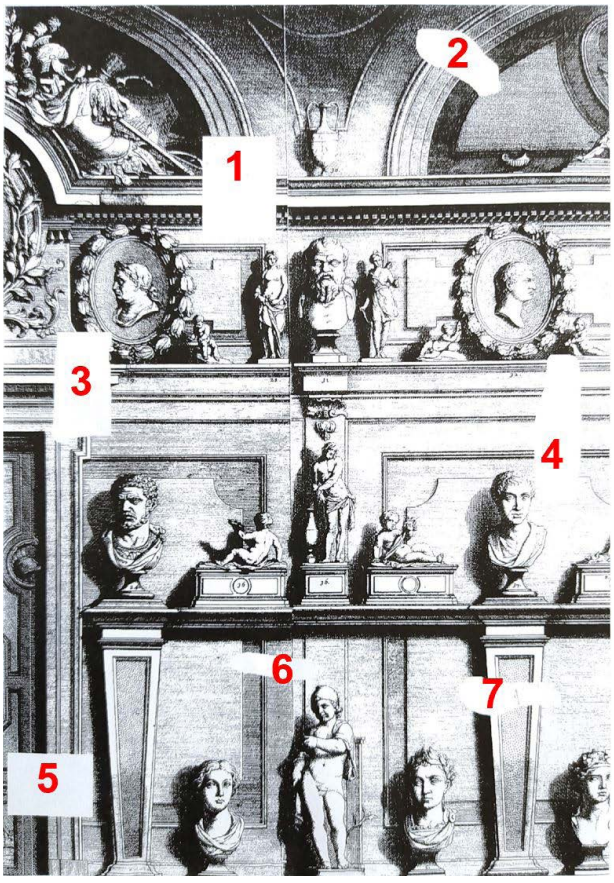


Fig. 1. Example of the selected work, showing the losses and the different levels of difficulty. Exercise prepared by professor from a digital copy with losses. Self-authored

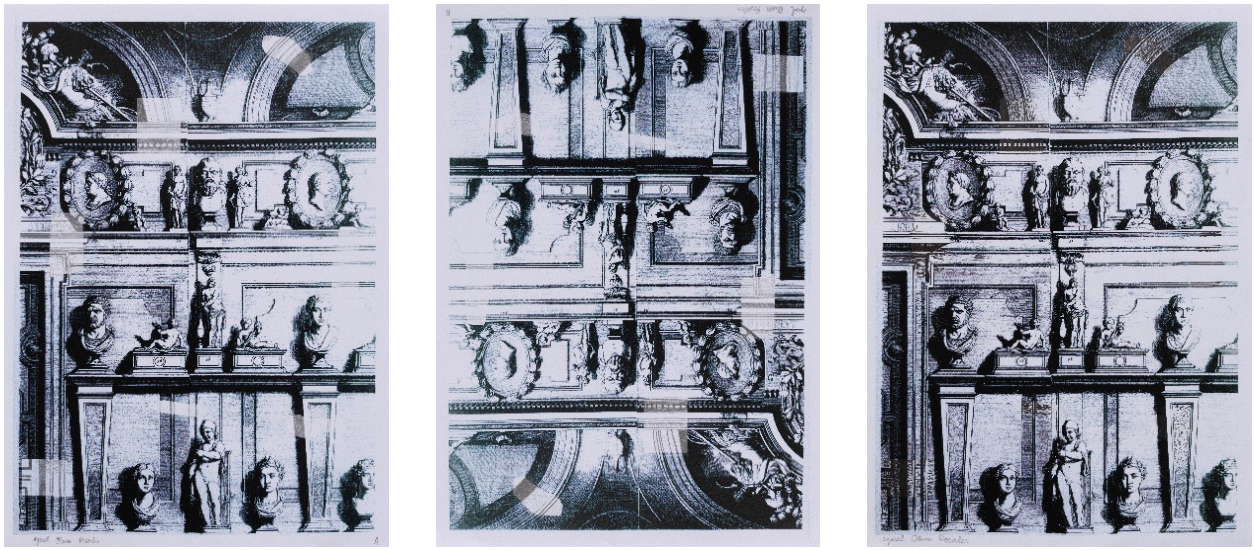
The exercise is carried out in three parts on the model with different losses of support material. Each student has three mock-ups and only one opportunity to work on

each of them. They cannot be repeated.

In the first exercise, the students have to retouch, trying to imitate the missing lines of the evoked shapes. The second exercise consists of working on the work in reverse. In this case, the students have to retouch the missing parts of the drawing line by line, concentrating on the shapes and isolating them from the whole. (**Fig.2**-Model A-B; **Fig.3**- Model A-B)

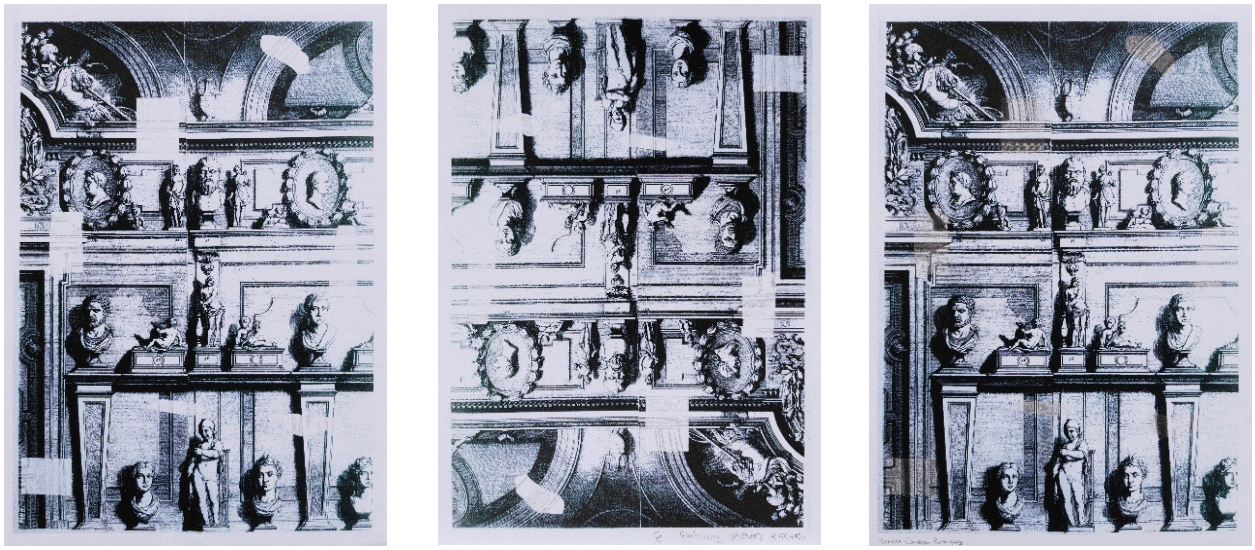
Before moving on to the third model, a comparison is made between the two models in order to identify the details that are not immediately apparent but which are highlighted by the inverted model. The third exercise is to complete the retouching of the missing parts, adjusting lines and tones according to illusionist criteria. (**Fig.2**-Model C; **Fig.3**-Model C)

The first two exercises take 15 minutes, while the third



Model A Model B Model C

Fig. 2. Example of the three models made by the same student. Retouching with dry techniques in the right direction, completing the shapes seen, line by line. From left to right: Model A, dry retouching in the right direction. The student draws the lines defining the missing shapes in 15 minutes. Model B, dry retouching, inverted drawing; The student draws the lines defining the missing shapes in 15 minutes. In general, losses 3 and 5 are interpreted differently in models A and B. Model C, final retouching, the student apply the details tested in models A and B in one hour. Models made by the student Yisel Oliva.



Model A Model B Model C

Fig. 3. Another example of the three models made by the same student. Retouching with dry techniques in the right direction, completing the shapes seen, line by line. From left to right: Model A, dry retouching in the right direction. The student draws the lines defining the missing shapes in 15 minutes. Model B, dry retouching, inverted drawing; The student draws the lines defining the missing shapes in 15 minutes. In general, losses 3 and 5 are interpreted differently in models A and B. Model C, final retouching, the student apply the details tested in models A and B in one hour. Models made by the student Natalia Carbajal.

takes at least an hour. The use of the different dry techniques depends on the quality of the print or photocopy, trying to imitate both shape and colour as closely as possible.

Results and discussion

Before describing the results obtained, it should be mentioned that the students who participated in the study had very little experience in drawing. In the first year of the course in Conservation and Restoration of Cultural Heritage, they had taken only one subject in drawing. The content of this subject is based on theoretical and practical knowledge of the structuring and configuration of graphic form.

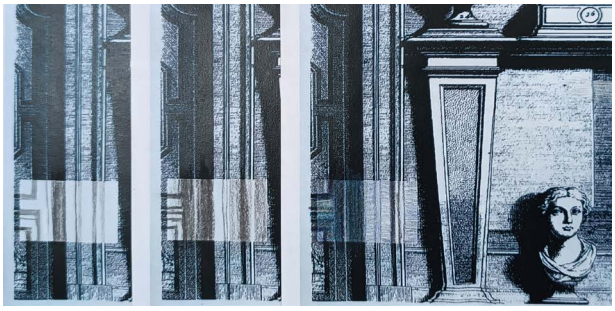
In general, after the exercises, we can see that there is an evolution in the retouching of details in each of the models made, based on the interpretation of shapes, colours and the execution of lines.

If we compare the exercises carried out by each student and if we compare the students' exercises with each other, we can observe the following aspects:

- Less detail is observed in model A compared to models B and F. (**Fig.4**)
- There is an improvement in the drawing of curved lines in Model B. (**Fig. 2**; **Fig.3**)
- Most students do not use line shading in models A and B. **Fig. 2**; **Fig.3**)
- Most students avoid drawing part of loss 1 (Fig.2; Fig.3)
- Losses 3 and 5 show the greatest variation in the interpretation of the drawing. (**Fig. 2**; **Fig.3**; **Fig.4**; **Fig.5**)
- In Model C, students have no difficulty in retouching the shadows. (**Fig.6**)
- Most students concentrate on the shape and do not consider the tone or colour of the loss. (**Fig.5**)

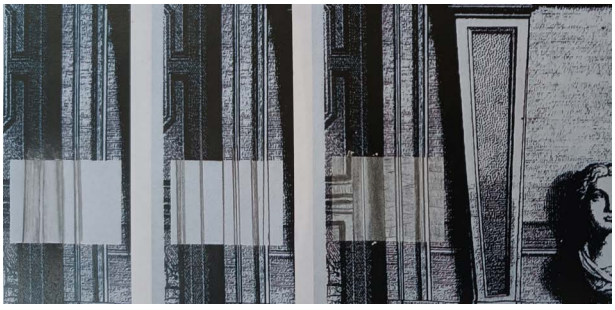
Model A Model B Model C

Fig. 4. From left to right: Models A, B, C. The three exercises illustrate the idea of understanding lost shapes. The interpretation of the lines that make up the cornice is different in each. Details of loss n°3 in the models made by the student Gara Negrín.



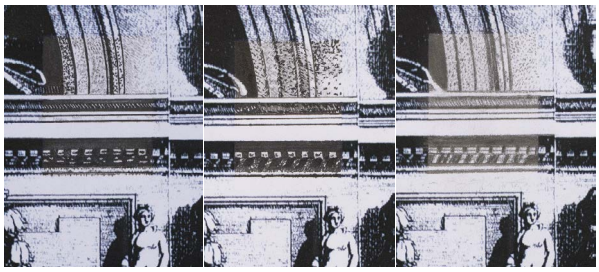
Model A Model B Model C

Fig. 5. From left to right: Model A, B, C. Figure 5. From left to right: Model A, B, C. The bluish tone comes from the printing system used to make the copy. To imitate this bluish tone, different pencils are combined and the colours are superimposed. Details of loss n°5 models made by the student Aitana Marcos.



Model A Model B Model C

Fig. 6. From left to right: Model A, B, C. In the final model or Model C, the drawing lines are changed to try to fill in more detail and correct the lines. Shadows are also added. Details of the loss n°5 in models made by the student Erika Gabriela.



Model A Model B Model C

Fig. 7. Comparison of details in the final models, models C. Details of the loss of model n°1 in the models of the students Amaya Bello, Axel Chacón and Gara Negrín. There is a change in the way the volumes are interpreted, using different means: perspective lines and shadows.

Conclusions

Proper and satisfactory retouching of works of art on paper is difficult. As mentioned in the introduction, paper is a very fragile material and a mark made by a conservator is difficult to remove. It is therefore necessary to provide learning resources for expressing elementary ideas through basic drawing. This requires practice in both drawing and restoration techniques.

The first results of this experiment show that retouching with the inverted work makes it possible to see details that are different from those made in the reading direction.

In addition, the final retouches are more precise in the definition of shapes and details.

In terms of colour sensitivity, we have not obtained good results in practice. It is necessary to revise this part and propose appropriate exercises.

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POSSIBILITIES OF USING YINMN-BLUE IN CHROMATIC REINTEGRATION OF PAINTINGS

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Abstract

The research reported in this article consisted of determining the color properties of painting layers containing selected blue pigments, as well as changes in those properties during the aging process - i.e. determining lightfastness. For this purpose, painting layers were made according to the requirements of the standard for testing artistic materials which use several binders considered stable and are used for retouching. Samples – varnished and unvarnished were subjected to accelerated aging in Xenotest® under both indoor lighting conditions and established climatic conditions. The color characteristics of the samples before and after aging were determined instrumentally by colorimetric measurements with a sphere spectrophotometer and by microfadeometric testing. Their interpretation and the results of additional tests of application features allowed to determine the possibility of using YInMn-Blue for inpainting of restored paint layers.

Keywords:

YInMn-Blue,

ultramarine blue,

cobalt blue,

pigments lightfastness,

retouching,

restoration of paintings

Introduction

The purpose of the activity concluding the process of conservation and restoration of paintings or polychrome works is primarily the reintegration of damaged fragments of the painting layer, aimed at restoring the aesthetic and artistic values of a given historical artefact. Color harmonization of retouchings, intended to ensure appropriate quality and durability, requires careful selection of pigments.

The effects of their use in the contemporary conservator's palette depend, among others, on: the color properties, the hiding power, physicochemical stability - including lightfastness, and compatibility between pigments. Non-toxicity is also not to be overlooked. Despite the availability of a wide range of materials, new and better materials are still being sought. Based on this assumption, an attempt was made to determine whether the blue inorganic pigment *YInMn-Blue*, invented in 2009, can be used on a conservation palette or even become a substitute material for other blue pigments of a similar shade, which have traditionally been used.

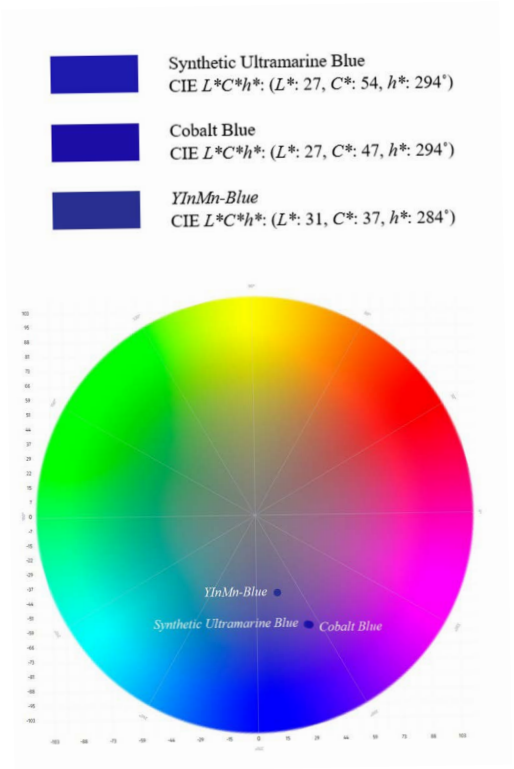

Fig. 1. Synthetic ultramarine, cobalt blue, *YInMn-blue* and color coordinates based on exemplary paint layers (with PVAc binder) positioned on chromaticity diagram CIE a*b

Experimental

Materials

Mock-ups of paint layers

The research embraced dark blue pigments with a violet-blue tint, which appeared among painting materials as a replacement for the valuable mineral pigment – natural ultramarine – Lapis Lazuli (N/A, C.I. 77007). Those were: synthetic ultramarine (PB 29, C.I. 77007) synthesized independently by J.-B Guimet and Ch. Gmelin, in production since 1930s, cobalt blue (PB 28, C.I. 77436), well known ever since its invention by Thénard in 1802, here applied in its cobalt-zinc silicate, phenakite variety (PB 74, C.I. 77366), as well as the new 'Oregon blue' *YInMn-Blue*, invented in 2009 (Smith, Subramanian and others, 2009) (figure 1). The latter has been available in paints since 2016 (in Europe). With the aim of fully assessing the lightfastness, it is necessary to test the pigment not only in full tone, therefore, white pigment was included in the tests – titanium while rutile (a variety that is generally subjected to processing that limits its photocatalytic activity (Szmit-Naud, 2006, pp. 166–171).

Table 1. Tested pigments

Pigments	Colour Index	Manufacturer / distributor	Composition	Density (g/cm^3)
YInMn-Blue	PB 86	Kremer Pigmente, Germany	$YIn_{0.8}Mn_{0.2}O_3$	1,1
Cobalt Blue Dark	PB 74	Kremer Pigmente, Germany	$(Co,Zn)_2SiO_4$	4,1
Ultramarine Blue, dark	PB 29	Kremer Pigmente, Germany	$Na_{8\text{-}10}Al_{16}Si_6O_{24}S_{2\text{-}4}$	0,8
Titanium White Rutile	PW 6	Kremer Pigmente, Germany	TiO_2	0,25

The pigments (table 1) were tested in the form of painting layers, where the film-forming substances were three different synthetic resins, considered stable, as well as gum arabic (table 2). A resin commonly used in conservation varnishes was used to insulate a part of each paint layer.

Table 2. Resins used as film-forming substances in paint layers and varnish

Film-forming substances	Trade name	Manufacturer/ distributor	Density (g/cm^3)	Application
ethyl methacrylate and methyl acrylate (70/30)	*Paraloid® B-72*	Rohm & Haas, USA	1,15	paint binder
polyvinyl acetate copolymer	*polyvinyl acetate K40*	C.T.S., Italy	0,92	
urea-aldehyde resin	*Laropal® A81*	C.T.S., Italy	1,11	
Acacia tree secretion – a mixture of polysaccharides	gum arabic *008*	Talens, Netherlands	-	
hydrogenated hydrocarbon resin	*Regalrez® 1094*	Eastman, USA		varnish resin

In order to create paint binders and dilute obtained paints glycol ether solvents were used. The varnish was the resin dissolved in white spirit (table 3).

Table 3. Solvents used to dissolve synthetic resins and dilute the mixtures created

Solvents-composition	Trade name	Manufacturer/ distributor	Density (g/cm^3)	Application
propylene glycol methyl ether	*propylene glycol methyl ether Dowanol® PM*	Dow Chemical Company, USA	0,92	solvent in binder
Di(propyleneglycol) methyl-ether, a mixture of isomers	*DPGME - dipropylene glycol methyl ether, a mixture of isomers*	Sigma–Aldrich, Germany	0,95	
a mixture of paraffinic and naphthenic hydrocarbons	*white spirit D40*	C.T.S., Italy; Blik, Poland	-	solvent in varnish

PGME (Dowanol ® PM) was used to dissolve the resins. The paints were diluted with a mixture of the above solvents (PGME and DPGME 4:1).

The ready, commercial gum arabic solution was diluted with demineralized water. When creating paints with it, an addition of glycerin (POCH, Poland) was used as a plasticizer.

Varnish, a 30% (w/w) resin solution, was used to insulate the surfaces of some samples Regalrez® 1094 in white spirit WD40 with the addition of photostabilizers: Tinuvin® 292 and Tinuvin® 1130 (BASF, USA), in the amount of 1% and 2% (resin weight), respectively.

Support of paint layers

Two types of substrates were used to make samples of painting layers - completely non-absorbent, and an insulated layer of mastic layer to create a system similar to that used in practice for inpainting. The non-absorbent base for the painting layers were glass plates whose surface had been sandblasted in order to obtain better adhesion of the applied layers. The mastic was applied to cardboard and printing foil - to enable easy cross-sectioning of the layers, if necessary. The mastic, with a recipe used at the Department of Conservation and Restoration of Polychrome Painting and Sculpture, contained methylcellulose, polyvinyl as binders and a filler - natural chalk, and a small amount of Primal® AC 33 acrylic dispersion (C.T.S., Italy) as a plasticizer. The insulation was a layer of Regalrez® 1094 resin varnish.

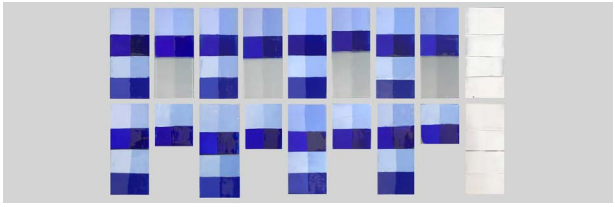

Fig. 2. Mock-ups of paint layers prepared for artificial aging

Methods

By means of the above materials paints were created and then 112 samples were made on various substrates (figure 2). During the preparation of the samples, the application features of the obtained paints were visually assessed, including their hiding power, flow, agglomeration of pigment particles, their tinting strength and the change in appearance after varnishing. The painting layers were subjected to accelerated aging and colorimetric and glossymetric assessment.

Samples of painting layers on glass and foil (samples on the cardboard base were left as controls) were subjected to accelerated aging in the light of a xenon lamp of the Xenotest® Alpha High Energy apparatus (Atlas Material Testing Technology GmbH, USA). Conditions imitating daylight indoors were created by using a Xenochrome 320 filter, obtaining a spectral range of radiation λ = 320–800 nm. The temperature on the samples was controlled (BST not higher than 66˚C). Accelerated aging was performed by rotating the samples around the light source and their respective axes. The irradiation energy measured in the range λ = 320–400 nm amounted to 40 kJ/m2, the cycle was two-phased with variable relative humidity (60% and 46%), and the aging was finished with a short phase with constant relative humidity maintained at 60%. Blue Wool Standards (ISO 105) were aged simultaneously with the samples to control the progress of aging.

To determine the color of the samples and its changes, instrumental measurements were performed. The interpretation was made in the CIE L*C*h* color space (where L* stands for lightness, C* – chroma, i.e. color saturation, and h* – the hue angle). To determine the total color difference, the formula ΔE*2000 was used. The measurements were performed using a SP-64 X-Rite sphere spectrophotometer (X-Rite, Inc., USA) with d/8˚ measurement geometry. The following were used: illuminant CIE D65, standard normal observer 10˚, spectral range 400–700 nm, measurement in spectral interval 10 nm, the diameter of the measurement field was 8 mm. The measurements were made with the SCI specular component included, which takes into account the influence of gloss on the perception of color (total reflection of the tested material), thanks to which the color measurement result takes into account the gloss of the surface which produces results independently of whether the surface of the layer is shiny or matte. This measurement mode is used to assess color objectively and was chosen to record possible changes in an absolute manner.

Regardless of the described colorimetric assessment of samples subjected to accelerated aging in Xenotest®, a Micro Fading Test of selected samples was performed using a Microfadeometer (Photon Institute ltd., Poland). The method is meant largely for assessing the potential damage caused by light in museum conditions (Łojewski, Grzelec, 2020, p. 79). Both the aging and the measurement

concerned a point on the surface of the sample of the painting layer with a very high-intensity LED light beam; with a light spot diameter of 0.3 mm, in the spectral range of 400–750 nm. The product of radiation intensity and exposure time at the focal point was 1,000,000 lux*h.

The surface gloss of the samples and its changes resulting from aging were assessed with a Zehntner Gloss ZGM 1110 multi-angle glossmeter (Zehntner GmbH Testing Instruments, Switzerland). Measurements were made for an angle of 85˚.

The course of the research

Sample preparation

The sample substrates were adapted to the dimensions of the Xenotest® holder. Individual samples of painting layers therefore had dimensions of 3 x 4.5 cm, extreme 4 x 4,5 cm. The mastic substrates were seasoned for two months.

With attention to specific features of the appearance of the painted layers, including: the appropriate gloss of the retouchings, and based on literature, a 20% concentration of resins in the binders was assumed. This allows, depending on the type of pigment, to obtain a concentration of 14-18% of the film-forming substance in the dry painting layer (Szmit-Naud, 2005, p. 78). A lower concentration of the resin solution would result in a dull and porous film surface after evaporation of the solvent, due to an insufficient amount of resin surrounding the pigment grains (Szmit-Naud, 2006, pp. 67–72).

20% (w/w) solutions of *Paraloid*® B-72, K40 polyvinyl acetate and *Laropal*® A81 were prepared, each in 1-methoxy-2-propanol (*Dowanol*® PM).

The varnish was prepared by dissolving *Regalrez*® 1094 resin (w/w) to 30% in WD40 white spirit with the addition of light stabilizers *Tinuvin*® 292 and *Tinuvin*® 1130 (BASF, USA), in an amount of 1% and 2% respectively (by weight of the resin).

All three commercial pigments were pre-ground with ethanol to break down any agglomerates that might have formed and dried up during storage.

The absorption of the above-mentioned binders by pigments was experimentally determined using information about their oil absorption, as well as taking inspiration from the systematic determination of the oil number (PN-EN ISO 787-5:1999). However, this assessment is merely a hint. The amount of binders that are solutions of synthetic polymers cannot be compared to oil, due to the high content of low-volatile solvents that will evaporate. .

In the case of gum arabic, the concentration of which in an aqueous solution was undetermined (Royal Talens does not provide information) - preliminary tests were performed. The cohesion and shrinkage of the painting layers applied to the polyester foil while drying were visually assessed. Glycerin was added to reduce the brittleness of the layers.

Using the recommendations of the ASTM D4303-10 standard, in addition to full-tone paints, tones were lightened with the addition of titanium white to obtain more conclusive. information on the lightfastness of a given pigment (Szmit-Naud, 2005, p. 80, Szmit-Naud, 2021, p. 191). The mutual proportions of each color pigment in the mixture with titanium white were determined to obtain layers with an appropriate reflectance (R).

Mixtures of pigments in binders were made while strictly maintaining the proportions of ingredients determined in previous tests. The paints were obtained by gradually adding drops of binder to the pigment and mixing to a thick consistency that allowed application to substrates after adding a thinner, (i.e. the pigments were not preliminary ground with the concentrated binder itself to paste consistency). They were diluted with a mixture of PGME and DPGME solvents (4:1) to the extent that they could be freely spread in a thin layer with a spatula. The samples were made in the form of strips (PN-EN ISO 1513:2010) with the predetermined dimensions.

During the preparation of paints and paint layers, the hiding power and flow of the obtained paints as well as the agglomeration of pigment particles and - during reducing with the white pigment - the tinting strength of each of the three blue pigments was assessed visually. After initial evaporation of the solvents, the resulting layers were subjected to additional drying at 80˚C in a dryer, after which half of their surface was covered with the varnish described above. The application of varnish served the purpose of reflecting the system (painting layer - varnish) created when retouching. Several applications of the varnish were dictated by the high absorbency of the painting layers. After the solvent evaporated from the surface of

the layers, its release from the samples was furtherly accelerated in a dryer at a temperature of 80˚C maintained for seven days. Changes in the appearance of the sample surfaces after varnishing were also visually assessed.

Accelerated aging of the samples in *Xenotest*®

The samples were aged in Xenotest® under the conditions described above. The accelerated aging process lasted a total of 606 hours, as a result of which the samples received an irradiation dose of D 87,808 kJ/m2 in the range of 320–400 nm (which means 122.9 or 92.2 years of exposure at 150 lux or 200 lux respectively, 8h a day). Several breaks were taken during accelerated aging to assess the progress of changes in the BWS and samples. The aging of the samples was completed when a change which occurred on the BWS standard no. 7 corresponded to a contrast of 4-5 on the gray scale for assessing color changes (ISO 105 A2).

Color and color change assessment

On each sample a fixed measurement area was determined in order to record changes. Colorimetric measurements were performed before, during (when 6 the BWS pattern showed a step 3-4 in the gray scale) and when the accelerated aging of the samples has been completed. In the conditions occurring in the aging chamber, after stopping its operation in order to control the progress of changes some of the samples revealed damage within the marked measurement fields. Peeling of the samples on a foil substrate and streaks on the surface occurred on many samples, regardless of the substrate. This forced a change or shift of the color measurement zone in relation to the one designated (before aging), which could affect the result of the measurement-based assessment of changes.

Microfadeometry was performed on several selected samples on cardboard substrates - not aged in *Xenotest*® and on glass substrates in the unaged zone. Measurements were made on: unvarnished cobalt blue, ultramarine and *YInMn-Blue* in binders made of an aqueous solution of gum arabic and a 20% solution of *Paraloid*® B-72 on cardboard substrates; unvarnished cobalt blue, ultramarine and *YInMn-Blue* in a 20% solution of *Paraloid*® B-72 on a glass substrate; unvarnished and varnished titanium white in a 20% solution of *Paraloid*® B-72, 20% solution of polyvinyl acetate *K40* and 20% solution of *Laropal*® A81 on a glass substrate.

Gloss measurements were made for several selected samples: unvarnished and varnished ultramarine layer in polyvinyl acetate, full tone and reduced with white, unvarnished cobalt blue in *Paraloid* B-72, reduced with white, and unvarnished YInMn blue layer in *Paraloid* B-72, full tone and reduced with white. The measurement was performed in zones exposed during aging and in protected zones, not identical to those where color measurements were made. Therefore, they were intended to be indicative only.

Results and discussion

As a result of the observations and measurements carried out, it was found already at the beginning that the blue color of *YInMn-Blue* is characterized by lower saturation compared to dark ultramarine and dark cobalt blue, the color of which is brighter.

In practical use, *YInMn-Blue* is easily wetted with a solution of *Paraloid*® B-72 in methoxypropanol, the pigment particles do not agglomerate, the paint obtained from it in this binder is liquid. Very little of the above binder was used to create a satin gloss layer. In mixtures with titanium white, after applying the painting layer, the pigments separated slightly during mixing and did not create a uniform mixture, however, after drying, this defect was not visible. Dots created with it flow properly off the brush, but the pigment migrates to the edges of the dot, creating a halo.

Dark cobalt blue is also easily wetted with a solution of *Paraloid*® *B-72* in methoxypropanol, the resulting paint is very flowable - it is difficult to spread a layer of uniform thickness. A small amount of binder allowed for obtaining a layer with a satin gloss. In the mixture with titanium white, after applying the painting layer while it was drying, the pigments separated - white streaks emerged, also visible after drying. In the case of stippling, i.e. applying paint with dots, these defects do not manifest themselves. It can be used to create uniform dots that flow easily from the brush.

Dark ultramarine behaved similarly to cobalt blue. It wetted well in solvent-based binders, but required a slightly larger amount of binder than cobalt blue to create a satin-gloss layer. The paint flows easily. When mixed with titanium white, the pigments also separated - white streaks

emerged, noticeable after drying. The dots are uniform (i.e. the pigment does not flow to the edges) and flowed easily from the brush.

Low hiding power was characterized by paint layers of dark ultramarine and full-tone dark cobalt blue. It was also found that secondary flocculation occurred in the paint and agglomerates were formed, which caused the roughness of the surface of the dried layer. Mixing these pigments with titanium white, which has a very fine particle, visibly improved the packing of particles in the painting layer and, as a result, ensured better surface quality. Compared to *YInMn-Blue*, ultramarine and cobalt blue were distinguished by greater tinting strength, which was observed when making tones reduced with titanium white.

It was observed that *YInMn-Blue* dispersed well in all tested binders, which resulted in easy application of smooth, opaque layers.

Covering part of the sample surfaces with varnish resulted in visible changes in color saturation and brightness in each of them, regardless of the type of substrate (**Fig. 3**), which was also recorded by measurement. On the surface of samples applied to a substrate made of insulated mastic, the varnish was distributed more unevenly.

When interpreting instrumental color measurements of aged samples, results exceeding the value of 2.5 calculated according to the ΔE*2000 formula were considered borderline in terms of accepted color changes in the samples. Unfortunately, it was found that in the conditions occurring in the aging chamber, after stopping its operation (several times) to control the progress of changes, some of the samples were damaged within the marked color measurement fields. The damage took the form of flaking in samples on a foil base as well as streaks - on the surface of many samples, regardless of the substrate. As mentioned above, in some cases this forced a change or slight shift of the color measurement zone compared to the one designated before aging.

Based on colorimetric measurements of all tested samples, it can generally be concluded by analyzing the hue angle values (h*) that the tendency of the shade to change in a certain direction, can generally be found regardless of the binder of the paint. Cobalt blue and ultramarine slightly changed their hue to a more blue-green shade, in contrast to *YInMn-Blue*, which slightly changed its hue to a more violet one.

Considering the results for paint layers in various binders, it must be stated that some layers created with a gum arabic solution binder cracked very visibly and peeled off, making further analysis impossible. In others, there were less visible surface defects, which, however, affected the measurement results for the rubber layers. Their occurrence is due to the physical characteristics of the binder used - the brittleness of the gum arabic films, which, combined with most likely too high gum concentration of the factory solution used, the layer thickness and its insufficient plasticisation, caused the cracks.

Regardless of the type of pigment tested, the changes in the layers containing gum arabic the measurement of which remained possible, achieved higher values compared to those recorded in the layers with resin binders, but also a more visible decrease in color saturation. This can be explained by the described changes on the surface of the samples having mechanical causes, but also by color changes of the rubber itself (not necessarily expressed in a change in the hue angle - this changed similarly in the layers with resins).

Considering the test results from the point of view of the binders used, it can be noticed that the direction of the registered color changes was influenced by the Tg of the polyvinyl acetate resin. Its content in some unvarnished samples, regardless of the type of pigment, under the aging conditions in Xenotest® resulted not in an increase but in a decrease in the lightness and saturation of the color of the painting layers.

Comparison of the results of the colorimetric assessment of changes allows us to notice that the unvarnished and varnished layers, especially those reduced with white, containing the Laropal A81 binder with ultramarine and *YInMn-blue*, changed significantly (figure 3), although slightly more than the layers containing these pigments in the other two resin binders. Therefore, it can be assumed that Laropal A81 may have an impact on this result.

Another general observation was also made - accelerated aging in Xenotest® caused greater changes in full-tone layers, especially varnished ones compared to reduced ones. The reason for this was carefully analyzed, as it was a result that differed from standard expectations. After performing exemplary calculations of the pigment volume concentration in layers with *Paraloid* B-72, it turned out that it was lower in full-tone layers and a large differ-

ence concerned the layers with cobalt blue - where dE* values were particularly high. Further in-depth analysis led to the conclusion that all full-tone painting layers were, due to the suboptimal ratio of binder to pigment, too porous and absorbent, especially those containing cobalt blue and ultramarine, and this was the reason for their poorer behavior in the aging process. Therefore, it was decided to focus the interpretation of the test results on the layers reduced with titanium white, where the proportions of the pigments to the binder were more accurate. Moreover, colored pigments in the presence of white in the painting layer are more susceptible to changes due to increased light scattering in the layer, so the results obtained for such layers provide more reliable information about the actual lightfastness of the pigment. Additionally, in the case of the described experiment, the samples of reduced paint layers had a better quality surface - tighter and smoother, as well as a more uniform hiding power. The transparency of ultramarine and cobalt blue makes it difficult to create a sufficiently uniform hiding, especially when applied manually. Non-homogeneity of hiding is important for the correctness of measurements, shifting or changing the measurement place (justified by the occurrence of streaks on the surface of the samples) - from the opaque zone to the less opaque zone - influenced the registration of differences that did not result from actual color changes within the layers. This situation could apply to approximately ¼ of the tested samples and this fact was taken into account when interpreting the results. The following practical conclusions were also drawn from the situation. When manually preparing experimental paints for testing, it would be necessary to first ensure the appropriate amount of binder in the layer by grinding it with the pigment to a paste consistency until the necessary minimum amount of it in the mixture is achieved, and then adding further portions of binder to obtain paint. In addition, the creation of more uniform hiding layers in the case of transparent or semi-transparent pigments would allow the use of an applicator. Due to the small size of the aged surface of the sample, the principle of multiple and average measurement was adopted, in one marked place, the most opaque, (in a consistent, most opaque, precisely marked place) and was considered the most appropriate in this case. However, the unforeseen changes caused by water condensation suggest that it may be more appropriate in this case to take average multiple measurements of the entire aged surface. Nevertheless, despite the described shortcomings, and partly thanks to them, the research results allowed to draw constructive conclusions.

In the case of unvarnished reduced with white paint layers with all three resin binders, higher dE2000 values were recorded in those applied to an absorbent substrate, but compared to the non-absorbent these differences are small (not exceeding 0.5). In the same layers covered with varnish, this pattern does not occur everywhere, and in the case of reduced varnished layers with ultramarine, the situation is the opposite - higher values of changes were recorded in painting layers on a non-absorbent substrate (glass plates). The abovementioned facts and the inability to establish, also in full-tone layers, a clear regularity, i.e. the relationship between the size of the change and the type of binder and the presence or absence of varnish layer or the type of pigment, leads to the assumption that the amounts of binder in the painting layers as well as the degree of paint thinning during application are responsible for these differences, not aging processes.

Layers obtained from *YInMn-Blue* showed high resistance to artificial light aging. For paint layers reduced with white, these are very low ΔE*2000 values of 0.11 to 0.45 in the case of varnished layers. The unvarnished ones show higher change values, but not exceeding 1.75, even in the case of layers with gum arabic.

In the case of unvarnished cobalt blue tints (reduced with white painting layers, the ΔE*2000 values ranged from 0.65 to 2.87, and for the same varnished layers from 0.39 to 0.69, so they were also very low. Changes were only noticeable in the case of non-varnished layers on an absorbent base. The changes were most often accompanied by a slight increase in lightness and a decrease in color saturation.

Paint layers containing ultramarine reduced with white, unvarnished, showed ΔE*2000 of 0.4 -2.2 as a result of aging, and those covered with varnish - 0.16 to 0.61. Therefore, these are also negligible changes. Here, too, they most often consisted of a slight increase in brightness and a decrease in color saturation.

Samples of painting layers containing only titanium white with various binders displayed stable behavior. The changes recorded by measurement that are subject to interpretation concern only the layer with gum

arabic (those undamaged), which slightly darkened and changed the color saturation.

All samples subjected to microfadeometry turned out stable after irradiation of 1,000,000 lux*h in the spectral range of 400-750 nm, i.e. within the visible light spectrum. The calculated values of ΔE*2000 range from 0.12 to 0.41, which makes them negligible. This result indicates a very high lightfastness of blue pigments under the test conditions.

As noted, the evaluation of gloss changes concerned several samples. Two of them, varnished samples - with the highest gloss, are also the ones that lost it the most as a result of accelerated aging: a varnished layer containing full-tone dark ultramarine in a 20% K40 polyvinyl acetate solution: changed the gloss from 70.8 GU to 21.1 GU; varnished whitened layer with dark ultramarine in a 20% K40 polyvinyl acetate solution: 66.6 GU per 39 GU. Changes in gloss therefore indicate changes on the surface of the layers, increasing their irregularity, resulting in greater light scattering and, as a result, an increase in lightness. Unvarnished painting layers in full tone are matte, while reduced ones are semi-matte. Their gloss decreased slightly or remained unchanged.

The most matte: painting layers - unvarnished ultramarine in a 20% solution of polyvinyl acetate K40 and cobalt blue in a 20% solution of *Paraloid*® B-72, also showed clear color changes, this result was caused by an insufficient amount of binder in the painting layer.

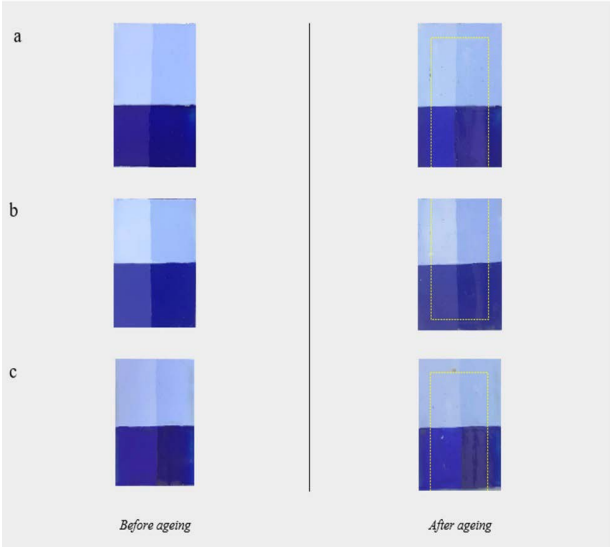

Fig. 3. Samples of painting layers in a 20% solution of Laropal® A81on a glass plate: a) cobalt blue, b) YInMn-Blue and c) ultramarine, in white and full tone, varnished zone on the right. Aging area marked.

Conclusions

The tested painting layers containing three blue pigments showed their high lightfastness. The result of fadeometry allows us to assess the lightfastness of the tested YInMn blue, synthetic ultramarine and cobalt blue as very high. It should be noted, however, that materials used in the conservation and restoration of paintings are often exposed to ultraviolet light and climatic factors affecting them over time, hence accelerated aging, which imitates these conditions to a greater extent, provides additional knowledge that allows them to be optimally assessed.

The results of the conducted tests indicate that the *YInMn-Blue* layers after receiving an irradiation dose of D = 87,808 kJ/m2 measured in the range of λ = 320-400 nm and 1,000,000 lux*h in the microfadeometric test behaved in a very stable way. There was no significant impact of the binders used to create painting layers with this pigment on the test results. It was found that as a result of aging, the color of this pigment may slightly change to a more violet one. The obtained results allow us to conclude that *YInMn-Blue* can be an alternative to pigments of a similar shade traditionally used in the restoration of works of art. It can constitute an alternative to synthetic ultramarine thanks to its resistance to mild acids (including acidic atmosphere) (Plesters, 1966, pp. 62–75), as well as its photocatalytic effect (Szmit-Naud, 2006, p. 126) and the crystallization of epsomite on its surface as a result of aging (Harrison et al., 2021) - and for cobalt blue, due to its content of harmful cobalt (Roy, 2007, p. 152).

The imperfection of *YInMn-Blue*, from the point of view of restoration practice, is primarily its low tinting strength, which becomes visible when combined with other pigments, and its lower color saturation than in the case of ultramarine and cobalt blue. However, lower color saturation may be beneficial in the reintegration of old painting with reduced color intensity (among other factors due to aging processes).

Paints obtained from the tested blues are characterized by similar application properties in the binder used, made from a solution of *Paraloid*® B-72 in methoxypropanol: they are easily wetted and flow from the brush, and are flowable. However, it can be noticed that the points made with *YInMn-Blue* are distinguished by the form of a halo (migration of pigment towards the edges). This shortcoming can probably be limited by the appropriate

selection of the solvent.

The key drawback influencing the widespread use of this pigment is its high price, imposed by the rarity of yttrium (Y) and indium (In) in nature. Difficulties also include limited distribution - on the European continent, *YInMn-Blue* is only available from Kremer Pigmente (Germany).

We hope that the results of the above research will signal a real possibility of using *YInMn-Blue* in the field of conservation and restoration of works of art, and the presented conclusions will support the selection of the optimal conservation material and encourage further research on this pigment.

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METAMERISM AND BLUE RETOUCHING IN CERAMIC CONSERVATION: COMPUTER COLOR-FORMULATION AND APPLICATION IN THE CONSERVATION STUDIO

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Abstract

When surfaces match under one illuminant but differ under changing light sources, they form a metameric pair.

When dealing with restored ceramics, metamerism can arise between cobalt blue ceramics and conservator's paint due to variations in their reflectance spectra. This discrepancy can cause retouching to appear purplish, negatively affecting the object's aesthetic.

Since the early 2000s, computer-based non-metameric formulas have been studied, yet their practical application in studios has been limited. This research seeks to overcome this challenge by adapting algorithms. The primary aim is to formulate a color recipe consistently matching under various lighting conditions, adhering with lighting standards. Secondly, the methodology's reproducibility is ensured through the use of Golden Artist Colors database. The research is developed on the basis of a spectrocolorimetric study of Delft earthenware from the Royal Museum of Art and History in Brussels.

Keywords:

Metamerism,

Retouching; Chromatic Reintegration,

Computer Color Formulation,

Golden Artist Colors,

Delft Earthenware

Introduction

The production of ceramics is marked by the ubiquity of blue shades, primarily attributed to the extensive use of Cobalt. Cobalt oxide is renowned for creating vibrant blue enamel decorations. Its historical availability and resistance to high firing temperatures have made it the material of choice for ceramists. Furthermore, during the 17th and 18th centuries, the widespread importation of Chinese blue and white porcelain greatly influenced European ceramic production, fostering a strong predilection for blue decoration.

However, blue tones are more sensitive to chromatic variations caused by metamerism than other colors. In ceramic conservation, it can raise issues when reintegrating lacunae chromatically. Metamerism frequently occurs between the ceramic surface and the retouching layer applied on the filling materials. It often results in a purplish hue that negatively affects the overall aesthetic of the restored objects.

To address this recurring issue, studies have investigated the use of computational processes to formulate non-metameric recipes. While this approach seems quite interesting, it is not yet easily applicable in studio practice and requires further improvement. This study aims to provide guidelines to facilitate the retouching process of blue ceramics using computer color-matching.

Metamerism and Light

Metamerism refers to the optical phenomenon wherein two colors that appear identical under specific lighting conditions diverge when the light source changes [**Fig.1**]. While visually similar, these colors, such as those on a ceramic surface and a retouched area, have different compositions. In conservation, this phenomenon often manifests after treatment when the object is moved from the conservation studio to be displayed in a museum, a gallery, or to be photographed. This discrepancy arises from two primary reasons: first, the distinct reflectance spectra of differently colored surfaces; and second, the varying spectral compositions of different light sources.

The first factor is directly linked to ceramic materiality.

Fig. 1. The same plate is photographed under two different light sources. In the picture on the left, the retouching is not visible, whereas on the right, metamerism occurs, giving it a purplish hue. Delft plate, the first quarter of the 17th century, Rijksmuseum, Amsterdam. Isabelle Garachon©.

Decorations, formed by fired Cobalt oxide, contrast with the retouching done by conservators using paint mixtures, typically with acrylic binders. Despite achieving a visual match, chromatic reintegration never have the same nature as the original enamel composition, and as a result can exhibit differential behavior under varying light conditions. A color shift can occur, making the retouching unintentionally visible. It is also important to recognize and understand the subjective nature of chromatic reintegration. Retouching reflects conservators' sensitivity. While parameters like reintegration level, materials, and techniques strictly align to conservation ethics, the choice of pigments themselves is much more about personal preferences and established practices. It's means that various recipes of paint mix can achieve the same hue, with none objectively 'better' than another. Ultimately, retouching's essence lies in the final result, the visual appearance.

The second factor concerns color rendering influenced by light sources. In addition to natural daylight, exhibition centers and conservation studios are illuminated by three artificial sources: incandescent bulbs, fluorescent tubes, and light-emitting diodes (LEDs). Each source has a unique spectral composition linked to its light production process [Fig.2 & 3]. Moreover, within each type, variations occur based on bulb type, quality, manufacturing origin, and other factors.

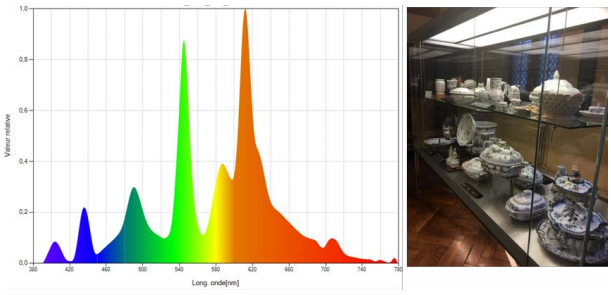

Fig. 2. Spectral composition of a fluorescent tube

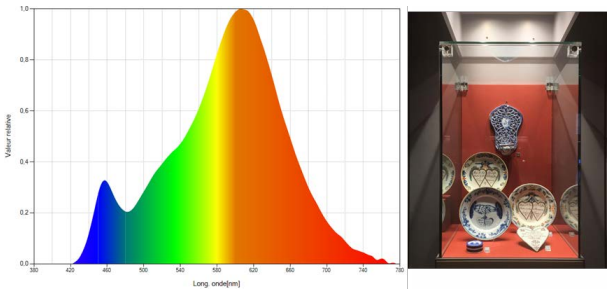

Fig. 3. Spectral composition of a LED bulb

Due to the direct correlation between light and color perception, the diversity and inconsistency in lighting conditions within exhibition spaces increase the risk of metamerism occurring.

Computer color formulation

Metamerism represent a well-known challenge in the paint and dye industries. Since the 1950s, with the advancement of colorimetry, researchers have endeavored to address this issue through computational methods. Leveraging the Kubelka-Munk theory, which delves into light absorption and scattering in turbid media, they proposed a computational approach to formulate non-metameric paint recipes. By defining the precise composition of the colorant mixture, this method uses algorithms to precisely replicate a reference color. Predefined constraints are imposed upon the formulation's objectives, such as the pigment database, paint mix tolerance, and the chosen reference illuminant.

Computer color-matching was initially introduced by Sarah Staniforth in 1985 for the conservation of old master paintings. She highlighted the link between the similar reflectance spectra of the original and the retouching materials, when addressing the issue of metamerism. However, her study cannot be directly applied to fired materials like ceramic enamel decoration, as the original and the paint have distinct natures.

In the early 2000s, Norman Tennent and James Nobbs applied computer color formulation to ceramic conservation. Their research proved the method's effectiveness in producing non-metameric retouching. However, it was initially designed for a case-by-case approach, limiting practical application in everyday conservation practice. Computer color-matching is notably time-consuming, involving complex algorithm development and numerous colorimetric measurements of both pigments and ceramics. Nonetheless, their study highlighted that certain groups of ceramics share similar reflectance properties despite exhibiting various shades of blue. These findings inspire us to further explore computer color formulation with the aim of standardizing the approach and simplifying its usability.

Experimental

Materials

Delft Blue-and-White Earthenware

The primary objective of the research was to establish a reproducible method. This ensured that chromatic reintegration could align with the results obtained through computer color-matching without the need to rerun the algorithm or conduct spectrocolorimetric assessments for each new treated object. Inspired by Norman Tennent's research, our focus was directed with a group of ceramics that shared similar spectral properties in their blue decorations. Using the resources from the Royal Museum of Art and History (RMAH) in Brussels, our study focused on twelve Delft earthenware plaques [**Fig.4**]. These objects were chosen for several reasons: they displayed significant variations and contrasts in shades of blue, ranging from deep, dark hues to lighter, grayish blues. Moreover, they presented extensive colored areas suitable for measurement, and their flat surfaces facilitated colorimetric assessments. To ensure a diverse representation, we selected plaques dating from the XVIIth to the XIXth century, originating from different regions such as Delft, Rotterdam, Arnhem, Amsterdam, and Utrecht.

Fig. 4. Selected Delft's plaques from the RMAH, Brussels.

Pigment Database: Golden Artist Colors

The success of computer color-matching hinges, in part, on the selection of pigments incorporated into the database. This selection process relies on two primary criteria: the materials used and the color range. Regarding the first aspect, both literature and practical investigations highlighted that ceramic conservators work commonly with acrylic-bonded paint. This can either be dry pigment mixed with a solvent-based medium or industrially prepared acrylic paint. Our study revealed that Golden Artist Colors are predominant for ready-to-use paint. With a broad array of pigments available in various fluidities, these paints prove adaptability in numerous retouching contexts. Given the minimized margin of error when using pre-made paints compared to dry pigments plus binders, our research is based on Golden Artist Colors.

The second parameter concerns the diversity of pigments introduced into the database. In this study, we expanded the pigment selection to include almost the entire range of 45 pigments, including 2 whites, 2 blacks, 8 blues, 3 purples, 11 reds, 3 oranges, 6 yellows, 3 greens, and 5 earth pigments. This decision enhances the algorithm's capability to propose suitable, meaning non-metameric, paint mixtures. The advantage of computer color-matching lies in its capacity to transcend conventional pigment combinations, thereby formulating innovative recipes that conservators might not have tested due to common habits.

Lighting References

When considering computer color formulation to limit metamerism, it is crucial to consider the operational framework of the algorithm. Metamerism arises from variations in the lighting environment in which objects are presented. Therefore, the framework in question pertains to the lighting references for which the algorithm must generate non-metameric recipes. Light plays a significant role in the field of conservation, covering both preventive conservation and the visual appreciation of artworks. Since the early 21st century, experts in lighting have advocated for museums to adopt LED lights, aligning with current exhibition lighting guidelines that emphasize the urgency and advantages of this lighting source. However, in practice, LED lights have not universally become the standard, primarily due to various reasons associated with the economic considerations of rethinking lighting strategies in institutions and more conceptual factors. For instance, some alternative light sources provide unique renderings that contribute to creating specific atmospheres for understanding artworks. Nevertheless, practical investigations conducted in exhibition spaces during this study revealed that the majority of lighting devices are LED, while in conservation studios, fluorescent tubes appear to be the predominant artificial lighting source. In this context, we choose to select four reference lighting sources for the generation of non-metameric recipes using the computer. We selected two CIE illuminant standards, D65 (daylight) and A (incandescent), along with two high-quality real sources: one LED and one fluorescent tube. The former two represent the lighting commonly encountered in a well-established conservation setting, anchoring our research in practical reality.

Methods

Defining Color Reference: Colorimetric study of Delft earthenware panel

The initial step of the method involved establishing the reference color for the computer formulation process, based on the colorimetric analysis of twelve Delft plaques. We conducted measurements using a spectrocolorimeter Xrite i1 Pro® set for a 2° observer under D65 illuminant. Reflectance was measured across the spectrum from 376 nm to 730 nm at intervals of 10/3 nm, resulting in 107 measurement points for each coordinate. For each plaque, 20 points were measured, strategically distributed across 5 points within each colored area, which included the white background, light blue, medium blue, and dark blue regions [**Fig.5**]. Reflectance spectra were then generated and subsequently compared for analysis [**Fig.6**].

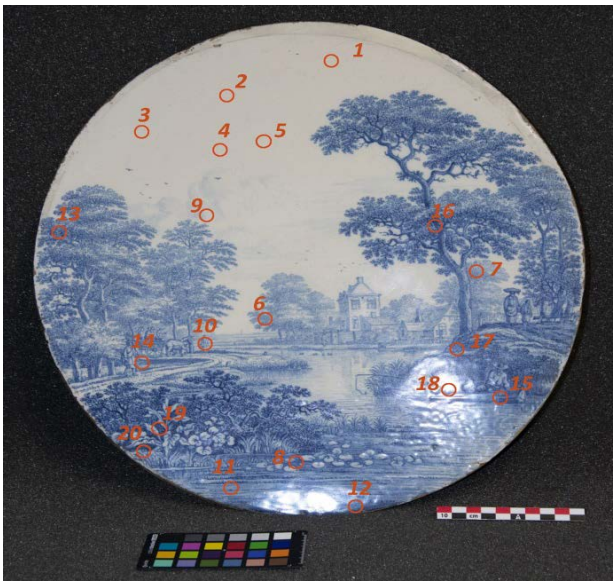

Fig. 5. Example of the measured point on one of the plaques.

We noted substantial similarities in the blue tones, all displaying a distinctive peak around 560 nm. However, discernible variations were observed, particularly in the very light blues and white backgrounds [**Fig.7**].

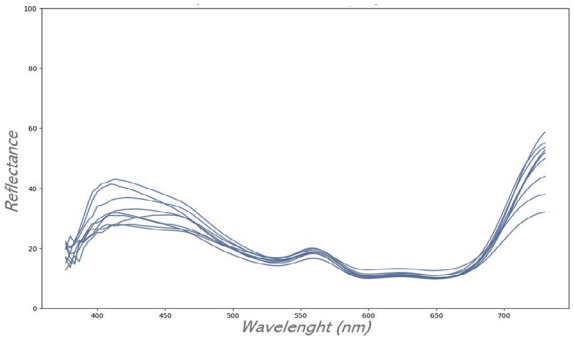

Fig. 6. Reflectance spectra measured for the medium blue shade on the Delft plaque panel.

When working with blue and white earthenware, it is crucial to note that, unlike paintings where the ground and pictorial layers remain separate, the blue enamel and tin-glazed background fuse together during the firing process. As a result, the intensity of the blue is influenced by its concentration in the white tin-glaze; darker blues indicate lower concentration in the white, whereas lighter blues reveal a higher prominence in the white. In earthenware, the white is not purely reflective due to the composition of the glaze and the origin of production, often manifesting as a greyish tone with subtle hints of red, green, or yellow.

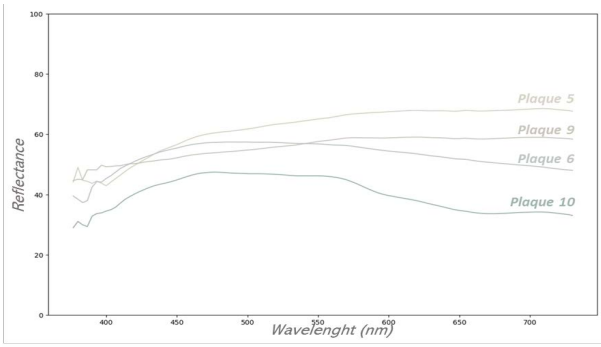

Fig. 7. Reflectance spectra of the white background on four plaques display significant differences

Comprehending the material characteristics of earthenwares is essential to understand this influence on both visual appearance and reflectance of the blue. Based upon the findings of the colorimetric study, we hypothesized that the creation of a 'universal Delft blue,' a reliable reference color for computer color matching, required isolating the blue's reflectance from that of the white. Thus, we treated the blue as a transparent colorant applied to a colored background, a method more aligned with conservation practices. We noted that conservators frequently employ a two-step chromatic reintegration process: ini-

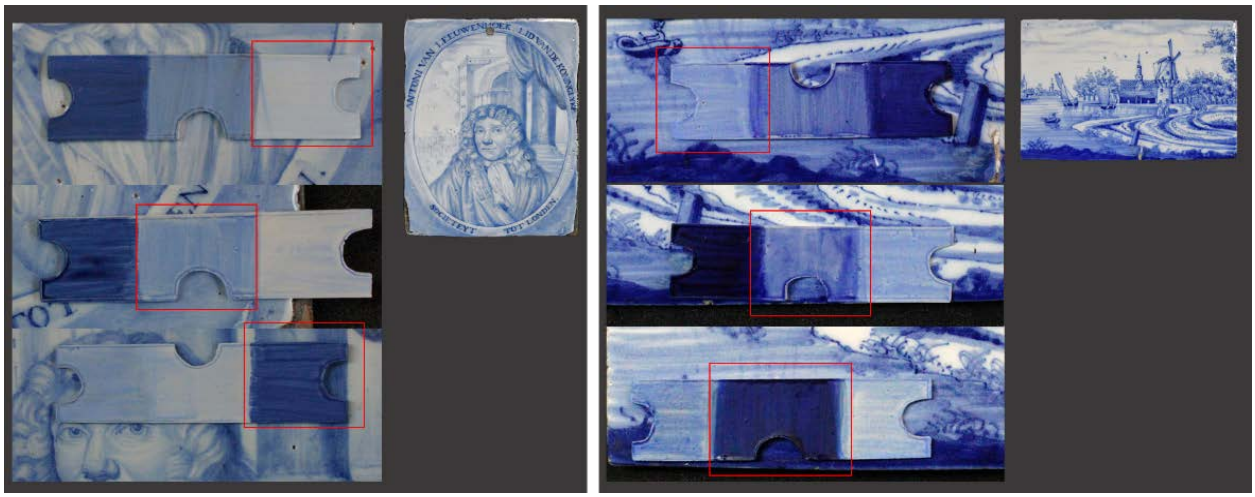

Fig. 8. Examples of samples created to replicate the blue tones of the five selected plaques using each of the seven recipes.

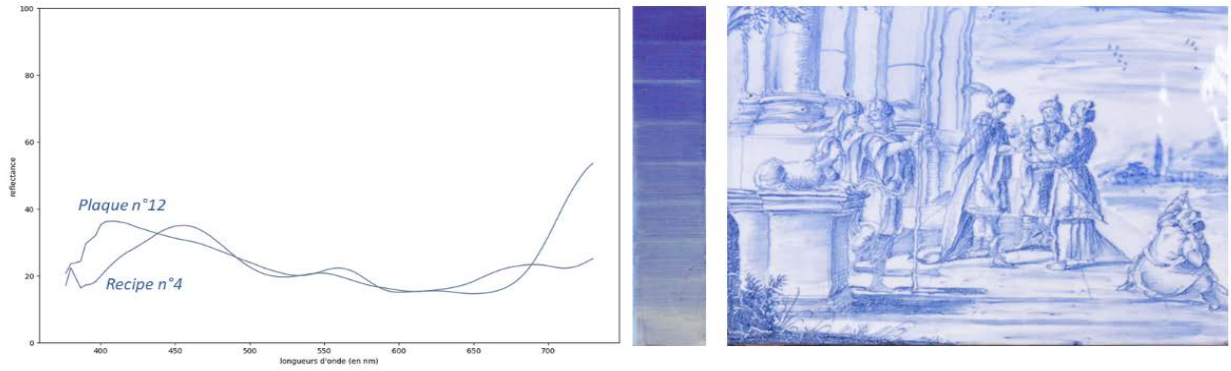

Fig. 9. Comparison of the reflectance spectra of one of the plaques and recipe number 4. The graph shows that the two colors form a good metameric pair.

tially, applying opaque retouching to background tones, followed by reintegrating decorative elements through layered, more or less transparent paint applications.

Formulation of Paint Recipes

The algorithm employed for color formulation was specifically developed by the artist Adrien Lucca. It was designed to consider all the previously selected parameters and propose recipes consisting of Titanium white along with two additional pigments. Limiting the number of pigments was a deliberate choice to optimize the algorithm's outcomes. Restricting the number of pigments in the recipes enables a more precise prediction of paint mix behavior under different lighting conditions. Furthermore, the observation was made that conservators often use more pigments than necessary to reproduce colors, whereas, in reality, only two pigments are frequently sufficient for this purpose. Another significant aspect of this research was a shift in focus. Instead of striving for a completely non-metameric paint mixture, our goal was to create a color that could exhibit slight metamerism, imperceptible to the naked eye within the tolerance level of human vision.

To facilitate data analysis, recipes were formulated for only five out of the twelve plaques, as they all shared similar colorimetric properties. The computer generated all possible recipes for the 75 points measured in the blue area on the selected plaques.

Results and discussion

Following the formulation process, the computer-generated thousands of recipes, specifying precise concentrations for each of the three pigments (Titanium White + 2 pigments). However, as the intention was to tailor the method for studio practice, the concentrations were in-

tentionally disregarded. By solely considering pigment composition, we initially obtained 122 recipes. To narrow down this number, we ranked the recipes from the most recurrent to the least. Through this selection process, we isolated 7 recipes involving 8 pigments [Table 1].

Table 1. Composition of the selected recipes.

Recipe	Pigment 1	Pigment 2
1	Anthraquinone Blue	Ultramarine Blue
2	Anthraquinone Blue	Ultramarine Violet
3	Anthraquinone Blue	Dioxazine Violet
4	Phtalocyanine Blue (Green Shade)	Ultramarine Violet
5	Anthraquinone Blue	Quinacridone Magenta
6	Anthraquinone Blue	Quinacridone Red
7	Anthraquinone Blue	Quinacridone Violet

Interestingly, these pigments primarily comprised very vivid colors, predominantly blues, purples, and reds. This was initially surprising, considering that the Delft blue sought for reproduction tended to exhibit more greyish tones. These observations prompted practical tests and sample trials. The first set of experiments involved applying each of the seven recipes to two backgrounds: one requiring a perfectly white base (achieved using Titanium White), and the other aiming for a Delft-like white (prepared using Titanium white + Raw umber + Raw Sienna). These experiments revealed that the bright blues, once applied to a colored background, produced subtle blue tones suitable for mimicking Delft Blue. Subsequently, the second round of tests aimed to match three shades of blue (light, medium, and dark) for each plaque using the seven recipes resulting in 105 color samples [**Fig.8**]. The visual outcomes were highly promising and were further validated by spectral and colorimetric assessments related to metamerism [**Fig.9**].

Additionally, we observed a consistent color shift—slightly redder under LED light— in both the ceramic and paint samples. However, this change remained imperceptible to the naked eye, indicating that both the original material and the retouched area displayed similar behavior, affirming the efficacy of our method.

Simultaneously, our study allowed us to identify pigments more prone to inducing metamerism. Interestingly, it suggests that Cobalt-based blues, such as cerulean blue, should be avoided. This recommendation is notable, considering that blue decorations in ceramics are traditionally produced using Cobalt oxide.

Conclusions

The improvements made to the method enhance its adaptability for everyday practice, enabling us to propose guidelines for retouching blue ceramics. We cannot overemphasize the importance of conducting retouching under good-quality lighting, preferably LED. It is noteworthy that a recent European law will phase out fluorescent lighting in 2024. We encourage museum professionals and conservators to adjust their lighting environments accordingly. Additionally, we recommend a two-step approach for chromatic reintegration: mimicking the white background using a tinted filling or paint layer, and reproducing decorative elements using the developed methods.

This method is centered around three key points. Firstly, conservators should select one of the seven proposed recipes based on personal preferences and the object being treated, adhering to it throughout the entire retouching process. Some recipes are more suitable for greenish blues, while others work better for paler tones. Secondly, conservators should also minimize the number of pigments used for chromatic reintegration, employing only two pigments for each layer in addition to black and white. Lastly, we found that adjustments to the retouching color can be achieved solely using Titanium white and Carbon black. These pigments do not interfere with the paint mix's reflectance spectra signature while allowing conservators to create lighter, darker, and grayer tones.

In conclusion, this study affirms the utility of computer color-matching in limiting metamerism during the chromatic reintegration of blue ceramics.

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Gaelle Silvant holds a Master's degree in Conservation of Ceramics and Glass (2023) from La Cambre, Brussels, Belgium. Her Master's thesis focuses on the chromatic reintegration of Delft blue and white ceramics, addressing the issue of metamerism. Her training encompassed several internships in museums, including the Musée National de la Céramique de Sèvres in Paris and the Royal Museum of Art and History in Brussels, conservation-restoration laboratories, and various private studios.

Since 2009, **Adrien Lucca** has developed a multidisciplinary body of work around color and light that questions our perception of the physical world. In search of practical means of action to set up aesthetic experiences, he has set up a research and production laboratory where he autonomously conceives his works at the intersection of art and science. Lucca believes that one can highlight the strangeness of the link between the physical world and our perception of it by appropriating scientific and technological resources. His most recent work aims at redefining the very concept of "color".

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THE INFLUENCE OF HISTORICAL INTERVENTIONS ON THE PRESENTATION OF ECCLESIASTICAL ART FROM THE CROATIAN ADRIATIC COAST

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Abstract

On the Croatian Adriatic coast, the conservation profession is dealing with works of ecclesiastical art that have been repeatedly restored, reconstructed, repainted or transformed due to damage caused by environmental conditions, the need to fit into a new setting and/or changes of stylistic and aesthetical preferences of the community and the owner. This paper illustrates various issues practitioners face when conserving artworks affected by the turbulent past, overpainted and subjected to amateur interventions or historical conservation treatments, often resulting in visual discontinuity and illegibility of the artistic unity. On the example of two-panel paintings and painted relief depicting the Virgin and Child, conservation materials and techniques applied throughout history are examined, focusing on aesthetic revaluation in accordance with contemporary ethics elaborated by Salvador Muñoz Viñas. These three different studies outline the valorization of the totality of aesthetic, historical, and conservation changes with a review of different chromatic reintegration and presentation options.

Keywords:

social context of artworks,

historical interventions,

conservation valorization,

chromatic reintegration,

visual presentation

Introduction

In this article, through three works of art from Dalmatia from the 15th century depicting Virgin and Child, various problems related to the presentation of artworks will be elaborated on regarding the influence of historical interventions that condition conservation approaches and methods. In Dalmatian conservation practice, since 1954 such decisions have been made in cooperation between art historians, conservators, restorers, owners and users (Šustić, 2016). Guidelines for this kind of thinking can also be found within contemporary conservation theory. As stated by Muñoz Viñas the contemporary criteria for the chromatic reintegration of a work of art differ from case to case, implying critical judgment of the conservator obliged to interpret the structural, visual and historical values of the work of art, based not only on scientific truths but also taking into account the function, value and meaning of the artwork in a wider context concerning the people who are the end users (Muñoz Viñas, 2017).

Case study 1: Virgin and Child (The Lady of Weeping), Cathedral of St. Jacob, Šibenik. A 15th-century, unknown artist, tempera and gilding panel painting. 62,5 cm x 50 cm

The first example of this practice is the image of the Virgin and Child, Our Lady of Weeping, which is located on the Main Altar of the Šibenik Cathedral of St. Jacob, a Renaissance masterpiece of George the Dalmatian and Nicolas of Florence, which is the central place of life in Šibenik. "Miraculous Lady" is an event that had great significance for the city of Šibenik and the cathedral because it gathered citizens in very difficult historical moments around this most revered and perhaps the most important icon in the past of this small commune. About this, don Krsto Stošić relays the record of the chronicler Daniele Farlati- from May 1635, when Our Lady in the picture cried (Farlati, 1769). After the miraculous event was established by court proceedings and hearing witnesses, the painting was transferred to the cathedral from a niche on the defensive wall next to today's theater, which was the outer edge of the (then) fortified city. In 1635, the image of Our Lady of Weeping was placed on the canteen of the main altar, in a silver box above the stone tabernacle. The altar was built in its entirety by Sepot and completed by 1638 in honour of this venerated image.

Owing to the archives of the Conservation Department of the Ministry of Culture and Media in Split, it was possible to research the documentation of the conservation and restoration of the icon carried out in the Workshop of the Regional Institute for Dalmatia in 1966 and 1967. The photographs of the found condition from 1966 show the extent of conservation and restoration of the painting, which were carried out at the end of the 19th century. It is not difficult to imagine the extent of damage to the wooden support and the painted layer if we know that the painting was placed on the outer defensive wall, car-

Fig. 1.- 3. The painting "Lady of Weeping "– first evidence of historic overpaint from the 19th century (Photo: archive of the Conservation Department in Split, 1967)

ried in processions where tears were wiped away as part of a vow to Our Lady, and kissed and touched in prayer (don Krsto Stošićmentions the custom wiping away Our Lady's tears with a handkerchief when the painting was available to the public on holidays, processions or when it was exhibited in the nave of the cathedral). (Stošić, 1935)

Conservation intervention, 19th century

In addition to major damage to the wooden support, which was replaced by inserting new wood, it is evident that the faces of the Virgin and Child were completely erased and replaced with a complete overpaint featuring expressionless, typified physiognomy.

Conservation intervention, 1966 – 1967

The conservation intervention 1966 – 1967 included making a new cradling for the wooden support and removal of overpaints, revealing complex problems due to missing flesh paint. In the spirit of the times, it was decided to copy the faces of the Virgin and Child Jesus from the polyptych of the great master Blaž Jurjev of Trogir. Blaž Jurjev from Trogir, 1390 - 1450, the most significant representative of the so-called "Dalmatian school of painting". It combines the spirit of late Gothic style with a number of personal and local characteristics. typology of long faces with almond-shaped eyes and specific painting of palms and fingers. During the restoration of the polyptych from Čiovo in 1961, his autograph was discovered, which led to the completion of his oeuvre according to archival data.

Fig. 4. The painting Virgin and Child after conservation intervention 1967 (Photo: archive of the Conservation Department in Split, 1967).

Fig. 5. Backing of the painting with cradling done in intervention 1966 (Photo: G. Tomljenović, 2015).

Apart from the fact that Blaž's oeuvre was then already systematically researched thanks to the restoration works, this choice was supported by the same dating (late 15th century) as well as the fact that the works of Blaž Jurjev Trogir are found in almost all cathedrals in Dalmatia (Prijatelj, 1965).

Conservation-restoration treatment, 2015 - 2018

The painting was restored in Croatian Conservation Institute, Split Department for Conservation, in 2015 – 2018 by Branko Pavazza, Conservator-restorer consultant.

After inspecting the archival material and collecting documentation on historical interventions, the original technology and materials of the painting were researched. Paint layer investigations and multispectral imaging additionally showed structural surface damage to the wooden base and layers of the painting, but almost no traces of the original layer of paint were found on the faces of Our Lady and the Child.

Damage to the painted layer and gilding is considerable on the entire surface of the picture, and the preserved remains of paint and gilding are worn and in many places have disappeared or are preserved only in microscopic particles of the original colour. The damage on the faces of the Lady and the Child is specific and radical because the painted layer is completely lost, except for very small

remains around the eyelids of the Lady. The probable reason is the frequent touching and kissing of revered faces, as don Krsto Stošić mentions in his book (Stošić, 1935) . The face of the little angel next to Our Lady was not treated in this way and is the only face through which we can see the colour, texture of the flesh tone and the exceptional, original quality of this painting.

Fig. 6. Craquelure found in the paint layer of the Angel (Photo: G. Tomljenović, 2015)

Fig. 7. Child's head overpainted in the historical intervention. (Photo: G. Tomljenović, 2015)

Fig. 8. During the removal of rigid metal cradling (Photo: Branko Pavazza, 2017)

Fig. 9. The back of the icon with flexible wooden cradling. (Photo: Branko Pavazza, 2017)

The rigid metal cradling made in the last intervention caused cracks in the wooden support and the painted layer, which is why the backing of the icon was reinforced with new flexible wooden cradling. Historical interventions on the paint layer (oil retouches and overpaint, artificial gilding, putty of past interventions) are removed mechanically, using microscopic magnification.

In agreement with the experts from the Conservation Department in Split, it was decided to keep the overpaint from the 1967 restoration. A partial new retouch of both faces was carried out, i.e. adapted to the way of painting the flesh found on the original, preserved face of the angel, which helped to achieve a certain uniformity of the painter's expression. The overall procedure enhanced the visual reading of all the preserved original painted layers and thus restored this severely damaged and revered painting to its integrity as much as possible (Pavazza, 2019).

Fig. 10. The icon before conservation. (Photo:Goran Tomljenović, 2015).

Fig. 11. The icon after conservation. (Photo: Jovan Kliska, 2017).

Case study 2: Virgin and Child, Church of the Holy Spirit, Hvar, island Hvar

The case study 2 is from the last quarter of the 15th century, an unknown workshop; is a relief replica of the stone relief of Antonio Rossellini, a polychrome relief of the paper mâché with the dimensions 71 cm x 48 cm × 6 cm. Another example that significantly shows the difference in the approach to chromatic integration is guided by ideas that can be sublimated in a theoretical guideline R. Arnheim:

"A loss can increase or decrease its magnitude in direct proportion to its location within the pictorial composition. For example, when the retouching of the significant figural loss is located in the centre or near the centre of the painting it tends to draw more attention from the observer, than if it was placed near the marginal area of the artwork. Thus, the treatment of central lacunas is the most delicate one and needs to be executed with great prudence and accuracy so that the authenticity of the artwork, in its aesthetic and historical aspects, remains intact" (Arnheim, 1982).

Central lacunas were particularly evident on the polychrome relief of the paper mâché Virgin and Child from the Church of the Holy Spirit on the island Hvar which is placed on the side altar made by Zefferino Grassi in 1898. The relief represents the miraculous image of Our Lady with Child, which according to legend was located in the basement of the nearby Stanić house. The brotherhood takes care of the church to this day, with special devotion to the miraculous image of the Mother of God (Kovačić, 1982). Considering the quality of the workmanship and the polychromy, it is probably a direct cast of the marble original known as the "Madonna delle Candelabre" by Antonio Rossellini (1427-1479). (Budicin, 2015) It is a lost marble prototype with the composition of the Virgin with candelabra. During its history, the relief has been repainted several times. In 2001, it was restored on the occasion of the "Tesori della Croazia, Restaurati da Venetian Heritage" exhibition held in Venice. (Caglioti, 2001)

Copies of Antonio Rossellini's stone model were cast in plaster, terracotta, stucco and laminated paper (Italian cartapesta), polychromed and gilded, and were mostly intended to decorate small household altars. This iconographic solution was extremely popular during the 15th century throughout the area of Florentine artistic influence. The information that this particular relief was found in the basement of the family house speaks in favour of this theory. The moving of the image to the church and

the construction of an altar for it is attributed to a series of miraculous healings after devotion to the image. (Kovačić, 1982)

Historical interventions

Several historical interventions of the relief were detected. The first overpaint probably happened in the 19th century, while the second took place during the 20th century. By that time the relief was decorated with jewels and metal crowns. The third conservation treatment happened in Studio Scarpelli 2000 – 2001.

Fig. 12. The Virgin and Child before conservation in Studio Scarpelli (Photo: Ministry of Culture and Media Conservation Department in Split archive, D. Domančić, 1971).

Fig. 13. Detail with visible overpaints from historical interventions. (Photo: courtesy of Studio Scarpelli, 2000).

Fig.14. During conservation and restoration in 2001 in Studio Scarpelli - removal of overpaints (Photo: courtesy of Studio Scarpelli, 2000).

Conservation-restoration work by Studio Scarpelli, 2000 – 2001

Fig. 15. Details of the reconstruction of damage tothe painted layer: the blue background, halos and Child's hair using natural retouch (Photo: P. Gamulin, 2020)

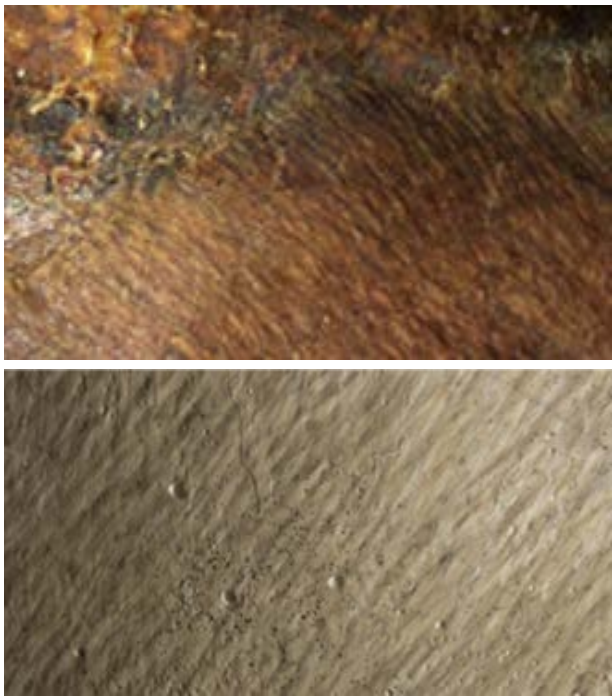

Fig. 16, 17. Details of the reconstruction of damage to the painted layer using the *tratteggio* technique: Our Lady's Brown Hair and Child's Leg - intervention from 2001. (Photographs under Microscopic Magnification: N. Tomašević, 2022)

Fig. 18. Details of the reconstruction of damage to the painted layer of the The child's leg using the *tratteggio* technique (Photo: P. Gamulin, 2020)

Because of the delicate support made of laminated paper and fragile polychromy, the overpaints were removed under a microscope, and the extremely sensitive original painted layer was consolidated throughout the entire conservation procedure. To improve the appearance of the original, most of the losses were retouched using neutral tones. A retouch of the damage on the flesh tone located on the central figures was performed with *tratteggio* technique (underpainting in tempera and glaze with Canada balsam varnish).

Recent conservation at the Croatian Conservation Institute, 2020 - 2022 (Lujić, 2022)

The painting was restored in Croatian Conservation Institute, Split Department for Conservation, in 2020 - 2022 by Zrinka Lujić, Senior conservator-restorer.

As part of the works of preventive conservation of the collection of liturgical objects of the Church of Holy Spirit in Hvar in 2020, the condition of the relief was inspected. The adhesive properties of the original painted layer degraded and both figures suffered losses. Concerning the conservation treatment in Florence about twenty years ago, diagnosing the cause of the rapid deterioration of the original painted layer on the relief was necessary to prevent major losses. The object was placed in the controlled microclimate conditions of the Restoration Department in Split to consolidate the unstable painted layer and reconstruct the lost parts.

Fig. 19. Condition of the paint layer (Photo: N. Tomašević, 2022)

Fig.20. Condition of the paint layer (Photo - side light: P. Gamulin, 2020)

Sampling for microchemical and instrumental analyzes in laboratories and multispectral imaging of the relief were carried out. The cause of the unstable and very fragile painted layers was determined by the radiographic technology of computed tomography (MSCT) – a three-dimensional range of projections through the relief discovered zones of air gaps where the painted layer is separated from the support, distributed over the entire surface of the figures.

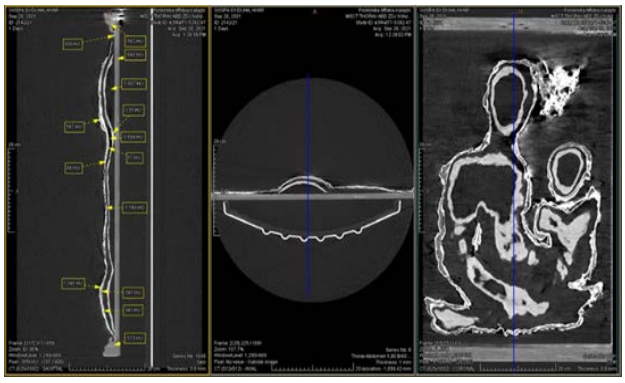

Fig. 21. On the MPR (Multiplanar Reconstruction) image sections of the relief recorded by computed tomography on the sagittal section HU values of the material are marked, and on the transverse and frontal sections the location of the sagittal section of the relief is marked with a blue line (Photo: bacc. Rad. Tech. A. Sokol, Polyclinic Affidea Kalajžić, 2021, computer software processing: A. Grga, 2023).

Fig. 22. Graphic representation of the relief with markings of the air space zones between the painted layer and the paper mâché support, which are recognized on MSCT recordings (Graphic made by: N. Tomašević, 2022).

The main challenge of this restoration was to find a balance between:

- leaving visible traces of the object's history,
- respecting the concept of the past restoration,
- the sensitive condition of the construction materials of the artwork itself,
- conservation ethics (respecting the technology using materials compatible with the creation of reliefs) as well as aesthetics.

This is precisely why reinforcing the areas of the undamaged painted layer that detached from the support required the design of an optimal physio-chemical method that should meet the requirements of the support and the painted layer of different hydrophilicity, as well as the need for as more viscous glue as possible that can penetrate through small cracks. Respecting the original technology of this painted relief, animal glue injected with a Winnie consolidation pen tool with heat regulation for precise application was used for undergluing. By increasing the conductivity of the treated zone of paint and glue with alcohols, the penetration process was accelerated, and the unstable painted layerwas successfully bonded.

The missing parts of the ground layer were reconstructed with materials compatible with the technology of making the painted relief. During the work, it was noticed that the

traditionally used chalk ground is not suitable for paper support due to its weight so a lighter, more compact variant was designed with better adhesion to the edges of damaged areas. Due to the sensitivity of the artwork material and the need to avoid any unnecessary vibrations during the processing of the ground, the reconstruction of the ground layer was performed under the microscope via injection. The aim was to apply it as accurately as possible and with minimal corrections of surface texture using a scalpel.

The concept of the visual presentation of the relief from the last restoration carried out in Studio Scarpelli has been partially modified. In this sense, losses of the painted layer in the zones of the Virgin and Child flesh tones were reconstructed using integral retouch in watercolour glazed with resin varnish colours, depending on the condition of individual parts of the original and following the retouch from 2001. Paint losses in the lower part of the relief and gilding on the halos were kept and presented with a neutral retouch from the previous restoration. All other loss reconstructions in the painted layer, toned in brown and azure neutral retouch as part of the previous restoration, were covered with watercolour according to the given original colour, which contributed to the integrity of the artwork and facilitated its visual reading.

The aesthetic integrity, important for the revered miraculous icon in the cult was respected, as well as the most important requirement: the return of the artwork in the altar built specifically for it. In the Hvar church of the Holy Spirit, it is safeguarded by the Brotherhood and venerated by the local community of believers.

Fig. 23. The relief before conservation (Photo: P. Gamulin, 2022)

Fig. 24. The relief after conservation (Photo: P. Gamulin, 2020)

Case study 3: Virgin and Child, Church of Our Lady of Stomorija, Gornje Selo, I. of Šolta

15th century, unknown artist; panel painting (icon), egg tempera on wood, 32,8 x 80 x 3 cm

The third example shows us that there is no right or wrong approach to the chromatic integration of art, but only attunement to the original layers of the work of art as well as the intertwined circumstances in which the interaction with the environment takes place. Paolo Mora's thoughts seem to reflect the condition and work on our third example, his sentence most clearly depicting the direction in which the conservation and restoration were carried out:

In general, some losses can be very difficult to repair, e.g. figural losses that dominate areas of the face making the personality of the figure invisible. These are cases that could require archaeological intervention, to preserve the historical aspect and avoid the loss's prominence about the image. (Mora, 1984)

The painting of the Virgin and Child from the 15th century is located in the Marian shrine, in the church of Our Lady of Stomorija (Our Lady of the Pines), on the Island of Šolta in the village of Gornje Selo. 'The history of the sanctuary is connected with the church that was built on the territory of the former Benedictine abbey, under which a late antique sacral layer was recognized. It should be emphasized that today the church has been turned into a burial chapel, far from the sparsely populated village. This posi-

tion on the island and the function of the church, which is rare (holding funerals and the Feast of the Assumption) are security factors that guided the handling and treating of this valuable artwork. (Island Šolta: monograph, 2012) On the eve of the Feast of the Assumption, the painting becomes part of the festive procession.

The image is placed on the main altar in a marble niche. A silver relief cover is attached to the painting, which covers almost the entire painted surface, except for the faces of the Virgin and the Child. Copper crowns decorated with red and green precious stones are also applied to the figures. The Virgin is depicted on the throne as a heavenly queen holding Jesus on her lap in front of her, which corresponds to the oldest iconographic type of the Virgin in Byzantine painting, the so-called Kyriotisse ("She who reigns in glory"). (Demori, 2017). However, the position of Jesus and of the Lady's hands indicate the Hodegitria type of representation. Traces of a halo can be seen in the area of the Virgin's head, and her feet are not on the ground, but are placed on a wooden plinth according to the Byzantine ceremonial protocol. The Virgin on the throne with the Child Jesus in her arms is a common theme in medieval art. (Badurina, 1990)

Historical interventions

Conservation intervention, 19th century

In addition to the natural decay caused by time and the action of biological invaders, the complex state of the mentioned painting is largely caused by the human factor, i.e. the results of restoration procedures carried out in the past. The picture shows traces of two restoration interventions that affected the original appearance of the work. The historical interventions in the picture have been researched and documented in detail. (Šustić, 2014)

Fig. 25. Graphic representation of the second historical intervention in the current state of conservation, (Graphics by S. Š. Cvetković, 2017)

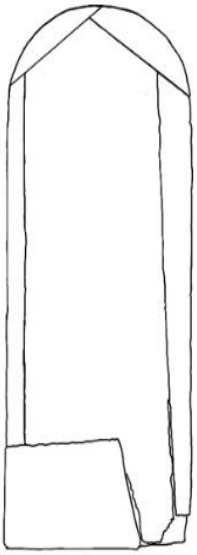

Fig. 26. Graphic representation of the wooden structure - The central panel is original, and the side panels have been added (Graphics by S. Š. Cvetković, 2017)

Fig. 27. Visual interpretation of inserting picture into a wooden structure in the 19th century - first intervention, (Design: D. Gazde, 2019)

The first intervention in the painting dates from the 19th century. Although from today's point of view, it was a radical operation, the restorer at the time, bearing in mind that it was a miracle-working painting of Our Lady, somehow conserved it and hid it in a "safe" place, under a newly painted layer. At the moment when the worm-hole-infested image came into his hands, he estimated that only by reducing the image format would he prevent its further deterioration. Therefore, in the upper part, he cut its arched end in the shape of a triangle. He slightly narrowed it on the sides and also reduced its larger square fragment in the lower part. He placed the picture on a monolithic wooden panel and replaced all the other missing parts with wooden slats (two lateral slats, two that form an arched end in the upper part, and a square slat in the lower part). With the mentioned construction with these additions, he compensated for the assumed dimensions of the image.

Conservation intervention, 1963

The second intervention from 1963, carried out at the Conservation Institute for Dalmatia, included the conclusion of restorer F. Dobrošević that the painting was copied, but also that the painted layer was badly damaged. He did not decide to further remove the replicas, but repaired the existing damage with a wax mixture and directly reconstructed the head of the Virgin and Child with oil paints.

Fig. 28. – 32. Archives of the Conservation Department in Split. The found condition of the painting in 1962 with and without silver covering, and a picture in the process of dry cleaning – intervention 1963.

Conservation at the Croatian Conservation Institute, 2013 - 2017

The painting was restored in Croatian Conservation Institute, Split Department for Conservation, in 2013 - 2017 by Ratka Kalilić, Senior conservator-restorer.

Several historical interventions were investigated, along with a detailed analysis of painting technology, i.e. the materials used (pigments and binders). IC, UV and X-ray imaging was performed. The results of thorough investigative work have contributed to a better understanding of the sequence of interventions carried out on the artwork until today. Based on historical, ethical and technological valorization, and under laboratory research, it is still uncertain to what extent the original has been preserved. The radiographic image did not help understand the compositional elements, which is partly due to the interference of the materials used in the historical interventions.

Fig. 33. Probe of the segment of gilding in the area of the Virgin's head (Fig. 33.-35. photo: S. Šustić, 2013)

Fig. 34. Probing from the end of the 20th century, the original decoration on the edge of the mantle of the Virgin is visible.

Fig. 35. The original dark red painted layer in the Virgin's left-hand.

In 2013, old probes were found on the icon of the Virgin and Child, which were carried out at the beginning of the 21st century. Guided by restoration intuition and the belief that an extremely valuable original layer lies beneath the overpaint, the expert committee decided to completely remove the overpaints and present the painting in such a state of preservation. (Kalilić, 2019)

The conservation-restoration procedure of removing overpaints was performed exclusively mechanically, using a surgical scalpel under a microscope. This procedure revealed the icon's authentic appearance, original colours, textures and details that were covered by layers of overpaint. Following intuition, we came to the original painted layer on which important, hitherto unknown, elements were discovered. The discovery of the donor, most likely an Augustinian monk, is the most important discovery, but it is also worthwhile to mention the border on the mantle of the Virgin and the pomegranate, the Christian symbol of the Resurrection, which he holds in his left hand.

Fig. 36. and 37. Details of the painting after the removal of the overpaint from 1963, up to the outline of the Virgin's face and her left-hand holding fruit and a figure of small donor and her left-hand holding fruit and a figure of small donor (Photo: G. Tomljenović, 2017).

Fig. 38. Visual interpretation of the historical layers (viewed from left to right) - Original layer, copy in the 19th century, reconstruction of the face in 1963, the appearance of the image after the installation of silver fittings in 1963 (Design: Davor Gazde, 2017)

The presentation of the restored painting has been carefully planned to ensure that its beauty and authenticity are best highlighted while respecting the cultural, artistic and historical context. Considering the numerous losses of the original parts of the composition, the original painting is stored in the parish museum, while a copy will be made according to the original intended for the procession. Making copies is a challenging topic in the work of conservators-restorers, especially when it comes to objects that have been worshipped in sacred spaces for centuries.

Fig. 39. The icon before conservation, (Photo: D. Gazde, 2013)

Fig. 40. The icon after conservation, (Photo: G. Tomljenović, 2017)

The theory of the great connoisseur of icons Uspenski (Pavičić-Prijatelj, 1998), conveying the belief of icon painters that every new icon is a copy of the first portrait of the Virgin that St. Luka painted, encouraged us to proceed with this decision: the trace of holiness that fell on him in those moments also falls on every new painter who works according to the old template.

Conclusions

The main challenge of these conservations was to find the balance between leaving the visible traces of the history of the objects, the conservation ethics as well as the aesthetics and expectations of the recent owners. Through these three case studies, we wanted to emphasize that there is for each case, for each work, a new solution, which will satisfy both the public, which seeks aesthetic sensation and the conservation and restoration professional. However, it is important to note that this issue depends on the sociocultural environment in which it is set. (Ruhemann, 1968).

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Ivana Svedružić Šeparović graduated in art history and archaeology at the faculty of Philosophy on the University of Zagreb. From 1994 to 2017, she was employed as a senior advisor for movable cultural. Assets in the conservation Department of the Ministry of Culture RH in Split, and the Department for conservation and Restoration of the Art academy in split, where she teaches the course “Ethics and aesthetics in conservation-restoration “. Since 2017, she has been employed at the Croatian Conservation Institute in the position of Head of Division for Branch Departments 2.

Zrinka Lujić is currently employed as Head of Split Department for Conservation at the Croatian Conservation Institute. In 2000, she graduated in Art Academy University of Split as Professor of Fine Arts – Conservator-Restorer, since then she is working on paintings on different supports, on wooden artefacts and preventive conservation. In 2010, she is specialized in the restoration of paintings on different supports. She mentors’ trainees and students studying conservation-restauration on easel paintings in Croatia, as well as students on Erasmus program.

Ratka Kalilić graduated in 2002. at the Art Academy University of Split as Conservator-Restorer of easel painting and polychrome sculpture. Since then, she is part of the expert team during the conservation and restauration works at the Croatian Conservation Institute, Split Department for Conservation. In 2006., she is specialized the restoration of paintings on different supports. She is the manager of the conservation-restoration works of paintings on different supports.

THE USE OF TYLOSE® MH 300 IN THE CHROMATIC REINTEGRATION OF MATTE CONTEMPORARY PICTORIAL SURFACES

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Abstract

The chromatic reintegration of matte contemporary artworks poses countless challenges due to the artist's usage of new techniques and materials which result in surfaces that are extremely susceptible to physical and chemical damage and that tend to present alterations and losses that interfere with the comprehension of the artworks. To find compatible inpainting materials, several binders were prepared into samples, put through natural and accelerated aging tests, and evaluated for physical stability, chromatic and gloss variations, solubility, and removability. One presented an outstanding result: Tylose® MH 300 P2, a water-soluble non-ionic cellulose ether, highly matte and stable, with positive results on chromatic stability. To validate the tests' results in a practical context, Tylose® was used as a retouching binder for two artworks presenting characteristic problems of matte-surfaced artworks. It proved to be versatile, and easy to handle. This research aims that Tylose® becomes a viable alternative binder for retouching matte-surfaced artworks.

Keywords:

contemporary artworks,

matte surfaces,

chromatic reintegration,

binder, Tylose® MH 300 P2,

reversibility

Introduction

The chromatic reintegration of contemporary artworks poses countless challenges due to the artists' usage of new techniques and materials, many of which were not developed for artistic use. Among the main issues found at the chromatic reintegration phase are the use of incompatible materials, the use of modern paints – such as acrylics, vinyl, nitrocellulose, alkyd paints, dyes, etc., all of them having intense saturation and finely ground pigments –, the use of specific textures and voluminous impastos, the presence of color fields and flat uniform surfaces, the absence or excess of gloss in the paints, and the choice of leaving the painting unvarnished. All these factors result in surfaces that are extremely susceptible to physical and chemical damage and that tend to present alterations and losses that interfere with the comprehension of the artworks (Scicolone, 2002).

It should be highlighted that artworks with smooth and delicate surface finishes tend to pose the biggest problems for inpainting: the interruption of the homogenous pictorial surface can cause an irreparable loss in the artist's message, and a perfect *mimetic* retouching may be impossible to achieve (Santabárbara Morera, 2016; Schinzel, 2003; Scicolone, 2002). This is especially true in monochromatic artworks, in which space is created through gradual changes in color and/or gloss. Consequently, any alterations on the surface gloss can cause great disturbances on the work's spatiality, and the simpler the composition and the fewer the colors that are used, the more disturbing the alterations seem (Llamas Pacheco, 2009; Mezzadri and Sidoti, 2020; Santabárbara Morera, 2016; Schinzel, 2003).

A matte surface is characterized by diffuse superficial reflection, which means the incident light is dispersed in all directions (Johnston-Feller, 2001). Although a matte surface is not always an intentional choice by the artist, being only a consequence of the chosen material or its aging, it becomes an essential characteristic of the artwork's appearance. Added to that, generally, is the absence of a varnish layer, an intentional choice by the artist (Llamas Pacheco, 2011). Unvarnished matte surfaces are very susceptible to abrasions, grease deposits, stains, and yellowing, especially around the borders of the artwork due to bad handling and the usual absence of frames by choice of the artists (Llamas Pacheco, 2009). The conservation intervention itself can cause damage to such sensitive paint layers, such as abrasions, friction, and polishing of areas during the cleaning process, or tide marks after aqueous cleaning treatments or chromatic reintegration, drawing more attention to the damaged area (Mack, Sturman and Escarsega, 2007).

Regarding contemporary artworks with matte surface finishes, traditional reintegration materials don't always provide satisfactory results: since they cannot mimic properly characteristics such as the saturation and the luminosity of the colors, the finely ground pigments, or the surface gloss, they tend to create a visual disturbance (Llamas Pacheco, 2009; Mezzadri and Sidoti, 2020; Sims, Cross and Smithen, 2010).

Even though there isn't one ideal or perfect material for use on every occasion – each presents advantages and disadvantages –, having a broad range of versatile possibilities will facilitate the selection-making process, based on the different characteristics of the artwork's surfaces (Jacqmin and Soldano, 2020).

Experimental

After bibliographical research and aiming to find alternative binders for the chromatic reintegration of matte contemporary artworks, a technical study was made using six different binders. They should fit the fundamental criteria of reversibility and stability, and also present a desired versatility, especially regarding gloss levels. Other desired characteristics were the ease of handling and preparation, durability, and their applicability regarding different artists' techniques and practices.

Considering the general sensitivity of the most usual paints used in contemporary art (acrylics, vinyl, oils) to

most solvents – even hydrocarbons with low aromatic content –, it was defined that the binders should be soluble and reversible in adjusted water, which is deionized water with its pH and conductivity altered by volatile alkalis and acids until the desired/appropriated value is obtained for different uses. For acrylic paint layers, the recommended pH is 6, and the conductivity is 6mS/cm. That should cause minimal swelling of the acrylic paint layers (Ormsby et al., 2015).

Materials

The six selected binders were gum arabic (a natural polymer), carboxymethylcellulose (CMC), Klucel® G, Tylose® MH 300 P2 (three cellulose ethers, semi-synthetic polymers), Aquazol® 500 (a synthetic polymer), and Lascaux Water Resoluble Medium (an acrylic based industrialized medium). After the whole set of tests, being them natural and accelerated aging tests, digital microscopy, spectrophotometric readings, and solubility and removability tests, followed by application in actual artworks in different media, the material that achieved outstanding results was Tylose® MH300 P2, the one to be discussed from this point onwards.

Tylose® MH 300 P2 (methyl-2-hydroxyethyl cellulose) is a non-ionic, cold-water soluble, medium viscosity (300 mPa·s) cellulose ether. It's used as an adhesive and consolidant for paper works (Bartolone et al., 2015; Carnazza et al., 2020; Kremer, n.d.a). It is considered an adhesive with good elasticity and malleability, easy to prepare, resistant, and fast drying, besides being atoxic, reversible, and biodegradable. Also, it has low adhesive power, which makes it more easily reversible (Bartolone et al., 2015). It must be noted that, due to the high-water content necessary in the formulations and the binder's high hygroscopicity, Tylose® shouldn't be used in water-sensitive substracts (Carnazza et al., 2020).

In previous studies found in the literature - most of them unrelated to its use as a binder for inpainting -, Tylose® has presented very good results: one of the most matte binders, with reflectance values inferior to 0.01 (Carnazza et al., 2020); very small color alterations in colorimetric evaluations after accelerated aging tests, being considered stable (Abdel-Kareem, 2005; Bartolone et al., 2015); some loss of elasticity after accelerated aging, and resistance to biodegradation (Bartolone et al., 2015); easy reversibility and no decrease in its solubility after accelerated aging (Bartolone et al., 2015; Feller and Wilt, 1990).

Each of the binders was prepared following proportion suggestions found in scientific papers, considering the goal of a matte result. No additives, such as dispersants, conserving agents, etc., were mixed in any of the binder solutions, to guarantee that any alterations found would be a result of the pure binder and its dispersion in water. The Tylose® preparation suggested by Carnazza et al. (2020) was a dilution of 2% in deionized water. The dilution took about 3 hours, resulting in a low-to-medium viscosity and slightly cloudy solution.

Three equal groups of samples were prepared with two different kinds of support, Fabriano® drawing paper, and an industrial acrylic-prepared linen canvas: a control group, a natural aging group, and an accelerated aging group.

The pigments used for the preparation of paints with the binders were Kremer® XSL Titanium White, reference #26000, very lightfast, easy to disperse in water and water-based binders (Kremer, n.d.b), and Kremer® Cadmium Yellow nº 4, light, opaque, and very lightfast (Kremer, n.d.c).

The acrylic paints used were Winson & Newton Galeria Acrylic™ Mixing White (color number 415), Series 1, Permanence AA ("extremely permanent"), Lightfastness I ("excellent"), PW6 pigment, composed of Zinc and Titanium (Winsor & Newton, n.d.a), and Winson & Newton Galeria Acrylic™ Cadmium Yellow Medium Hue (color number 120), Series 1, Permanence A ("permanent"), Lightfastness I ("excellent"), PY73 and PY83 pigments (Winsor & Newton, n.d.a).

The gouache paints used were Winson & Newton Designers Gouache™ Zinc White (color number 748), Series 1, Permanence A ("permanent"), Lightfastness I ("excellent"), PW5 pigment (Winsor & Newton, n.d.b), and Winson & Newton Designers Gouache™ Primary Yellow (color number 527), Series 1, Permanence A ("permanent"), PY74 and PY138 pigment, containing Quinophtalone (Winsor & Newton, n.d.b).

Each binder originated 12 samples, with total dimensions of 7 × 15 cm, in which were tested: white and yellow bound pigments (in a proportion of approximately 1:1 weight/volume), the pure prepared binders over the

support, as well as the binders over the acrylic paints and the gouaches, to evaluate the binders' behavior and interaction in different situations.

The application of the paints was done by paintbrush, straight from their packages and without any dilution. After their drying time, the binders were applied, also by brush. Each different binder was identified by numbers.

In the sample preparation stage, it was already possible to perceive some of the binders' characteristics, related to preparation, application, and paint consistency when mixed with the pigments. Tylose® resulted in a slightly viscous, easy-to-apply paint with good pigment dispersion and good covering power. Regarding the pure binder application over the acrylic and gouache paints, Tylose® originated relatively uniform films, although seemingly bulky, perhaps due to its viscosity. After the films dried, Tylose® presented a very discreet gloss over the paint layers but was completely matte when mixed with both pigments. In the paper samples, both the pure binder and the white Tylose® paint had the most matte results, while in the canvas samples, the pure Tylose® had the most matte results along the CMC.

Methods

Natural Aging Test

The samples set for the natural aging test were aged from March 6 to June 27, 2022. They were attached to the inner part of a transparent glass windowpane that was exposed to sunlight (with daily direct sunlight for approximately 5 hours) in the city of Porto, Portugal. The exposure was 115 days.

Accelerated Aging Test

The samples were aged in the Polytechnic Institute of Viseu, in a Q-SUN Xe-3 Xenon Test Chamber (Q-Lab), with xenon arc lamps and Window Glass filters, using the conditions of ISO 4892-2 norm's Cycle 5: dry condition, 50 W/m² irradiation, 300-400 nm, black panel temperature of 65 °C, chamber temperature of 38 °C, and 50% relative humidity. The total exposure time was 258 hours, which equals 55 years in museum conditions (100 lux, 8 hours/day, 6 days/week).

Besides the samples, another comparative aging parameter was put in the test chamber: a Blue Wool Scale. Before that, a third of the wools were covered, to evaluate the posterior alterations. After 258 hours, 6 of the 8 dyed pieces of wool presented remarkable alterations, with the 7th presenting subtle changes as well. This should correspond to a period of 50 to 100 years of aging (Materials Technology Limited, n.d.), a superior time than the indicated through the time exposure calculation.

Digital Microscopy

A Dino-Lite Edge Digital Microscope with the DinoCapture 2.0 Version 1.5.44B software was used to get macrophotographies from the samples before and after the aging tests.

Colorimetry

The readings in all sets of samples were done with a Konica Minolta CM-700d Spectrophotometer (standard illuminant D65 and standard observer 10°). Since the binder films weren't completely uniform, some readings were unequal. Hence, three readings were done in each division of the sets, and the arithmetic average of those was considered the definitive value (Johnston-Feller, 2001). The measurements are within the CIELAB color space, using the L*, a*, and b* values to calculate the ΔE*, meaning the color difference, through the formula $\Delta E^* = [\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*}2=^{2}]½$ (Abdel-Kareem, 2005; Freeman, 2021; Froyen and Postec, 2009; Johnston-Feller, 2001; Konica Minolta, n.d.).

Gloss Evaluation

The gloss changes were measured through the formula presented by Carnazza et al. (2020), ΔSCI-SCE(L*), using the spectrophotometer measurements from the colorimetry evaluation. According to these authors, "Making a comparison between the glossmeter 60° curve and the ΔSCI-SCE curve, it was possible to notice almost the same pattern. This evaluation allowed us to consider the reliability of the values detected with the colorimeter in relation to the reflected component." (p. 387). Hence, the higher the obtained value, the glossier the sample – even if the value isn't in Gloss Units, but in reflectance percentage.

Solubility and Removability Test

The solubility test was run on the three sample sets, in both supports, in the bound yellow pigment areas. Through a gentle mechanic rolling action with swabs dampened in distilled water, two aspects were measured:

the time and the number of rolling movements necessary to solubilize and remove the paint. The removal test would be stopped in case this action started to cause damage to the support. These tests evaluate the solubility of the paint, as well as the ability of the solvent to remove, ideally, the totality of the applied paint. The ease and the controllability of removing the materials were taken into account, observing any damage or changes to the support/ground layer and if the removal was complete (Froyen and Postec, 2009; Sims, Cross and Smithen, 2010).

Practical test on artworks

This section considers the desirable characteristics (gloss, color, solubility) and the adequate behaviors (viscosity, ease of handling, durability, drying time) of a binder when used as retouching media on actual artworks. The intervention was carried out on two different artworks, composed of diverse supports and materials that are representative of matte contemporary artworks.

The first one was an untitled painting by Maria Isabel Fraga Pereira (1948-), measuring 139 x 173 cm and belonging to the Faculdade de Belas Artes of the Universidade do Porto's collection. Its support is fibreboard with a wood structure glued to its back with PVA glue, prepared with a thin white ground layer, painted with plain color acrylics, and with superficial layers painted with an airbrush. It has some of the most characteristic features of contemporary artworks: matte finish, big areas of plain and homogenous colors, and areas with the characteristic airbrush texture. Chromatically, the palette is defined by the major presence of two colors, yellow and grey, with tonal and chromatic variations towards orange, red, and blue. The damages present in the artwork demand diverse approaches for their reintegration: there's abrasion, transfer, and accumulation of residues due to friction and rubbing between surfaces, grease stains, surface polishing by friction, loss of pictorial layer resulting from mechanical impacts (exposing the support and/or the ground layer), and dirt deposits all over the surface. Many of those damages result from the work's exhibition outside controlled environments, allowing direct contact and close circulation of people and objects.

The other artwork is Forma, Descriptio, Graphis, by Francisco Laranjo (1955-2022), painted in 1982, measuring 223.5 x 145 cm, and belonging to a private collection, yet deposited since 1994 in the Fundação de Serralves – Museu de Arte Contemporânea. It's an Indian ink painting on backdrop paper attached to a fiberboard support, probably with PVA glue. There is also a wood structure glued to the auxiliary support with PVA glue as well. It's unknown when the paper was affixed to the fiberboard, or by whom. However, it's noticeable that several tears were glued - with more or less refinement - during this intervention. It's unclear if those damages were the reason for the attachment of the secondary support or if they were caused by this operation, such as a central tear caused by bad manipulation, adhered with a large amount of wrinkles. As a result of the penetration of the PVA glue, the paper acquired a slight satin gloss and some slight tonal variation. The painted areas remained matte, though. The main damages identified were abrasions with partial loss of support (lifted paper fibers and loss of paint layer). All around the artwork, but especially on the edges, there were chromatic alterations caused by friction, like the polishing of the surface. The tears that were adhered inadequately presented lifted fibers and their consolidation was done in unconformity with the original position. The tears in the bottom of the work had been previously reintegrated with inadequate color matching. There were also tide lines in many areas around the edges of the work, being more visible where there was no paint layer.

Results and discussion

Of all of the tested materials, Tylose® MH 300 was the one that most positively distinguished itself, especially presenting the most matt results on the gloss evaluations and great gloss stability even after accelerated aging. In the following sections, the individual results will be discussed.

Digital Microscopy

On the control set, the paints composed of Tylose® MH 300 and pigment have a film with some body, homogeneously filling the spaces between the paper fibers, even if some of the bigger ones are still visible. The pure binder applied over the paper has a similar result, being the most matte of the tested binders. On canvas, the Tylose® paints generated a very homogenous matte film that didn't fill the whole topography of the support/ground layer.

On the natural aging set, there seems to be a slight de-

crease in the gloss of the pure Tylose®, but no other observable changes.

On the accelerated aging set, no visible changes are observable in comparison to the natural aging.

Colorimetry

According to the information gently provided by Professor PhD Luisa Hora de Carvalho, a standard observer recognizes color difference conforming to the following indicators: $0 < \Delta E < 1$ – no difference; $1 < \Delta E < 2$ – only an experienced observer notices any difference; $2 < \Delta E < 3.5$ – an inexperienced observer notices a difference; $3.5 < \Delta E < 5$ – the ibserver notices a clear difference; $5 < \Delta E$ – the observer perceives two completely different colors. Hence, considering that a ΔE inferior to 1 is the most desirable result, in the calculation between the control and the natural aging sets (Table 1), the best results were obtained by Tylose® and the Lascaux® medium, both with 3 out of 7 samples in this range. On canvas, Tylose® also had 3 out of 7 samples in this range.

In the calculation between the control and the accelerated aging sets (Table 1), the pigments bound with Tylose® presented results between 0.29 (yellow pigment on paper) and 1.19 (yellow pigment on canvas), demonstrating chromatic stability. The pigments mixed with Tylose® were among the best results obtained among all binders.

Gloss Evaluation

It must be considered that gloss changes vary according to diverse factors, such as the pigments present, the substrate, and the paint brands (Ormsby et al., 2007), which means the results obtained here aren't absolute and many variables are present.

In the control set (Table 2), the binder with less gloss on paper support is the Tylose®, with 0.1, while it has 0.13 on canvas. The pigments bound with Tylose® got results between 0.07 (yellow pigment on paper) and 0.13 (white pigment on canvas).

In the natural aging set (Table 2), the binder with less gloss is the Tylose®, with results of 0.16 on paper and 0.19 on canvas. The pigments bound with Tylose® got results between 0.07 (yellow pigment on canvas) and 0.15 (white pigment on canvas).

In the accelerated aging set (Table 2), the binder with less gloss on paper is the Tylose®, with results of 2.17, while it gets 2.11 on canvas. The white pigments bound with Ty-

Table 1. Color difference between the aging sets, in both supports.

	Name	ΔE* Control-Natural Aging	ΔE* Control-Accelerated Aging
PAPER	White pigment + Tylose®	0.837019	0.652227
	Yellow pigment + Tylose®	1.085081	0.2995
	Tylose®	1.840598	**10.87929**[1]

	Name	ΔE* Control-Natural Aging	ΔE* Control-Accelerated Aging
CANVAS	White pigment + Tylose®	0.347131	0.924824
	Yellow pigment + Tylose®	0.671193	1.193189
	Tylose®	1.23503	3.967569

Table 2. Gloss values in each aging set, in both supports.

	Name	ΔSCI-SCE Ctrl.	ΔSCI-SCE Nat. Aging	ΔSCI-SCE Acc. Aging
PAPER	White pigment + Tylose®	0.1	0.12	2.07
	Yellow pigment + Tylose®	0.07	0.12	-0.04
	Tylose®	0.1	0.16	2.17

	Name	ΔSCI-SCE Ctrl.	ΔSCI-SCE Nat. Aging	ΔSCI-SCE Acc. Aging
CANVAS	White pigment + Tylose®	0.13	0.15	2.05
	Yellow pigment + Tylose®	0.09	0.07	1.95
	Tylose®	0.19	0.19	2.11

[1] The paper support *ΔE**was of 9.82, which reflected on all of the pure binders' *ΔE**.

lose® got the lowest gloss results: 2.07 on paper and 2.05 on canvas. The yellow pigment got the lowest result on paper (-0.04), while on canvas, got a result of 1.95. It's noticeable that Tylose® constantly presents the lowest gloss values, especially on paper.

Comparing the numbers between the control and the natural aging sets (Table 3), Tylose® kept stable results on canvas and a slight variation on paper (0.06). The pigments bound with Tylose® got variations between -0.02 (yellow pigment on canvas) and 0.05 (yellow pigment on paper).

Comparing the results of the control and the accelerated aging sets, the variations were much more significant than in the natural aging set. Tylose® presented a variation of 1.92 on canvas and 2.07 on paper. The pigments bound with Tylose® got the smallest variations among all the binders, with values between -0.11 (yellow pigment on paper) and 1.92 (white pigment on canvas).

Solubility and Removability Test

The tests on the control set obtained the best results. It must be taken into account that the paper support presented bigger frailty and reactivity towards the water than the canvas support. On paper, the friction of the swab may easily result in some degree of raised fibers while attempting to remove the paints. In the case of the Tylose® sample, there was no lifting of fibers, but lots of pigment remained on the support, seemingly having penetrated it. On canvas, its removal was easy and well-controlled, not causing damage to the ground layer or leaving residues.

On the natural aging set, there was a bigger difficulty in removing the paints. None of the binders presented excellent behavior on paper: all of them resulted in at least a slight degree of raised fibers and none allowed complete removal of the yellow pigment. However, among all the binders, Tylose® was one of the best results - even if it raised some fibers and left pigment residue behind. On canvas, the results were better, even if some yellow remains were still visible in the topography of the ground layer when analyzed on the digital microscope.

On the accelerated aging set, the removal time is longer, meaning a bigger difficulty, especially on the paper support. According to Horie (2010), low molecular weight polymers are more easily solubilized than high molecular weight ones, as they demand less energy to break the bonds that unite their molecules (Horie, 2010). This could explain the results obtained by the cellulose ethers. Tylose® was relatively easy to remove, even if remains of yellow pigment were still on the fibers (**Fig. 1**). On canvas, the removal was well-controlled but difficult, leaving yellow residue behind.

Fig. 1. Tylose®-bound yellow pigment, accelerated aging set, after removal test (Photo: Joana Diniz).

Practical test on artworks

In the acrylic painting by Maria Isabel Fraga Pereira, the different kinds of damage required different approaches when chromatically reintegrating. However, pointillism was used since it mimicked the airbrush textures and tonal variations present in the paint layers.

In areas with actual losses, an infilling of Modostuc® was applied. The greatest challenge was finding the adequate tonality, as a very matte inpainting was easily achieved.

Some areas of friction damage had an accumulation of external residues, which were removed as well as possible without causing more damage to the paint layer (Figs. 2, 3, 5 and 6). In the areas where the residue was darker than the original paint layer, the treatment was more complex, since the covering power of the inpainting paint wasn't enough to completely hide the residual material. To control the color influence of that material, a layer of titanium white bound in Tylose® was applied since it possesses good covering power. Afterward, it was possible to follow through with the inpainting like in the other areas (Figs. 3 and6).

The most complicated damages to reintegrate were the ones where the friction polished the surface without removing the paint layer (Figs. 4 and 7). That generated extremely disturbing gloss and color alterations which implied a very matte reintegration to suppress the polish-

Figs. 2, 3 and 4. Kinds of damage present in the artwork: friction with accumulation of light residue, friction with accumulation of dark residue, and polishing of the pictorial surface. Photos: Joana Diniz.

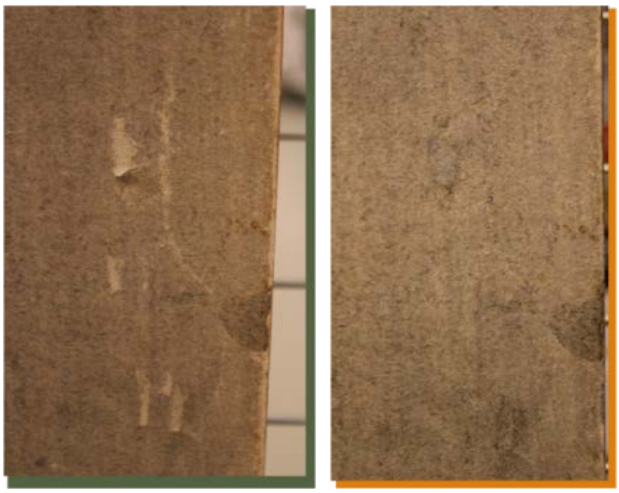
Figs. 5, 6 and 7. The same damages after retouching. Photos: Joana Diniz.

ing. Tests were done with Tylose®-bound pigments and with a layer of pure Tylose®, without obtaining satisfactory results. Then it was resorted to a method described by Bailão & Cardeira (2017) and Sims, Cross & Smithen (2010) for the use of funori, but instead applied to the use of Tylose®: applying the pure binder solution on the area to be inpainted, quickly followed by the application of dry pigments. This required the previous mixing of the pigments in the palette with water until the proper tone was achieved. Once the reintegration had dried, it was softly brushed so that the loose pigments would be removed. The resulting intervention was sufficiently matte, matching the original layer.

On *Forma*, *Descriptio*, *Graphis*, the inpainting treatment also had different specificities for each kind of damage. The first challenge was color matching: even though Indian ink in different dilutions was the only material used, the carbon black pigment available was of a colder tone than the ink. This effect was amplified by the color of the aged paper and of the glue used to adhere the paper to the fiberboard. Hence, ochre, diverse earthen pigments, and titanium white were necessary to reach the precise tone, depending on the damage's location. Once again, pointillism was the technique that was the most useful in mimicking the chromatic stain effects (Figs. 8-11).

The damage that had polished the surface required the same treatment as in the other artwork: the application of a thin layer of Tylose® followed by the dry pigments previously mixed to the adequate color. The results were once again extremely satisfying.

One of the main challenges was the inpainting of the badly consolidated tears and the central tear and its areas of support loss. They required infilling with cellulose pulp, which was much more matte than the surrounding original areas. Tylose® was too matte to achieve a match with the surface's satin gloss: even if, when faced straight, it looked integrated, the moment the observer moved to the side, the reintegration was thoroughly visible. The inpainting was easily removed with distilled water and redone with watercolors (Winsor & Newton®, Professional Water Colour series), to achieve more gloss on the surface. The result looked closer to the original, even though some angles still slightly reveal the outline of the tears.



Figs. 8, 9, 10 and 11. Tears and paint losses before and after inpainting. Photos: Joana Diniz.

After those inpainting experiences, it's possible to conclude that Tylose® has a very satisfactory behavior: a little amount of binder is needed to ensure the formation of a cohesive paint, the paint's appearance is extremely matte, the paint is durable and can be stored, and reutilized since, when resolubilized with water, it has the same properties as when freshly prepared. The only inconvenience noticed is a slight chromatic alteration after drying, desaturating a little when compared to its application, similar to what happens with watercolors and gouache.

Conclusions

As stated, the chromatic reintegration of contemporary artworks presents countless challenges, especially when dealing with matte pictorial layers. Their inherent fragility due to specific textures, plain and uniform colors, and lack of gloss easily expose them to damage that impacts their understanding, concept, and message.

During the testing phase, Tylose® MH 300 P2 was the binding media that outshone the other materials: it had a great absence of gloss and gloss stability and obtained mostly positive results regarding chromatic stability. When testing it in actual artworks, its behavior and results were excellent, being easy to prepare and handle, not requiring a lot of pigmentation, and allowing reutilization of the paint in the palette for long periods. The way it behaved in two different substrates with distinct dynamics (infilling and original paint layer with damages and alterations and paper, paint layer with different degrees of dilution and cellulose pulp) allowed the reintegration in two very different pictorial layers (acrylics and Indian ink), demonstrating great versatility and obtaining great results in color matching and matte finish.

Since Tylose® is a material very little used for chromatic reintegration, this technical study aims to insert it into the series of materials that can be used for this vital intervention stage, making it a viable alternative.

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DIGGING UP THE PAST: CHROMATIC REINTEGRATION OF A BURIED WOODEN SCULPTURE

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Abstract

The object of study is a polychrome wooden image of Infant Jesus dating back to the late 14th or early 15th century. It was discovered buried beneath an altarpiece in an advanced state of deterioration, revealing fragility in both the support and the polychromy, with significant areas of loss and risk of detachment.

The intervention methodology was influenced by the artwork's fragile condition, being the first step the stabilization of the few remaining areas of polychromy. The support was severed damaged by wood worm insects. Although the image is no longer an object of worship, the intervention aimed to restore some fullness to the sculpture.

Regarding the chromatic reintegration, the skin tones were retouched using a mimetic technique with Kremer® pigments agglutinated in Laropal® A81. An acqua sporca was applied to the remaining traces of the white ground layer. In this way, the lacuna areas were sent to the background, allowing the piece to be read continuously.

Keywords:

Buried Sculpture,

Wood,

Losses,

Retouching,

Decision-Making Process

Introduction

During a conservation and restoration intervention carried out in a church, a sculpture representing Jesus as a child was found buried beneath an altarpiece. The polychrome and gilded wooden sculpture, with approximately 0,60 meters tall, depicts Jesus as a child standing on a cherub and wearing a tunic. It can be dated to the late 14th or early 15th century (Fig. 1 and 2).

Regarding its artistic production technique, it is a hollowed-out image, as evidenced by the two air chambers on the back. The sculpture is carved from a single block, except the base that consists of two blocks - one round and another with a carved cherub. The latter two were secured using two nails. Although the right arm and left hand are missing, by examining the type of joint it suggests that they were carved separately.

In terms of the decorative techniques, while only a few traces were visible, it's noted the presence of green and gold on the tunic, possible remains of an estofado decoration. The belt shows some red traces, and at the base, there is evidence of a blue polychromy. The wings of the cherub at the base also exhibit traces of a red-toned *estofado*. The flesh areas had the more intact polychromy, while regarding the hair, only the cherub still show polychromy, in a dark brown shade.

Figs. 1 and 2. Polychrome wood sculpture of Jesus as a child. (© LabIPT)

The reason for burying the image is unknown. However, often due to changes in taste or a high degree of degradation, sculptures became unsuitable for worship. Two scenarios could follow: they were either moved to a less important area of the church or even to another church, or they were buried, as if they were deceased. Since these sculptures were considered sacred, they could not be destroyed (Brusadin, 2019).

The intervention on this sculpture carried out during the Master's program in Conservation and Restoration of Sculpture at the Polytechnic Institute of Tomar, became challenging due to its degraded state and significant dirtiness. This not only complicated the initial handling of the piece but also made it difficult to observe what remained, leading to complex decision-making on both the methodology and the materials to adopt.

Conservation state

Since the existence of the image was unknown, the conservation status it had before being buried remains uncertain. It is possible that the burial ritual was carried out due to its already advanced state of degradation however, the various factors to which it was exposed over the years contributed to the acceleration of the deterioration process.

When the image arrived at the Sculpture Conservation and Restoration Laboratory of the Polytechnic Institute of Tomar, its condition was so severe that it significantly restricted the handling of the piece.

Support

Throughout the support, the damage caused by an infestation of xylophagous insects was evident and upon examining the type of galleries, it can be inferred that they were caused by termites. The most noticeable volumetric gaps were the right arm and both hands. The infestation also led to losses in the hair, chest, right side, feet and some areas in the base. Due to the extensive network of galleries left by the biological colonization, the remaining support was significantly weakened (Figs. 3 to 5).

Due to the burial, there was also a large amount of soil and dirt encrusted in the galleries and deposited on the support.

Figs. 3 and 4. Chest and left foot: losses in the support caused by insect infestation. (©LabIPT)

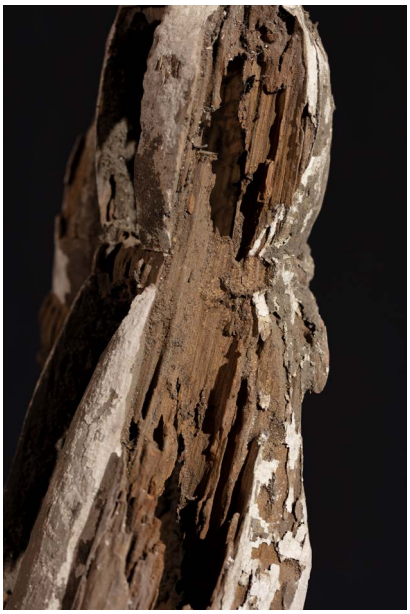

Fig. 5. Right side: losses in the support caused by insect infestation. (©LabIPT)

Decorative layers

The fragility and degradation of the support directly impacted the decorative layers. The few polychromy traces that remained were detaching and heavily dirty, with surface accretions, making it at times challenging to distinguish between the actual dirt and the polychrome layers. However, traces of a green estofado were found in the garments, where the visible gold also showed some abrasion, revealing the underlying layer of bole (Figs. 6 and 7). The polychrome areas in the best-preserved state were the flesh tones, where the presence of rosettes, eyes, lips, and eyebrows could still be observed (Figs. 8 and 9). The base, with a blue shade, was also where polychromy was found in greater abundance.

Fig. 6 and 7. Conservation state of the garments. Traces of the decorative layers. (©LabIPT)

Fig. 8 and 9. Conservation state of the flesh tones. (©LabIPT)

Intervention

Although this image depicts a religious theme and was even found in a church, the goal was not to return it to worship. The main goal of the intervention was not only to restore the physical stability of the image, but also to restore a sense of completeness without introducing too many new elements, thus avoiding the risk of creating false historical narratives.

Due to the sculpture's advanced state of degradation, after the conclusion of the initial overall and detailed photographic documentation, it became necessary to proceed with the consolidation of the support and polychromy. Although this step is typically carried out after at least an initial mechanical cleaning, the existing detachments, which also restricted the movement of the sculpture, made it impossible.

Once the support and polychromy were stabilized, it was time to start the mechanical cleaning of both. Only after a first initial cleaning, it was possible to look at the sculpture in a different light, enabling a better observation of its characteristics and the establishment of a more concrete intervention plan.

The following process involved the cleaning of the polychromed and gilded residues. It was decided not to replace the lost volumes, leaving the visual restitution of the fullness of the work to chromatic reintegration (Fig.10).

Fig. 10. Base after cleaning. (©LabIPT)

Fig. 11. Modostuc® before levelling. (©LabIPT)

Chromatic reintegration

As previously mentioned, chromatic reintegration played a crucial role in this intervention, making it possible to restore a sense of wholeness to the sculpture.

As flesh tones are the first (or even the primary) central point for the observer and considering the existence of a considerable area of remaining polychromy from which information could be extracted to reintegrate the missing areas, the decision was made to proceed with its chromatic reintegration using the *mimetic* technique.

For the garments and the wings of the cherub at the base, as there were only a few traces of polychromy, it was not possible to apply the same technique. In these areas, the visible white ground layer was toned to the wood colour using an acqua sporca. This way, the white of the ground layer ceased to be prominent, shifting these gaps to the background and highlighting the remaining traces of polychromy. Since the intention was only to tone the preparation areas, no levelling mass was previously applied in the areas where this technique was used. However, for the *mimetic* chromatic reintegration of the flesh tones, Modostuc® in ivory colour was applied with a spatula and after drying was then levelled using sandpaper of various grains (Fig. 11) (Bailão, 1989; Diniz, 2016; Bailão & Cardeira, 2018; Marincola & Kargère, 2020; Instituto del Patrimonio Cultural de Espanã, 2017).

Regarding the materials, the acqua sporca was applied using VanDyke Brown (403) watercolour from the Van Gogh brand. For the flesh tones were used Kremer® Pigments, bounded in Laropal A81. This urea-aldehyde resin stands out for its high resistance to ageing, compared to other natural resins. Due to its low molecular level, it also has low viscosity, ease of levelling and a high gloss (Bailão & Cardeira, 2018) (Figs. 12 and 13).

Figs. 12 and 13. Flesh tones before and after chromatic reintegration. (©LabIPT)

The extension of the retouching intervention can be easily assessed using UV radiation. The different materials reveal different colours under UV light, where the darker areas in the flesh tones correspond to the retouched areas (Fig. 14).

Fig. 14. Sculpture after chromatic reintegration exposed to UV light. (©LabIPT)

Conclusions

After the conservation and restoration intervention, it was possible to, not only restore the sculpture's physical stability, but also its readability. Although the most complex process was indeed the consolidation of the support and the polychrome layers, it was through chromatic reintegration that some of the lost information, due to years of burial, was recovered. By employing two techniques (acqua sporca and *mimetic*), as well as distinct materials (watercolour and Kremer® Pigments in Laropal A81), it was possible to deliver a sculpture with a uniform appearance and without incurring in false historical representations (Figs.15 and 16).

Figs. 15 and 16. Before and after the intervention. (©LabIPT)

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AIRBRUSH TECHNIQUES IN CHROMATIC REINTEGRATION

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Abstract

Airbrush techniques have been minimally addressed in the field of conservation and restoration. A review of existing literature reveals limited knowledge about their application, apart from their use in ceramics. This research explores the use of airbrushing as an alternative method for chromatic reintegration of tiles.

The objective of this study is to investigate the effectiveness of airbrushing in achieving precise chromatic reintegration, using the tratteggio technique and "reglatino" as starting points.

To reach this, several mock-ups were created to assess the most suitable methodologies for optimal results, noting their advantages and disadvantages. The most efficient methodology was then used on two 17th century tiles.

This paper aims to reflect on the potential application of airbrushing in chromatic reintegration, showcasing one of its many possible uses.

Keywords:

airbrush,

differentiated chromatic reintegration,

new methodology,

airbrush technique,

acrylic loom

Introduction

The airbrush, often viewed with skepticism in both artistic and conservation contexts, may now warrant renewed consideration. Contemporary challenges in chromatic reintegration, particularly with monochromatic artworks where traditional methods may be inadequate, suggest that the airbrush could offer a viable solution.

During a research internship at the Universitat Politècnica de València's Instituto de Restauración del Patrimonio (IRP), a new methodology for chromatic reintegration using the airbrush was developed. This research forms part of the master's dissertation titled "Aerógrafo – Estudo do seu Contributo para a Reintegração Cromática".

The new system is based on the Roman *tratteggio* technique, and a variant known as "reglatino." The *tratteggio*, initially introduced and developed by Cesare Brandi at the Instituto Centrale per il Restauro in Rome (Brandi, 1963, p. 149), was later explained by his students Paolo and Laura Mora in their work "Conservazione delle Pitture Murali" (Mora & Philippot, 1999, p. 336). This technique involves chromatic reintegration through vertical strokes approximately 1 cm in length. The initial strokes establish the base tone and are applied with consistent spacing and width. Subsequent strokes are made with a different color to fill in the intervals, continuing until the desired tone is achieved through the layering and juxtaposition of the purest colors possible (Mora & Philippot, 1999, p. 338).

Over time, the *tratteggio* evolved, leading to the development of the "reglatino," which features long, uniform strokes made with a ruler (Vivancos Ramón, 2007, p. 297). This method has been extensively employed in Spain for mural and tile interventions. It involves using watercolor pencils and a ruler to create a pattern of parallel vertical lines, typically applied over a base tone (Gironés Sarrió & Guerola Blay, 2021, p. 132) (**Fig. 1** and **2**).

Fig.1. Applying lines with a ruler and watercolour pencils on a tile. © Beatriz Doménech

Fig. 2. Chromatic reintegration using "reglatino" in the Church of San Juan de la Cruz in València. © Beatriz Doménech

The new methodology proposed here advocates for using the airbrush to achieve a distinguished chromatic reintegration by applying strictly parallel and adjacent lines of color. This is accomplished through stencil techniques, which allow for controlled adjustments in line width and spacing to create a pattern of straight, uniform lines. Similar to the "reglatino" technique, these lines are applied over areas of lacunae with a base *undertone* color.

In the Experimental section, detailed information is provided to clarify the procedure and objectives of the developed technique.

Experimental

Materials

For this study, five mock-ups were created using five square MDF panels, five tile prints, plaster, Vallejo® Game Air acrylic paints for airbrushing (**Fig. 3**), acetate sheets, and adhesive spray. Additionally, various other materials were tested during the preparation of the mock-ups, including rubber bands, paper, masking tape and nylon thread.

The airbrush used in this study was the Evolution Silverline Solo (v2.0) from Harder & Steenbeck®, which is a dual-action type that provides control over paint flow and airflow (Fig.4).

Fig. 3. Acrylic paints by Vallejo® Game Air. © Margarida Boavida

Fig. 4. Evolution Silverline Solo Airbrush (v2.0) by Harder & Steenbeck®. © Margarida Boavida

Methods

The mock-ups were designed to replicate tiles by attaching prints to five square MDF panels. The printed tile patterns included simulated losses, where two layers of plaster were applied, and the surface was leveled. With a smooth and uniform base, both formal and chromatic reintegration were performed using an *undertone*.

During this phase, a brush was used on four mock-ups, while an airbrush was used on one (**Fig.5**). The objective was to compare the processes and final appearances of chromatic reintegration between the brush-applied and airbrush-applied mock-ups.

When using the brush, a wet palette was necessary to prevent the paint from drying out. With the airbrush, the color is first selected using a brush and then replicated in larger quantities. Additionally, stencils made from acetate sheets were prepared to cover areas that should not be sprayed, serving as masks for each color (**Fig. 6**).

Fig. 5. Chromatic reintegration with an airbrush. © Margarida Boavida

Fig. 6. Stencil with acetate sheet. © Margarida Boavida

In addition to the initial example, stencils were prepared for all mock-ups to ensure that the areas of the print (simulating the original tile) remained protected during the airbrush application of the lines. The acetate sheets used for stencils were thicker, but it was crucial to apply spray adhesive to the side facing the mock-up. This step was necessary to prevent the stencils from shifting due to the airflow from the airbrush and to avoid paint seeping under the acetate and beyond the intended areas.

UHU® spray adhesive was used for this purpose. To achieve removable masks, the adhesive was applied to the stencils and allowed to sit for about 20 minutes before attaching the masks to the mock-up. While this stencil method produced satisfactory results, it's crucial to highlight that outlining the shapes on the acetate must be done with precision. Some irregularities were noticed after the paint misting due to small errors in stencil design (**Fig. 5**).

Precision is crucial in airbrushing, particularly when applying masks, as even minor errors can leave parts of the original work unprotected or result in incomplete reintegration due to blockages. Although such issues may be infrequent, their visual impact can be significant.

Following the reintegration process, we proceeded to apply the lines. The choice of line color involved a strategy of selecting a tone close to the dominant background color. The aim was for the lines to blend seamlessly into the composition while remaining distinguishable across all colors. The lines needed to be noticeable throughout the reintegration without creating a stark contrast, thus ensuring visual harmony among lines, shapes, and colors. To illustrate this approach, a standard model was created (**Fig. 7**), inspired by an example from Beatriz Doménech (2022, p. 147).

Fig.7. Example of the desired effect with the line application. © Margarida Boavida

The next step was to find the best methodology for the application of the lines. For this, three different techniques were tested:

1. Rubber bands were stretched across a painting strainer to create a grid of parallel lines.
2. Adhesive strips, which are pre-cut or customized to the desired width and length, were applied directly to the surface to create the lines.
3. Nylon threads were arranged on a "loom" (a frame or structure) to create a pattern of parallel lines. The loom held the threads in place and allowed for precise control over the line spacing.

Results and discussion

Rubber bands on a painting strainer

The first method tested involved using a small painting strainer to which rubber bands were attached, creating a stable mechanism for applying lines efficiently (**Fig. 8**). To ensure that the rubber bands remained in place during airbrushing, two weights were placed on the structure to apply pressure to the surface (**Fig. 9**).

In the initial attempt, the rubber bands were too thick, which created issues with paint application. The height of the bands prevented the paint from settling directly on the surface of the tile. Additionally, the airbrush was not held perpendicular to the surface as required, resulting in poorly defined and uneven lines (**Fig. 10** and **11**).

Fig. 8. Rubber bands on a painting strainer. © Margarida Boavida

Fig.9. Pressure applied against the surface by two weights. © Margarida Boavida

Fig.10. The result of the first mock-up. © Margarida Boavida.

Fig. 11. Detail of the blurred lines with distinct intensities in the first mock-up. © Margarida Boavida.

In response to the issues encountered with the first method, a second mock-up was created to improve upon the initial design. Thinner rubber bands were employed this time (**Fig.12** and **13**). Although this adjustment resulted in narrower and more closely spaced lines, similar to the first mock-up, the lines still lacked precision and appeared blurry (**Fig. 14**).

The use of thinner rubber bands introduced challenges in maintaining consistent alignment, leading to varying line widths—some narrower and others thicker (**Fig. 15**). Additionally, the height of the rubber bands cast shadows on the mock-up surface, complicating the visibility of the paint application. It was also observed that the color of the lines was too dark and required adjustment.

Fig. 12. Airbrushing on the second mock-up with the wooden structure with thinner rubber bands. © Beatriz Doménech

Fig. 13. Wooden structure with thinner rubber bands for the second mock-up. © Margarida Boavida

Fig. 14. The result of the second mock-up. © Margarida Boavida

Fig. 15. Detail of the thickness discrepancy of the lines in the second mock-up. © Margarida Boavida

It is also important to note that this second mock-up was the one reintegrated using an airbrush, with the exception of the contour lines around the shapes.

Adhesive strips

The second methodology aimed to achieve more defined and uniform lines. To this end, a material thinner than rubber bands was selected to reduce the height that previously obstructed the direct application of paint to the surface. Additionally, the paint tone was adjusted to ensure it was more distinguishable against certain colors, while still coordinating with the background color, albeit with a slightly lighter hue than used previously.

The process involved marking 2 mm thick lines on paper and applying UHU® spray adhesive to one side, allowing it to dry for about 15 minutes. The paper strips were then cut and positioned on the mock-up surface, with the adhesive side securing them in place. Efforts were made to maintain an approximately 1 mm gap between the paper strips, which corresponded to the thickness of the lines to be airbrushed (**Fig. 16** and **17**).

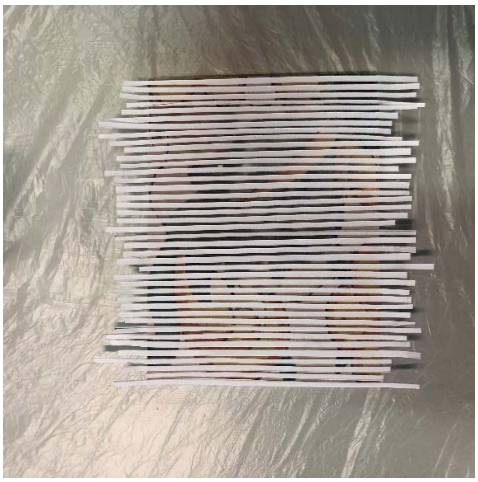

Fig. 16. Paper strips aligned and fixed to the surface of the third mock-up. © Margarida Boavida

Fig. 17. Airbrushing on the third mock-up with the paper strips. © Beatriz Doménech

Fig. 18. The result of the third mock-up. © Margarida Boavida

Fig. 19. Detail of the regular thickness of the lines in the third mock-up. © Margarida Boavida

The result of this method was more uniform, with evenly spaced parallel lines and consistent thickness (**Fig. 18** and **19**). Although the lines were clearer, the paper tended to become moist and lift during paint application, leading to a loss of adhesion.

Despite the improvement over previous mock-ups, this process was time-consuming. Preparing the paper strips—measuring, cutting, and affixing them to the tile—proved impractical due to the considerable time required.

For the fourth mock-up, masking tape was used instead of paper strips. The goal was to maintain the same 2 mm spacing between lines and achieve a line thickness of 1 mm (**Fig. 20** and **21**).

The available masking tape was 6 mm thick, so it had to be divided into three strips to achieve the desired 2 mm width. Although this process was also time-consuming, using appropriately sized modeling tape would reduce preparation time compared to the paper strips and adhesive.

The masking tape strips were aligned side by side, and paint was applied over them. The final result was parallel, straight, and well-defined lines (**Fig. 22** and **23**). However, during airbrushing, it was challenging to determine when to stop due to the color and opacity of the masking tape, which affected the visibility of the paint application.

Fig. 20. Strips of masking tape aligned on the surface of the fourth mock-up. © Margarida Boavida

Fig. 21. Airbrushing on the fourth mock-up with the masking tape. © Beatriz Doménech

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Fig. 22. The result of the fourth mock-up. © Margarida Boavida

Fig. 23. Detail of the regular thickness of the lines in the fourth mock-up. © Margarida Boavida

After the fourth mock-up, it became clear that the technique still struggled to achieve a unified composition, as the lines remained somewhat prominent and did not integrate seamlessly with the surrounding elements. The primary objective of this new approach is to achieve a refined chromatic reintegration with the airbrush while ensuring that the lines blend smoothly with the shapes and colors to create a cohesive and harmonious pattern.

Nylon threads on a "loom"

Based on observations from previous mock-ups, the objective of this test was to address the need for a practical and faster methodology, improve visibility of the color and paint quantity during airbrushing, and enhance the unification of the composition through the lines.

To achieve this, we reverted to the initial system—the wooden structure with rubber bands—due to its simplicity and quick application. However, improvements were made by adapting it into a "loom" that used transparent acrylic and nylon threads to allow clear visibility of the surface and color, and to employ thinner lines with closer spacing (**Fig. 24**).

For the fifth mock-up, 0.2 mm thick nylon strings were used, spaced 1 mm apart. Due to the lightweight structure, some pressure was needed to ensure the threads made contact with the tile surface (**Fig. 25**).

The transparency of the materials facilitated clear application of the color. However, the lines appeared excessively white, obscuring the underlying shapes and colors (**Fig. 26**). Although the resulting line pattern was more organized, coherent, and well-defined, it was noted that the lines were thicker than the spacing between them. This, combined with the white paint, highlighted the fading of colors and shapes, creating a hazy effect (**Fig.27**).

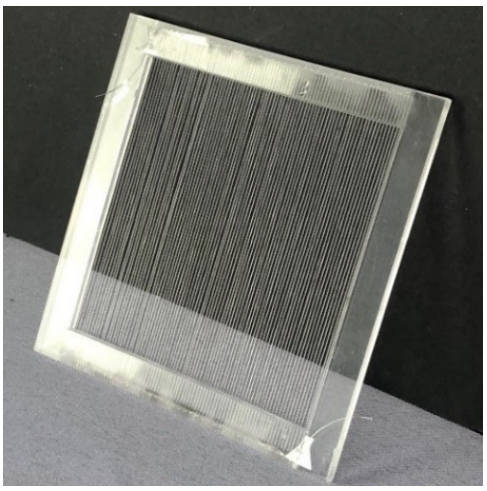

Fig. 24. Acrylic loom with nylon strings. © Margarida Boavida

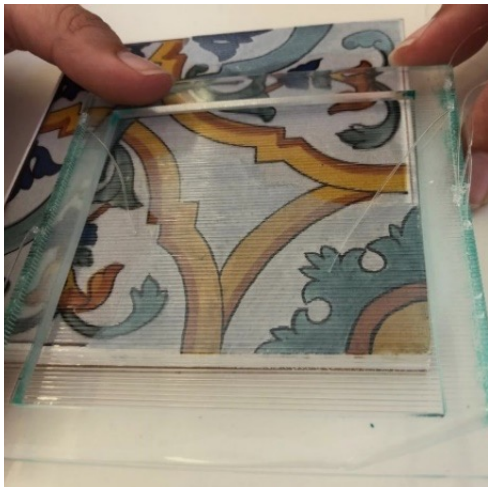

Fig. 25. Applying pressure against the surface. © Margarida Boavida

Fig. 26. The result of the fifth mock-up. © Margarida Boavida

Fig. 27. Detail of the organized and well-defined pattern of lines but with a whitish appearance. © Margarida Boavida

Fig. 28. Tile A. © Margarida Boavida

This approach highlights the importance of an efficient and pragmatic methodology that requires minimal pre-material preparation. The system involves simply positioning it on the surface and applying the pre-selected color. Additionally, it is reusable and adjustable, allowing for changes in line spacing as needed. The transparency of the materials facilitates clear observation of the color and paint quantity whilst minimizing shadows on the surface being reintegrated. Although some refinements are still needed, the latest methodology has demonstrated superior efficacy, prompting its application in tests on two authentic tiles.

The two tiles are part of a 17th-century ornamental panel featuring a human figure, which belongs to the collection of the Faculdade de Belas-Artes of the Universidade de Lisboa. For simplicity, these tiles will be referred to as Tile A (**Fig.28**), which exhibits the larger area of loss within a vegetal motif, and Tile B (**Fig. 29**), which presents a smaller area of loss in the background.

Fig. 29. Tile B. © Margarida Boavida

The chromatic reintegration process utilized professional Winsor & Newton™ watercolors and was executed using both brush and airbrush techniques. Initially, the formal and chromatic reintegration was performed with a brush to establish an *undertone*, followed by the application of airbrushed lines. The brushwork was applied in successive layers until the desired tone was achieved (**Fig. 30**).

After brushwork, lines were airbrushed. For Tile B, line color matched the background, using a less diluted mix-

Fig. 30. Chromatic reintegration in layers using a brush (from left to right). © Margarida Boavida

ture for saturation. Tile A required a neutral tone for lines, achieved by blending surrounding colors.

Stencils were prepared with acetate and UHU® spray adhesive, as in the mock-ups. Lines were applied with tiles positioned vertically, testing the method's efficacy on fixed panels. Positioning the 'loom' vertically proved challenging, requiring pressure to maintain contact with the tile surface (**Fig. 31**).

Fig. 31. Airbrushing the lines with the tile positioned vertically. © Margarida Boavida

The results varied between the two losses. While the lines on Tile A are visible, they are imperceptible on Tile B. Surface irregularities on Tile B prevented the threads from making close contact with the lacunae area, creating a gap between the 'loom' and the surface. Consequently, the airbrushed paint settled in this space, forming a color blotch instead of the intended lines (**Fig. 32**). Although the acrylic 'loom' did not achieve its intended purpose, the final appearance was favorable. The color blotch diminished the visual impact of the loss, effectively reintegrating it chromatically (**Fig. 33**).

Fig. 32. Detail of the reintegration after the lines were applied to Tile B. The lines were not visible. © Margarida Boavida

Fig. 33. Final result of the chromatic reintegration on Tile B. © Margarida Boavida

In Tile A, the lines provided visible differentiation when viewed up close, while remaining imperceptible from a distance (**Fig. 34** and **35**). The lines appear less clear than those applied in the fifth mock-up due to the dispersion of watercolor as it was absorbed by the filling paste.

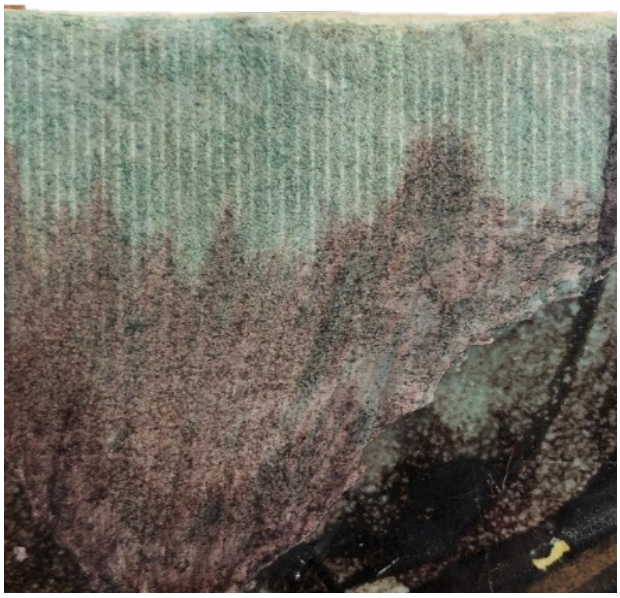

Fig. 34. Detail of the reintegration after the lines were applied to Tile A. © Margarida Boavida.

Fig. 35. Final result of the chromatic reintegration on Tile A. © Margarida Boavida.

Regarding watercolors, when sprayed over the acrylic "loom", they tend to drip and form droplets along the nylon threads, which could potentially drip onto the surface and distort the lines. To address this, it is recommended to clean the "loom" throughout the airbrushing process. However, this would require removing and repositioning it, which could be challenging due to the need to realign the threads with the already applied lines. The same inconvenience can occur if the structure is accidentally or intentionally moved to monitor the progress of the reintegration.

To further enhance the results, adjustments to the structure are required, such as methodology that allows for positioning that does not require applying pressure and makes it easier to use to it vertically. One disadvantage is that the structure is only viable on smooth, even surfaces; otherwise, applying the lines becomes difficult due to the challenge of keeping the structure flat against the tile. On the other hand, the advantages of this system are its rapidity and reusability. Also, the distance between the threads can be adjusted based on the desired effect, and with some improvements, it could also be possible to adjust the thread thickness. The transparency of the threads and the frame facilitates monitoring of the reintegration and does not interfere with color observation.

This model shows progress in achieving desired line thickness, contributing to harmonious integration of lines, forms, and colors within the composition, creating a distinctive effect without overemphasizing the intervention.

Conclusions

This research introduces a novel approach for distinguished chromatic reintegration using an airbrush with a stencil technique. Five mock-ups were created to test various systems and identify the most effective one. After testing, the best system was applied to two real tiles. The study highlights the necessity of a practical and rapid methodology that does not require extensive prior preparation. It is crucial to observe both the color and quantity of paint sprayed onto the surface to ensure well-defined results. The different models proposed have distinct potential, but it will be essential to refine each one to better utilize their advantages. The most successful methodology involved using an acrylic "loom" due to its transparency. This feature facilitates clear observation of the sprayed paint without casting shadows. Significantly, the reusability of the acrylic "loom" makes the process nearly instantaneous. The structure can be positioned, airbrushed, cleaned, and readied for reuse efficiently. The thin thread thickness of the loom minimizes height, ensuring that paint falls directly onto the surface, resulting in uniformly defined color lines. However, it is limited to flat surfaces.

Nonetheless, this study represents the initial stage in the potential development of an expeditious and efficient system. This system employs one of the most renowned techniques in airbrushing – the stencil – to produce a near-automated version of the Roman *tratteggio* and Spanish *reglatino*.

This work challenges the perception that airbrushing is difficult and requires extensive technical skills. It demonstrates the airbrush's potential and emphasizes the need to overcome the stigma associated with the tool, facilitating a fair assessment of its contributions.

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METHODOLOGY AND CONSIDERATIONS FOR THE TONING OF FILLS ON A NORVAL MORRISSEAU BIRCH BARK ARTWORK

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Abstract

An early artwork on birch bark by renowned Ojibway artist, Norval Morrisseau (1932-2007), in the collection of Kay-Nah-Chi-Wah-Nung Historical Centre (Rainy River First Nations) was treated for extensive structural issues at the Canadian Conservation Institute. The final step consisted of toning several fills to complement the bird subject and birch bark substrate. Consultations and a visual compensation spectrum helped to identify inpainting options. It was agreed with the client to use single hues individually matched to the surrounding colours for the smaller losses and subtly varied brown hues for the large loss, thereby providing a minimal visual aid to the viewer to support their interpretation of the artwork, while the fills remained distinguishable. Airbrush was the ideal technique for achieving the necessary gradations of colour, as well as the desired surface texture. Although no further suggestion of the subject was added, the client intends to include interpretive material alongside the artwork, which will enhance an understanding of its original appearance.

KEYWORDS:

Birch Bark,

Airbrush,

Paper fills,

Consultations,

Reintegration

INTRODUCTION

Background

An early artwork on birch bark by renowned Ojibway artist, Norval Morrisseau (1932-2007), was treated for extensive structural issues at the Canadian Conservation Institute. The artwork is in the collection of Kay-Nah-Chi-Wah-Nung Historical Centre, which is located on a similarly named National Historic Site of Canada in northwestern Ontario. Recognized as one of the most significant centres of early habitation and ceremonial burial in Canada, the Site encompasses ancient burial mounds and the remains of previous villages and campsites. Owned and operated by Rainy River First Nations, Kay-Nah-Chi-Wah-Nung Historical Centre has several galleries with interactive displays and exhibits, which are focused on the Ojibway culture of the area (About -: Manitou mounds, 2020). It hosts community events and gatherings and is a resource for Ojibway history, language, geography, and traditions (Interpretive centre -: Manitou mounds, 2021).

Norval Morrisseau is an important Canadian artist of the twentieth century, having created the Woodland School art style. Early in his career, he used a variety of supports for his artwork such as birch bark (Ruffo, 2014; Hill, 2007). The work from Kay-Nah-Chi-Wah-Nung Historical Centre is from this period and consists of a representation of a bird created by peeling and painting on three birch bark panels (**Fig. 1**). It could not be displayed because the bark panels were curling and fractured, with detached pieces and significant loss. Most notably, a large loss in one of the panels (approximately one quarter of its size) was in a central part of the bird image, thereby impacting the appreciation of the artwork (**Fig. 2**). The objects lab carried out extensive treatment, which included reshaping the bark, stabilizing delamination and splits, re-attaching fragments, and filling losses. The toning of these filled losses was one of the final steps in the effort to improve the legibility of the artwork and render it displayable before securing the panels to a new backing support and framing.

Fig. 1. Before Treatment
Peeled and painted (drying oil binder) birch bark artwork, Norval Morrisseau (1932-2007), 84,4 cm x 104,9 cm, 1960, Kay-Nah-Chi-Wah-Nung Historical Centre

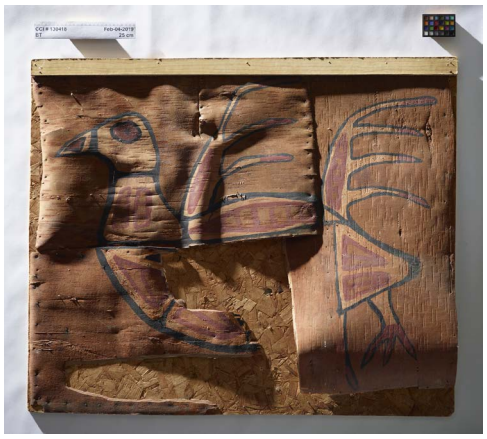

Fig. 2. Raking light photograph of artwork before treatment.

Goals and Considerations

The goal of this treatment step was to find and execute a technical inpainting solution which would complete the visual reintegration of the filled losses in the bird subject and birch bark substrate. Following conservation guidelines and meeting client expectations and needs were at

the forefront of our reflections. The factors to consider in the decision-making process were the texture and colours of the bird and bark, loss of central parts of the subject of which there is no known record, and large size of one of the fills. The final appearance of the toning was determined through consultation, testing materials and methods, and discussing different options using mock-ups.

TONING APPROACH

Elaboration of a common technical vocabulary

Consultation was going to be a vital part of determining the extent of visual compensation of the fills on the artwork, especially since there was no known image of the undamaged artwork. When we first began talking about the toning, we discovered that establishing a common technical vocabulary was in order since we are from different specialties. Not only would this aid us in framing our thoughts and weighing options, it would also help us articulate them to the client, as well as to our colleagues, and foster fruitful discussion.

Following what Cesare Brandi has described, we wanted to evaluate different philosophies and technical solutions for reestablishing form and colour, which had been disrupted by loss (Bailão & Calvo 2014). To do this, varying levels of reintegration were mapped out on what we termed a visual compensation spectrum (**Fig. 3**). At one end of it, there was a single hue used for all of the fills in the birch bark. This would be the most minimal way to suggest to the viewer what had been there before, and the fills would remain very distinguishable. Toward the middle of the spectrum were reintegration approaches that would elaborate on the original design elements, using hatching techniques such as *tratteggio*. These types of approaches support the viewer one step further in their interpretation while the fills still remain identifiable (Brandi, 2001). Finally, a *mimetic* or imitative approach to toning fell at the other end of the spectrum as it would fully recreate the colour and design of the image. Here, the viewer would not need to visually reconstruct the image, and the fill would not be readily distinguishable to an untrained eye. Since there is no record of the artwork before the losses were incurred, this was not considered to be an option, but still needed to be included to complete the spectrum.

Fig. 3. Visual compensation spectrum

Consultations

The level of visual compensation was then discussed with the client and several colleagues from other conservation specialties, using the spectrum as a framework for the conversations. A few possibilities began to be identified:

- Using one colour for all of the fills, which was evocative of the bark;
- Using brown hues for each of the fills, which closely matched the bark in the immediate surrounding area; and
- Recreating parts of the composition where it was strongly suggested that lines connected. Discussions were had over which lines fit this criterion and the technique (e.g. strokes, dots) and opacity that could be used.

There were multiple instances of consultation over a period of time, as mock-ups were made using different materials and methods, including imaging software. Files were sent to the client for their consideration and virtual meetings were held as the toning progressed in order to view and discuss the appearance of the artwork and fills.

MATERIALS AND METHODS

The choice of toning materials and application method was guided by stability, appearance (i.e. complementary to the bark substrate yet distinguishable from it), and practicality. As the fills were made from layers of Japanese paper (**Fig. 4**), the toning would be carried out on a paper substrate. The colourant selected had to be reasonably lightfast, match the matte appearance of the bark and provide the requisite saturation of colour. The application method needed to complement the texture of the bark and be capable of achieving subtle colour gradations. It was also preferred that a single type of colourant was used and if possible, one main technique to apply it. For these reasons, acrylic colours applied by airbrush were selected as opposed to dyeing paper or applying paint by hand using a brush. Although dyed paper is often a fitting choice for compensating loss in plant material components of art and cultural objects,

it was not ideal for this artwork because of the issues of lightfastness and the uniform appearance produced by dyeing, which would have necessitated a secondary step of overlaying other colourants using different methods in order to achieve variations of hue. Additionally, the use of a brush to apply colourant would not have created a surface as exempt of the conservator hand as with an airbrush application.

Fig. 4. The paper fills undergoing shaping before applying the toned top layer. ©Government of Canada, Canadian Conservation Institute.

Airbrush

An airbrush is a small metal tool spraying a variety of media by nebulization and powered by a compressor. It releases a fine mist of material which allows a very thin layer to be deposited on the surface (Engel & Siano, 2015). An airbrush can be single action where the air and paint are released by pressing the lever. If the lever can be moved backward, the amount of paint released can be controlled and this is called a double-action airbrush. Dual action airbrushes are more suitable for fine lines and gradation of colours (Parramon-Paidotribo, 2012).

For conservation treatments, the airbrush can be used for varnishing, inpainting or consolidation of very fragile surfaces. For visual reintegration, the airbrush has many advantages; the application is exempt of brushstrokes, a good saturation can be maintained, the feathering of colours is more easily executed than with a brush, and the film of material is very thin and dries quickly (Engel & Siano, 2015).

With airbrushing, preparation and testing are an integral part of the process and one that can take as much, if not more time, than the execution. An IWATA HP-B, a gravity feed, dual action airbrush gun which was available in the paintings and polychrome surfaces lab at the CCI (an older model comparable to the Iwata High-performance HP-B Plus Gravity Feed Dual Action Airbrush) was used for this project. The airbrushing was executed in a spray-booth and wearing a mask with particulate filters. The top fill layer was airbrushed before it was secured in place on the panel, so the need to mask the artwork to protect from the overspray was avoided. Additionally, if a mistake was made with the toning, another top fill layer could be prepared. If an airbrushing project allows it, having the infill separate from the artwork has been found to be quite advantageous.

Testing was necessary to determine the distance of the airbrush to the paper substrate, air pressure, motion used, type of paper for the top fill layer (Paper Substrate below), colour mixing, and layering of passes. The first step in the toning of the fills was trialling various palette and colour mixes to achieve the desired result. After this, the paper substrate was sealed and several passes with the airbrush were executed to gradually build the colour. A left to right movement with the gun was maintained to follow the directionality of the bark lenticels. The surface was regularly examined under different lightings and assessed near the fill or in the case of the large one, in position on the artwork. This was followed with small colour adjustments until the correct appearance was reached.

Medium

Golden High Flow acrylics were used for toning the paper. In addition to the paint medium, a clear matte medium was used to size the paper. It was also applied as a final coat to adjust the surface gloss, which was too shiny with the number of spray-out layers. This paint possessed the right properties to be used successfully with the airbrush, namely low viscosity and finely ground pigments which would not clog the nozzle (Engel & Siano, 2015). Given the delicate nature of the tool and the amount of time spent on cleaning and maintenance to prevent paint from creating an obstruction in the nozzle, this was quickly found to be an important consideration. Additionally, since little dilution is required with this product, both saturation and film cohesion were maintained.

Paper substrate

A variety of conservation-grade papers of an appropriate

weight and appearance were selected for testing with the airbrush. Arches Watercolour Paper (Natural White 90lbs Hot press), an acid-free, cotton rag paper, was ultimately chosen for the top fill layer. It has a smooth texture and is of sufficient thickness to not cockle when airbrushed, important factors to consider when choosing paper as a support for airbrushing (Parramon-Paidotribo, 2012). Fewer of its surface fibres were also raised by airbrushing than those of other papers. This issue arose during testing, when it was discovered that the airbrush technique tended to lift fibres from long-fibred conservation-grade papers. As a result, more paint landed on them, rendering them a darker colour than the paper's surface and thereby visually distracting. To counter this, several passes of clear matte medium were carried out to seal the paper during the preparation stage, as well as to flatten the fibres. To help the fibres stick to the paper surface, they were also pressed down by hand through silicone-release polyester film. Tweezers were used to remove any fibres that did lift, and a few spots were retouched by brush as necessary using Golden High Flow acrylics.

The paper was airbrushed before cutting for the top layers of the small and medium fills. The top layer of the large fill, however, was toned after it was cut in order to achieve subtle gradations of colour which complemented the image and surrounding bark. By airbrushing an already cut top fill layer, its appearance could be continually assessed in place on the artwork as the toning progressed. One drawback of this, however, was that the edges of the cut layer caught more paint and were therefore slightly darker than the rest of the surface. This was remedied by using an eraser to reduce the colour at the edges. Subtractive (or additive) adjustments like this are often used in conjunction with the airbrush and for a conservation context, it can be considered if the surface allows it.

The small fills were cut by hand, while the medium and large fills were laser cut because of their complex shapes. This allowed for more testing, as well as increased flexibility in case of mistakes since it was easy to laser cut a few extra top fill layers.

RESULTS AND DISCUSSION

In consultation with the client, the final appearance of the fills fell between the suggestive end and supportive middle of the visual compensation spectrum: design elements are starting to be suggested, providing a minimal visual aid to the viewer to support their interpretation of the artwork, while the fills remain distinguishable.

As a result, the toning of the small fills along the bottom of the panel (**Fig. 5** and **6**) complemented the colour of the birch bark in their surrounding area. Thus, each fill has a slightly different hue of brown. The colour is intended to visually compensate the substrate by bridging the gap without drawing attention. The medium-sized fill follows a similar methodology but with slight gradation across the surface to be more coherent with the variety of browns found in the bark around it (**Fig. 7** and **8**). For the large fill, a subtle gradation of browns travelling from its proper right edge down to the middle was decided upon rather than a uniform colour (**Fig. 9** and **10**). Visually reintegrating the image by incorporating the colour of both it and the substrate helps the viewer better interpret the main elements of the composition. Thus, the lower part of the large fill, outside the body of the bird, emulates the brown hues found in the bark substrate. Within the body of the bird, however, the brown hues are slightly different in order to evoke it. No further elements of the design are recreated, and the client intends to include didactics to enhance the full understanding of the work (**Fig. 11**).

Fig. 5. Two of the small losses along the bottom edge of the panel before filling. ©Government of Canada, Canadian Conservation Institute.

Fig. 6. Fills for the two small losses, which have been toned to complement the colour of the surrounding birch bark. ©Government of Canada, Canadian Conservation Institute.

Fig. 7. Medium-sized loss at the proper left top corner of the panel before filling. ©Government of Canada, Canadian Conservation Institute.

Fig. 8. Fill for the medium-sized loss, which has been toned with a slight gradation of colour across its surface to complement the variety of browns found in the bark around it. ©Government of Canada, Canadian Conservation Institute.

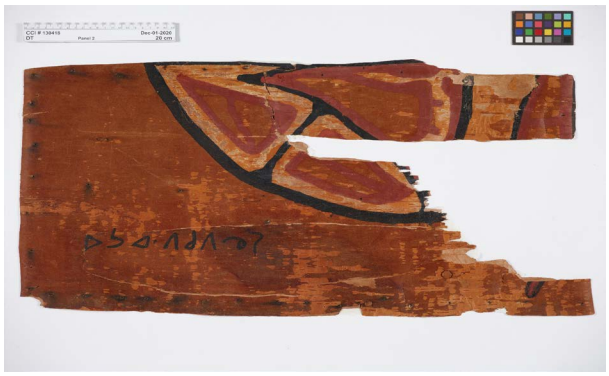

Fig. 9. Large loss in the proper left centre of the panel before filling. ©Government of Canada, Canadian Conservation Institute.

Fig. 10: Fill for the large loss, which has been toned with a subtle gradation of browns travelling from its proper right edge down to its middle. The lower part, outside the body of the bird, emulates the brown hues of the bark substrate while the hues within the bird's body are more evocative of it. ©Government of Canada, Canadian Conservation Institute.

Fig. 11. Mounted and framed artwork after treatment. ©Government of Canada, Canadian Conservation Institute.

Plotting the different inpainting options on the visual compensation spectrum helped to organize our thoughts by providing an overview of them. It was also a useful tool in the decision-making process as it gave a starting point for discussions with the client and our colleagues. The spectrum can be applied to other projects and adapted to a specific artwork.

The airbrush was the ideal technique with which to carry out the toning. It allowed for the subtle blending of colour and created a uniform paint layer, both of which complemented the colour gradations and texture of the bark. Given the size of the large fill, this would have been hard to do using conventional inpainting tools. A brush would have inevitably imparted a particular texture, attracting the viewer to the fills and bringing a greater degree of subjectivity to the visual reintegration.

CONCLUSIONS

Several filled losses in a Norval Morrisseau artwork were visually reintegrated with its bird subject and birch bark substrate using airbrush. Their final appearance was determined through consultation, testing materials and methods, and considering different options using mock-ups. The development of a visual compensation spectrum helped to identify these options and facilitate discussions with the client. It was decided that the toning would provide a minimal visual aid to the viewer to support their interpretation of the artwork, while the fills

would remain distinguishable. Airbrush was the ideal technique for achieving the necessary gradations of colour, as well as the desired surface texture. Although no further suggestion of the subject was added, the client intends to include interpretive material alongside the artwork, which will enhance an understanding of its original appearance.

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MATCHING A BETTER PAST: A NEW RETOUCHING APPROACH ON CHINESE WOODEN PLAQUE IN THE EARLY 20TH CENTURY

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Abstract

Wooden plaques are among the essential ornaments in Chinese traditional architectural space, such as family halls, government halls or Buddhist halls. By reading the written contents in wooden plaques, people can easily identify the functions for which the plaques were hung. During the conservation practice on one wooden plaque from 1921 in the Chung Tai World Museum, the conservators had run over various approaches to match the unusual texture on the centre area of the plaque.

Unlike the commonly seen smooth surface, the finishing layer of the plaque in this case seems more like a sand-painting surface in dark red. To achieve improved and uniform visual performance, the conservator first tried a skill similar to traditional Makie finishing. However, the Makie practice may not produce satisfactory adherence. Correspondingly, the conservator proceeded to mix coloured quartz sands with different concentrations of Paraloid B72 and Laropal®A81 respectively. Eventually, a relatively nice and accordant present was obtained by mixing quartz sands and pigments in Laropal®A81 5~10% (w/v) in xylene, which were then applied to target areas using a spatula. This conservation practice, which achieves both functional needs and aesthetic expression, enhances the conservator's confidence in treating other Chinese traditional furniture with lacquered or similar decorative layers.

Keywords:

chinese wooden plaque,

sand-painting texture,

Laropal®A81, quartz sands,

Makie,

Chung Tai World Museum

Introduction

Wooden plaques with carved inscriptions, called pai (tablet) in the Yingzao Fashi (Treatise on Architectural Methods) of the Song dynasty (960-1279), are considered among the most essential ornaments in Chinese traditional architectural space and are frequently encountered in oriental heritages. They are typically hung above the doorways of temples or houses, such as family halls, government halls, or Buddhist halls. Those inscriptions on the wooden plaques could generally reflect the values of the times or social trends of a specific era, enabling people to readily recognize the historical and cultural context behind them.

In 2021, the conservation team of the Chung Tai World Museum proposed a conservation project on a Chinese wooden plaque for a following exhibition (**Fig. 1**). The plaque has suffered from typical deterioration of wooden cultural objects, which not only caused obvious cracks but also affect the viewing of the plaque. Therefore, a series of condition checks and discussions on potential treatments had been put into practice to match a better past with some new methods.

Fig. 1. The front and back of the wood plaque of "拈Nian 花hua 說shuo 法 fa".

As we can see in figure 1 above, the plaque mainly comprises three long boards. In the central panel, the character 'Nian Hua Shuo Fa' (拈花說法,, which means 'holding a flower while conveying the dharma') can be seen carved in relief. On the other ends, the inscriptions respectively read 'Minguo shi nian xinyou yuanchun gudan min' ('on an auspicious day of January, the tenth year of the Republic of China; the Year of Xinyou) and 'Dizi Wang Guolu, Huang Huichun, Lin Rentang, Lin Yupei tong jing li' (respectfully erected by disciples Wang Guolu, Xie Ziyou, Huang Huichun, Lin Rentang, and Lin Yupei). The inscriptions suggest that this plaque was created and finished in the first month (reasonably in the Lunar Calendar) of the tenth year of the Republic of China, which is in 1921. Regarding the latter, judging from the modest appellation that the "Disciples" (Dizi) Wang Guolu and others used to address themselves, it is probable that this plaque was collaboratively contributed to by members of a temple. Furthermore, the inscription "Nian hua shuo fa" alludes to a Buddhist ancient record describing the origins of Zen Buddhism during the Song Dynasty, which narrates the story of Buddha's sermon that was preached non-verbally, encapsulating the spirit of Zen. Based on this aforementioned information, the plaque may hang at a place were associated with a Zen monastery.

Condition check and examination

Regarding the condition of the object, although the plaque remained relatively solid structurally, signs of breakage, loosening joints, and shrinkage-induced opening in certain areas of the plaque were concerned by the conservator. As for the decorative parts, some attractive carvings with gilded surfaces are alongside the central area, and the inscriptions themselves are also gilded. The red surface of the central part seems to be finished by a special decorative technique, resulting in a coarse and sand-like texture. The red surface surrounding the inscription and the gilding surface along the plaque's border had manifested conservation issues, such as cracking and peeling, etc., which may be due to the deterioration of adhesive materials or other factors (**Fig. 2**). Moreover, the old repairs and retouching could also easily catch viewer's attention (**Fig. 3**). No painting on the back of the plaque could be traced, however, some grounding and mounting fabric layers were found during the preliminary check.

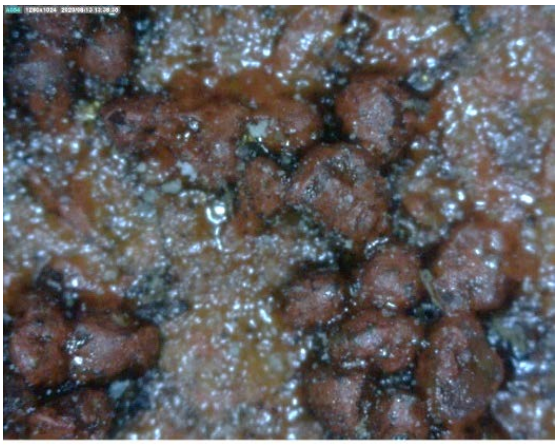

Fig. 2. The micrograph shows that some red grains of the rea decorative surface is already lost (200x in visible light).

Fig.3. The old retouching reflected and caught eyes.

To preserve this wooden plaque's cultural significance and recreate its visual integrity, the conservator conducted a few quiet examinations for further drawing a better conservation plan to conserve this wooden plaque.

Firstly, in terms of the old repairs on the plaque, two different materials could be detected under UV light. The reddish gluey repairs on the background can be swelled with water and subsequently removed, while the brown old repairs on the gilded inscriptions seem to be relatively stable. For those brownish surfaces, we opt to retouch them directly if needed (**Fig. 4**). However, for those reddish old repairs, figuring out how to bring back a similar appearance after the removal of the repairs is crucial for the following conservation and retouching practice. Hence, the conservator carried on a series of experiments with different binders and fillers in order to better match the original surface texture and gloss (described in the following section). Secondly, upon closer examination of the enlarged and cross-section images of the red decorative surface, those coarse grains seem to be solid, rounded, and evenly spread, and most have adhered to one or two layers of the surface.

Interestingly, as the colour of the red surface reminds us of the typical adhesive used in oriental gilding, it suggests us to have another quick analysis with XRF (X-ray fluorescence). According to the XRF test results, the components of the red grains contain lead. This would then suggest that the material used in finishing the decorative surfaces of this wooden plaque may be similar to that used in traditional oriental lacquerware, which is minium (red lead, saturnine red, Pb3O4).

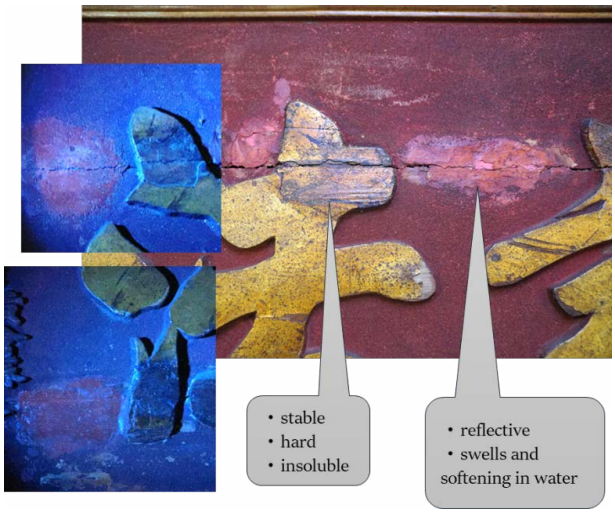

Fig.4. Someone had restored the plaque with at least two different materials, which have different fluorescent reflections under the inspection with UV light.

Experiments and decision-making

To match a relatively befitting appearance to the original red decorative layer on the plaque, the conservator conducted a brief experiment with 2 adhesives and 2 fillers; namely the *Paraloid* B72 and Laropal®A81, and the dry lacquer powders (**Fig. 5**) and quartz sands.

It would be valuable to note that the solvent-based artificial adhesives were picked mainly because of the sensitivity of the wooden object against water. Also, the object presents a rather safe condition under a solvent test, and the mix of synthetic resins and the fillers seem to be compatible with the surrounding surface. Besides, the humid weather in Taiwan also urges the conservator to make the initiatory decision.

Afterwards, the dry lacquer powders and quartz sands were chosen to be bonded with the aforementioned adhesives for further comparison with the texture of the

original surface. The dry lacquer powders were drawn into the testing list mainly because the original surface looks similar to one part of oriental lacquerware techniques. The dry lacquer powder can be prepared from coloured lacquer. Specifically, oriental-coloured lacquer needs to be applied multiple times on a glass plate or vinyl sheet, and it must be peeled off, crushed, and then sieved according to particle size after totally drying. It may then be sprinkled on the surface to create a coarse, rough and unique texture. However, it was found risky to apply dry lacquer to the solvent-based adhesive as they will get progressively dissolved and would probably not be able to achieve the ideal sense of 'grains' on the surface.

Fig. 5. Dry lacquer powders; made by using oriental lacquerware methods.

To cooperate with solvent-based adhesive, the conservator selected artificial coloured sands (120 Mesh ,<0.125mm), which are made of fine marble or quartz sands. Among them, the red colour is obtained through high-temperature sintering during the firing process, which allows artists or conservators to reduce the use of extra retouching and gain a better performance. Moreover, the red grains are generated by glaze firing, so there will be no chemical dissolution in the organic solvent. During the experiment, it was also found that the sharp edges of these red sands can also be distinguished from the original materials under close examination, e.g. through a magnifier or microscope. Coincidently, it could fortunately be perfectly integrated with the whole plaque when viewing them from a distance.

In a further test on practical application, the red quartz sands were spread and let them stick on the pre-applied adhesive, which is alike the technique in decorating oriental lacquerware called *makie* (蒔絵, まきえ). However, the results were not satisfactory, because of the workability in controlling the final appearance. Hence, the conservator tried to use a small spatula to mix the red sands with adhesive in advance, and to spread the mixture directly on the surface. In the last test, using a spatula as a filler can control the thickness remarkably well. And the finished layers seem to be thin and quite orderly, which has been put into the following practice and brought us a relatively satisfactory result (**Fig. 6**). In terms of the adhesives, although both *Paraloid* B72 and Laropal®A81 can work with the red sands, the 10% Laropal®A81 w/v in xylene were thus chosen to obtain a better workability on spreading red quartz sands.

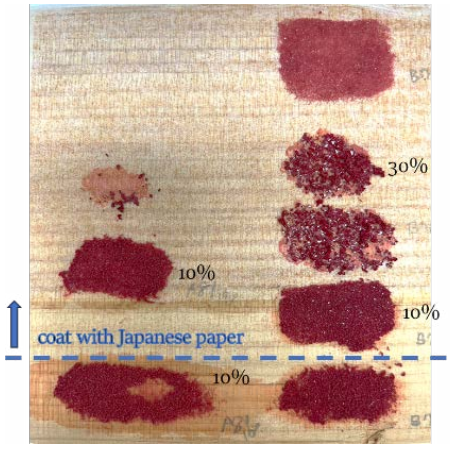

Fig. 6. Make test pieces to compare the effects of methods.

The brief treatment process

Consequently, the treatment of the plaque was proceeded in the following steps:

1. To clean the whole object with a vacuum cleaner;
2. To swap the object, mainly the front, with Deionized water;
3. To swell and remove the old repairs and retouching (**Fig. 7**);
4. To consolidate the loosened parts with *Paraloid* B72;
5. To fill gaps with balsa wood slices and calcium carbonate with *Paraloid* B72 (**Fig. 8**);
6. To coat a layer of Japanese paper to obtain a better adhesion between the foundation layer and the surface layer (**Fig. 9**);
7. To apply a layer of the mixture of red sands with Laropal® A81 in the red background area (**Fig. 10**);
8. Finally, apply a little retouching with pigments to tone the colour (**Fig. 11**).

Fig. 7. After the cleaning process, the old repairs and retouching were removed.

Fig. 8. Consolidated loose parts were then filled with Balsa Wood or calcium carbonate with acrylic resin *Paraloid* B72.

Fig. 9. After the filling process, a layer of Japanese paper was coated with *Paraloid*® B72 20% w/v in Xylene before the final retouching.

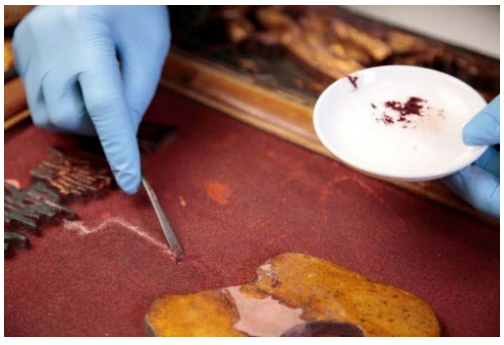

Fig. 10. A small spatula was used to mix red sands with adhesive and spread the mixed paste directly on the surface.

Fig. 11. The layout after the final retouching.

Examination after treatment

The enlarged images of the original and retouched parts help the conservator to further understand that the red sands are smaller than the original red grains, and their edges are sharper, lying in multi-layer condition, which allows the conservator to locate the retouched area. Nevertheless, just due to the different shapes and sizes of the red sands used in retouching, the gaps among those sands would increase the number of adhesion areas. This may therefore enhance the stability of the retouching layers. In the case of some original red grains that are already worn and lack their gloss, the use of Laropal® A81, at a concentration of 10%, seems to be highly appropriate to the original gloss and thickness around (**Fig. 12-13**). In the end, the plaque can finally be put into the exhibition with a better-matched appearance for visitors to enjoy (**Fig. 14**).

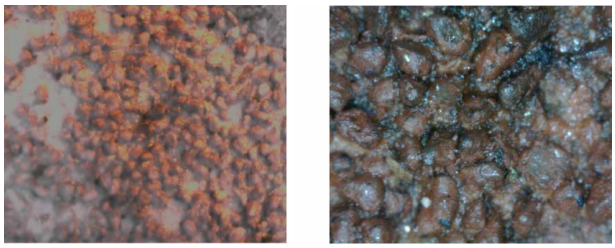

Fig. 12. The micrographs of the original surface.

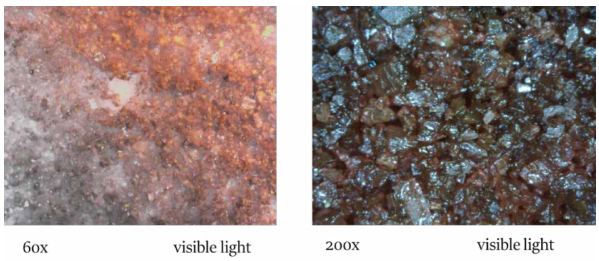

Fig. 13. The micrographs of retouching surface.

Fig. 14. The plaque can be finally enjoyed in a better condition in the exhibition room after the conservation practice.

Conclusions

In Asian heritages, such as furniture, plaques, and lacquerware, rough and grainy surface texture as a form of decorative embellishment would occasionally be encountered. They may be made from ground shellfish, carbon powder, dry lacquer powder, or quartz sand. In some techniques, oriental lacquer or glue is usually applied on sparkling particles for adhesion. They are then polished into a flat surface to form a special texture. Therefore, gaining more comprehensive understanding of these traditional techniques and making processes would always help greatly in conservation practices.

If a longer preparation time is available, conservators may consider oriental lacquerware methods to produce powdered substances that mimic similar surface characteristics. However, the lacquer powder particles that are produced using oriental lacquer may undergo colour change over time. Experienced craftsmen have also observed that the raw lacquer layer tends to become increasingly transparent and brighter gradually, while the tung oil that is added to the lacquer may undergo a yellowing process, making the colour change unpredictable. As a result, artificial adhesives may be advisable, especially when the object is sensitive to water.

Acknowledgements

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HANDCRAFTED AND SELF-PRODUCED DRY PASTELS AS REINTEGRATION MATERIAL FOR WALL PAINTINGS

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Abstract

This paper discusses the effectiveness of handcrafted and self-produced dry pastels as reintegration material of insoluble stains, lacunae and abrasions on the pictorial film of dark plaster wall paintings.

Refining traditional recipes for restoration, a handcrafted pastels wide range has been initially produced using gum tragacanth, various pigments and Meudon white (calcium carbonate) and kaolin as fillers. Then, these pastels have been compared with commercial Rembrandt and Schmincke dry pastels. All materials UV stability, adhesion, and cohesion have been investigated by spectrophotometric analysis and tape test. Handcrafted pastels have shown good properties, with high potential as a fast, easy, non-toxic and reversible reintegration material.

Finally, handcrafted pastels have been made easily recognizable adding into their mixture low percentages of zinc oxide, a fluorescent marker visible to UV radiation that ensures them easy recognition over the reinstated original material.

Keywords:

wall paintings,

handcrafted dry pastels,

commercial dry pastels,

reversibility,

UV fluorescence,

zinc oxide

Introduction

The study about dry pastel was conducted at the Istituto Centrale per il Restauro (ICR) in Rome specifically for the wall paintings restoration inside the Church of S. Marta al Collegio Romano (Rome) (Massarelli & Procopio, 2021-2022). The discovery of pastel as the original finish of the paintings and the necessity of its use during their aesthetic presentation phase have suggested the exploration of pastel both as an execution technique and as a tool in the mural paintings' reintegration.

The purpose of this research was to realize a series of handcrafted and self-produced pastels to investigate their features and behaviour over time, aiming to assess their suitability as restoration material. Another aspect of the experimentation was the study of a system that could easily identify the product as a restoration material once applied. Dry pastel is composed of a substance similar to that of mural paintings and inexperienced eyes could potentially confuse the intervention material with the original one, even upon close inspection.

In graphic arts history, the term "pastel" refers to a small cylindrical and pointed instrument produced through a mixture of pigments, inert minerals, and, if necessary, a minimal amount of binder (Mayer, 1991; Watrous, 1967). The combination of ingredients and their proportions was crucial to achieve tools that were both resistant to hand pressure and soft enough to leave a full stroke.

In general, the pigments employed for modulating colour were the same used in other painting techniques and needed to be finely ground to ensure better adhesion of pastel to the support.

The filler was an inert mineral and had to be finely powdered. Its type and quantity depended on the desired tone and consistency of the pastels. It was possible to use white materials like calcium carbonate or kaolin for lighter tones to darker materials like graphite or Armenian bole for deeper tones.

The binder, dissolved or swelled to give very diluted aqueous solutions, was usually added in very small quantities to give the pigment and filler particles the right cohesive strength to remain compact. The adhesion of the powdery material was mainly reliant on the roughness of the support, which mechanically retained it. Historical recipes mentioned various types of binders, both vegetable and animal, like gum tragacanth, must, animal glues or milk. The choice of binder depended on its properties and, above all, on its compatibility with the mixed pigments.

The origins of dry pastel are traced back to the late 15th century and the early 16th century, primarily associated with France. Among the names linked to the early use of pastel in Europe is the French artist Jean Perréal. In Italy, Leonardo da Vinci seems to be among the first artists to experiment with this new tool (Innocenzi, 2018).

By the early 16th century, this technique began to spread and gain appreciation from patrons. The diffusion of the new graphic medium was accompanied by an increased awareness of its expressive autonomy, receiving more attention in treatises (Pozzo, 1700).

During the 17th century, the term "pastel" acquired a specific meaning, indicating a well-defined instrument. Its use intensified alongside the appearance of numerous recipes.

The 18th century represented a golden age for pastel, as it firmly established itself, especially in portraiture, as an autonomous technique, used to decorate the entire support it was no more just as a "graphic" material for small elements. The significant success was reflected in the extensive treatises produced during this period, especially in France and England.

During the 19th and 20th centuries, pastel experienced a decline, being utilized more sporadically by artists and often combined with other materials such as coloured pencils or watercolours. There were no innovations in material production and the treatment of pastel did not experience significant changes (Baroni, 2001; Jeffares, 2006).

Experimental

Materials

This work involved the realization of three sets of specimens, each involving the handcrafted production of dry pastels.

The first set of pastels was carried out following traditional recipes, complemented by a scientific approach to establish reproducibility standards.

For this purpose, pigments with a composition similar to those identified through scientific analysis on the restored Santa Marta mural paintings were chosen: lead white, cinnabar, Malaga hematite, Persia red ochre, Verona red ochre, yellow ochre, lead antimonate yellow, smalt, Cyprus raw umber, Cyprus burnt umber, green earth, malachite (Bevilacqua et al. 2019; Eastaugh et al. 2008).

About fillers, Meudon white (calcium carbonate) and kaolin (Eastaugh et al. 2008) were selected and used in pastels recipes, either separately or in combination. The quantities ranged from 5-30% for the first and 9-25% for the second, in each pastel.

The chosen binder was gum tragacanth, a natural vegetable exudate primarily composed of polysaccharides. Water solutions with different concentrations were prepared (Table 1).

Table 1. Gum tragacanth solutions prepared during the experimentation

Solution	Ratio (binder/water)	Gum tragacanth %
A	1:30	3,22%
B	1:90	1,07%
C	1:270	0,35%
D	1:810	0,11%

Solutions B, C, and D were selected for this study. For each pigment, two to four pastels were realized, with variations based on the presence or absence of filler, its type and the addition of different binding solutions (B, C, and D) or water alone. After the production, the pastels were left to air-dry for three days.

The second set of pastels was produced in order to test their validity as a material for reintegration of mural paintings portions characterized by insoluble stains or lacunae and abrasions in the pictorial film that reveal dark preparatory plasters. Moreover, handcrafted pastels were compared with commercial ones. Mixtures of pigments for handcrafted pastels and colours for commercial ones were chosen to achieve a final colour resembling beige. This choice aimed to strike a balance between the hues of pastels used in the restoration of S. Marta wall paintings.

Beige pastels were manufactured using dilutions from B to D and both Meudon white and kaolin as fillers in a 3:1 ratio to achieve the right degree of softness and plasticity. Finally, the pigments used were raw and burnt Sienna, raw umber and burnt umber, vine black, titanium white, Verona red and Malaga hematite, appropriately blended to obtain three different shades of beige.

According to the results obtained through an online survey for conservation experts, commercial pastels from the Royal Talens Rembrandt series and Schmincke brand were selected for comparison (Rembrandt technical sheet; Schmincke technical sheet). Similar to artisanal ones, their colours were chosen to obtain a final beige shade (Table 2).

Table 2. Chosen Rembrandt and Schmincke pastels

Brand	Number	Colour	CIGN
Rembrandt	227,10	*Yellow ochre*	PY42
Rembrandt	408,10	*Raw umber*	PY42, PR101, PBK7
Rembrandt	409,7	*Burnt umber*	PR101, PBr7, PBrk7
Rembrandt	409,8	*Burnt umber*	PR101, PBr7, PBrk7
Rembrandt	409,9	*Burnt umber*	PR101, PBr7, PBrk7
Schmincke	030 M	*Greenish umber*	PY42, PB29, PBk11
Schmincke	037 M	*Sepia brown*	PBr6, PBk11
Schmincke	037 O	*Sepia brown*	PBr6, PBk11
Schmincke	093 O	*Greenish grey 1*	PY42, PB29, PBk11
Schmincke	098 O	*Neutral grey*	PW6, PBr6, PBk11

Through FT-IR and XRD, fillers in the two commercial brands were identified by analyzing three pastels per brand (Schmincke: 030 O, 037 M, 093 O; Rembrandt: 227,10, 408,10, 409,8). In Schmincke, barium sulfate, rutile, calcite, dolomite and talc were identified. In Rembrandt, barium sulfate, kaolinite, analcime and calcite were identified. Thermogravimetric investigations on a pastel from both brands (030 O, 227,10) estimated a weight loss of the organic component, attributable to the binder, at about 0.45% for Schmincke and 0.17% for Rembrandt (Report, 2023).

For pastels comparison, four types of mortar specimens (8×8×2 cm3) simulating mural paintings were realized. After applying two preparatory layers, a beige lime painting

strip was painted on each sample to simulate a pictorial film and provide the necessary chromatic reference for the application of reintegrative materials. The remaining surface of each specimen represented various degradation phenomena, including lacunae/abrasions in the pictorial film on dark plasters, generic dark stains, dark insoluble protein-based stains and dark insoluble lipid-based stains. The first degradation phenomenon was achieved by leaving the dark plaster layer visible. The generic dark stain was created by applying Cyprus burnt umber in fresco technique. To obtain the last two types of degradation phenomena, a diluted rabbit glue solution at 0.5% was applied for the protein-based stain and linseed oil diluted in white spirit at 1% was applied for the lipid-based stain, both in Cyprus burnt umber layer.

Referring to the application phase, all the chosen pastels have been applied to the different specimens, simulating real-world applications and reaching the beige chromatic lime painting reference (**Fig. 1**).

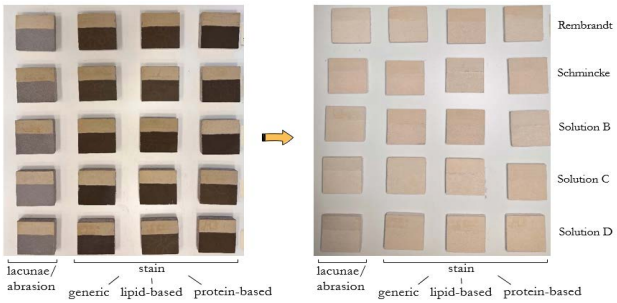

Fig. 1. The four types of mortar specimens before and after handcrafted and commercial pastels application. It is possible to observe the complete coverage of the surface in accordance with the beige lime painting strip. Authors' photo.

The third set of pastels was produced by adding a distinctive mark to artisanal pastels, easily identifiable on the artistic artefacts surfaces. To accomplish this, small quantities (1-3%) of zinc oxide (Feller, 1986), a stable material chosen for its UV fluorescent property, were incorporated into their composition (Mezzadri et al, 2021). Additionally, as it has the appearance of a white powder, it is well-suited for pastel production, serving both as a pigment and a filler.

Cylinders in four colours – white, black, beige and green – have been produced, each containing various pigments with differing responses to UV light. Six powdered pigments were used for production: titanium white, vine black, raw Sienna, Cyprus raw umber, Cyprus burnt umber and malachite. The binder used was gum tragacanth C solution, deemed the best tested in the production of the first set of pastels. Instead, as fillers Meudon white and kaolin were employed, either separately or in combination. Therefore, seven fluorescent cylinders were manufactured.

Finally, for comparative purposes, the same recipes were used to produce seven pastels without zinc oxide.

Methods

The pastels of each specimen set were produced by the dry method, involving the precise mixing of weighed pigment and filler powders. Then, the selected binding solution was added to produce a mouldable paste, ensuring it was not excessively wet. The obtained mixture was worked with spatulas until achieving a homogeneous and lump-free compound, which was then shaped into a pointed cylinder (**Fig. 2**, **Fig. 3**).

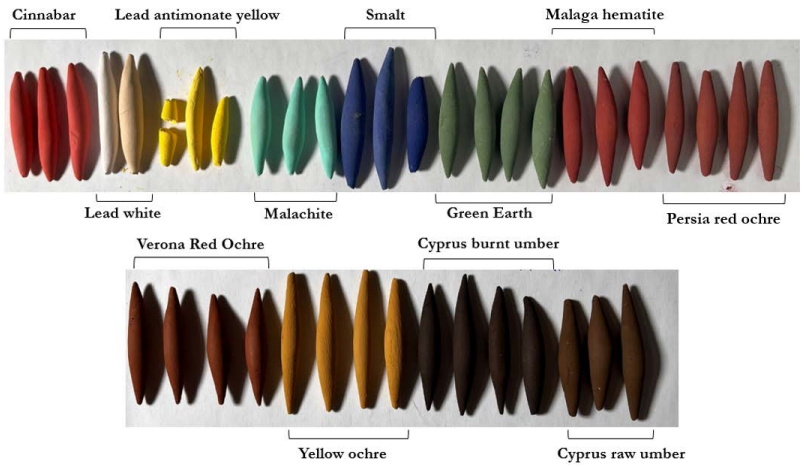

Fig. 2. First pastels set produced with twelve different pigments. For each pigment, two to four pastels were realized, with variations based on the presence or absence of filler, its type and the addition of different binding solutions (B, C, and D) or water alone. Authors' photo.

About the third pastel set, in the blending phase of pigments and fillers, zinc oxide was added. Only after confirming with a Wood lamp that the mixture was sufficiently fluorescent and well amalgamated, the binder was incorporated (**Fig. 4**).

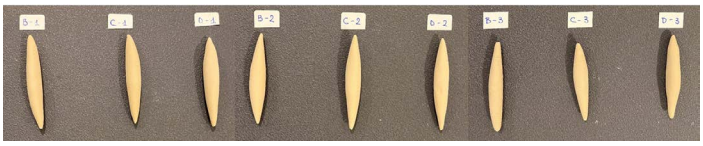

Fig. 3. Second pastels set. The handcrafted pastels were produced by mixing pigments to create a beige colour, using gum tragacanth solutions from B to D, with Meudon white and kaolin as fillers. Authors' photo.

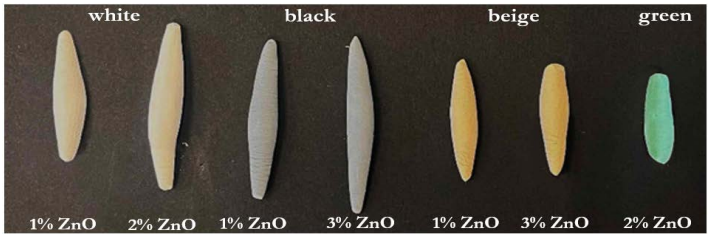

Fig. 4. Third pastels set. The handcrafted pastels were produced in four different colours (white, black, beige and green), with the addition of zinc oxide (1-3%) as a fluorescent marker to aid in the identification of the restoration material. Authors' photo.

The first pastels set was tested on two surfaces differentiated by roughness: a smooth white paper sheet (F3, Fabriano®) and a mortar specimen simulating a mural painting surface. Manual writing tests were performed on these surfaces. In the first, a line with consistent pressure in a single pass was drawn for each pastel. While, in the second, the applied pressure was increased, retracing the line over the same area to create a perfectly homogeneous fill. The purpose of these tests was to verify pastels drawing capability, simultaneously monitoring their softness and coverage. What has been observed is the result of subjective evaluations, grounded in a practical and perceptual approach.

The second pastels set, applied on mortar samples, was undergone artificial ageing. The goal was to assess the effects of prolonged exposure to ultraviolet light, studying the photochemical resistance of different products. A climatic chamber (Q-Lab Corporation, QUV Solar Eye model) with UVA-340 fluorescent lamps and devices maintaining a constant temperature at 50 °C and relative humidity at 20% was employed. The exposure was continuous, with an irradiance of 1 W/m2 per lamp, for a total of 40 days. These correspond to roughly 28.5 years of cumulative UV irradiance on mural paintings, following Italian museum conservation regulations (D. Lgs. n.112) (Ministero della Cultura, 2001) and considering eight hours of light per day.

Various analyses and control methods were adopted to evaluate the different materials: spectrophotometric analysis, mechanical adhesion and cohesion tests and reversibility tests.

Spectrophotometric analysis was used to detect chromatic alterations associated with ageing of pastels drafts by repeating measurements several times throughout the cycle. The Konica Minolta CM-700d spectrophotometer was used, adopting the CIE L*a*b* measurement system according to FprEN 15886:2010. Measurements were made in triplicate on the same point and the average was automatically calculated. For more representative values, the medium-sized spot with an 8 mm diameter (MAV) was utilized. With these settings, three measurements were taken on three distinct areas for each specimen and the average was subsequently quantified. To ensure repeatability and an exact correspondence between the measurement points, masks were created using acetate sheets of the same size as the specimens.

The tape test was conducted on all specimens to verify the adhesive and cohesive properties of both aged and non-aged materials. Strips of 4 cm from a black adhesive tape (Yiwu Baijia Plastic Products Co.; 0.18x19 mm2) were employed for the test. This tape was chosen for its flexibility, resistance to deformation and moderate adhesive power. Following the ASTM D-3359/2009 standard, each adhesive strip was weighed and then applied to the specimen surface. To exert a consistent pressure uniformly for each measurement, a weight of 1100 g was placed on the strips. For each specimen, three pulls were performed at different points, weighing the amount of material removed.

As a final examination, reversibility tests were conducted exclusively on the pastels subjected to artificial ageing. Three distinct cleaning methods were selected and tested on three different areas of the specimens: dry brushing, with a cotton pad soaked in water and using both combined systems. At the end of the test, verification of pastel removal was assisted by observation with a high-magnification digital video microscope.

Regarding the recognizability theme through the addition

of zinc oxide in the third set of pastels, a spectrofluorimetric analysis was conducted to assess its fluorescence degree. For this purpose, the material powder was exposed to 365 nm UV radiation without visible residues.

Moreover, a spectrophotometric analysis was carried out to examine the possible desaturation of the pastel due to the insertion of zinc oxide. Measurements were performed on layers created on abrasive paper with malachite cylinders, fluorescent and non-fluorescent, where the pigment was used pure without the addition of fillers.

Subsequently, the produced pastels were tested using various reintegration methods to simulate typical procedures on artworks. The selected test surface was a sample painted with the Roman technique of sixteenth-century frescoes. Reintegration was carried out with small points and strokes of different colours, juxtaposed and overlapped. This methodology mirrors real aesthetic presentation operations for mural paintings.

The first test (a) involved reintegrating exclusively with fluorescent pastels, covering the entire surface. In the second (b) the reintegration was made through points and strokes with pastels without zinc oxide for a significant part of the operation. Only in the last phase, a fluorescent cylinder was utilized to produce small well-spaced strokes in the treated area. For the third test (c), the same method as the previous one was applied, using fluorescent pastels only to outline the retouched area through a dashed line or dots. Lastly, both fluorescent and non-fluorescent pastels were used to reintegrate some micro-lacuna areas (d). A Wood lamp was used to verify the system's effectiveness.

After the fluorescent pastel tests, reversibility tests were performed. Removal was done with a dry brush, refining the area with a water-soaked pad. At this stage, the UV emission of the drafts was exploited to verify with a Wood lamp the complete removal of the intervention product.

Results and discussion

The objective of the first specimen set production was to achieve a valid product in terms of workability and applicative functionality. The observations from the comparisons made among these pastels were meticulously documented on sheets dedicated to each one.

Except for earths and ochres, cylinders with pure pigments were obtained without the addition of fillers. Regarding the quantity of gum tragacanth in each pastel, the values are all below one percentage point, mostly even below 0.1%. These results demonstrated that minimal doses are sufficient to produce a functional pastel.

In general, except for lead antimonate yellow and smalt, all the pigments used were found to be suitable for processing and modelling. Lead antimonate yellow proved particularly challenging, likely due to its poor grinding degree. In contrast, the low cohesive power of gum tragacanth made difficult the compaction of the smalt glassy particles.

Once dry, pastels were all quite compact and sufficiently durable. Only the pastel with smalt showed a strong lack of cohesion between particles due to its glassy nature.

In writing tests, most pastels produced homogeneous and very covering strokes, differentiated based on the tip obtained in processing and the softness of the mixture that depends on the binding solution, filler, pigment and their proportions.

However, the earths and Verona red ochre were very hard, releasing little pigment on the surface and producing scratches. Conversely, lead antimonate yellow and smalt were excessively soft. Yellow pigment pastels fragmented during application, while smalt pastels shattered upon contact with hard surfaces, releasing a lot of dust that adhered minimally to the rough support (**Fig. 5**).

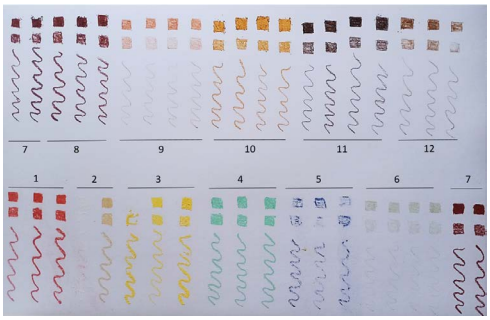

Fig. 5. **The writing test results allowed to verify the pastels' drawing capability while simultaneously monitoring their softness and coverage. Authors' photo.**

In all pastels, slight differences were often noticed between those with calcium carbonate and those with kaolin. The clayey nature of the latter provided greater plastic properties to the final products. However, this aspect did not result in differences in softness compared to pas-

tels with Meudon white.

Considering these observations, it can be concluded that among the pastels made in this first phase of experimentation, those suitable for application on mural paintings, based on their consistency, are pastels made of red ochre, especially Persia and Malaga types, Persia yellow ochre, malachite, cinnabar, white lead. Regarding the last two, however, their toxicity and stability need to be considered.

For more resistant surfaces, the use of Cyprus burnt umber, and Verona red ochre is not excluded, despite their hardness and poor covering ability.

Finally, it was observed that pastels with smalt, green earth and Cyprus raw umber should be discarded due to their low adhesion capacity to the support and their hardness.

The studies conducted to examine the behaviour of the second handcrafted pastels set and commercial ones highlighted advantages and disadvantages in terms of applicability, photochemical stability, adhesive and cohesive capacity and reversibility.

The application is swift, convenient, easy for both types of pastels and allows an immediate examination of the stroke result. However, there are differences between artisanal and commercial pastels. In handcrafted ones, self-production is primarily a method of controlling raw materials and a potential cost-saving measure. This permits for the calibration of formulations based on personal needs. Moreover, using colours close to the area to be reintegrated allows the use of a smaller quantity of intervention material on the artwork. Furthermore, self-production permits to realize dual-point pastels, useful for creating small strokes. Finally, the possibility of using a more or less diluted binding solution in production allows for the creation of tools with different consistencies. In this experimentation, the best results were obtained with recipes using solutions C and D, producing pastels with a soft and fluid stroke. Conversely, tools with solution B appeared slightly harder and more abrasive. On the other hand, commercial pastels have a cylindrical shape without tips, that makes more challenging the creation of small strokes. Additionally, finding a commercial pastel with a closest colour to the reference area can be difficult. These aspects result in a slower reintegration characterized by a greater number of applications. Regarding consistency, among the examined commercial pastels, Rembrandt ones showed greater compactness and hardness, similar to artisanal cylinders with solution B. For Schmincke pastels, however, greater fragility and pronounced softness were observed.

About spectrophotometric analysis, its comments are based on data acquired in SCI mode, evaluating colour independently of surface conditions. This choice was made because of samples surfaces have different constituent materials and have undergone treatments that altered their roughness. The primary observation from the data study is that, for all aged mortar samples monitored over time, the recorded ΔE value is below 1. Secondly, it was noted that the surface treatment of the various samples did not influence the recorded chromatic variations (**Fig. 6**).

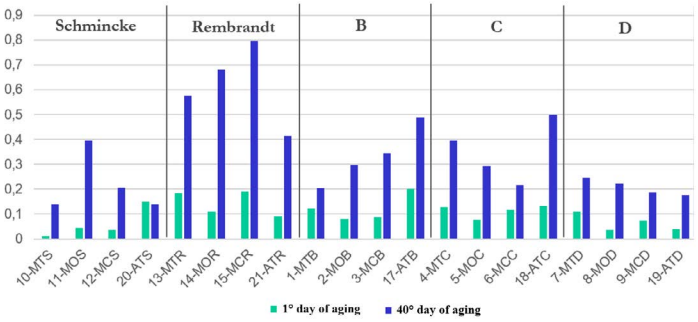

Fig. 6. Mortar specimens ΔE - After the 1st and the 40th day of ageing. Despite the difference between before and after ageing, the recorded ΔE value is below 1 for all specimens.

Comparing the data obtained from the tape test conducted on aged and non-aged samples, minimal weight differences were observed for all materials. Indeed, all pastels showed perfect adhesion and less cohesion, resulting in a consistent material release on the tape, without highlighting the sample surface (**Fig.7**).

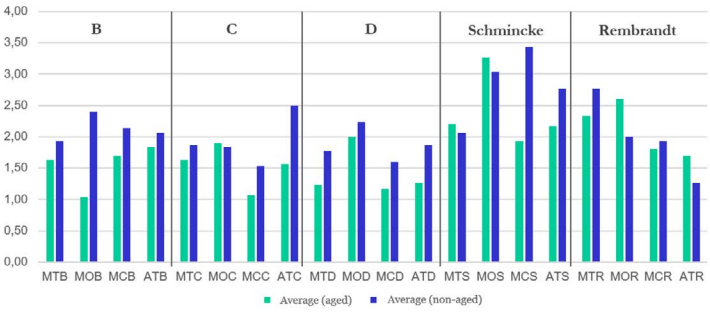

Fig. 7. Amount of material released (mg) - comparison of aged and non-aged specimens

Concerning reversibility, various cleaning tests on aged handcrafted and commercial pastels applications

demonstrated the easy and complete reversibility of the materials. In general, the combined action of dry cleaning and a water-soaked pad yielded better results in all samples (**Fig. 8**). Dry removal alone made it more challenging to completely remove pastel dust, especially from surface irregularities. Conversely, the water action on the compact substrate mixed the powder, making complete removal more difficult.

Additionally, a slightly different outcome was noted depending on the samples surface treatment. Particularly, the best result was achieved on samples with lacunae/abrasions surfaces, generic stain and linseed oil stain. On the contrary, on all samples with rabbit glue, minimal and mostly visible residues remained.

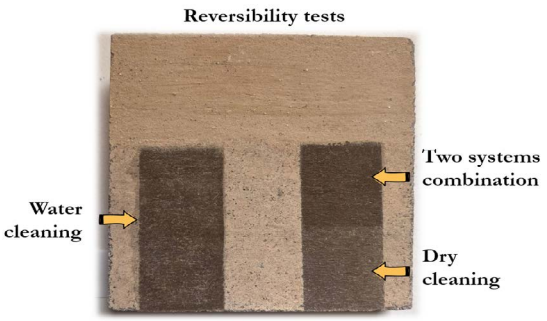

Fig. 8. Pastels reversibility tests. The combined action of dry cleaning and water cleaning yields the best results. Authors' photo.

Concerning the study on the dry pastels recognizability, the spectrofluorimetric analysis conducted on zinc oxide added into the pastels mixture of the third specimens set showed its yellow-green fluorescence, peaking at around 505 nm. Through the examination, it was possible to establish its high potential as a suitable material for the recognition of pastels once incorporated into their blend, as shown in the photo (**Fig. 9**).

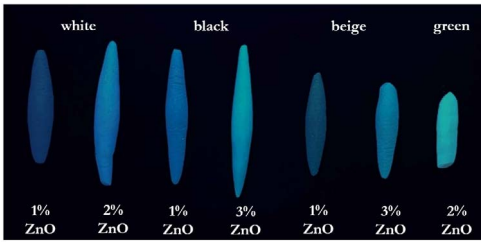

Fig. 9. Handcrafted pastels with a low quantity of zinc oxide (UV light). Based on the percentage of zinc oxide present, a varying intensity of fluorescence can be observed in the pastels. Authors' photo.

About spectrophotometric analysis, observing the calculated average values of L*, a*, b* for the three measurements, both for SCI and SCE data, minimal differences between the two measurements were noted. There was a slight increase in brightness L* for the pastel with zinc oxide, accompanied by a reduction in a* and b* values. However, there are no perceptible differences to the naked eye, precisely due to the low concentrations of added zinc oxide. Therefore, the addition of this marker does not result in pastel colour desaturation.

In the application test, the use of the Wood lamp allowed the observation of excellent results for all conducted tests. In the first one (a), the overlap of different pastels with zinc oxide resulted in a uniform and highly fluorescent application under ultraviolet light. Similarly, in the other three tests (b, c, d), despite their reduced size, the strokes appeared clearly visible, standing out from the non-fluorescent area. Therefore, it is possible to simultaneously use both non-fluorescent and fluorescent pastels based on the proposed methods, provided that the latter are applied above the former to be clearly visible under radiation (**Fig. 10**).

Fig. 10. Pastels application test - VIS and UV light. The photo shows how small strokes made with pastels containing a low amount of zinc oxide allow for clear recognition of the intervention. Authors' photo.

Finally, pastels removal in the third phase of the experimentation also had a positive outcome (**Fig. 11**).

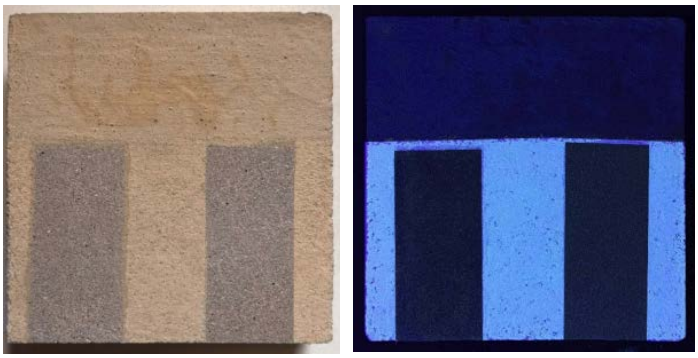

Fig. 11. Fluorescent pastels reversibility tests - VIS and UV light. Pastels fluorescence can also be useful for verifying the complete removal of the intervention material, as seen in the picture. Authors' photo.

Conclusions

In conclusion of this study, it can be asserted that hand-crafted and self-produced pastels represent an excellent material for reducing the visual interference of insoluble stains and lacunae/abrasions in the pictorial film on dark plaster.

The self-produced pastel offers numerous advantages:

- Use of raw materials to realize tools with desired characteristics
- Ease in production and use
- Photochemical stability
- No changes in adhesive and cohesive abilities over time
- Complete reversibility
- Easy recognition thanks to the addition of minimal amounts of zinc oxide

The handcrafted pastel, therefore, emerges as a suitable, fast and functional alternative to lime painting and varnish colours, traditionally employed to address the aforementioned degradation phenomena. Furthermore, its added value of UV recognition makes it potentially transferable to other intervention contexts. An example is the possibility to indicate the presence of detachments of wall paintings preparatory layers identified during the emergency response. The fluorescent pastel could also be used to make more identifiable a mortar filling on a white stucco decoration. This could be challenging to distinguish with the naked eye due to the affinity between restoration materials and the original ones. Considering that both original and added calcium carbonate can be fluorescent, applying a pastel with zinc oxide on the surface of the plaster could enhance this fluorescence. This would help to highlight the difference between the two materials.

The fluorescent pastel could thus be positioned as an innovative material easily transferable from the realm of pictorial reintegration to that of sculptural plastic.

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BARSON COLLAGE BY VICTOR VASARELY: RESEARCH AND CONSERVATION WORK

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Abstract

The collage Barson, owned by the Museum of Contemporary Art in Zagreb was created by the father of Op art Victor Vasarely in 1967 and is his only hardboard collage in Croatian public cultural institutions. It was purchased in 1969 after Vasarely's solo exhibition in the former City Gallery of Contemporary Art in Zagreb. The collage was created with the screen printing technique under the influence of leading objectivist artistic and philosophical trends and knowledge of the time.

Works of Op art imply an undisturbed perception of the artwork, which in the case of Barson was impossible due to the resulting damage. The collage was very dusty with traces of insect activity and had damaged paper support. From 2019 to 2020 conservation works were carried out, which included extensive art historical research, tests and technical analysis, followed by dry cleaning, removal of biological traces, and gluing in order to stabilize the damaged and detached support, and minimal retouching.

Keywords:

conservation work,

screen printing,

collage,

Op art,

Victor Vasarely

Introduction

At the *RECH 7* Meeting, a video about the works on the Barson collage was presented, and the text that follows describes this interesting work of art and the complex process of its conservation in more detail (**Fig. 1**).

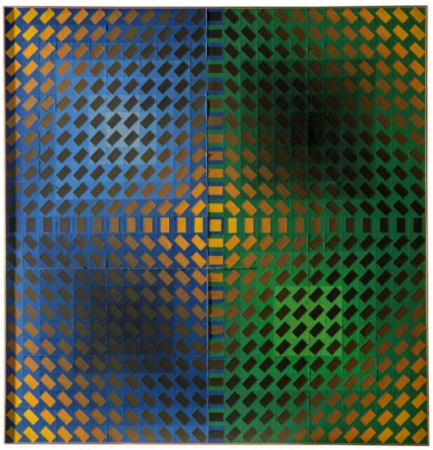

Fig 1. Victor Vasarely, Barson collage, condition of the collage before conservation work, Zagreb, Museum of Contemporary Art (HRZ archive, photo: J. Kliska, 2019).

Victor Vasarely and his art

Victor Vasarely (Vásárhelyi Győző) (Pécs, 9 April 1906 - Paris, 15 March 1997) is a French artist of Hungarian origin known as the originator of optokinetic art, or Op art. It's a geometric trend in abstract art that is based on the deception of visual perception, which developed following the constructivist research of Bauhaus from the 1930s and the work of Josef Albers. The focus of Op art is on movement, and it requires active participation of the viewer by observing the artwork from different angles and distances.

The early adopted scientific approach and objectivity would mark Vasarely's entire creativity output and lead to his early Op art compositions dynamized by parallel and winding black and white lines, the first of which is the famous Zebra from 1938.

The creation of Barson coincides with Vasarely's great popularity. At that time and in the following decades, Vasarely returned to colour and worked with square, circle, diamond, hexagonal and spherical shapes. Besides painting, Vasarely also engaged in kinetic sculpture, digital art and computers, templates for large-scale tapestries and abstract films. He popularized the screen-printing technique and linked it to industrial production that is independent of human touch, encouraging massification and denying the individualization of artwork because he considered art to be a social phenomenon and a general treasure.

It is known that Vasarely used classical pigments that he called constants: cadmium red, chrome yellow and cobalt blue. By vigorously grinding the pigments, he would obtain quality inks, which he then mixed with white spirit or some retarder. Having patented his plastic unit (fr. unité plastique) and plastic alphabet (fr. alphabet plastique) based on simple geometric units in 1959, he had a whole series of ready-to-use units in preparation (**Fig. 2**). Each plastic unit consists of a square on which another basic shape is placed: square, rectangle, circle, ellipse, triangle, etc. He made these units in 20 different colours, and each colour in six shades which he numbered from 1 to 6, arranging them from lightest to darkest. In order to facilitate the process he introduced alphabet letters for colours, so for example, blue is labelled with the letter "B" (fr. bleu) (Vasarely, 1959, p. 6-7).

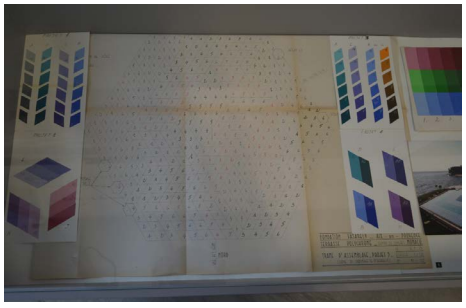

Fig. 2. Aix-en-Provence, Vasarely Foundation, plastic units (*fr. unités plastique*), (HRZ archive, photo: M. Begić Jarić, 2020).

The *Barson* collage

Barson is a large-format paper collage on a hardboard base, measuring 2,5 x 2,5 m. The paper support is glued to the base in two layers; the upper layer is executed in a screen printing technique and consists of plastic units made of square-cut elements measuring 10 x 10 cm into which rectangles measuring 5 x 8 cm are inserted. These squares are glued to the lower layer measuring 50 x 60 cm and 50 x 70 cm, which is glued to the hardboard base. The face of the lower layer is marked with a grid drawn with a blue felt-tip pen, which serves as a guide for glueing the upper layers. Each grid field is marked with a felt-tip mark ranging from H-1 to H-20 (H indicating haut, French for high, i.e. upper), the numbering increasing from left to right. Marks H-3, H-7, H-10, H-11, H-12, H-13 and H-15 were partially separated from the hardboard base and could be read off the back of the lower paper layer, while the rest of the marks, glued to the hardboard, could not be read (**Fig. 3**). In the upper corners, additional numbers were also visible which indicate connections with adjacent fields. It is assumed that the sheets were cut and stacked on the worktop, then numbered and later glued to the hardboard base.

This interesting and complex Op art composition is made of two basic quadrilateral shapes: rectangle and square using three colours (blue, green and yellow) which are represented in their 12 shades. The aforementioned plastic units create a visually two-layered composition. The lower layer consists of blue and green squares and is divided vertically into a blue and a green side whose upper and lower parts differ in the darkest or lightest central colour shade, thus creating a four-part composition. The upper layer consists of rectangles laid diagonally ranging from bright yellow to dark brown shades. The rectangles are moving towards the centre, where the only plastic unit consisting of two squares is located, with the lower square being blue and the upper one being bright yellow.

Each quarter of the composition consists of 144 plastic units, between each quarter there is one strip of 12 plastic units, which gives a total of 48 plastic units. The lower layer of horizontal strips consists of blue squares on one side of the composition and green squares on the other, while in the case of vertical strips, blue and green squares appear alternately visually merging in one strip that seems connected by a tongue and groove system. Along

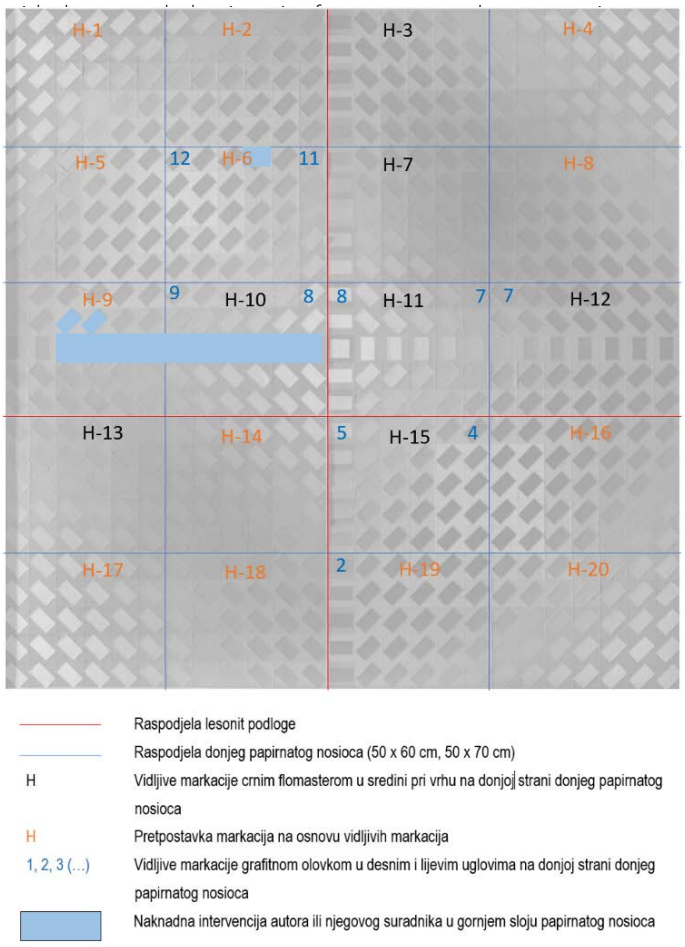

Fig. 3. Victor Vasarely, *Barson* collage, graphical representation of collage parts and layers, Zagreb, Museum of Contemporary Art (HRZ archive, photo: M. Begić Jarić, 2020).

Condition of *Barson* collage

The collage was found very dusty with impurities and damage caused by insect activity and stains of different origins. As a result of the weakening of the binder, layers of paper support had separated and dried out.

A network of craquelures with losses to the screen printed layer was found on the entire surface of the upper paper layer. In addition, detached layers, delamination and separation of paper support were visible. Large areas of grey-blue lower paper layer had separated from the hardboard base. Small parts of paper support were missing on all edges (**Fig. 4**). The hardboard base is well preserved, as is the screen printing ink, which is adhering well to the surface of the support.

Fig. 4. Victor Vasarely, *Barson* collage, detail of the collage before conservation work, Zagreb, Museum of Contemporary Art (HRZ archive, photo: M. Begić Jarić, 2019).

International cooperation

During the research work, communication was established with the CICRP institute (Centre Interdisciplinaire de Conservation et Restauration du Patrimoine) in Marseilles and the Vasarely Foundation in Aix-en-Provence. The CICRP institute kindly provided us with a handbook of texts, and The Vasarely Foundation donated paper samples produced with screen printing which Vasarely used to create his collages, and which share similar traits with Barson.

Experimental

Research and technical analyses

A simulation of surface dirt was created by applying powdered chalk with a soft brush to the side of the paper support with screen printing ink on a paper sample. Trials for dry cleaning were performed and it was determined that the Akawipe powder was the best cleaning agent (**Fig. 5**).

Fig. 5. Victor Vasarely, *Barson*, simulation of surface impurity and dry cleaning, Zagreb, Museum of Contemporary Art (HRZ archive, photo: M. Begić Jarić, 2020).

Adhesion trials were conducted on a paper sample donated by the Vasarely Foundation. Almost all the adhesives tested caused marked deformation of the paper sample, as well as a slight surface change to a darker tone, except the 4% cellulose adhesive *Tylose MH 300 P2* and the industrial starch glue *Eukalin DK*, which caused the slightest deformations and little darkening of the paper.

Analysis of the upper and lower paper layers of the collage established the presence of linen and cotton fibres as well as wood pulp and lignin (Klofutar, 2020). The FT-IR analysis showed the presence of starch glue. It was established that upon removal of the self-adhesive paper and tape, no traces of glue remained; therefore, for easier handling, an adhesive paper was used to isolate the original paper during the glueing.

Retouching trials were conducted on paper samples by first simulating craquelures by folding. Upon folding outwards, there were no visible cracks in the surface ink, while folding the sample inwards led to visible irregular lines with separated ink. Also, some folds were mechanically treated by surface scraping to achieve as much damage as possible. Retouching trials with various media were performed on the sample prepared with simulated craquelures. Retouching trials showed that watercolour paints should be used for the best coverage of simulation cracks. Thus, watercolours were used for the first layer of retouching, while the second layer was performed by scraping dry pastel and mixing it with 2% Tylose MH 300 P2, which proved to be the best choice for blending (**Fig. 6** and **Fig. 6-a**).

Fig. 6. Victor Vasarely, *Barson* collage, first layer of retouching with watercolours, Zagreb, Museum of Contemporary Art (HRZ archive, photo: M. Begić Jarić, 2020).

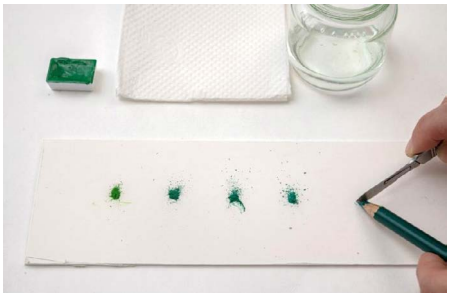

Fig. 6-a. Victor Vasarely, *Barson*, preparation for the second layer of retouching by scraping dry pastel, Zagreb, Museum of Contemporary Art (HRZ archive, photo: M. Begić Jarić, 2020).

Conservation work

The conservation work began with the creation of photographic documentation under visible, infrared and ultraviolet light spectra. The infrared image showed no visible changes, while the ultraviolet image showed scratches and cracks on the damaged surface. The acidity of the paper support was measured with a pH meter, and values between 6.55 and 6.28 pH were obtained, which are considered stable for artworks on paper support. This was followed by mechanical removal of the metabolic activity of insects and dry surface cleaning. The work continued with glueing the lower and upper layers of paper support onto the hardboard base. The unglued parts were additionally glued with industrial starch glue *Eukalin DK*. The entire surface was covered with non-woven fabric and absorbent paper and weights were placed upon for a 24 hours drying process.

Reconstruction of the missing parts of paper support was performed with Japanese paper *Bib Tengujo* 12 g/m2 and 4% *Tylose MH 300 P2*.

This was followed by the necessary minimal retouching, which was performed in two layers. The first was performed with a dense *Winsor & Newton* watercolour while the second was performed with a mixture of *Stabilo* dry pastel powder and 4% *Tylose MH 300 P2* to achieve the final three-dimensional effect of the ink structure.

The dense watercolour was chosen as the most suitable technique for the first layer of retouching because of its good coverage properties and the dry pastel powder was chosen for the second layer, i.e. blending, after testing the combination of different techniques with watercolour, all with the aim of obtaining a structure closest to the screen printing technique (**Fig. 7** and **Fig. 7-a**).

Through combining these two methods of retouching, the surface reflection of the ink has been calmed down, thus harmonizing the surface appearance. After the conservation work, the installation of the *Barson* collage was carried *in situ*, in the premises of the Museum of Contemporary Art in Zagreb.

Fig. 7. Victor Vasarely, *Barson*, condition of the collage before the retouching, Zagreb, Museum of Contemporary Art (HRZ archive, photo: M. Begić Jarić, 2020).

Fig. 7-a. Victor Vasarely, *Barson*, condition of the collage during the retouching, Zagreb, Museum of Contemporary Art (HRZ archive, photo: M. Begić Jarić, 2020).

Conclusion

The *Barson* collage was made by Victor Vasarely in 1967 with screen printing technique on paper and glued on hardboard. It was purchased in 1969, after Vasarely's solo exhibition in the City Gallery of Contemporary Art (now the Museum of Contemporary Art) in Zagreb. Given the numerous damages caused by physical, chemical and biological agents, within the period of 2019 and 2020 demanding conservation work was carried out, which included extensive art historical research and basic conservation work for the purpose of stabilization of the damaged and detached paper support, as well as retouching, to enable the complete perception that is inherent in Op art works. (**Fig. 8**). It should be noted that no comparable example of conservation had been found, so the conservation work was challenging in many ways. During the rea-

search, all stages of Barson's creation were determined, and notes on its back were discovered, which were not known until the conservation work started. Bearing in mind the optical character of this artwork, the execution of retouching was somewhat demanding, because it had to be done very precisely and carefully, given that the screen printing technique doesn't tolerate mistakes.

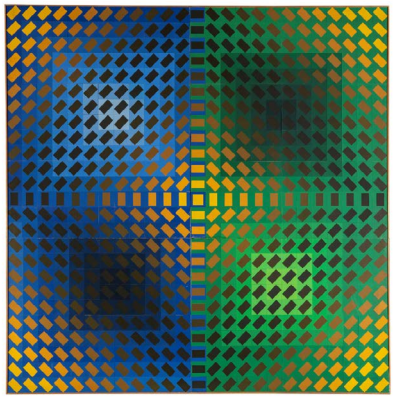

Fig. 8. Victor Vasarely, *Barson*, condition of the collage after conservation work, Zagreb, Museum of Contemporary Art (HRZ archive, photo: J. Kliska, 2020).

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We sincerely thank Pierre Vasarely and the Vasarely Foundation for kindly providing us with the paper samples for our tests.

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MIXED REINTEGRATION TECHNIQUES TO RESTORE THE READABILITY OF MID -20TH-CENTURY MEDICAL POSTERS

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Abstract

AA group of three chromolithographic mid-20th-century medical posters from the Museum of Institute of Hygiene and Tropical Medicine, exhibited severe distortions, damaging previous interventions, soiling, foxing and mould stains, tears, and losses at image and support levels. These issues compromised the posters' chemical and physical stability. After undergoing chemical and physical stabilization treatments, image reintegration was deemed necessary due to the posters' primary exhibition function and the distracting nature of some of the damages. Japanese paper infillings were toned with liquid acrylic inks or with coloured pencils by stippling and cross-hatching, depending on the area being treated (plain colours or dotted areas characteristic of chromolithography). Burnishing techniques were employed to replicate the posters' glossy surfaces. The reintegration materials applied were of high colour fastness and are readily detectable by common examination methods (e.g. UV light, magnification, raking light). The performed treatment successfully restored visual continuity to the posters and enhanced their readability. .

Keywords:

medical posters,

image reintegration,

chromolithography,

paper conservation,

chromatic reintegration

Introduction

Chromatic reintegration is often crucial for restoring the visual integrity and minimizing the distraction of losses in paper-based artworks. However, unlike paintings, paper objects are single-structured, making repairs more obvious and challenging the application of isolating layers. These objects are also typically meant to be viewed at close range, making it more difficult to create a repair thar integrates with the whole. Furthermore, media applied to this porous, absorbent material will penetrate the matrix, rendering its removal virtually impossible, which makes chromatic reintegration an irreversible intervention in most cases. According to Poulsson (2008), there are two main types of reintegration on paper: interventive retouching, which is performed directly on the original artwork, and non-interventive retouching, which is done on paper infills. Non-interventive retouching is generally preferable as it can be reversible and easily identified as a later addition to the original work. Due to these considerations, the pros and cons, materials, and techniques of chromatic reintegration require careful evaluation before proceeding. Nevertheless, this remains a controversial treatment option with limited documentation in the specialized literature (Jean et al., 2014; Hsiao et al., 2016; Grenda, 2010).

In this paper, we describe and discuss the approach we employed to reintegrate a group of three mid-20th century medical posters. Our aim is to contribute to the sharing of experiences on this important topic.

The posters' collection

The Museum of the Institute of Hygiene and Tropical Medicine (IHMT) in Lisbon, houses a collection of 12 posters dedicated to hygiene promotion, healthcare, and tropical diseases (IHMT, 2021). Three of these posters, in particular poor condition, were selected for treatment as part of the paper conservation course in NOVA University's Master's program in Conservation and Restoration.

Fig. 1. The selected posters before treatment (photography under incident visible light): a) Poster on malaria prevention awareness; b) Poster on the promotion of child nutrition; c) Poster on the promotion of childcare.

These printed posters, designed in 1946 by Mofid Jaid, are written in Arabic and address malaria prevention awareness, child nutrition and childcare (**Fig.1**).

These posters were originally used for medical propaganda, but today they are museum objects primarily used for exhibition purposes, holding significant value to the history of medicine.

Their dimensions range from 825x610mm to 814x613mm, with an average thickness of 0.2mm. The printing technique was identified as chromolithography, employing the three primary colours and black (**Fig.2**).

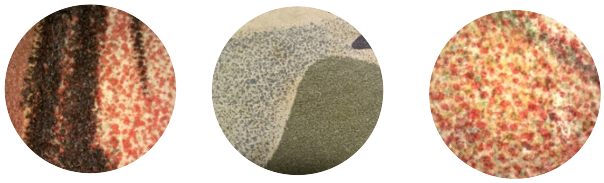

Fig.2. Digital microscope Dinolite observation of three posters.

The primary supports of all three posters are machine-made wove papers, composed of a mixture of mechanical pulp, bleached chemical pulp and unbleached chemical pulp, with some lignin content (identified by Herzberg, Lofton-Merritt and phloroglucinol + HCl stains (International Organization for Standardization, 1990a, 1990b; Odegaard et al. 2000). The posters were initially mounted on secondary cardboard supports (only remnants of these supports remained on two of the posters). The cardboards share the same pulp composition as the primary supports but a higher proportion of mechanical pulp and consequently a higher lignin content.

All posters exhibit a finishing layer, evident by a slight sheen on the surface, which was identified as shellac resin by External Reflectance FTIR spectroscopy. Due to the reactivity of this resin with organic solvents, only aqueous solutions were employed throughout the treatment process.

Condition of the posters

Overall, the posters were in poor condition, showing substantial physical-chemical deterioration caused primarily by direct water exposure, inappropriate past repairs, mishandling, and inadequate storage conditions. Beyond pronounced deformations, they displayed superficial soiling, foxing stains, tidelines, scratches, tears, and losses of both the image layer and the paper support. Previous repairs included application of masking tape, the adhesion of a paper towel, and the attachment of a new secondary support to one of the posters, which was contributing to further warping. In two posters, the secondary support had been ripped off, causing layers of the primary support to be ripped off as well. One poster exhibited purple stains and weakened areas due to microbial attack. The paper support of all the posters was acidic (average pH= 4.7) and displayed some degree of brittleness (**Fig.3**).

Conservation intervention

The conservation intervention commenced with gentle surface cleaning using a soft brush. Superficial incrustations were removed with a cotton swab moistened with distilled water. Weakened areas, including tears and paper delamination, were reinforced beforehand by facing with Japanese paper and methylcellulose. The residues of original and new secondary supports were removed using localized humidification with agar-agar hydrogels. The masking tapes were removed with a heat spatula to soften the adhesive and detach the paper carrier. Crepe rubber was used to remove adhesive residues. This process required utmost care as the area was highly fragile due to microbial deterioration, and the presence of shellac on the poster precluded the use of organic solvents. To neutralize the acidic paper support, the posters were immersed in distilled water with calcium hydroxide, ad-

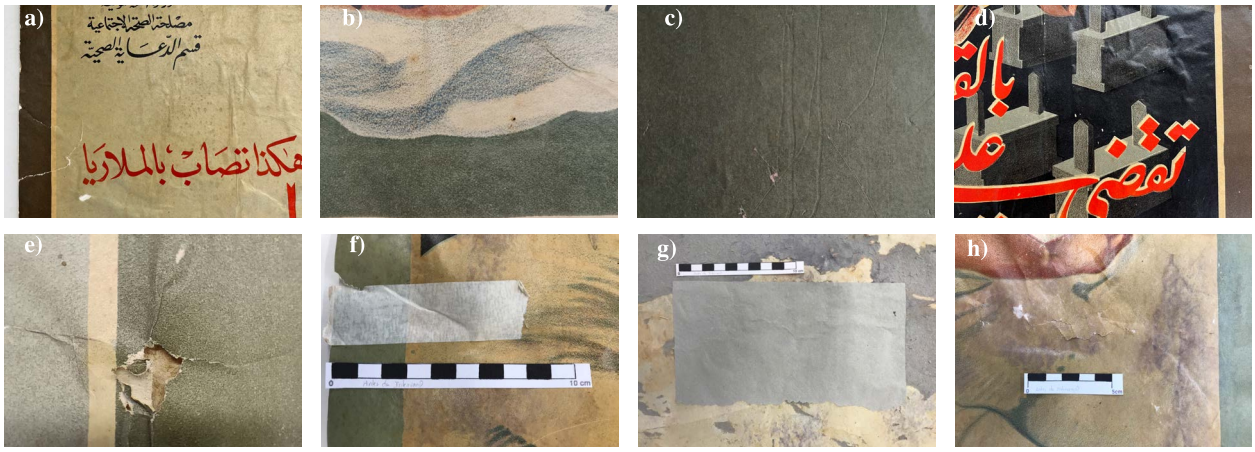

Fig. 3. Details of the condition of the posters: superficial and embedded dirt (a); foxing stains (b); scratches (c); tears (d); image and support losses (e); previous interventions: masking tape (f), and pasted paper towel (g); weakened areas and stains caused by microorganisms (h).

justing the pH to 8.0. Subsequently, they were dried and flattened under pressure on a stack. Tear mending and stabilization of fragile areas was accomplished using lightweight Japanese paper and methylcellulose.

Regarding the filling of losses, we had to evaluate, along with the museum stakeholders, the need to reintegrate them chromatically. Considering the aesthetic value and exhibition purpose of these posters, it was decided to proceed with reintegration.

To enhance the reversibility of this intervention, all reintegration was made over paper infills, rather than over the original materials. The selection of materials was guided by the following criteria:

- Insolubility in water after drying: This ensures that the reintegration materials will not irreversibly migrate onto the original support in case of water contact.
- Chemical stability and compatibility: These properties prevent alterations caused by ageing or reactions with the original materials.
- Glossy finish: This matches the original appearance of the posters.
- Lightfastness: This prevents colour fading during exhibition

Based on these criteria, two main types of reintegration materials were selected for testing: acrylic liquid paints and coloured pencils (Soleymani et al., 2016; Book and Paper Conservation Wiki, 2001).

To dye the paper with acrylics, *Sennellier* Abstract acrylic inks (Naples yellow 567/OT***, Primary blue 385/T***, and Raw Sienna 208/OT***) were mixed with distilled water and applied on paper by immersion or brushing, followed by drying with a hair dryer over a polyester film (Fig. 4).

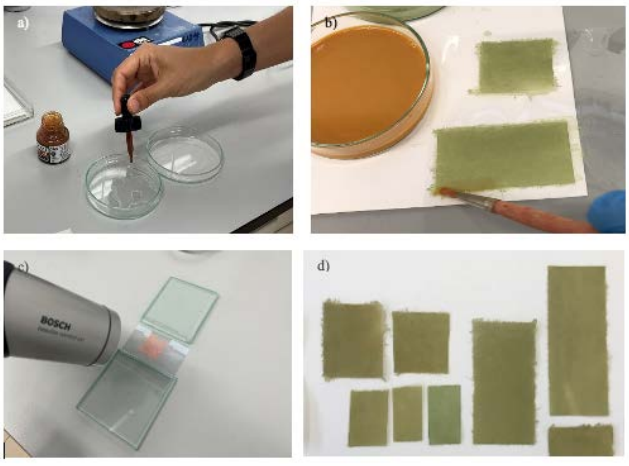

Fig. 4. Methods used to dye the Japanese papers with liquid acrylic inks: a) preparation of the paint solution; b) application by brushing; c) drying with hair dryer; d) final result.

The colour was subsequently evaluated, and the process repeated, if necessary, by adjusting the paint solution hue. The method that achieved a more uniform and intense colour, closer to the original, was to brush the paper several times with the paint mixture. To approximate the characteristic gloss of these prints, which significantly impacted on the perception of the reintegrated areas, it was necessary to burnish the dyed paper with a bone folder. This technique resulted in homogeneously coloured areas, which were ideal for single-coloured, flat-toned printed areas.

The coloured pencils used were *Caran D'Ache* Pablo (high lightfastness and water-resistance), applied by cross-hatching and stippling on the Japanese paper. Repeated applications were necessary to obtain the desired colour density and opacity. However, due to the friction during this application and the lack of sizing in the Japanese paper, this technique caused lifting of the paper fibres. Small quantities of methylcellulose had to be applied to the surface of these infills to paste down the lifted fibres, but this darkened the colours, so it had to be taken into account beforehand. Reintegration with coloured pencils was very useful for areas of image heterogeneity, such as areas with image/letters discontinuities (Fig. 5). Another advantage of pencils was that small dots could be added to obtain a visual result similar to the original characteristic stipples of chromolithography (Fig. 6). This could be done over paper toned with acrylics, in a simultaneous use of both techniques – acrylics and coloured pencils. The pencils also had the advantage of showing the final colour immediately and already giving a gloss to the paper due to the binder.

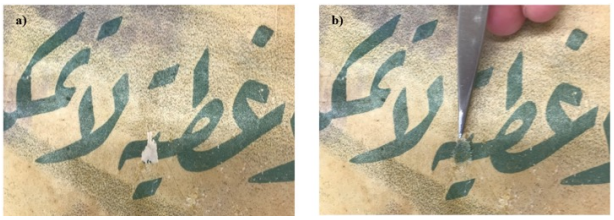

Fig. 5. Details of colouring method with coloured pencils: filling of losses with image discontinuity. a) loss before reintegration; b) testing the reintegrated infill.

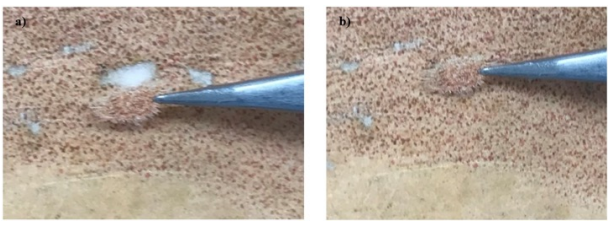

Fig. 6. Details of reintegration with acrylic inks as a base hue and stippling with coloured pencils on Japanese paper infills. a) loss before reintegration; b) testing the reintegrated infill.

The reintegrated paper infills were adhered onto a pre-applied layer of lightweight Japanese paper on the reverse side of the poster. In areas with fine cracks, small portions of coloured fibres from the toned Japanese paper were picked up with a dental probe and applied locally (Figs. 7 and 8).

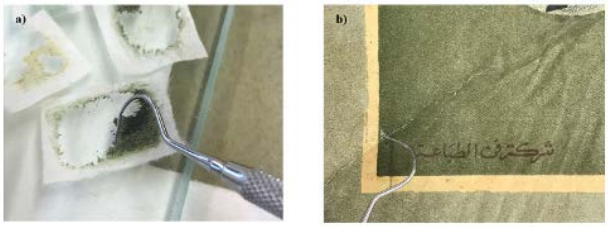

Fig. 7. Details of reintegration with coloured pencils: a) fiber picking with dental probe; b) crack filling with picked fibers.

Fig. 8. Bottom left corner detail of poster on malaria prevention before (a) and after (b) reintegration.

Fig. 10. Detail of one of the posters after intervention under visible (a) and UV light (b), respectively.

After reintegration, the posters were all re-flattened under pressure in a stack, with previous moistening using a damp pack with a vapour permeable membrane.

Conclusions

The adopted materials and techniques enabled a reversible and visually harmonious reintegration, restoring the aesthetic integrity of the posters (Fig. 9).

By employing different application methods and media tailored to each specific area requiring infilling, we were able to match the desired tones and superficial texture of the printed posters. In some instances, combining both materials proved beneficial, such as toning the paper with a solid colour followed by stippling with coloured pencils. Achieving the desired tones with acrylics required a more extensive trial-and-error process, while the use of pencils was more expeditious. However, repeated application of pencils had the drawback of lifting fibres, necessitating the application of an adhesive afterward.

The reintegration materials applied are also readily detectable through common examination methods, such as UV light, magnification, or raking light (Fig. 10), ensuring they do not interfere with the posters' authenticity.

Fig. 9. The selected posters after conservation and restoration intervention (photography under incident visible light): a) Poster on malaria prevention awareness; b) Poster on the promotion of child nutrition; c) Poster on the promotion of childcare.

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FORMULATOR'S EMOTIONALITY

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Abstract

Even if today the composition and the production of colors is no longer the responsibility of the artist, but of new figures, the formulators, they cannot be considered technicians free from emotions. There are many limits within which the formulator must move. There are therefore many limits within which the formulator must move (stability, low toxicity, rheologic properties), but there is also an emotional aspect in the choice of certain pigments and in the compilation of a range of colors that often remains hidden for end users.

Keywords:

color production,

emotionality,

paint maker,

formulator chemist,

technician

It is well known that the work of artists is characterized by emotion and that the colors used influence the moods of those who observe an artistic work. In the field of restoration, and retouching in particular, the search for a shade intended to integrate a lacuna is not always exempt from these influences. If it is true that the chromatic reintegration of a loss must reach a certain color, the choice of the base color and subsequent stratifications may be different, based on personal choices, on one's own experience and taste.

In everyday life, as in artistic production, the choice of certain colors over others is influenced by our tastes and our character and mood of the moment: some colors are nice to us (sympathy from the Greek sympátheia, composed of syn 'with' and pathos 'sensation, emotion') and others not.

It is, therefore, logical to think that those who use colors choose them according to their sensations, thus influencing their work, the emotionality of artistic creation or, in our case, of the act of restoration.

Today the composition and the production of colors is no longer the responsibility of the artist, who usually does not know either the pigments or the binders he uses, but of new figures, the formulators, mistakenly considered technicians free from emotions; of course, this is not the case.

Surely today some parameters must be respected, such as the stability of both the pigments and the binders used. To do this, and also to be able to keep the shades of the colors obtained unchanged, we are now oriented on monopigment formulas: since manufacturers can provide batches with very slight tonal differences, relying on a single pigment reduces the risk of obtaining variations, more likely instead if a given color is the result of a mixture of three or more pigments. This is not always possible, especially in the search for colors of the past, such as Naples Yellow, or Bruno Van Dyck, or certain organic lacquers.

Finally, let's not forget the problem of toxicity: if this is negligible for watercolor or tempera colors (the question is solely linked to the type of pigment), it is not so for formulations, such as retouching colors, where it is still essential to use organic solvents; In this case, the careful selection of low-toxic, aromatic-free solvents is a big step forward for operator safety.

The formulator is not only concerned with the dosage of pigments and fillers, or with the selection of binders, or about rheological properties such as viscosity or spreadability, but also with evaluating how the final result is influenced by the set of these parameters. There are therefore many limits within which the formulator must move.

However, there is also an emotional aspect to the choice of certain pigments and the compilation of a range of colors that often remains hidden for end users. The examples that can be given are many and make us understand how there is also an emotionality of the formulator; the very choice to produce certain colors and not others is also a matter of sympathy.

A matter of white

In our time the most used white pigment in colors for artists and not only, is titanium dioxide, TiO2, which in the last century has almost completely replaced the other white pigments in many applications, for its high refractive index and covering (or mattifying) power; In addition, titanium is one of the most common elements on the earth's crust and therefore available in large quantities and at low cost.

Titanium white comes mainly in two crystalline forms, anatase and rutile, the first, however, finds less application due to the greater tendency to yellowing and chalking. We will then examine the white titanium rutile which is the type of dioxide used by everyone to produce colors and which is mainly prepared in two ways, called " sulfate process" and " chlorine process".

The first process is the oldest and consists of reacting the mineral ilmenite (FeTiO3) and sulfuric acid with the formation of a mixture of titanyl sulfate and ferrous and ferric sulphate, from which, following other reactions, the dioxide is separated.

The second method is more recent, in this case, we already start from the rutile mineral that is heated with chlorine and coke; The reaction produces titanium chloride which is released in gaseous form and subsequently with hot oxygen dioxide is obtained.

At this point, in both cases, the production of the titanium white is not concluded because the dioxide obtained does not yet have the required technological characteristics. Depending on the needs of the various applications, it is post-treated with different substances, such as silicon, zirconium or other materials, obtaining products that have different amounts of dioxide, which in any case must always be greater than 80%.

So, the pigment is never made of 100% dioxide due to the presence of additives introduced to improve various characteristics such as, in some cases, dispersibility, in others moisture resistance, etc. Therefore, if we talk about titanium white we must think, as we have seen, hundreds if not thousands of different versions.

Among the factors that most differentiate the characteristics of the pigment, the method of preparation of dioxide is one of the main ones.

- From the "sulphate process", the product contains, as already mentioned, iron sulphate residues that impart slightly warm yellow shades.
- In the "chlorine process", on the other hand, the dioxide is purer and colder, sometimes with blue-green shades probably due to small traces of chlorine.

The latter, being obtained by vaporization, is also more crystalline and finer than the "sulfate process" which is more amorphous and softer.

The general trend today is to prefer increasingly white products and therefore the "chlorine process" has largely replaced its competitor in a race that seems to imitate that of detergents for washing machines.

Once again, the choice of a pigment is subjective and personally, we have always preferred the mistreated "sulfate process" because it gives a warmer and more natural white and also its more amorphous shape gives more "fullness" to the tint. The "chlorine process" has always aroused a sort of dislike for its coldness, and it is much harder to grind, having an excessive crystallinity.

Even the mixture with other colors is too cold especially with yellows and reds, and then, to think well, in nature there is no white like this. Or maybe it's just our idea, a matter of taste.

A DIFFICULT COLOR

One of the most difficult colors to select is, for the writer, violet. Recently we found ourselves having to select a violet for a line of paint colors for restoration: the choice was clearly linked to the stability and non-toxicity of the pigment. However, several products met these specifications, and all had appeared since the end of the 800. The choice was therefore also based on personal taste and sensitivity. It seems useful to briefly retrace the history of this very particular color.

The study of techniques tells us how artists had to develop a multi-layer approach to obtain it. Violet, in fact, with rare exceptions, does not exist in nature as a pigment. The artists had to resort to a first blue draft based on the classic azurite, smaltino, or ultramarine, on which to overpaint a transparent red, like an organic lake.

An exemplary study (Wyld et al. 1979, pp. 51–65) of this procedure was carried out on a painting by Gerard David of the National Gallery in London, executed in 1510, in which a red lacquer obtained from a Polish cochineal had been applied over the azurite.

In terms of dyes, the ancient purplish plant extracts oricello, alkanna and wood of Brazil tended to be reddish and were unstable to light, while a more stable red lacquer with a purplish hue was known as "*pavonazzo*".

Due to the lack of natural violets, attempts were made for centuries to synthesize one: only the Chinese succeeded, during the Han dynasty (208 BC – 220 AD), obtaining the so-called Purple Han, a barium and copper silicate ($BaCuSi^2O^6$) used only in China and on a very small number of artefacts. Its formula was ascertained thirty years ago (Fitzhugh & Zycherman, 1992, pp.145-154), and we can therefore conclude that the existence of an ancient purple pigment, both natural and synthetic, is to be considered an exception confined to a very limited geographical area and for a limited period.

To access a stable purple pigment we will have to wait for the end of the '700, with the synthesis of the first iron oxides called Mars Violet; for their high cost they did not have much luck, and it was therefore necessary to arrive in 1856 with the historical synthesis, by Perkin, of mauvein, not a pigment but a dye, but also arrived on the palettes, many years later, as lake.

It was precisely the triumphs of mauveine, prevailing in the field of fashion in the decade following its synthesis, to push chemists to synthesize new violet pigments: in 1859 Salvetat synthesizes the intense Cobalt Violet, or co-

balt (II) phosphate, with a dark hue, which is flanked by the similar, but toxic, cobalt arsenate.

These two violets tickled (or rather, struck in their emotionality), the color producers, who included them in their lines, first of all, in 1896, the formulators of Winsor & Newton: arsenate with the name "Cobalt Violet" and phosphate as "Cobalt Violet dark"; for its toxicity arsenate will be eliminated in the 60s of the twentieth century.

It will be once again the Winsor & Newton, always attentive to innovations, to have included a few years earlier, in 1892, the Manganese Violet; Seurat was immediately fascinated by it and used it in the same year in one of his last paintings, "The Channel of Gravelines".

It is exceptionally stable and completely non-toxic, which makes it suitable for use not only in cosmetics but also as a dye for all types of plastics, especially those used for food containers and toys. Due to these two strengths, it remains present in almost all oil color lines today, even under different names.

Other violets are available to formulators: from Ultramarine Violet (born in 1878) to the more modern but less stable Dioxazine, ending with the fleeting Ultramarine Pink, each with tonal varieties that go towards red or blue. Here we come back to the initial question: how to make a choice?

The Catholic Church, in her millenary wisdom, had preferred to associate the times of change and renewal, therefore Advent and Lent, with the two extremes of the violet range, adopting liturgical vestments of bluish-violet in Advent, and reddish-purple ("morello"), in the Lenten season. In our case, given that for reasons of limits to the number of colors in the palette, we were obliged to choose only one pigment, here came into play our personal taste, falling on the Manganese Violet, which we could define a "true violet", not really reddish, but which moves decidedly away from the bluish shades of an Ultramarine Violet. Again, a matter of taste.

Final considerations

For fine arts and restoration colour formulators, the selection of materials is closely linked to their colour stability over time, and their reversibility. The complexity of the materials and the enrichment of the available palette however involves choices that also depend on taste and emotionality.

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A STUDY FOR THE VISUAL PERCEPTION OF COLOUR REINTEGRATION APPLICATIONS ON PAINTED SURFACES IN TURKEY

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Abstract

In Turkey, restoration aesthetics in cultural heritage conservation studies have developed considerably in recent years. In this context, some conservation experts have made progress in both practical and theoretical terms in the phenomenon of colour retouching. However, some problems are encountered in chromatic retouching applications made for missing parts on the painted surfaces of artworks. For this reason, this study evaluates the perception and knowledge of authorized persons in terms of chromatic reintegration approaches and techniques. The research study group consists of conservation specialists in Turkey. Restoration aesthetic perception and knowledge of them is measured in the context of retouching techniques. A web application will be designed to collect data. Participants engage in the research by selecting or identifying suggestions for retouching the missing parts of the images.

Keywords:

restoration aesthetic perception,

conservation perception in Turkey,

chromatic reintegration,

colour theory

Introduction

There are quite a few chromatic reintegration studies on the conservation of cultural heritage in Turkey. These can be evaluated separately as academic and practical studies. Academic studies are papers or graduate thesis studies conducted in line with the international literature on the subject. Apart from the studies conducted in Turkey, students benefit from the book of Weyer et al. (2015) during undergraduate education. It is prepared in different languages, including Turkish. It is a kind of dictionary on murals and architectural surfaces that also mentions chromatic reintegration. Kaptan (2009) and Çağlar Eryurt (2017) mentioned chromatic reintegration in their theses on the conservation of canvas paintings. Eskici (2018) mentioned the problems of chromatic reintegration on ceramic materials. Yetiş et al. (2021) explain retouching approaches and chromatic retouching techniques in detail in their study. Furthermore, they emphasized the connection of chromatic reintegration techniques with colour and perception theories.

Accordingly, the scientific use of chromatic reintegration techniques in the conservation and restoration of paintings or painted surfaces is quite rare in Turkey. Eryurt and Eskici (2017), Çağlar Eryurt (2020), and Çağlar Eryurt (2021) investigated retouching and material use in canvas paintings, and they have taken their place in the literature. Also, Kaptan (2012) examined retouching applications in the context of incorrect restorations in canvas paintings.

Besides, there are only a few chromatic reintegration applications in wall paintings, except for a few studies. Various retouching techniques, such as *acqua sporca* and *tratteggio*, were used in cooperation with Italian restorers in the wall paintings of the Cappadocia region (Yalçınkaya, 2021). For a period, *tratteggio* applications were made by Italian restorers on some of the Roman wall paintings in Ephesus Terrace House. These examples are essential applications of tratteggio that were carried out in Turkey.

When it comes to the retouching of Ottoman wall paintings, overpainting applications are generally encountered. These consist of decorative original paintings being renewed or repainted with similar colours and patterns during their restoration (Yetiş, 2018). In recent projects, only illusionistic retouching of missing parts is carried out without treatment of the original paintings (Yetiş, 2015).

If the literature on chromatic reintegration of paintings and other painted surfaces in Turkey becomes richer, the respect for the original work in restoration practices will also change aesthetically. Thus, the legibility of artworks and the aesthetic distinguishability of missing parts will increase. Conservation education in Turkey is like that in Europe. In recent years, qualified conservation education has been provided at undergraduate and postgraduate levels in Turkey, especially in Ankara and Istanbul. In the past, people who graduated in art, archaeology, and other fields used to work as conservation professionals in the relevant state institutions, but nowadays, conservation professionals have replaced them.

Those actively participating in conservation projects in Turkey are mostly conservation professionals working for the Ministry of Culture and Tourism. In this sense, universities also influence conservation projects and applications. However, academicians were not included in this study. This research aims to measure and evaluate the visual perceptions of some conservation experts working in the relevant institutions in Turkey about the approaches and techniques of colour reintegration in painted surfaces and paintings they may encounter in conservation practices.

Materials and methods

The study sample consists of “conservation professionals” working in relevant governmental institutions in Turkey. The Ministry of Culture and Tourism and its affiliated organizations constitute a significant part of the relevant institutions — also, a small number of institutions that are active in conservation work, such as municipalities. Universities are excluded here. Academicians working in universities, whom we will accept as conservation professionals, generally do not play an active role in restoration

projects and works. In addition, they will distort the research results because they already teach conservation. A separate study can be planned among academicians. Here, some conservation professionals working in relevant state institutions in Turkey were selected using the purposive sampling method (Neumann, 2000: 273-275). At this point, sampling should be done from a qualified group of people who are knowledgeable about the subject. All relevant conservation professionals are assumed to be knowledgeable and experienced individuals with a background in the subject.

Research data were collected through interview questions with various visual content. A case study was conducted, and the data were evaluated qualitatively (Neumann, 2000: 42). 32 participants from the sample were interviewed and asked to answer 18 questions, which consisted of visuals. Before answering the interview questions, the participants provided their name, surname, contact information, and educational (optional) information. 10 of the questions were multiple-choice, and the other 8 were open-ended. The Kastamonu University Ethics Committee approved the ethical compliance of the questions and data collection tool.

In the multiple-choice questions from 1 to 10, images of painted surfaces or historical paintings with missing parts are given. In each answer, the missing parts of the images are retouched using different techniques. There are 2 or 3 different answer options in these questions. There is also an open-ended answer option if one option is unsuitable for the participant. Images with missing parts are also encountered in the open-ended questions numbered 11 to 18. Then, to retouch the missing parts, the participants were asked to change the buttons to match the colour/tone quality. In the five questions here (11 to 15), it is asked to reach a suitable colour and tone for retouching by adjusting the opacity of the hue, black, and coolness (blue) buttons. In the other three questions (16 to 18), the saturation and lightness settings of the existing colour essences of the missing parts are changed to set the appropriate colour/tone. The two images in all questions are monochrome surfaces, red and light yellowish. The others are original paintings from the Ottoman period. One of the decorative ones is a 19th-century mural from the Süleyman Pasha Mosque in Edirne, and the other is a 16th-century painting on wood from the classical Ottoman masterpiece Selimiye Mosque. The landscape painting is an example of a mural from a 19th-century Anatolian mansion in the Westernization period. The figurative painting, called "The Tortoise Trainer" is oil on canvas and was painted by famous Turkish painter Osman Hamdi (**Fig. 1**).

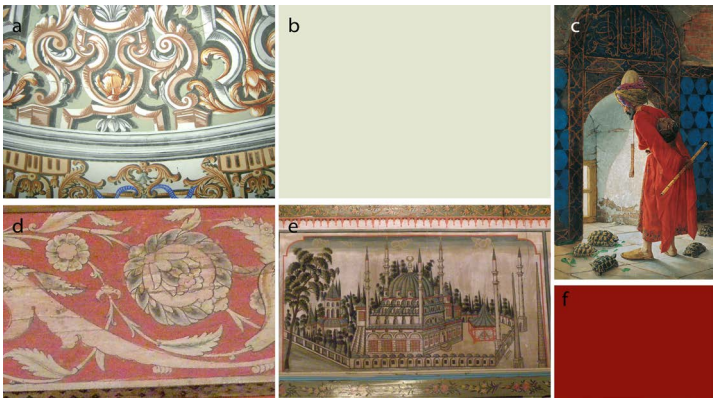

Fig. 1. Painting in the research questions without specifying missing parts. a) Decorative wall paintings from Edirne Süleyman Paşa Mosque (E. Yetiş); b) light surface (E. Yetiş, Ş. Turgut); c) *The Tortoise Trainer*, Osman Hamdi Bey, 1906 (Osman Hamdi Bey, 1906); d) decorative painting on wood from Selimiye Mosque (E. Yetiş); e) landscape wall painting from Tokat Madımaklar mansion (E. Yetiş); f) red surface (E. Yetiş, Ş. Turgut).

As is well known, Brandi (1977) and Baldini (1997 and 2001) have taken essential steps in retouching techniques and described them in their books. At first, traditionally, imitative chromatic retouching is often used. Unfortunately, these retouching applications can sometimes turn into overpainting applications. Even non-chromatic reintegration approaches to missing parts have become widespread. So, paintings in archaeological sites are usually not preferred colour retouching (Botticelli, 2003: 147-148). Later, Cesare Brandi developed Italian *tratteggio* retouching, a technique already common in the 19th century (Brandi, 1977: 74; Nicolaus, 1999: 291; Muir, 2010).

Baldini (1997 and 2001) considered *tratteggio* unsatisfactory and developed the techniques for chromatic selection and chromatic abstraction depending on *tratteggio*. Apart from these techniques, the neutral retouching (*neutral tint*) mentioned by Mora et al. (1984: 312) and Gordon (2000: 63) are often used. In particular, the missing parts of the paintings should be expressed in a slightly lower tint. However, it should be greyish, and average or neutral chroma in the context of original one. The missing parts should not look different from the surrounding colours and should be an average or neutral mixing that gives the slightest disturbance (Conti, 2007: 435). Mora et al.

(1984: 307) mentioned *undertone* technique. It is defined as equalizing tonality, reducing whiteness, and reaching a slightly lighter or slightly cooler tone to prevent the missing parts from appearing more in the foreground. Similar to this technique, Brandi (1977: 92-97) and Baroni (2003: 149) refer to *velatura*, and Napoleone (2008: 22) mentioned *acqua sporca*.

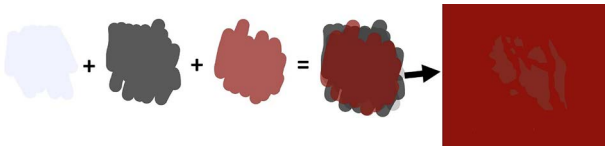

Fig. 2. Color mixing in the layers of missing parts (E. Yetiş, Ş. Turgut).

Retouching of missing parts is carried out to incorporate them into the totality of the work, preserving its potential unity (Brandi, 1977). It increases the artistic readability of the artwork. At the same time, it should respect the artwork by providing distinguishing features. Research questions were prepared using colour theory and photo editing software in the context of these requirements and techniques. Firstly, the missing parts of the specified images were determined with the Photoshop program, aiming to be seen as a real missing part. A glazing mixture was preferred while adjusting the colours and tones of the missing parts. This mixture is made by overlapping each layer with different chroma and tones. Briggs (2012) defined physical mixing as additive-averaging mixing. It is because the colours do not mix exactly, and some mix on the eye's retina. The same situation is seen in the layers made with the glazing effect in the watercolour technique. So, it will be slightly grey and less bright (**Fig.2**). In the Photoshop program, the opacity of each layer is reduced and superimposed, like the glazing effect. The same mixing technique is used in the research images for all questions. After testing some visuals and necessary on Photoshop, the interface is prepared in the React software library. Questions are shared with the participants using a website (https://ezginyetis.com/). After participants share their personal information and answer the questions, they are sent to us via e-mail after clicking the confirmation button (**Fig. 3**).

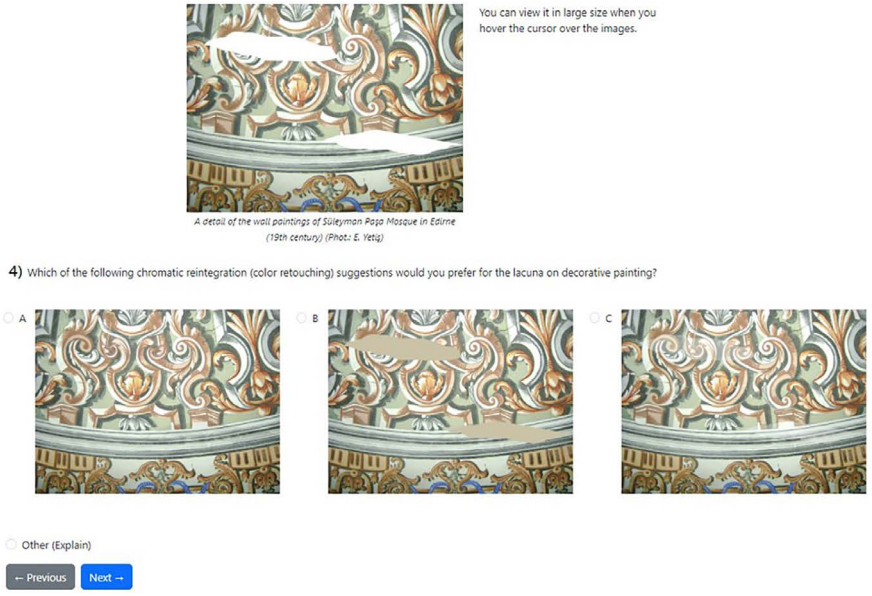

Fig. 3. Screenshot of one of the questions (https://ezginyetis.com).

Fig. 4. Retouching selections in the questions 1 to 10 (E. Yetiş, Ş. Turgut). a) 1st question, *undertone*; b) 2nd question, *undertone*; c) 3rd and 4th question, *neutral tint*; d) 4th question, reintegration of drawing (low saturation and lightness); e) 8th and 9th question, reintegration of drawing (*neutral tint*); f) 8th question, *neutral tint*; g) 9th question, reintegration of drawing (low saturation and lightness); h) 5th question, reintegration of drawing (*neutral tint*); i) 5th question, *neutral tint*.

In questions 1 and 2, the painted surface was retouched in *mimetic* and *undertone* techniques and presented as two options (**Fig. 4, a** and **b**). In the 3rd question, one of the options in the decorative painting is *mimetic* retouching. The other one is a *neutral tint* mixed according to the colours surrounding the missing part (**Fig. 4, c**). Question 4 is the same as the previous one; only a pattern/drawing retouching image was added (**Fig. 4, d**). Here, lighter chroma was preferred on pattern/drawing retouching. In question 5, many missing parts are created on the decorative picture. One of the retouching options is a very grey chroma prepared for all missing parts. Here, to prepare an average chroma, the hue ratio of the retouched areas was kept relatively low (**Fig. 4, i**). The other retouching option is a *neutral tint, in which* chroma partially follows the pattern/drawing (**Fig. 4, h**). However, it is different from the pattern/drawing retouching in question 4. It is carried out in a slightly lighter tone. In question 6, a small missing part was created on the figurative painting. *Neutral tint* retouching was applied by following the chroma of the drawing as in the previous questions (**Fig. 5, a**).

In question 7, the image from the previous question was used but with larger missing parts. One of the three retouching options is *neutral tint*, which refers to the average chroma around the missing part. The chroma of the three different large missing parts was created differently. It was determined depending on the colours surrounding every missing part (**Fig. 5, c**). The other two options are pattern/drawing reintegration. One of them is a fully detailed drawing reintegration but slightly lighter than the original (**Fig. 5, b**). The other one is a partial reintegration of the drawing and determined average *neutral tint* following the colour of the drawing, unlike the other (**Fig. 5, d**). In the image in question 8, there are three small-sized missing parts. An average chroma was created in all the missing parts in one of them. However, it is a quite greyish chroma in order to represent all areas (**Fig. 4, f**). Another is the partial reintegration of drawing, such as the previous question (**Fig. 4, e**). In question 9, there are two different reintegration of drawing options. One is the partial reintegration of drawing, such as the previous question (**Fig. 4, e**). The other one is a detailed reintegration of drawing in a slightly lighter tone and lower saturation (**Fig.4, g**). In question 10, there is a figurative painting with larger missing parts than the painting in question 7. One of the retouching options is a fully detailed reintegration of drawing in a slightly lighter tone and lower saturation (**Fig. 5, e**). The other is partial reintegration of drawing. It is a neutral tint, which refers to the average chroma around the missing part (**Fig. 5, d**). Each of the three different missing parts of chroma is created differently. It is determined depending on the colours surrounding every missing part.

From the 11th to 15th questions, the participants tried to identify the missing parts of the images using the buttons (**Fig. 6**). The same images with the previous questions were used in these 5 questions, but the missing parts were different. The missing parts are quite basic here because of the challenges in software. They are mainly determined within a single chroma in every image. For example, among the many colour areas in the images, only the part dominated by red (or other single colour) was edited as a missing part. Participants first see the missing parts in white instead of the filled area. They decide on the retouching chroma of the missing part by using the

Fig. 5. Retouching selections in the questions 1 to 10 (E. Yetiş, Ş. Turgut). a) 6th question, *undertone*; b) 7th question, reintegration of drawing (slightly low saturation and lightness); c) 7th question, *neutral tint*; d) 7th and 10th question, reintegration of drawing (*neutral tint*); e) 10th question, reintegration of drawing (low saturation and lightness).

hue, black, and coolness (blue) buttons. Here, hue refers to the hue colour of the relevant missing part. Hue blue is used as a coolness button. As Ocvirk et al. (2013: 199) say, the coolness associated with blue makes the surfaces look far away.

In the software, the colours and tones are created on different superimposed layers. Here, as Yetiş et al. (2021) state, the glazing effect should be preferred to mix layers. The hue colour should be determined depending on the surrounding area of the missing part. The additive-averaging mixing, as mentioned, will increase legibility by incorporating the missing part into the potential unity of the artwork. Due to the transparency, it will appear greyish with slightly lower saturation. It will make the missing parts appear slightly behind. Moreover, slightly blue glazing will also help this. Changing the opacity of blue and hue colours is the same as changing their saturation. With the black button, the lightness of the relevant layer can be changed. Ocvirk et al. (2013: 251-252) state that decreasing saturation and increasing greyness (caused by black) affect depth and space. In this case, increasing the opacity of black will create greyness.

For this reason, value ranges were limited, and upper values were determined. Here, the participants first encounter the value "0" on each button. Every layer opacity ranges from zero to upwards. While the upper values on Photoshop are 100, here they are limited to hue-60, black-90, and blue-30. So, the participants cannot make the layers look fully opaque (**Fig. 6**).

From the questions 16 to 18, three pictures were used: figurative, landscape, and decorative. The saturation and lightness buttons were changed to retouch the missing parts by the participants. While the saturation and lightness values are in the range of 0-200 in the software, they are limited by using the range of 50-150 in the interface. It was done to reduce the margin of error and to prevent the participant from reaching values that were too extreme. For example, participants cannot reach black and white colours extreme values. Apart from this, the Photoshop range is from 50 to 150 while the interface range is from -50 to +50. When the buttons are set to "0", the participant reaches the *mimetic* retouch in the software. The highest saturation value is +50, and the lowest is -50. With this, the darkest is -50, and the lightest is +50. As mentioned, the darkest value is not black, and the lightest is not white in the range of limited values. Here, the participants are expected to determine differentiation in a detailed pattern/drawing reintegration physically. Is it light? dark? high saturation? low saturation? or is it mimetic?

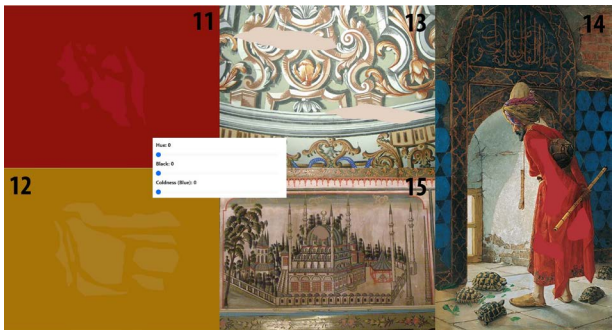

Fig. 6. Average of hue-black-blue in questions 11 to 15 (E. Yetiş, Ş. Turgut).

The answers received via e-mail are converted into frequency percentage tables. The percentages of each answer preference in the optional questions are determined. The average table of values in the questions of 11 to 18 is prepared using buttons. In 5 questions (11 to 15), values giving the opacity changes of hue, black, and blue are taken, while saturation and lightness values in the other three questions (16 to 18). Then, data values are evaluated using coolness (blue), black, and the related hue colour in terms of the averages values, extreme values, and the percentages of extreme values. For example, as Ocvirk et al. (2013:199) and Yetiş et al. (2021) say, slightly blue usage ensures the shapes look slightly behind. In this situation, whether the participant uses the blue button or not is an essential factor. Also, the percentage of high and low saturation, dark and light values, and extreme saturation and lightness values.

Results and discussion

The percentages of the answers are determined for the questions from 1st to 10th. When the results are analysed in general, the preference for *mimetic* is slightly higher in the questions with the *mimetic* option. Although there is the same image in the 1st and 2nd questions, the percentage of *mimetic* options is different for each other. *Undertone* retouching is preferred, with a rate of 75% (24 people). It is considered that a high preference for the undertone in 1st question is caused by the dark colour usage. In both questions, one of the open-ended answers is "It depends on the physical properties of the surface" and

the other is “lighter tone.” Another question with many *mimetic* answers (11 people) is question 6 with a figurative painting. Here, *mimetic* is preferred instead of a pattern/drawing reintegration in average *neutral tint*. However, open-ended answers from 8 respondents should not be underestimated. Here, some participants suggest a retouching between *mimetic* and *neutral tint*, while others argue that no retouching should be made (Table 1).

Table 1. Frequency percentage table of the questions of 1st to 10th (Ş, Turgut).

Question	Mimetic	Under-tone	Neutral tint	Reintegration of drawing (neutral tint)	Reintegration of drawing (low sat./ tone)	Open-ended
1- red surf.	%16-5p.	%75-24p.	-	-	-	%9-3p.
2- light surf.	%56-18p.	%38-12p.	-	-	-	%6-2p.
3-decorative	%62-20p.	-	%13-4p.	-	-	%25-8p.
4-decorative	%25-8p.	-	%3-1p.	-	%59-19p.	%13-4p.
5- decorative	-	-	%0	%91-29p.	-	%9-3p.
6-figurative	%53- 17p.	-	-	%25-8p.	-	%22-7p.
7- figurative	-	-	%0	%31-10p.	%56-18p.	%13-4p.
8-landscape	-	-	%16-5p.	%59-19p.	-	%25-8p.
9- landscape	-	-	-	%69-22p.	%25-7p.	%6-3p.
10- figurative	-	-	-	%56-18p.	%28-9p.	%16-5p.

There are decorative paintings in questions 3 to 5. In question 3, the mimetic retouching option was highly answered. However, pattern/drawing reintegration with lower saturation and lighter tone, as in question 4, is surprisingly high against the mimetic option. In question 5, a partial pattern/drawing reintegration with a neutral tint is very high at 91% (29 p.). No one chose the option of average greyish chroma for all missing areas. The open-ended answer rates of these questions are quite high in question 3 (Table 1). In general, participants suggest retouching such as “lighter tone,” “retouching in a separate chroma for each missing part,” or “making all gaps mimetic.” When participants see the mimetic option as an alternative option in figurative pictures, they generally prefer it (question 6). However, there is no mimetic option in questions 7 and 10. In these questions, the participants are informed about whether previous documents are available before they are destroyed or not. For example, in question 7, there are original documents before the painting was damaged. So, the option of detailed pattern/drawing reintegration with lower saturation and slightly lighter is high. Surprisingly, participants choose the partial reintegration of drawing with average chroma for the figurative painting (10th question) with large gaps due to the knowledge of previous documents. In questions 8 and 9, the participants also decide depending on whether there is a document before the damage in the retouching of landscape paintings. They are not facing a mimetic retouching option in these questions. In question 8, in which no previous document is available for the painting, 5 people (16%) chose the same greyish retouching for all missing areas. On the contrary, 19 participants (59%) choose partial reintegration of drawing. It is done by determining the average neutral chroma separately for the relevant colour areas. However, the number of open-ended answers is also quite high, at 25%. They suggested some options such as “mimetic,” “detailed linear retouching in a light tone,” and “pointillism.”

Results are not very surprising at the average hue, black, and coolness value in questions 11 to 15. The missing parts of the images should be watched slightly behind the original part, and the paintings should be aesthetically readable. Naturally, correct and clear answers are not expected from the participants. It is very relative, but certain value ranges exist for the readability and distinguishability conditions. The average data in the result table is re-entered on the photo editing program for every question from the 11 to the 18. Then, the screen photos of them are taken. In question 12, the average of answers was so satisfying. Because this chroma makes the painting more readable and appears slightly behind the original part. It is a desired result. On the contrary, the same result is not valid for the mean values of the other questions. So, a lighter tone of hue and a more greyish tone are needed in questions 11, 13, 14, and 15. However, a lighter tone of hue and more blue chroma are needed in questions 13 and 14 (**Fig. 6**).

Fig. 7. The average of the hue and black values of those who never used blue in questions 13, 14, and 15 (E. Yetiş, Ş. Turgut).

Readability and distinguishability are also examined for the other three questions (from 16 to 18). However, saturation and lightness values are very close to “0” when averaged. It means that the participants seek quite close to the chroma of the original of the main artwork (such as *mimetic* retouching) to reintegrate the drawing. In this

case, the rule of distinctiveness seems to be ignored (**Table 2** and **Fig. 8**).

Table 2. Average table of saturation and lightness in the questions of 16th to 18th (Ş, Turgut).

	Saturation	Lightness
16. Question	-4	4
17. Question	-5	8
18. Question	-6	10

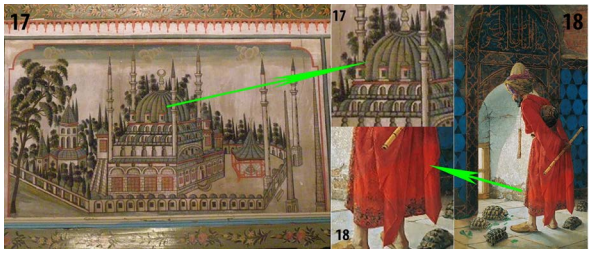

Fig. 8. Average values of those using high saturation (E. Yetiş, Ş. Turgut).

Some participants did not use the coolness button, which helps the missing part be seen at the back. 8 participants never used the coolness button in question 14 (**Fig. 7**). The same situation is also observed in questions 13 and 15 (respectively, 7 and 5 participants). Participants can change the lightness by using the black button. As mentioned, this button makes the missing part appear to be further back. However, 5 participants never manipulated it to retouch the decorative painting in question 13. A few of them did not use hue buttons in questions 13 and 15. Only a few people did not manipulate black and blue buttons in some questions and only used hue colours. Only one person did not use them, leaving the gap white (Table 3).

Table 3. Percentage of participants who do not use the buttons of hue, black, or blue in the questions 11 to 15 (Ş. Turgut).

	11. Question	12. Question	13. Question	14. Question	15. Question
Hue	%0	%0	%9 (3 p.)	%0	%3 (1 p.)
Black	%0	%3 (1 p.)	%16 (5 p.)	%0	%0
Coolness	%9 (3 p.)	%3 (1 p.)	%22 (7 p.)	%25 (8 p.)	%16 (5 p.)

The average of low and high saturation and lightness are evaluated in questions of 16th to 18th. The average of low (S/L) values are shown between -50 and 0 on the buttons of the interface. And between 0 and 50 for the average high (S/L) values. The proportions of low and high-saturation users are close to each other. Only users who choose lower values are slightly more than those who use high. The use of low saturation (even if it does not have a specific value) is important to pretend the missing part is slightly behind (**Fig. 9** and **Table 4**).

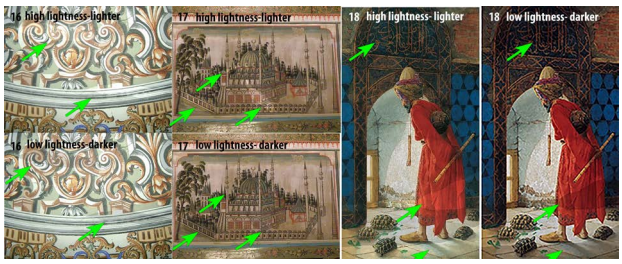

Fig. 9. Average values of participants who use high and low lightness (E. Yetiş, Ş. Turgut).

Low and high values are close to each other in the use of lightness in the questions of 16th to 18th. The use of high lightness is relatively high, with 63% in question 18 when compared to the others. High lightness means a lighter tone, and low is darker. Using high lightness, it pretends the missing part is slightly light. As mentioned, it is an essential factor to use a slightly lighter tone in the reintegration of the drawing. However, it can change depending on the value around the missing part, and sometimes, it can choose a slightly darker tone. For example, if the surrounding area of the missing part is quite light, a slightly darker tone can be applied, depending on its surroundings (**Fig. 9** and **Table 4**).

Table 4. Percentage of participants who use high and low lightness (Ş. Turgut).

	Saturation		Lightness	
	Low (-50-0)	High (0-50)	Low (-50-0)- Dark	High (0-50)- Light
16. Question	%56	%44	%50	%50
17. Question	%59	%41	%44	%53
18. Question	%53	%44	%31	%63

Conclusions

The research results provide important information about the approaches and experiences of conservation specialists in Turkey regarding chromatic retouching. In the questions, there is a tendency to reintegrate the missing parts in a chroma close to the original, but answers depend on whether there are past documents before the damage of the painting. In decorative paintings, it is observed that a single chroma determined for all missing parts is not preferred. The same result is almost valid for figurative and landscape paintings. Answers close to the expectation are encountered in the multiple-choice,

although expectations are not fully the same in the questions with adjustable buttons. The expectation of a slightly lighter tone and low saturation was not fully achieved in the questions with buttons. In questions with three buttons, the chroma of the missing parts appears slightly brighter and more saturated on average. This situation causes them to appear slightly ahead of the original parts. In addition, the number of questions in which blue was not used is considerably high, and several experts do not prefer to use blue. The data averages of the binary buttons show us that the experts tend to near-*mimetic* retouching. As a result, new research can be carried out by improving the technological possibilities of retouching diversity, and more detailed results can be obtained. Accordingly, new suggestions can be put forward to overcome the problems.

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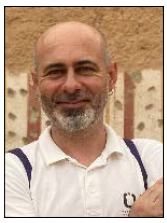

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CONSERVATION STRATEGIES FOR THE COPY OF CARLO DOLCI'S (1616-1686) MADONNA DEL DITO: AN EXPLORATION OF MATERIALS AND METHODOLOGY APPLIED IN AN OIL ON IRON

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Abstract

This article presents the results of the restoration treatments of a copy of Carlo Dolci's (1616-1686) Madonna del Dito on a tinned iron plate. Based on the experience and expertise of the Department of Conservation of Paintings and Polychrome Sculpture, and Metal Conservation Studio of the Department of Conservation and Restoration of Architecture and Sculpture at the Faculty of Fine Arts at Nicolaus Copernicus University in Toruń (Poland), materials and methods have been combined to enable a comprehensive restoration of the painting. The treatments in question relate to the conservation and restoration of metal support as well as to the reconstruction of the painted surface. The criteria, materials and methodology used in this unusual case are discussed in detail.

Keywords:

metal support,

iron support,

tinned steel,

painting on metal,

painting on iron

Introduction

The artistic motif commonly identified as the "Madonna del Dito", may be translated as "Our Lady of the Finger" or "Our Lady of the Thumb". This terminology originates from a distinctive feature within the original composition - the solitary tip of the left index finger, that gently protrudes from the dark blue veil surrounding the Madonna's face. The original version of this artwork, now held in a private collection in London (Baldassari, 2015; Borghese, 2023), is most commonly attributed to Carlo Dolci, a prominent Medici painter in the 17th century and still appreciated to this day (Nasher Museum of Art at Duke University, 2020).

From the very beginning, the motif of Madonna del Dito gained considerable popularity as a devotional work of art. Over the centuries, it has received many reproductions, including works by Dolci's disciples, in particular Bartolomeo Mancini (Lemme, 2008). Presently, copies of this masterpiece grace numerous museum collections and auction houses (Bartolommeo Mancini | Artnet, 2023). The 17th-century copies by Mancini were made mainly on copper supports and according to the available photographs, they appear to have endured remarkably well in terms of their preservation status. Conversely, the painting under examination in this discourse embodies a distinct narrative. Procured by a private collector through auction, its historical provenance remains elusive and upon arrival at the conservation studio, it exhibited a rather dismal state of preservation (**Fig. 1**). Accordingly, measures were undertaken to inhibit the ongoing corrosion processes of the support and restoration of the object's display and aesthetics values.

Object Overview: Essential Information and the General State of Preservation

The object in question is an oil painting prepared on a tinned steel support. The metal plate is oval-shaped with a slightly curved and convex surface measuring 26.3 × 20.6 cm and boasting a plate thickness of approximately 0.05 cm. Upon initial assessment during the conservation process, the object exhibited a state of noticeable degradation. Particularly conspicuous were the evident signs of corrosion products visibly present on the back of the artwork (**Fig. 1a**), alongside a considerable number of small losses of paint on the front - this aspect becomes more evident in the raking light, as depicted in the intermediary image within **Fig. 1b**. Although the paint layer was covered with a fine and dense network of cracks, its adhesion to the support was very good. It is noteworthy that the entire painting surface was also covered by thick, deteriorated and whitened layers of varnish, and overpainting, which are equally clearly observable under the UV light examination (**Fig. 1c**).

Fig. 1. **Object before restoration: back of the painting (a), front of the painting in the raking light (b) and in the UV-induced VIS fluorescence photography (c).**

The Reverse Side of the Painting

Examining the artwork's reverse side reveals a protective layer primarily composed of tin, with small traces of lead and copper in the alloy. **Fig. 2** displays the entire reverse surface covered in iron corrosion products, complicating the assessment of the underlying tin layer's condition. Our research efforts were enhanced using X-ray fluorescence (XRF) analysis, which confirmed the presence of the tin alloy, however, it was the MAXRF scans that provided invaluable insight into the structural state of this metallic

surface. Maps depicting the elemental distribution, notably of tin and iron, revealed the heterogeneous nature of the tin layer, discerning cavities where bare iron was exposed.

It is worth noting that in this context, tin serves as an anodic protective layer, the role of which depends on its integrity and adhesion to the steel support. It is necessary to recognise that when this protective layer is breached and destroyed, corrosion processes in the steel are intensified at the cost of oxidising iron. Hence, deliberation regarding the restoration or recreation of the tin layer arises, yet the decision is deferred until the culmination of the cleaning process. At this stage, our strategic focus remains directed towards the removal of iron corrosion products from the reverse side of the painting, postponing a conclusive response to this issue.

Fig. 2. The reverse side of the painting shows intricate details, including the presence of multicoloured iron corrosion products and residual traces of tin.

Conservation process

In order to protect all the residues of the tin layer, it has been decided to choose the approach distinct from the relatively conventional steel conservation methods that typically involve sandblasting (which is an abrasive technique)[1], or the application of orthophosphoric acid[2].

Instead, the restoration commenced with a nuanced process aimed at eliminating iron corrosion products from the artwork's reverse side. This involved a combination of mechanical and chemical methods. A gel compound based on xanthan gum, supplemented with an EDTA chelating agent and a 10% sodium hydroxide solution, was meticulously employed for this purpose[3].

Fig. 3. Back of the painting after the first gel application for 15 minutes (a) and after its removal with acetone (b).

The gel was applied to the affected area with a brush and then covered with a transparent foil for approximately 15-20 minutes. After this time, the treated area was gently cleaned using a fibreglass pen. Following this duration, the treated region underwent a meticulous cleansing process using a fibreglass pen. The choice of gel proved advantageous for the restorer, as it effectively contained glass fibre particles and dust within the moist amalgamation of gel and iron corrosion products. Subsequently, residual cleaning traces were meticulously eliminated using cotton swabs soaked in acetone. This iterative procedure was repeated 4 to 5 times at each location to ensure comprehensive corrosion elimination (**Fig. 3**).

Upon completion, the entire reverse surface underwent degreasing with acetone before the application of an iron corrosion inhibitor. The reverse was covered by a brush with a 10% tannin solution in ethanol. This treatment was repeated once again after 24 hours. Finally, the protected surface received a coating of a 10% solution of *Paraloid* B44 in xylene, with photostabilisers Tinuvin 171 and Tinuvin 292.

Figure 4 depicts a detailed representation of the conservation outcome juxtaposed with the precise area scrutinised through MAXRF analysis. The obtained maps of the distribution of elements allow one to see the boundary between the different metallic areas effectively. In particular, the shiny part of the tin layer is well visible, bearing a clear structural trace that contains information about its degradation process over time. As such, consideration of the potential restoration of this layer was therefore firmly on hold. The protective coatings applied in our Metal Conservation Studio, namely tannin and *Paraloid* B44 solutions, are deemed sufficient safeguards against corrosion, contingent upon providing suitable and stable environmental conditions.

1 Sandblasting is categorically discouraged for paintings because of the danger of damaging the paint layer.

2 Phosphorus acid may be successfully used for the conservation treatments on iron, but it has a destructive effect on the tin coating, dissolving it.

3 Gel ingredients: 1% water solution of EDTA, 10% water solution of NaOH for the pH=7, xanthan gum for gel consistency, about 1,5% solution in the above mixture.

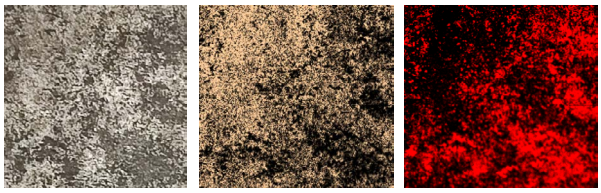

Fig. 4. Detail of the painting's reverse after conservation (VIS), alongside specific areas highlighted in MAXRF maps depicting tin (Sn) and iron distribution (Fe)

The Front Side of the Painting

The object's poor condition mainly comes from extensive small losses within the paint layer and a fine grid of cracks, in which the varnish from later intervention has accumulated (**Fig. 5**). The effect of its degradation is a white veil visible over the entire surface of the artwork. The repainting took place probably when the metallic support began to corrode. Notably, localised losses in the paint layer above the Madonna's head were detected, filled with a brownish overpainting. The distribution of lacunas across the painting's surface exhibits considerable variation. Particularly well-preserved segments are those employing a mixture of lead white with other pigments, which is notably evident in the Madonna's facial region. Despite significant paint losses and exposure of the metallic support, the artwork's frontal surface shows minimal presence of iron corrosion products, with only a few markedly rusted spots and a few bare, undamaged tin areas. This makes the condition of the front side of the painting fundamentally different from the reverse of the image, and it will be reflected in the following conservation actions taken.

Fig. 5. Details showcasing the preservation state of the painting before undergoing conservation treatments.

Conservation process

The initial step involved the elimination of deteriorated varnish using a specifically formulated blend of organic solvents applied via cotton swabs. Based on prior test outcomes, an azeotropic solution comprising ethanol and methyl ethyl ketone (MEK) in a 34:66 ratio demonstrated optimal efficacy. Following the removal of the secondary varnish, a substantial layer of brownish, glossy overpainting persisted on the surface, notably conspicuous in the painting's upper section. This layer was removed using an azeotropic combination of isopropyl alcohol and MEK (30:70), augmented by a minor dimethylformamide (DMF) addition. Progression at each intervention stage was meticulously monitored under UV-light illumination, with the corresponding effects documented in Figure 6.

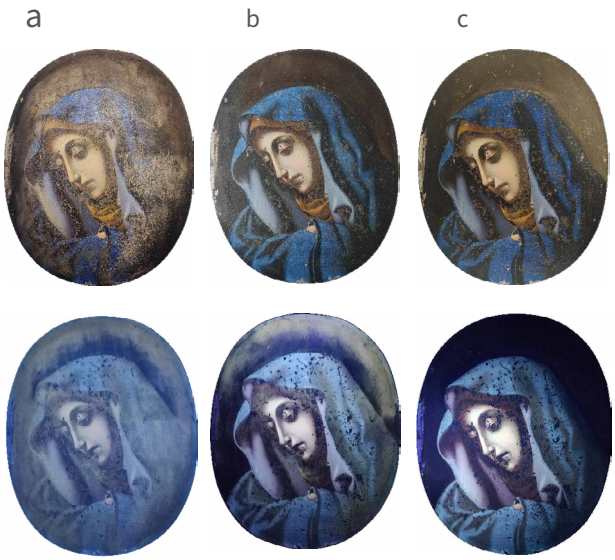

Fig. 6. The front side of the painting during the following stages of the conservation treatments, recorded in visible light and in UV-Induced VIS fluorescence photography: before conservation (a), after removal of the secondary varnish (b), and after the removing of the glazy, brownish overpainting (c).

Subsequently, localised and minor corrosion products were removed using a fibreglass pen. Following this, an iron corrosion inhibitor was delicately applied with a small brush across areas where the paint layer had suffered losses, exposing the iron support. A day later, a retouching varnish, specifically Lefranc & Bourgeois' Matte-Satin UV Resistant Retouching Varnish, was applied.

Fig. 7. Putty designed explicitly for the conservation of iron support painting. The image on the left shows the filler's consistency, gloss and characteristics shimmering effect within its container. Conversely, the right image exemplifies the precise application of this filler into tiny lacunas, which can be skilfully manipulated to form well-defined edges while safeguarding the integrity of the fragile paint layer.

The filler used in this case is a customised variant derived from the emulsion putty extensively utilised within my department over several decades (Łękawa-Wysłouch, 2010a, 2010b; Rouba & Łękawa-Wysłouch, 2005). It consists of an emulsion formulated from a blend of synthetic binders and natural resins[4]. This formula has been tested among many other potential putties for ground and paint losses on the metal supports as a part of an ongoing PhD research project, which results will be published after the dissertation defense. Concerning this putty, there is usually chalk with other pigments used as a filler but in this case the addition of aluminium powder, which provides additional protection against oxygen molecules, has been proposed. The aluminium particles do not corrode, but permanently passivate, and the oxidation products are resistant to the acidic environment (Davis et al., 1987; Koleske, 2012; Källbom, 2022). According to tests conducted in a humidity chamber, this variation shows great corrosion resistance. This particular putty was also selected for its low toxicity and well-applying properties. It has a pleasant consistency, so it can be applied with a thin brush even on very small losses (**Fig. 7**). Removal methods include the use of distilled water-soaked cotton swabs or, for fresh applications, white spirit. Sharp edges around the lacunas can also be achieved with balsa wood or simply mechanically with dental tools, without moistening the object (**Fig. 8a**). Furthermore, most paint types exhibit excellent adherence to this putty. Incorporating chalk and aluminium powder imparts a white surface to the putty, adorned with a faintly lustrous silver effect. This attempt to replicate the shimmering quality of the underlying tin layer beneath the original paint influenced its application in retouching areas.

The subsequent phase in restoring the painting's front side involved the application of retouching varnish - spe-

Fig. 8. Image (a) displays the painting's front following the putty application, while images (b) and (c) respectively showcase the entire front and back of the painting after the conservation and restoration process.

4 Putty dedicated for the conservation of paintings on iron, with tiny spread losses of ground and paint layer - ingredients in weight parts: 1 part of water solution of 7% polyvinyl alcohol, 1.5 part of water solution 2% methylcellulose, 0.3 part of 25% mastic resin in turpentine oil, 0.1 part of venetian turpentine, 4 parts of a filler e.g. chalk and pigments, in this case also aluminium powder.

cifically, Lefranc & Bourgeois Superfine Anti-UV Retouching Varnish Aerosol Matte-Satin.

Chromatic reintegration was made by Kremer Retouching Colors paints in *Paraloid*™ B72 (Śwituszak & Tomaszewska-Szewczyk, 2021). The methodology adopted here was to by pinpointing apply several layers of diluted colour to create the vibrating effect but with a local hue (**Fig. 8b**). It is worth remembering that this artwork is smaller than an A4 sheet of paper, and with so many small and scattered paint losses, we are not talking about reconstructing the motif, but rather how to combine these tiny paint-islands with each other in colour, without imitation. This was possible because, when properly dissolved, these paints can act like watercolours, so it was possible to achieve the effect of lightness. Finally, the concluding phase of restoration encompassed the application of Lefranc & Bourgeois Anti-UV Picture Varnish Aerosol in a satin finish.

Recommendations and Storing Conditions

Optimal preservation of the object necessitates storage within stable temperature and humidity environments, as these fluctuations might lead to water condensation on the metal surface (**Fig. 8c**), resulting in the initiation of corrosion processes. Consequently, maintaining lower temperature and humidity levels ensures enhanced safety for the object. Adhering to storage conditions not exceeding 40° C and keeping humidity levels at or below 40% stands as an optimal measure, particularly concerning the object's metal support

Conclusions

Conducting a comprehensive restoration of a painting prepared on a tinned iron plate requires the combined experience of both an easel painting conservator and a metal conservator. However, prevalent techniques within metal conservation often pose risks to the delicate paint layers on easel paintings, mandating the exploration of alternative methodologies. In this case, it proved adequate and safe for the conservator to use a gel when removing iron corrosion products from the reverse side of the painting. The support's metallic nature was also why the search for a new putty began. This new product had to meet several requirements, from good adhesion and chemical neutrality to the support to the ability to be applied and worked on in tiny lacunas. After testing, a putty based on a recipe well known to the article's authors, with the modification of adding aluminium powder, emerged as the preferred choice. Despite the object's small size, its conservation was a multistep process, each stage requiring compatible materials. Consequently, the array of conservation materials discussed herein culminated in a comprehensive and gratifying restoration of a painting with a motif prevalent since the 17th century yet distinguished by its unconventional technological structure.

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INFILL AND RETOUCHING APPROACH ON PAINTING ON COPPER SUPPORT, 1790 – 2022. MATERIALS AND TECHNIQUES

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Abstract

The scarcity of literature on the methods and materials used to restore copper paintings underscores the historical significance of this research. This article provides an overview of the infills and retouching materials applied to paintings on this metallic support from 1790 to 2022. The research identifies at least eight historical written sources produced before 1899 and fifty-five contemporary sources produced between 1900 and 2022. The range of products and procedures applied varies from traditional materials like carbonate calcium mixture with animal glue to synthetic resins, and from using brushes to carving heat pencils for application, respectively. Exploring the diverse practices over the last two centuries will not only help conservators make informed decisions on which materials and techniques to use during painting on copper restoration, but will also aid scientists in accurately interpreting the data collected from these objects during scientific analyses.

Keywords:

painting on copper,

infills,

retouching materials,

restoration,

conservation

Introduction

Oil painting on copper plates probably started to be executed in Italy or Flandres in the 16th century (van de Graaf, 1976). Although its production declined to the end of the 17th century in European countries, it reached new flourishing markets worldwide, especially in the Viceroyalty of New Spain (Bargellini, 1999). Its small dimensions and high resistance (Vega et al. 2018) presumably made it an excellent means of transport for the taste and faith of the old world.

When comparing these types of paintings to the two principal forms of easel painting—those on canvas and wooden panels—certain similarities in their structural systems can be identified. From the back to the front, all of them have 1. the support, 2. the size layer, 3. the ground layer, 4. the paint layer, 5. the glazing (not always present), and 6. the varnish coating (**Fig. 1**).

Fig. 1 Representation of the painting system of a painting on copper (a) and a painting on canvas (b)

1. Support; 2. Size layer; 3. Ground layer; 4. Paint layer; 5 Glazing and 6. Varnish

Besides using non-hygroscopic support, the most evident difference within these easel paintings is the thickness of the whole system over the substrate and the ground layer composition. Paintings on metal are extremely thin. According to microscopic and μ-Raman spectroscopy analysis, the ground layer has an average thickness of 20 microns. It is mainly composed of a mixture of oil, lead white and earth pigments [3], while paintings on canvas and wooden support have an average thickness of 100 microns. The ground layer is composed of carbonate calcium or calcium sulphate with a hide glue (Valada et al., 2016). Another substantial difference, not directly connected with their materiality, is related to the conservation and restoration literature dedicated to each. Paintings on metallic support are the group with the scarcest detailed literature.

To date, systematic research has yet to be conducted to comprehend the evolution of conservation and treatment procedures for paintings on copper. However, due to the development of a database at the University of Fine Arts in Lisbon aimed at studying paintings on metallic supports, it has become possible to achieve this objective. This research underscores the urgent need for further exploration in this field, as it identifies a significant body of literature related to infills and retouching materials for paintings on copper.

Documentary research

The text provides an overview of the extensive research conducted on painting on metallic support. Various sources, including art treatises, artists' manuals, encyclopedias, scientific articles, and dissertations, have been compiled, totalling over 650 references from 1600 to 2022. Among these, 77 documents delve into topics related to conservation and restoration treatments (Fig 2). Spanish contributions to the study of painting on copper support stand out, with notable mentions of artists such as Carducho (Carducho, 1633) and Pacheco (Pacheco, 1649) detailing their experiences with paintings on copper in the 17th century. Moreover, Universitat Politècnica de València has been consistently producing academic works on this subject since 2017, likely driven by the organisation of the inaugural symposium "Paintings on copper and other metal plates: Production, degradation, and conservation issues" (López et al., 2017).

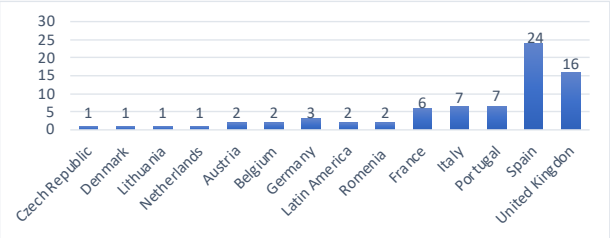

Fig. 2. Distribution of the bibliography concerning Conservation and Restoration treatments

These 77 documents give us a better understanding of the

most common practices applied to paintings on copper (Fig 3). 90% of the restoration treatments are executed on the chromatic layers. Of these percentages, 16% and 18% correspond to Infill and Retouching procedures, respectively. The literature available represents 55 sources.

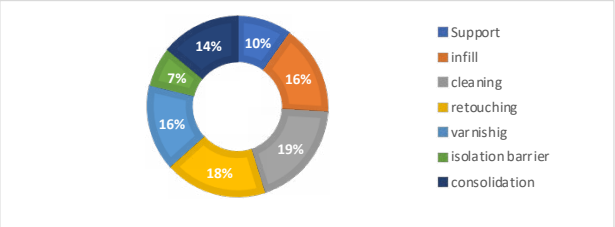

Fig. 3. Distribution of the leading conservation and restoration topics in the consulted bibliography

The losses

Loss in the context of oil painting refers to a disruption in the layer system. In the case of paintings on metallic support, losses are usually extensive, affecting all layers from the upper organic coatings to the inorganic substrate (Fig 4), regardless of whether the loss stems from mechanical, physical, or chemical causes. Poor handling, for instance, can lead to loss in the chromatic layer and its support, often evidenced by damage along the edges of metallic plates. Chemical decay processes are attributed to the metal's tendency to corrode, determined by factors such as purity, alloying, crystallographic structure, and surface characteristics. Exposure of the metal due to losses or cracks can lead to the migration of water and ions to the oil paint/copper interface, initiating electrochemical reactions and promoting adhesion loss (Fig 5). Lydia Pavlopoulou and David Watkinson note that destabilisation begins with bond failure, laying the groundwork for delamination (Fig 6) (Pavlopoulou & Watkinson, 2006). Furthermore, aqueous surface treatments and conservation procedures could hasten degradation (Fig 7).

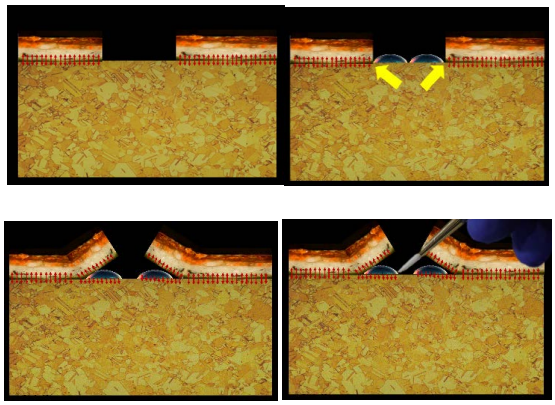

Fig. 4. (a) Representation of the typical loss present on painting on copper, (b) Representation of ingress of water to the oil paint/copper interface, (c) Representation of beginning of the failure bond within the system, and (d) Representation of surface treatment or conservation treatments that use moisture.

Written sources before 1899

Documentation consulted points that three traditional infills were possible to use for losses on painting on copper support (Table 1):

1. An inert, such as calcium sulphate or the pigment Spanish white, mixed with an animal glue. Vicente Polero mentioned that calcium sulphate could not be substituted for any other material since the infill property would be compromised (Polero, 1853). Filling the loss had four steps: 1. Place the infill over the loss, 2. Remove the excess material; 3. Clean the area, and 4. Texturing the infill to imitate the surrounding area. The same author advised the extreme necessity to work consciously and remove all possible dust after levelling the infill so as not to contaminate the retouching or the new varnish coat (Polero, 1853). Forni adds extra information. He suggested that the gypsum would not adhere correctly to the support by itself and, consequently, it would be impossible to level the surface, so fresh garlic should be crushed before applying the infill. Its juice is applied over the metallic surface of the loss by brush (Forni, 1866). For his part, De la Roca detailed better some of the steps that Polero mentioned: the infill must be taken in a small portion with the tip of the palette knife and placed on the palm of the left hand, then it was beaten again and collected towards the centre; it was taken with the knife the portion that is enough for filling the loss, taking care that it was placed in such a way that it would form a slight prominence, which was necessary for the scraping operation (Delgado, 1871). According to De La Roca, the step that Polero referred to as 'clean the area' involves using a fine sponge moistened with clear water, which is gently passed over the infill to dampen it, followed by scraping it with a standard sharp knife.
2. An oil putty. It was prepared by mixing a drying oil and a resin with pigments. Diderot mentioned the type of pigments/inert to add to the oil putty, umber and clay. Drying oil was not the same for preparing oil paints (linseed oil); it was walnut oil (Diderot & Alambert, 1791). Secco is the only author who has given us the ingredients and proportions to prepare the oil putty. On the other hand, Picault and Hampel disclosed exciting details about the practice of restoring painting on copper. Picault said that the

paint layers did not need to be consolidated; they just needed to be scrapped off till the sound paint layer before applying the putty. Although Hampel did not directly mention the word "oil putty", he said the "coloured infill" must be applied gradually by brush till the level of the surrounding area (Hampel, 1846).

3. Wax-resin. This infill is just mentioned by Deón (Deón, 1851); he also suggested the possibility of just applying virgin wax. According to the same author, adding ***sanguine*** was not just added to give some colour to the infill but also to make it harder.

Regarding the retouching approach in this literature, Picault wrote vaguely about how retouching was performed (Picault, 1793). He just recommended applying colour over the losses, not to mention the kind of binder used. Hampel, who probably was familiar with coloured oil putty, recorded that the "coloured infill" must be applied in the area of lack of paintings. Polero advised that the tint used in the retouching should be diluted more in oil than the original to achieve the transparency, delicacy, and tenuity of the other colours applied to the work. Forni and Secco (Secco, 1866) had a practice closer to modern ateliers; they suggested using watercolours in the first layers, followed by a thin layer of varnish to saturate the painting. After that, retouching colours must be prepared with Dammar resin to match perfectly the original. On the contrary, De la Roca suggested that the binder should be mastic resin.

Table 1. Written sources before 1899

		Infill			Retouching binder	Chapter/ pages
Year	Author	Inert + hide glue	Oil putty	Wax-resin		
1791	Diderot	-	Walnut oil + umber + clay	-	-	24
1793	Picault	-	Yes	-	oil?	XXXIII
1846	Hampel	-	Yes?	-	oil?	51-2
1851	Deón	Spanish white	-	+ red blood-	-	20-1
1853	Vicente Polero	Gypsum	-	-	oil-	
1866	Forni.	Gypsum	-	-	Sheepskin glue, honey, gum Arabic?, Dammar resin	77, 151-2
1871	De la Roca y Delgado	Gypsum	-	-	Mastic resin-	98-101 102-105
1886	Secco	-	Walnut oil: turpentine (1:4) Walnut oil: mastic resin (1:3)	-	Sheepskin glue, honey, gum Arabic?, Dammar resin	XILX LXV

Written sources after 1900

After 1900, a wide variety of products appeared in the common practice of restoring paintings on copper. Nevertheless, infills are not the primary concern among easel painting conservators since just 22% are concerned with this issue; in comparison, 78% are more attentive to the chromatic reintegration phase (Fig 8). This situation could be explained by the fact that the paint layer is extremely thin, and as we will see ahead, the retouching itself could be considered the filler itself.

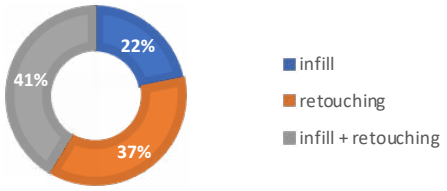

Fig 8. Distribution of the bibliography concerning Conservation and Restoration treatments

The infill materials can be classified as traditional, similar to older practices, and modern, which includes ready-made products, or a mixture of pure reagents bought in the shops and prepared at the studio. Simultaneously, all materials can be divided into aqueous and non-aqueous infills (Table 2).

Although aqueous products should be avoided since they could promote corrosion or retain moisture from the environment, some authors suggest the use of an isolating layer of synthetic resin that would act as a water barrier prior the application of an aqueous infill (Instituto del Patrimonio Cultural de España [IPCE], 1996; ICPE, 1998; Maule, 1999; Broers, 2002; ICPE, 2004; Campo et al., 2009; Cox et al., 2016; Vega et al., 2017; Albaladejo et al., 2017; Petcu, 2017; Rubio, 2019; Vergeer, 2019; Armero, 2020; Mora, 2021; De la Torre, 2021; Rodrigueza et al., 2022). The material most often used for the isolation is the copolymer of ethyl methacrylate and methyl methacrylate, most known as *Paraloid*-B72.

Paraloid B-72 is one of the few polymers with an estimated duration of 100 years. It can also be stored without changes in its transparency for more than 200 years (according to accelerated ageing studies) (Feller & Curran, 1975). It is a stable resin. Nevertheless, compared with other resin acrylics, its high-water permeability decreases its useful life (Kovács et al., 2021).

The aqueous ready-made products listed (Modostuc, Fine Surface Polyfilla, Lascaux 500, Liquitex, and Daler Rowney Texture Paste) are commercial products with complex formulations described in their manufacturer's datasheets. As a result, the uncertainty surrounding their ingredients and the inability to ensure that the manufacturer will use the same formulations beyond the initial purchase means that these commercial materials cannot be relied upon regarding their longevity or repeatability.

The non-aqueous ready-made product listed is Gamblin Wax-resin. Although the material is a good option as an infill, it contains beeswax, which promotes metal corrosion (Vega, 2017; Vega et al., 2017; Vega et al., 2018).

In most cases, the application methods are carried out by brush, which is relatively straightforward. The primary concern with ready-made products is their aqueous nature and the potential presence of unknown ingredients. Non-aqueous infill mixtures are typically composed of a synthetic polymer, a solvent, a filler, and pigments. However, none of these materials are suitable as infills for paintings on metal supports, except for acid-free pigmented wax resins (refer to Table 3).

Finally, according to some authors, Paraloid® B72 resins could be used in a reduced percentage of 5-10% with the addition of a pigment and applied in multi-layers to build up the level of the loss with the surrounding area (Bjarnhof, 1987; Arestiño & Guimil, 2006; Mugniot, 2007; ICPE, 2007).

Table 2. Written sources after 1900

		Infill				Retouching			
Year	Author	Traditional	Ready-made	Mixture	Not specified	Traditional	Ready-made	Mixture	Not specified
1981	Schneider	-	-	-	-	-	-	-	X
1983	Réunion des musées nationax	-	-	-	-	-	-	-	X
1983	Leegenhoek-Wade	1,2	-	-	-	-	-	-	-
1987	Bjarnhof	-	-	-	-	-	-	PBp	-
1990	Alvarez	-	-	4	-	-	-	4	-
1990	Guinea J.	-	5	-	-	-	M	-	-
1992	Garrell	2	-	-	-	-	-	4	-
1993	Moncrieff	-	F	-	-	-	-	PBp	-
1994	IPCE BM 116-42	-	-	-	-	-	-	R	X
1995	Berger	-	-	6	-	-	-	6	-
1996	Horovitz	-	L,R	7	-	-	-	-	-
1996	IPCE NM 97-35	-	-	-	-	-	-	-	X
1996	IPCE BM 117-5	-	-	-	-	-	-	4	-
1998	IPCE BM 97-27	-	-	-	-	-	-	4	-
1999	Moule	1	-	-	-	Egg	-	MS	-
2002	Broers	-	H	-	-	-	-	-	-
2002	Horovitz	-	L,a	-	-	-	-	-	-
2003	Vivancos	2	-	P67p	-	-	-	-	-
2004	Koltz	1	-	-	-	w	G	-	-
2004	Orietta	3	-	-	-	-	-	4	-
2004	IPCE BM 460-8	-	A	-	-	w	-	-	-
2006	Terenzi	-	R	t,ac	-	-		4, 7	
2006	Arestiño	-	-	-	-	-	-	PBp	-
2007	Mugniot	-	-	-	-	-	-	PBp	-
2007	IPCE BM 275-2	-	-	-	-	d	M	PBp	
2008	Rizzo	-	Md,Gr	-	-	-	-	4	-
2008	Bergerovi	2	-	-	-	or	-	-	-
2009	IPCE BM 514-5	-	-	-	-	-	-	-	X
2009	Campo	-	-	-	-	-	-	4	-
2016	Coxs	-	-	PB72	-	-	-	4	-
2017	Vega	-	GWR	2		-	-	-	-
2017	Vázquez	-	-	-	-	-	M	-	-
2017	Kasiulvte	-	-	Px	-	-	-	op +Px	-
2017	Petcu	1	-	-	-	-	-	PBp	-
2017	Magdaleno	-	-	-	-	-	-	-	X
2017	Horovitz	-	L,a	-	-	-	-	-	-
2017	Vega	-	-	2	-	-	G	-	-
2018	Gonzalez	-	-	2	-	-	-	-	-
2018	Lalli	-	-	3+3	-	-	-	LP	-
2019	Aranda	-	-	-	-	-	-	4	-
2019	Vergeer	-	-	2	-	-	G	-	-
2020	Armero	-	-	PB72	-	-	-	-	-
2020	Sonoc	-	-	Bg	-	-	M	4	-
2021	Mora	-	-	PB72	-	-	G	-	-
2021	Sánchez	-	-	-	-	-	-	-	X
2022	Rocher	-	-	-	-	-	-	4	-

Regarding the retouching materials, conservators prefer to use synthetic materials, namely PB72 or retouching varnish mixture with pigments. Commercial brands such as Gamblin Conservation Color or Maimeri retouching colours are also preferred. Hamilton Kerr Institute has a long tradition of using egg tempera as a

References: 1- chalk/ Gesso + hide glue; 2 – Wax-resin; 3 – Wax; 4- Varnish + pigments; 5- Varnish; 6 – *Paraloid* B72 + Chalk; 7- PVA + pigments; 7- resin + pigments; a- acrylic infill; ac – Acylic colours; A- Acrylic Texture Paste; Bg- Beva Gel 37 + chalk; d – dammar + pigments; F- Fine Surface Polyfilla; G- Gamblin Colours; Gr- Gel Relief Lefranc & BOUGEON; GWR – Gamblin wax-resin; H- Hydrogrund Lascaux 500; L – Liquitex M- Maimeri colours; LP– Laropal + pigments; Md – Modostuc; op- Oil paint; or- Oil resin + pigments; PB72- *Paraloid* B72; PBp-*Paraloid* B72 + Pigments; MS- MSA2 + pigments; P67p – *Paraloid* B67 + Pigments; Px- Plextisol P550-40 + pigments; R- Darler Rowney Texture Paste; t- tempera; w – water colours //blue: aqueous materials orange: non-aqueous materials

retouching material. Conservators who use egg tempera say that this product is a healthy option and that once it has dried, it is less hygroscopic than either gouache or watercolour (Kempsky, 2010).

Table 3. Application methods and observation of the ready-made infill behaviour

Type	Product	Application method	Observations
Ready-made	Polyfilla	Brush	Pro: ease of application, spread well Cons: unknown components on the formulation, white ghosting, and water required for cleaning and texturing.
Ready-made	Modostuc		
Ready-made	Liquitex	brush	Pro: ease of application, spread well, useful for significant losses Cons: unknown components on the formulation, rubbery texture, difficult to carve once dried.
Ready-made	Acrylic texture medium	brush	Pro: ease of application, spread well Cons: unknown components on the formulation, rubbery texture, difficult to carve once it dries.
Ready-made	Hydroground Lascaux 750	brush	Pro: ease of application, spread well, hydrophobic when dries (?) Cons: Unknown components of the formulation swell when relative humidity increases.
Ready-made	Gamblin wax-resin	Warm spatula, Wooden skewer	Pro: Naturally hydrophobic, colour reintegration match possible Cons: acidity of the beeswax used
Mixture	Paraloid B72 (20%)	brush	Cons: difficult to apply; it could act over the isolation varnish
Mixture	Paraloid B48 (20%)	brush	Cons: difficult to apply, it could act over the isolation vanish
Mixture	Plextol B500-40	brush	Cons: adhesion to the support is altered when the filler is added
Mixture	Beva 371	brush	Cons: no adhesion to the metallic surface
Mixture	Pigmented wax-resin	Warm spatula, wooden sticker	Pro: control over the progression of the infill, colour matching possible, acidity problem controlled, double isolation system over the losses. Cons: time-consuming when compared with other solutions.

Conclusions

In the realm of painting on copper, the selection of appropriate infill or retouching materials requires a comprehensive exploration. The evolution of past practices and materials has rendered this task increasingly complex, as each object presents unique requirements that demand careful consideration in aligning with a suitable polymer. With many options available today, professionals are tasked with meticulously evaluating the features that render a specific product ideal for the painting. Parameters to contemplate include application, rheology, reversibility, ageing characteristics, and solubility in particular solvents. An investigation revealed 63 written sources offering insights into infill and retouching materials, indicating a notable shift from traditional to synthetic materials during the latter decades of the 20th century. Presently, conservators' prevalent application of non-aqueous infills is indicative of this transition, coupled with a discernible inclination toward employing ready-made materials. Notably, products formulated with *Paraloid* B-72 and microcrystalline wax emerge as particularly promising among the listed options.

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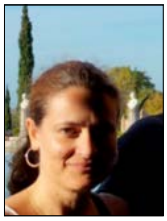

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REINTEGRATION OF LARGE-SCALE LOSSES ON A BLACK MONOCHROME OIL PAINTING BY THE AUSTRIAN ARTIST ARNULF RAINER

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Abstract

*In 1994, the unvarnished, black monochrome oil painting "Übermalte Landschaft" (1960) by Arnulf Rainer (*1929), was severely damaged by vandalism. An aggressive slogan in red oil paint defaced the artwork. An earlier attempt to remove this overpaint, using strong solvents, resulted in severe damage of underlying original paint layers. Approximately one fifth of the paint surface was affected by abrasion, colour change, as well as substantial paint loss.*

For the recent treatment, a comprehensive technical study and condition assessment of the painting was conducted as part of a diploma thesis by Ludovicy (2021) at the Academy of Fine Arts Vienna. An artist interview provided further information regarding aesthetic intention and the painting process.

The choice of retouching materials was limited by the water sensitivity of the oil-based paint used by the artist. This paper describes the use of MSA Conservation Paints to re-integrate the large-scale losses on the black monochrome oil painting.

Keywords:

retouching ,

MSA conservation paints,

monochrome,

unvarnished painting,

oil paint,

water sensitivity

Introduction

Arnulf Rainer's abstract painting "Übermalte Landschaft" (1960) had suffered greatly from its eventful history.

In 1994, the black monochrome oil painting was severely damaged by vandalism. During a break-in at Rainer's studio at the Academy of Fine Arts Vienna 38 paintings were extremely damaged with oil paint. (Arnulf Rainer served as a professor of painting at the Academy from 1981 to 1995.)

Most of them were completely overpainted in black, except the artist's signature. "Übermalte Landschaft" was defaced with an aggressive slogan "UND DA BESCHLOSS ER AKTIONIST ZU SEIN" (**Fig. 1**), which translates to "AND THEN HE DECIDED TO BE AN ACTIONIST". (The slogan was interpreted as a variation of Adolf Hitlers sentence "But I decided to become a politician" from his manifest "Mein Kampf". The red letters covered nearly two-thirds of the painted surface.

The subsequent attempt to remove this overpaint from the surface of "Übermalte Landschaft", using strong solvents, resulted in severe damage of the original paint layers and, in addition, left behind a strong negative relief (following the form of the lettering) (**Fig. 2**). Approximately one fifth of the paint surface was affected by abrasion, colour change, as well as substantial paint loss. Unable to address the situation, the painting, which remains in the artist's possession, was stored.

In 2019 "Übermalte Landschaft" was brought to the Institute for Conservation-Restoration at the Academy of Fine Arts Vienna to evaluate treatment options.

The technological investigation and condition assessment were supported by Fourier transform infrared spectroscopy (FTIR) and x-ray fluorescence analysis (XRF). An artist interview provided further information regarding intention and the painting process.

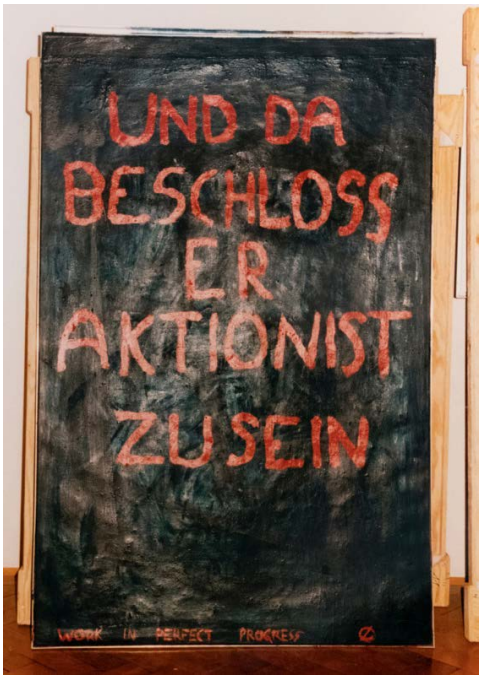

Fig. 1. "Übermalte Landschaft" (1960, 201 x 130 cm) after the act of vandalism of 1994, in which the painting was defaced with an aggressive slogan. Photo: © Studio Arnulf Rainer, 1994.

Fig. 2. Overall photograph of "Übermalte Landschaft" before treatment, raking light. Photo: © E. Hammerschmid, INTK, 2019.

The Artist Arnulf Rainer and his Overpaintings

Arnulf Rainer (*1929) is one of the best-known contemporary Austrian artists. As a self-taught painter, he developed over seven decades a multi-layered and unique oeuvre that includes drawings, prints, paintings, photographs and films.

In 1954, the artist started to create his signature series – "Übermalungen" or "Overpaintings" in English. These predominantly monochromatic paintings evolve through the layering of brushstrokes over pre-existing artworks in what Arnulf Rainer calls a "passively creative process" (Rainer & Thierolf, 2020, p. 30), which can last for years or even decades. The first "Overpaintings" were created more by chance and out of a shortage of materials. However, Rainer increasingly realised that reworking other people's and his own paintings evoked empathy and creative stimulation. In an interview with Antonia Hoerschelmann, Rainer noted: "My aim is to emphasise, to bring subtleties to light, to pay homage. There is a kind of communication that takes place, which, as a result of this artistic dialogue leads to a new flowering of expression." (Hoerschelmann, 2014, pp. 201-202).

The artist has continued to explore the possibilities of this process over the course of his entire career.

The painting "Übermalte Landschaft" (1960)

"Übermalte Landschaft" (1960) is one of the early "Overpaintings". The large format painting (201 ×130 cm) has a support of linen canvas. FTIR analyses of the ground layer detected mainly oil as a binder component and a mixture of dolomitic chalk and lithopone as filling material.

The abstract painting is dominated by a dark colouring. The layer build-up can be traced on the original aluminium strip frame and tacking edges, even though it is not possible to get a clear idea of the image hidden beneath the black paint. Cross-sections identified a total of ten different paint layers (**Fig.3**). The individual layers are clearly separated from one another and testify to a successive build-up.

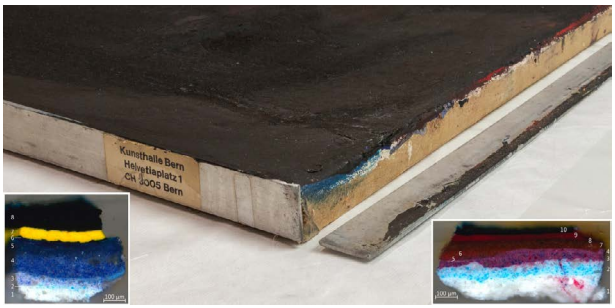

Fig. 3. Aluminium strip frame removed from left edge of the painting. Tacking edge and inside of frame show different paint layers. The cross-section on the left has been taken from the upper edge. On the right is a cross-section taken from the left edge showing the full layer built-up with the ground layer containing chalk and lithopone (1). The second last layer contains synthetic alizarin madder (9) and the final layer Prussian blue (10). Photo: S. Ludovicy, 2019.

FTIR-analysis revealed that Prussian blue was used in the final layers. Together with the underlying alizarin madder paint layer a deep dark appearance was achieved.

The painting's unique "coarse-grained" surface texture was created using self-made oil paints containing various pigment agglomerations which accumulate with each added layer. Rainer mainly used linseed oil as a binder and turpentine substitute as a thinner. No varnish has been applied to the painting.

Condition and decision-making process

The painting's condition and appearance had highly suffered from the removal of the red slogan after the 1994 attack. The uncovered original red paint was visible in areas where the upper Prussian blue paint layers were removed (**Fig.4a**). Only small traces from the red overpaint were found upon closer examination. According to FTIR analyses the red overpaint consists of barium sulphate and synthetic organic naphthol-AS pigments in oil medium.

The removal left behind shallow losses, making the red letters appear in strong negative relief, especially in raking light (**Fig.4b**). The pressure exerted caused a pronounced craquelure, particularly visible in raking light. The dissolved paint also penetrated the back of the canvas.

The fabric support exhibited insufficient tension, along with deformations and stretcher bar marks.

The weight of the paint has caused a noticeable sag in the

lower half of the canvas, resulting in slight bulging and folds. A polyester wadding attached to a cardboard has been applied as a supportive backing to the reverse of the painting, as the artist did not wish to increase tension on the canvas.

Furthermore, the painting's surface was affected to varying degrees by a grey or white haze, identified by FTIR as free fatty acid efflorescence (**Fig.4a**). Cleaning the surface was particularly complex, because the oil paint was not only extremely sensitive to mechanical action but also to water. A method was developed in which dirt deposits and free fatty acids on the unvarnished surface were removed with a 4% agar gel, which was applied in a semi-liquid state.

Fig. 4.-4a Paint surface showing fatty acid efflorescence and losses in the letters, exposing underlying paint layers. 4b Pronounced craquelure caused by the removal. Photo: S. Ludovicy, 2019.

During the treatment, the most intriguing question concerned the approach of loss compensation.

For Arnulf Rainer, the artist who owns and created the artwork, restoring the visual appearance held great significance. The size as well as the shape of the losses affected a large part of the monochrome surface, disfiguring the artist's abstract intention. Rainer acknowledged the challenges of the conservation-restoration, but also expressed that he believes reworking the painting himself would be inappropriate as it could only lead to a completely new piece. In an interview with Stefanie Ludovicy, the artist stated: "I'm not a conservator, so the best I can do is to create a new painting based on it. I did not feel confident attempting to restore the painting's old state due to the potential issues that could arise. Above all, you need to be able to treat the damage so that you can no longer see it." (Ludovicy, 2021, p. 101).

A complete reintegration of the large-scale losses was deemed necessary to reestablish the visual integrity of the artwork.

Although the surface texture is reduced and paint is missing in the damaged areas, the use of the remaining texture and hue of the surrounding areas allows a conclusive reconstruction of the missing parts.

The most challenging aspect was the necessity to retouch over original paint in order to achieve the treatment objectives. The choice of material was also limited due to the water-sensitivity of the oil paint. Only binders based on non-polar solvents were considered to be safe to use. Furthermore, the retouching material should at the same time enable to create impasto. Different combinations of materials, as well as the use of an isolation layer, were considered. In the end, Gamblin Conservation Colors and MSA Conservation Paints were shortlisted. MSA Paints were selected as they require a lower aromatic content (25%) compared to Gamblin Conservation Colors (35-40%), according to test results.

Restoration treatment – Materials and Methods

GOLDEN MSA Conservation Paints are composed of a butyl methacrylate binder, soluble and removable in mineral spirits with a low aromatic content (Jablonski et al., 2011, p. 228). These paints exhibit very good aging properties (Szmit-Naud, 2003b). Straight from the jar, the paints have a buttery consistency and can be shaped into impasto. Once dried, they have a matte to satin appearance.

It's important to note that, according to Szmit-Naud, MSA Conservation Paints remain soluble in white spirit after artificial aging. However, Feller et al.'s (1971) research indicates that n-butyl methacrylates exhibit cross-linking. Nevertheless, Feller's assessment shows that the synthetic resin films remain swellable even after extensive aging, making them easily removable.

Sims et al. (2010) discovered in their study that after subjecting MSA colors to artificial aging, they exhibit minimal swelling in petroleum distillates (petroleum spirits) and can be removed mechanically. They can be removed more efficiently using white spirit (Stoddard solvent) with aromatic components. The paints remain fully soluble in xylene.

The paints were blended to the desired consistency with a mixture of hydrocarbons resulting in 25% aromatic content (White Spirit, containing 14–17% aromatic hydrocar-

bons, and Shellsol A with 99% aromatic hydrocarbons, in a ratio of about 10:1). Dry pigments were added and where necessary, gloss was reduced by adding Acematt HK 125. Wearing black gloves, using a black palette and painting the ferrules of the brushes black, helped to reduce the reflections of the working tools (**Fig.5**).

Fig. 5. Transparent palette covered with black foil, double-dipper with hydrocarbon diluent, dry pigments and matting agent in little containers glued to the palette. Photo: S. Ludovicy, 2019.

The reconstruction was tricky and had to be divided into several steps. First, the missing texture was built up with a layer of more viscous MSA paint mixed with dry pigments and matting agent (**Fig.6a**). The paints exhibit some shrinkage, so several layers were necessary to fill the shallow losses. The next day, it was possible to continue working in glazes, to adjust the colour (**Fig.6b**). To imitate the porous, rough surface texture, the dried paint was slightly softened with the hydrocarbon blend (**Fig.6c**) and then shaped with the help of a bristle brush (**Fig.6d**). In some areas, this procedure had to be repeated multiple times. In the last step, gloss was added locally using a Golden MSA Varnish (Gloss) diluted with the same hydrocarbon blend. Optimal lighting of the workplace was important, and different light sources were used, but not simultaneously. During the retouching process, the painting was rotated so that the inpainted areas could be inspected and adjusted from all sides.

Fig. 6. 6a Creating impasto with viscous MSA paint. 6b Adjusting colour by glazing. 6c Resolubilizing dried retouching with hydrocarbon mixture. 6d Shaping of the softened retouching with bristle brush to imitate porous surface texture. Photo: S. Ludovicy, 2019.

Conclusions

The retouching process turned out to be very challenging. Long drying times and the constant checking from various angles and with different lighting situations were very time consuming. Colour matching on dark and monochrome surfaces is generally extremely difficult and, in this case, extensive retouching was required in areas of damage with strongly defined outlines.

The act of vandalism and subsequent interventions will still impact the painting's trajectory. The original substance was severely damaged and permanently altered. In particular, the cracks caused by the removal of the red overpaint remain visible to some extent in raking light.

Nevertheless, the applied retouching method proved successful in integrating the large-scale losses and altered original paint (**Fig.7**-**8**).

Fig. 7.-7a Detail of an area with abraded paint, exposing red underlying layer before retouching. 7b Same area after retouching. Photo: S. Ludovicy, 2019.

Fig. 8.-8a Overall photograph of “Übermalte Landschaft” before treatment. 8b Painting after treatment. Photo: S. Ludovicy, 2019.

Materials

Surface cleaning: Agar 05040 (Sigma-Aldrich); demin. water (Kremer); Retouching: MSA Bone Black (Golden Artists Colors); Prussian blue pigment (Schmincke); Alizarin Dark pigment (Schmincke); Acematt HK 125; Shellsol® A (all from Kremer); Testbenzin 140/200 (Neuber‘s Enkel).

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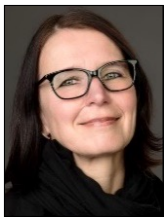

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ANALYSIS OF HISTORICAL RETOUCHINGS WITH MULTI-BAND PHOTOGRAPHY

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Abstract

This work focuses on using non-invasive multi-band imaging techniques, particularly UV fluorescence, to document and characterise retouching and chromatic reintegration in works of art. The study uses systems sensitive to a 360-1100 nm spectral range, using a FujiFilm X-T1 IR camera and the ARTIST multispectral system. The research is based on a comprehensive review of current conservation and restoration methods derived from specialist literature. The captured and post-processed technical images provide a comparative method for analysing varnishes, repainting, compositional changes and material aspects such as pigment identification. The research includes case studies. Among these, the painting of Amaro Pargo (1678-1747), a figure erroneously associated with piracy in oral tradition and romantic literature, stands out. The research sheds light on the evolution of works of art, emphasising chromatic reintegration, while avoiding historical inaccuracies perpetuated by fiction.

Keywords:

chromatic reintegration,

visible fluorescence,

multiband analysis,

retouching

Introduction

Image analysis is a form of non-destructive physical-optical analysis that provides scientific support for the characterisation and diagnosis of works of art. Image analysis is based on the use of recording systems sensitive to a spectral range of 360-1100 nm, together with different light sources and filters, to obtain a selection of technical images that provide information about the object under examination (Cosentino 2014; Cosentino 2016).

Multiband photography is one of the non-invasive documentation techniques that allow us to obtain information about the creation of works, but also about their ageing or the retouching they have undergone throughout their history (Dyer et al. 2013; Herrero et al. 2018). The main objective of the present work is to document and characterise these retouches, overpaintings and chromatic reintegrations using multiband techniques, especially UV fluorescence, but also through comparison with other bands.

The electromagnetic spectrum is divided into several parts (**Fig. 1**). The visible spectrum is the only part of the spectrum that can be seen by the human eye and allows us to analyse the surface layer of a work of art and carry out an organoleptic examination. The ultraviolet range can show us interventions such as retouching or reintegration, the method of applying protective layers or the presence of bio-deterioration. The infrared range can penetrate the surface layers and allows us to analyse the preparation layer, where preparatory drawings or regrets can be found (Cosentino 2015; Pereira 2015; Keats 2019). X-rays can penetrate through the material to its support, making it possible to study an entire work from the inside out.

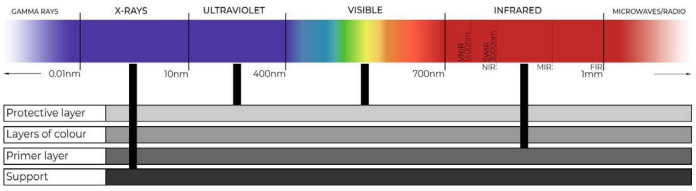

Fig. 1. Electromagnetic spectrum showing the layers of a work that can be reached by each band. Source: SADOA-SEGAI

The inspection of works of art begins with high-quality photographic documentation in the visible (VIS) range. These images allow an organoleptic examination to characterise the state of conservation of a work of art. Racking light (VISR) allows us to detect deformations of the support, lifting of the paint layer or painting techniques such as the presence of impasto. Transmitted light (VIST) reveals losses in the paint layer or preparation, cracks or losses in the support, or differences in the thickness of the canvas.

Both the materials that make up works of art and those used in their restoration, such as pigments, binders, varnishes, consolidants or adhesives, exhibit a certain phenomenon of fluorescence under ultraviolet radiation. Ultraviolet fluorescence (UVF) provides information on the presence and distribution of these materials. Using this technique, we can analyse the presence of repainting or reintegration of previous restorations, thanks to the response of the different materials that produce fluorescence (Bacci 2019; Herrero et al. 2018). We can also study the type of application and the nature of the protective layers. And we can detect the presence of different pigments with characteristic fluorescence.

These materials also show some fluorescence phenomena under ultraviolet reflectography (UVR) (Bacci 2019). Their recording provides information on the presence and distribution of these materials (Herrero et al. 2018; Herrero et al. 2022; Keller et al. 2019).

In the infrared (IR) range, some pigments lose their opacity, making it possible to see underlying drawings, signatures, inscriptions and hidden motifs. This reveals aspects of the process by which the artworks were created. In the same way that we can see preparatory drawings, we can find regrets where the artist has changed the design or the arrangement of the characters.

We can also see aspects of the state of conservation: hidden losses, repainting that interferes with the original

painting, we can see the actual state of the artwork. Transmitted infrared (TIR) allows us to see the weave of the canvas in greater detail, revealing small losses of support, as well as greater detail in the craquelure of the polychromy. Or the artist's remorse can be enhanced with transmitted light. Infrared False Colour IRFC is a technique that combines visible and infrared images. It is a graphic tool that highlights the distribution of materials and techniques, brings us closer to their identification and facilitates the distinction between original polychromy and later additions (Cosentino 2014; Cosentino 2016; Herrero et al. 2018; Herrero et al. 2022; Raïch et al. 2019).

Some molecules and minerals, including some pigments, fluoresce under infrared fluorescence (IRF). This photographic method allows us to identify and locate cadmium pigments (cadmium red, cadmium yellow or cadmium green) and Egyptian blue (Cosentino 2014; Grazia et al. 2019; Verri 2009).

In general, these techniques allow us to diagnose and see the underlying drawings, but they can also be used to analyse historical chromatic reintegration's and to confront the intervention of the artist and restorers. Our aim is to analyse, through different cases, the application of varnishes and repainting, compositional aspects that reveal the modification of the original image, and material aspects such as the identification of certain pigments, but always from the point of view of chromatic reintegration.

Experimental

Materials

To obtain the multi-band images in the study of the works, different devices and luminants were used (Table 1):

- Nikon® D850 (45MP, CMOS sensor) digital camera with Sigma 50mm 1:1.4 DG ø77 objective and the filters Hoya Pro1 Digital UV and B+W UV/IR cut 486 MRC Basic.
- Fujifilm® X-T1 IR (16MP, CMOS sensor) digital camera "full spectrum" with sensitivity between about 380 and 1000 nm, with Fujinon XF 18-135mm 1:3.5-5.6 R LM OIS WR ø67 objective and the filters Baader U-Filter, Hoya IR 720nm, Ultrapix IR 850nm and Hoya IR 900 (87 A/RM 90).
- Artist multispectral system (2MP, CCD sensor) with sensitivity between about 360 and 1100 nm.
- Two halogen lamps were used for the lighting (200W), the ultraviolet lamp PS135 UV Floodlight 230 VAC provided by Labino AB and the white light LED lamp Alice provided by CHSOS.

Table 1. Technical information on photographic devices.

Camera	Pixels	Sensor	Spectral sensitivity	Objective
Nikon® D850	45,7 millions	CMOS FX	400-700nm	Sigma 50mm 1:1.4 DG ø77
Fujifilm® X-T1 IR	16,3 millions	X-Trans CMOS II	380-1000nm	Fujinon XF 18-135mm 1:3.5-5.6 R LM OIS WR ø67
Artist multispectral system	2mp	CCD progressive	360-1100nm	-

The various case studies selected are paintings on canvas, whose identification data are added below (Table 2), reflecting the above differences, retouching by the artist, repainting and chromatic reintegration with multiband analysis.

Table 2. Basic information about the case study works

Artwork	Author	Century	Location
Retrato de Agustín Cabrera	Mariano de Cossio	XX	Universidad de La Laguna
Crucifixión	Unknown author	XVI	Monasterio Santa Catalina de Siena, La Laguna
Retrato de la Princesa Victoria	Unknown author	XIX	Private property
Santa Margarita	Unknown author	XVII	Parroquia del Santo Cristo de las Aguas, Teguise
Cristo de la Humildad y Paciencia	Unknown author	XVII	Ermita de Nuestra Señora del Rosario, El Rosario

The *Retrato de Agustín Cabrera* by Mariano de Cossio, painted in the 20th century, shows the artist's remarkable technical skill. It depicts Agustín de Cabrera, an important figure in the cultural life of the city of La Laguna, who held various positions such as director of the General and Technical Institute of the Canary Islands, professor at the University, councilor of the Island Council, and one of the most prominent figures in the cultural life of La Laguna (Real Sociedad Económica de Amigos del País de Tenerife, 2016). Mariano de Cossío painted genre scenes, landscapes and carried out restoration work. He belonged to the artistic movement known as the New Figuration, which emerged in Europe between the two world wars. Cossío was one of the main exponents in Spain of the in-

fluence of the German Neue Sachlichkeit movement (Rodríguez, 2014).

In the same city we find the painting of the *Crucifixion*, in the convent of Saint Catherine of Siena. The painting shows Christ crucified and other figures such as the Virgin, Mary Magdalene and Saint John the Baptist. The style of the painting and the colours indicate that it was painted around the 16th century. In the early centuries of Christianity, the crucifixion was avoided and symbols such as the lamb or the twin cross were used. Over time, it became more common to depict Christ nailed to the cross, but this representation varied according to religious beliefs and popular devotion. Changes occurred both in the shape of the cross and in the depictions of Christ crucified, which showed him alive and standing. Later they began to depict him dead, with his eyes closed and his head tilted to the right. The head of Christ is usually surrounded by a cross halo and may wear a royal crown as a symbol of his majesty. From the 12th century he is also depicted with a crown of thorns on his forehead (Rojas, 2013).

The *Retrato de la princesa Victoria* is a privately owned oil on canvas by an unknown artist. The iconography of the painting, in terms of the style of dress, dates from the first half of the 19th century. The painting is in the English neoclassical style, playing with architecture, light and a subtle chiaroscuro technique, and shows the princess in her youth before her coronation as Queen of England. The later period was known as the Victorian era and was characterised by industrial, cultural, political, scientific and military changes in the United Kingdom, marked by the expansion of the British Empire (Gallerix, n. d.).

The painting of *Santa Margarita* is of Flemish influence and its author is unknown. Of great historical value, it dates from the 17th century and is one of the most valuable pieces of the Canary Islands' religious heritage. It depicts the saint in the centre of the canvas, with different scenes from her life on either side. The painting is highly decorative and is reminiscent of Roman murals. Saint Margaret is a Christian saint, virgin and martyr who belonged to the group of the Holy Helpers. She was killed for her faith during the persecution of Emperor Diocletian, who reigned between 284 and 305 (Brugada, 2008). This artwork can be found in the church of Santo Cristo de las Aguas in Teguise, Lanzarote.

The oil on canvas entitled *Cristo de la humildad y paciencia* (Christ of Humility and Peace), in the hermitage of Nuestra Señora del Rosario, was painted by an unknown artist and its style and colours suggest that it dates from around the 17th century. It is notable for its depiction of characters from the period, such as the three figures in the lower part: Amaro Pargo, a Spanish corsair, moneylender and merchant; Sister María de Jesús, a nun of the Order of Preachers; and Fray Juan de Jesús, a Spanish Franciscan friar and mystic (Santiago, s.f.). The image shows Jesus physically suffering but accepting his sacrifice, naked, dejected and overwhelmed by suffering as he awaits crucifixion (Paz Sánchez & Pulido, 2015).

Methods

The method of taking the photographs is based on the application of all the techniques of multi-band imaging in each artwork (Table 3).

Firstly, the VIS photographs were taken with a Nikon® D850 digital camera using the Hoya Pro1 Digital UV filter. We illuminated the artwork with two halogen lamps placed at 45º to the work. For VISR and VIST we used the same equipment but changed the position of the lamp: a single lamp on one side of the work at 15º for VISR and two lamps on the back of the work at 45º for VIST.

For UVF we used the same camera with the B+W UV/IR filter cut 486 MRC Basic. In this case we used an ultraviolet lamp (365nm), PS135 UV Floodlight 230 VAC The Labino, which covers the entire surface of the work with circular movements and long exposure times. For UVR photography, the Fujifilm® X-T1 IR digital camera was used with the Baader U filter and the same UV lamp.

The infrared photographs were also taken with the Fujifilm® X-T1 IR digital camera, using different filters with cut-offs at 720, 850 and 900 nanometres: Hoya IR 720nm, Ultrapix IR 850nm and Hoya IR 900 (87 A/RM 90). For IR, two halogen lamps were used at the front, at an angle of 45º, while for IRT they were placed at the rear of the work. Finally, the IRF technique is carried out with the CHSOS Alice lamp, with detailed photographs as the focus has to be very close to the work.

For IR detail we use the Artist multispectral system, as it has a higher spectral sensitivity.

Table 3. Relationship of imaging techniques and equipment used in capturing shots.

Technique	Camera	Filter	Lighting
VIS	Nikon® D850	Hoya Pro1 Digital UV Filter 58mm	Halogen lamps (200W)
VISR	Nikon® D850	Hoya Pro1 Digital UV Filter 58mm	Halogen lamps (200W)
VIST	Nikon® D850	Hoya Pro1 Digital UV Filter 58mm	Halogen lamps (200W)
UVF	Nikon® D850	B+W UV/IR cut 486 MRC Basic	PS135 UV Floodlight 230 VAC, Labino AB
UVR	Fujifilm® X-T1 IR	Baader U-Filter	PS135 UV Floodlight 230 VAC, Labino AB
IR	Fujifilm® X-T1 IR	Hoya IR 720nm / Ultrapix IR 850nm / Hoya IR 900 (87 A/RM 90)	Halogen lamps (200W)
IR	Artist multispectral system	-	Halogen lamps (200W)
IRT	Fujifilm® X-T1 IR	Hoya IR 720nm / Ultrapix IR 850nm / Hoya IR 900 (87 A/RM 90)	Halogen lamps (200W)
IRF	Fujifilm® X-T1 IR	Hoya IR 900 (87 A/RM 90)	Alice lamp, CHSOS

These photographs were taken using target Colorchecker XRite and target AIC PhD modified by CHSOS for calibration of the technical photos. The images were shot in RAW mode and then its colour was corrected with white balance and exposure.

For IRFC image, VIS and IR photography are used and their RGB channels are combined.

By means of the different regions of the spectrum and thanks to multi-band photographic techniques, we obtain a complete documentation of the work with which we can carry out analyses and comparisons for its characterisation.

Results and discussion

The case studies are analysed by dividing the results into retouching, overpainting and chromatic reintegration. Retouching refers to small pictorial interventions carried out by the artist on the original work in order to perfect and correct final details. The concept of overpainting refers to the application of a new layer of paint to a polychrome painting or decoration to repair or conceal all or part of the damage to the original or to alter its appearance. Finally, the concept of chromatic reintegration is defined as the addition of material to facilitate the perception and understanding of an object. This process includes actions such as retouching, gap filling, insertion, repainting, among others. It is important to stress that reintegration is carried out in a way that respects the heritage value of the property and is based on evidence. (Calvo et al. 2018)

An example of retouching by the artist is *Retrato de Agustín de Cabrera* by Mariano de Cossio. This artist stands out as an important Spanish painter of the early 20th century. The pigments in this artwork are characterised by a unique fluorescence. A notable feature is the distinct fluorescence of the titanium white pigments used in the nose area of the portrait of Agustín Cabrera (**Fig. 2**). This difference in fluorescence adds an interesting feature to the artwork. A further analysis of the brushstroke provides an insight into the retouching process, with the understanding that the artist personally carried out these modifications.

Fig. 2. Detail of the artwork *Retrato de Agustín de Cabrera* by Mariano de Cossio. a) visible image; b) UVF reveals a fluorescence emitting titanium white pigment from the artist´s retouching. Source: SADOA-SEGAI

The *Crucifixion* from the Convent of Santa Catalina de Siena in San Cristóbal de La Laguna is an example of repainting that shows clear signs of retouching. The dagger and the crowns adorning the figures stand out, with a pronounced dark fluorescence, indicating that they were repainted after the work was executed, but of more contemporary origin (**Fig. 3**). It is possible that a nun with links to the convent was responsible for adding these elements in order to deliberately alter the iconography depicted. In addition, a floral decoration can be seen in the outline of the work, added at a later stage, probably in response to changes to the edges of the painting.

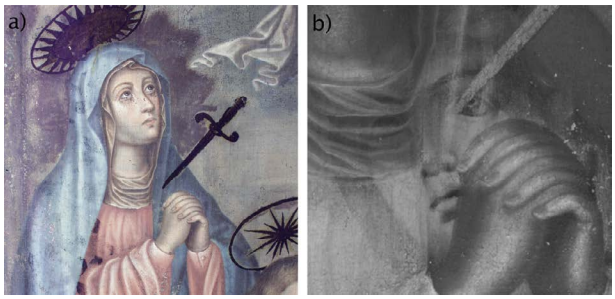

Fig. 3. Detail of the artwork *Crucifixión*. a) UVF reveals fluorescence on the dagger and crown, indicating that they were repainted; b) Infrared at 900 nm allows the underlying figure to be seen, indicating change in the composition. Source: SADOA-SEGAI

As an example of chromatic reintegration, we have three case studies. The first, Retrato de la Princesa Victoria,

shows chromatic reintegration using different techniques. Under visible light (**Fig. 4a**), the *tratteggio* technique, colloquially known as rigatino (Ciatti, 2003:197), can be seen. Under UVF, it can be seen that a plane colour was applied first, followed by the *tratteggio* (**Fig. 4b**). The use of IR and IRT provides a clearer view of the extent of the loss and illustrates how this chromatic reintegration invades a section of the original work of art (**Fig. 4c-d**). These observations provide valuable information on the historical processes of restoration and the methods used to carry out these interventions.

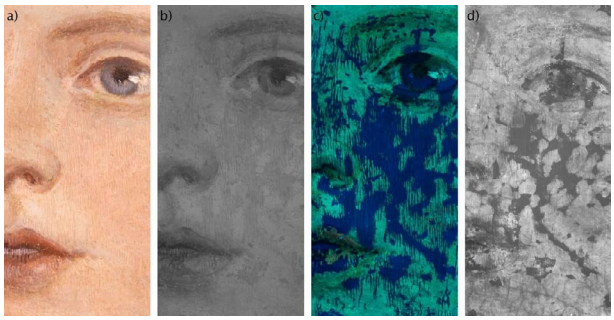

Fig. 4. Detail of the artwork Retrato de La princesa Victoria. a) the visible image shows that the work is reintegrated using the *tratteggio* technique; b) UVF reveals that first a plane colour is applied, then the *tratteggio* technique is applied; c) IR at 900 nm indicates that the chromatic reintegration invades the original work d) IRT at 900 nm shows the pictorial losses of the work and how the *tratteggio* technique invades the original work. Source: SADOA-SEGAI

The second case study is the Santa Margarita. The different hues visible in both the UVF and IRFC contribute significantly to deciphering the different historical reintegration's present in a work of art. The evidence suggests several instances of reintegration, characterised by different degrees of fluorescence (**Fig. 5c-d**): some lighter, some darker. The application of IRFC further reveals a spectrum of tones within these reintegrations (**Fig. 5b**), providing an overall understanding of the nuanced interventions made over time.

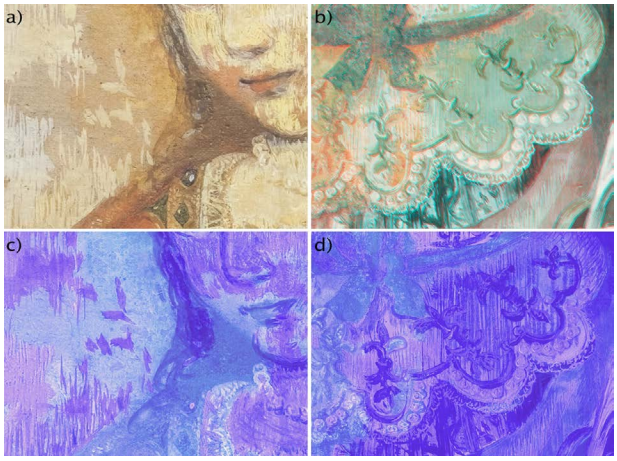

Fig. 5. Detail of the artwork *Santa Margarita*. a) visible image; b) IRFC reveals different shades in the reintegrations; c) UVF image; d) UVF, as in IRFC, shows different intensities in the fluorescence emitted by the reintegrations. If the UVF and IRFC images are compared, the different reintegrations can be seen. Source: SADOA-SEGAI

Finally, we will analyse the painting of the Christ of Humility and Patience. This painting is the only depiction of Amaro Pargo. The painting has suffered numerous losses, most of them on the lower edge, where the portrait of Amaro Pargo is located. In the archives consulted, there is only a small, partly blurred black and white photograph of the painting before the intervention. Observe in particular the anatomy of the faces and the boundaries of the reintegration work completed. In this case, as in the previous example, we can see several reintegrations carried out at different times, with the lower reintegrations having a weaker fluorescence than the upper reintegrations (**Fig. 6a-c**). Thanks to the infrared image, we can also see that these reintegrations cover part of the original polychromy (**Fig. 6d-f**).

Fig. 6. Detail of the artwork Cristo de la Humildad y Paciencia. a-c) UVF reveals chromatic reintegrations with different shades. This indicates several stages of reintegration; d-f) IR at 900 nm reveals the extend of losses in the paint layer. Source: SADOA-SEGAI

The study of these and other cases analysed allows us to deduce which imaging techniques are most suitable for identifying each of the three concepts defined as starting premises: Retouching, Overpainting and Chromatic Reintegration.

In general, the application of UVF allows the identification of these three colour contributions to a work of art. However, on the basis of more specific aspects based on the execution technique, but also on the restoration techniques, we establish the following classification:

Table 4. **Relationship of imaging techniques and usefulness of the results.**

Concepts	VIS	UVF	UVR	IR	IRT	IRF	IRFC
Retouching							
Overpainting							
Chromatic reintegration							

The green cells correspond to an excellent result that was achieved, while the yellow cells correspond to a partial result, the orange cells to limited results and the red cells to no results

Conclusions

After applying these techniques to different works of art, we can see how these examples lead to a double reading of the multiband images. In general, this type of analysis is applied with the idea of studying the execution of a work, either through the discovery of preparatory drawings and regrets, or even using specific pigments. However, this analysis also makes it possible to initiate the material history of the restoration, i.e. an analysis of the interventions carried out throughout the life of the work of art and the identification of the materials used in each of them.

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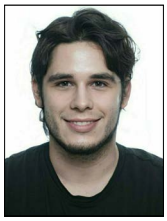

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AN INVESTIGATION ON THE PHOTOCHEMICAL STABILITY OF THE TRADITIONAL RETOUCHING MATERIALS USED ON EASEL PAINTINGS

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Abstract

This experimentation was carried out to verify the photochemical stability of the most common retouching materials and coatings used in conservation, such as gouache colours, watercolours, varnish colours and varnishes. The aim of this research was to identify the best performing materials to be applied in a practial conservation treatment. Two sets of mock-ups were prepared: the products (Winsor&Newton® designer gouache, Winsor&Newton® professional walercolours, Gamblin®Conservation Colors, Laropal® A81, Regal®varnish gloss, Regal® retouching varnish, Paraloid®B-72, mastice) were tested both individually and combined with each other in multi-layered systems. Both sets underwent un accelerated ageing process into a solar simulator (Hereus Suntest CPS) for 1500 hours to compare their lightfastness. To document any possible alteration, a diagnostic campaign was performed both before and after the accelerated ageing for lightfastness testing. Each mock-up was photographed in visible and ultraviolet light and analysed with a portable spectrophotometer. This last tool allowed us to compare the colour changes (ΔE00 values) before and after the ageing process.

Keywords:

retouching materials,

varnishes,

accelerated ageing,

photochemical stability,

lightfastness

Introduction

In the conservation process of a painted artefact, the retouching colours and the varnishes constitute the outer layers, which are more exposed to environmental factors and, consequently, more susceptible to degradation. Chemical stability, resistance to ageing and the reversibility of the materials used in the aesthetic reintegration are therefore fundamental in the perspective of minimal intervention that aims to limit the frequency of conservation treatments which sometimes can be unnecessary and potentially harmful.

Over the years, interest in the theme of retouching has matured, leading to the creation of conferences and workshops. Therefore, before initiating new experimental research, it was considered indispensable to consult the panorama of publications related to studies on the products used in the reintegration phase on easel paintings.

Even if there are many papers on the photochemical stability of retouching colours and varnishes used on easel paintings, usually tested individually or in layers with monochromatic surfaces, a conservator needs to know how they work together in a multi-layered system.

So, the goals of this experimentation were:

- To verify information about the photochemical stability of single specific materials
- To evaluate the ageing of the materials in a multi-layered system and their interaction.
- To select a combination of materials to use in a specific practical case.

This experimental research was conducted during a master's thesis project in 2022 at the University of Turin, in collaboration with the Centro Conservazione e Restauro "La Venaria Reale" (CCR), focused on the identification of the most stable to ageing and suitable materials to retouch and protect a large lacuna located in the sky area of an oil-on-canvas painting after the structural treatment.

The subject matter of the thesis was the oil on canvas painting "*Ingresso di Vittorio Emanule II a Venezia*", painted by Pierre-Paul Comba in 1867 and kept at the Castle of Raccongi in Italy. The artwork had a large L-shaped tear located in the proper left side, in the blue-sky area (Fig. 1). As this painted area is quite monochromatic, the retouch had to be very stable; otherwise, the alteration of the colours or of the varnishes over time could create a stain in the blue sky, interfering with the enjoyment of the artwork. The research activity helped us choose the best-performing products from a varied set of materials.

Fig. 1. The painting Ingresso di Vittorio Emanuele II a Venezia, by Pierre-Paul Comba, 1867

Experimental

To recreate the most realistic retouching and verify the photochemical stability of the retouching and coating materials, the products were tested both individually and in combination with each other in multi-layered systems (**Fig. 2**). Two sets of mock-ups were prepared: the first one with a multi-layered system and the second one with the same materials but applied individually.

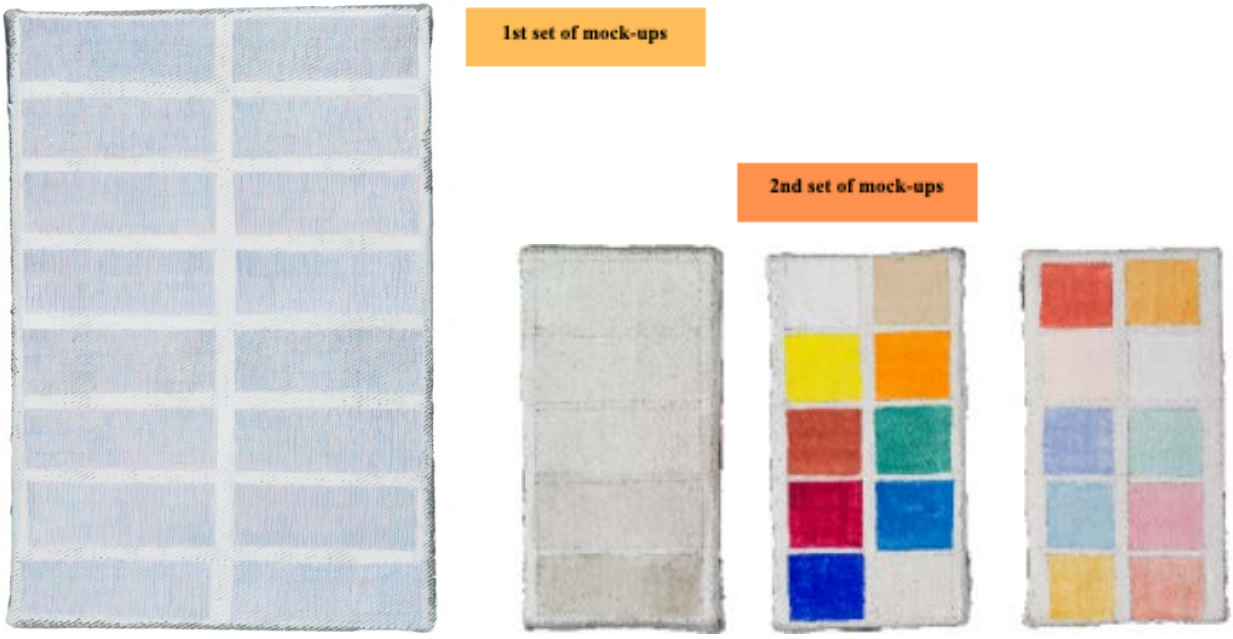

Fig. 2. On the left side the 1st set (multi-layered systems) and on the right side the 2nd set (individual materials).

This experimentation has been closely linked to the practical application of the conservation treatment. To do so, a small range of colours and a specific refractive index of the varnishes were selected to recreate the same properties detected in the painting in the case study. The materials were chosen based on the most common ones used in conservation of easel painting.

It is important to describe the multi-layered process that we typically use in Italy for retouching. First and foremost, we usually start by applying a monochromatic base on the gypsum with gouache colours to facilitate the following phase. Then, if we need to make a recognizable retouching, we proceed with "tratteggio" using watercolours. This technique involves small straight lines of pure colors juxtaposed to each other, creating the exact tone of the surrounding area. We protect these layers with a varnish applied by brush, allowing us to hydrophobize and saturate the surface. Subsequently, we proceed with "tratteggio" or glazes using varnish colours to fix the tone. Finally, we protect everything with a spray coating (**Fig 3**).

Fig.3. Retouching multi-layered scheme.

This process represents the most complete combination of layers, but it's not always necessary to use all of them. The choice varies depending on the needs of the artwork and the preferences of the owner.

Materials

Based on research, the most common materials used for retouching are often the same (Winsor&Newton® designer gouache, *Winsor&Newton® professional walercolours, Gamblin®Conservation Colors*). Meanwhile, for varnishes, the selection is wider (*Laropal® A81, Regal®varnish gloss, Regal® retouching varnish, Paraloid®B-72, Mastice*).

We selected 3 different *Winsor&Newton® designer gouache* colours to mix them and obtain the most similar pink as the original preparation, 6 different *Winsor&Newton® professional walercolours* for the tratteggio technique; 9 different *Gamblin®Conservation Colors* for the final glazes and 5 types of varnishes, three of them applied by brush and two by spraying (**Tab. 1**).

Winsor&Newton® designer gouache

Winsor&Newton® designer gouaches are composed by arabic gum as a binder and a higher percentage of the pigment than watercolours.

Colour	Elements	P.I.	B.W.S.	ASTM	Lightfastness Resistance
Permanent white	Ti, Si	AA	8	I	Over 100 years
Venetian red	Fe, Si	A	7	I	Over 100 years
Raw Siena	Fe, Si, Ca	A	7	I	Over 100 years

P.I. = Permanence index W&N (A-D)
B.W.S. = light resistance Blue Wool Scale
ASTM = light resistance ASTM code

Winsor&Newton® professional walercolours

Winsor&Newton® professional walercolours are composed by a pigment and arabic gum as a binder.

Colour	Elements	P.I.	B.W.S.	ASTM	Lightfastness Resistance
Raw Siena	Fe, Ca	AA	8	I	Over 100 years
Venetian red	Fe, Ca	AA	8	I	Over 100 years
Alizarin Crimson	/	B	7-6	II	50 – 100 years
Ultramarine	Fe,Ca	A	7	I	Over 100 years
Cerulean blue	Co, Zn, Cr, Sn	AA	8	I	Over 100 years
Viridian	Cr, Ca	AA	8	I	Over 100 years

P.I. = Permanence index W&N (A-D)
B.W.S. = light resistance Blue Wool Scale
ASTM = light resistance ASTM code

Gamblin®Conservation Colors					
Gamblin®Conservation Colors are composed by a pigment and the ureo-aldehyde resin Laropal®A81 as a binder. This resin is characterized by a high lightfastness resistance and its low molecular weight allowed to dilute them with low polarity solvents.					
	Colour	**Elements**	**B.W.S.**	**ASTM**	**Lightfastness Resistance**
	Titanium white	Ti	8	I	Over 100 years
	Titanium buff	Ti	8	1	Over 100 years
	Venetian red	Fe, Ti	8	I	Over 100 years
	Alizarin Crimson	Al	8	I	Over 100 years
	Cadmium orange	Cad, Zn, Ti, Se	8	I	Over 100 years
	Cadmium Lemon Yellow	Cad, Zn, Ti,	8	I	Over 100 years
	Ultramarine	Fe,Ca, Al, Si, K	8	I	Over 100 years
	Cerulean blue	Co, Zn, Cr, Sn	8	I	Over 100 years
	Viridian	Cr, Ca	8	I	Over 100 years
P.I. = Permanence index W&N (A-D) B.W.S. = light resistance Blue Wool Scale ASTM = light resistance ASTM code					

Varnishes				
Commercial name	**Resin**	**Origin**	**Dilution**	**Application**
Laropal A81	ureo-aldehyde	Synthetic	30% in a solvent mixture of Shellsol D40 and isopropyl alcohol (4:1)	By brush
Paraloid B72	methyl acrylate - ethyl acrylate	Synthetic	10% in butyl-acetate	By brush
Mastice	Chios resin	Natural	15% in trementin essence Lefranc&Bourgeois	By brush
Regal ®Varnish Gloss CTS (Regalrez 1094)	aliphatic resin	Synthetic	15% in Shellsol D40	By spray
Regal ® Retouching Varnish CTS (Laropal A81)	ureo-aldehyde	Synthetic	ready-to-use product	By spray

Table 1. List of all the tested products.

Methods

The first set of mock-ups was a multi-layered system of retouching and coating materials. It was a prepared set of canvas (22 x 15 cm) formed by 16 small test areas (2,4 x 7 cm) divided into four groups (A, B, C, D). Each group had the same retouching materials (Winsor&Newton® designer gouache, *Winsor&Newton® professional walercolours*, *Gamblin®Conservation Colors*) but a different pair of varnishes. Group A, B and D has the same final spray varnish (*Regal ®Varnish Gloss CTS*, *Regalrez 1094*) but a differ-

ent varnish applied by brush. Group C has *Laropal®A81* as first varnish and *Regal ® Retouching Varnish CTS (Laropal A81*) as the final one (**Fig. 4**). These pairs of varnishes were chosen to verify the performance of different double coating applications.

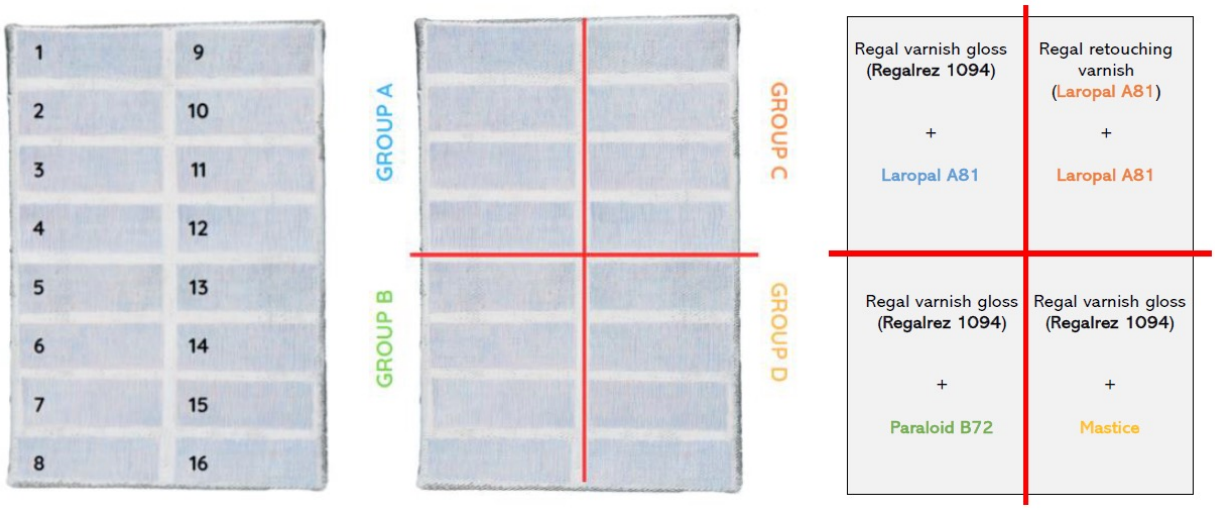

Fig. 4. Scheme of the 1st set of mock-ups: 16 small test areas, 4 groups with different pairs of varnishes.

Although we are aware of mastice's sensitivity to light, it is still occasionally used in conservation treatments. Therefore, it was interesting to observe whether applying a varnish on top could protect mastice from yellowing.

Each mock-up group was divided into four combinations of layers, mimicking all possible types of retouching systems. Among all the combinations, the one with all five layers is the second of the proposed scheme, while the others lack at least one component. This division also aided in understanding whether a component influenced the decay or not (**Fig. 5**).

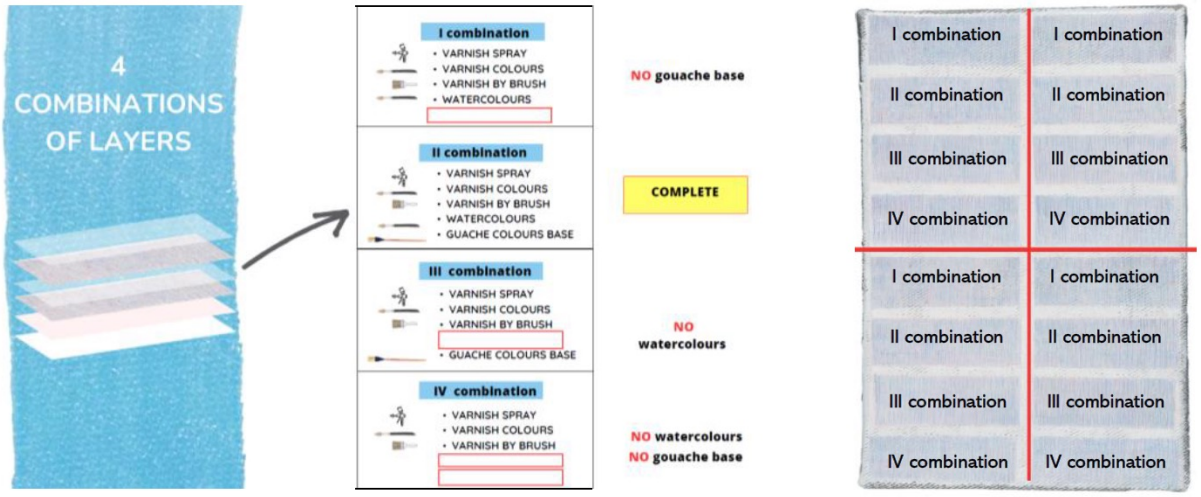

Fig. 5. Scheme of the combinations of layers in the 1st set of mock-ups.

The second set of mock-ups consisted of three prepared canvases, similar to those used in the first set, on which all the materials were applied individually (**Fig. 6**).

Fig. 6. Scheme of the 2nd set of mock-ups.

All the mock-ups have been documented before and after the accelerated ageing. They were photographed in visible and ultraviolet light. Every photo taken in visible light was captured with a diaphragm setting of 11, a shutter speed of 1 second, ISO 100, using the Xrite color chart as a reference. For photos taken in ultraviolet light, the settings were a diaphragm of 5.6, a shutter speed of 5 seconds, ISO 100, with the MADtec reference. The colorimeter results were collected using the CIELAB L*a*b* system. The colour difference for each specimen (ΔE), pre and post ageing, was initially calculated as the Euclidean distance between the two points in the plane identified the respective coordinate triplets (L*, a*, b*). Subsequently, the colour difference was also recalculated according to the formula, updated in 2000, known as CIEDE2000, and denoted as ΔE00. So, the ΔE00 values will enable us to scientifically verify the colour difference between the same point before and after the ageing. Every measurement was made using the portable contact spectrocolorimeter Konica Minolta CM-700d (calib. Konica Minolta CM-A177) with SAV mask Ø 3 mm. Fifteen measurements were taken on each test area for the first set of mock-ups, and ten measurements were taken on each test area for the second set of mock-ups at every step.

All the mock-ups were put in a solar simulator Hereus Sunset CPS (Xenon lamp with a glass quartz filter, cut off at 320 nm) with 750 W/m2 of medium irradiation and 50°C of inside temperature to accelerate ageing. The first set has been left in the box for 1500h. The second set has been left overall for 1500 h but it was monitored after the first150 hours and then after every 250 hours (150h – 250h – 500h – 750h – 1000h – 1250h – 1500h).

According to calculations performed, 1500h of irradiation with this lamp corresponds approximately to 90 years. The calculations were made on the basis of the maximum annual radiation exposure values (expressed in lux per hour/year) recommended by the Guideline Act on Technical and Scientific Criteria and Standards for the Operation and Development of Museums, 2000. Specifically, the recommended values for medium photosensitivity category artifacts, for which a maximum annual energy exposure of 500,000 lux hours/year is expected were taken as a reference.

Results and discussion

After the 1500h the first set showed a significant and general difference in hue.

There has been a complete loss of the red component (**Tab. 2**).

Thanks to a processed image where the white lines marked the red lines of the tratteggio, we could see that after 1500h all the lines had faded. This was caused by the photochemical decay of alizarin, both watercolour and varnish. This was shown also by the colorimeter results. Indeed, the coordinate a decreases towards negative values, which means the colour loses the red component (**Fig. 7**).

The products applied individually in the second set of samples were monitored through colorimetric measurements performed every 250 hours of accelerated aging, repeated 6 times until reaching a total of 1500 hours. The sample containing the alizarin watercolor was subjected

Campione	0 h			1500h			ΔE_{00}
	L*(D65)	a*(D65)	b*(D65)	L*(D65)	a*(D65)	b*(D65)	
1	76,69	-0,87	-2,75	80,60	-3,84	-1,40	4,94
2	77,94	0,22	-1,63	79,82	-3,23	0,91	5,41
3	77,83	-0,64	-0,19	80,24	-3,17	1,03	3,92
4	78,46	-0,17	-1,37	81,34	-3,88	0,19	5,52
5	78,92	0,29	1,47	81,34	-2,33	0,97	4,08
6	78,07	0,46	-1,30	80,12	-1,55	1,09	3,94
7	79,08	-0,61	0,49	80,42	-1,95	0,66	2,07
8	80,10	-1,61	0,75	82,55	-3,14	0,70	2,60
9	78,56	-0,76	-0,12	81,24	-2,96	1,96	3,93
10	79,07	-0,41	0,86	80,49	-2,71	2,48	3,53
11	79,24	-1,27	1,15	80,80	-2,40	1,63	1,89
12	79,66	-2,09	-1,06	82,24	-3,00	-0,77	2,14
13	78,30	-2,20	-1,01	82,22	-4,44	1,45	4,47
14	78,45	-0,96	0,46	80,16	-3,05	1,86	3,23
15	77,45	-0,35	0,14	79,63	-3,55	1,88	4,73
16	79,33	-1,12	0,00	82,70	-4,01	1,78	4,61

Table 2. Data of the 1st set of mock-ups

to an additional measurement after only 150 hours because literature data indicate that it has lower resistance to light radiation compared to others, as shown in the Table 1 (50-100 years compared to over 100 years). At the end of the aging process, the average values from the 10 measurements conducted for each sample were calculated. Subsequently, the ΔE00 colour difference was calculated for each ageing step compared to time zero. To

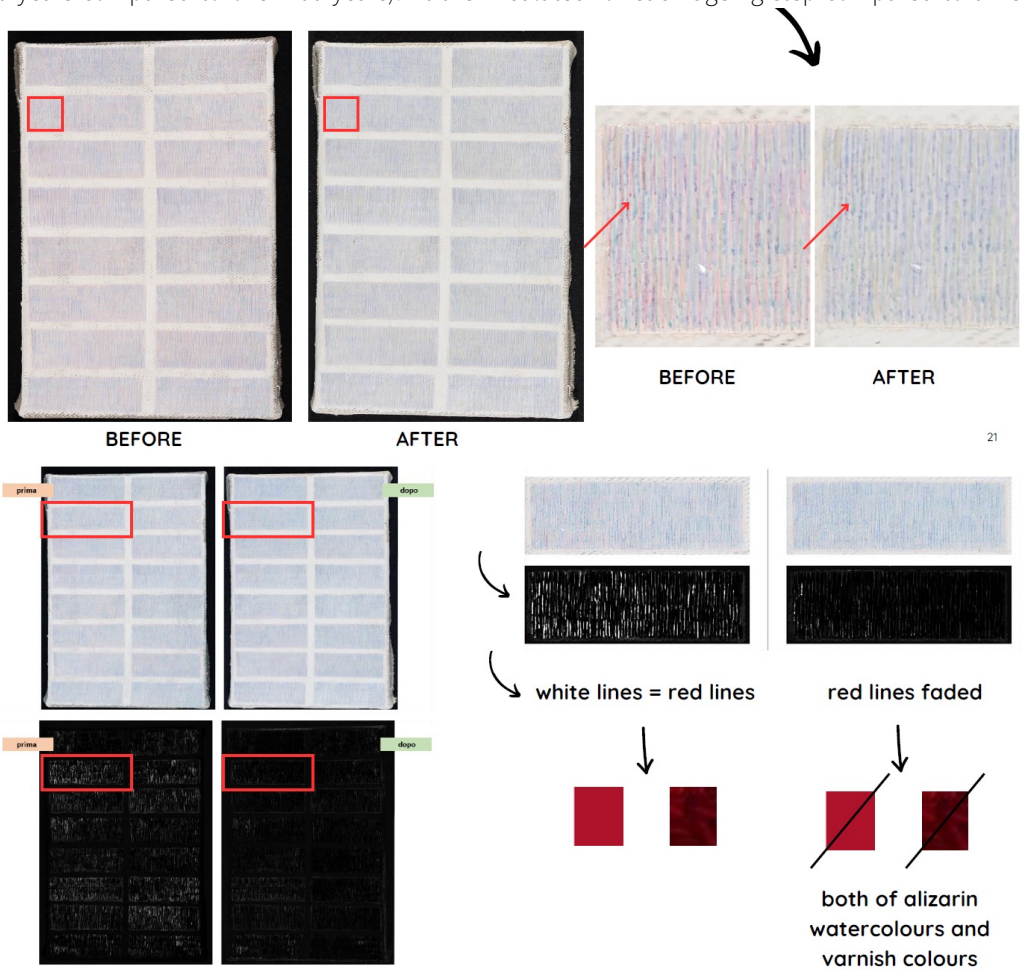

Fig. 7. Processed images showing the loss of the alizarin red component.

allow a prompt visual comparison of the data obtained, a bar graph was created: on the x-axis the 6 ageing steps for each sample are displayed (250h – 500h – 750h – 1000h – 1250h – 1500h), and on the y-axis the ΔE00 values are shown. Since the products were applied manually, they do not result in a perfectly homogeneous surface, and this can sometimes lead to fluctuations in values that nevertheless do not affect the result (**Fig. 8**).

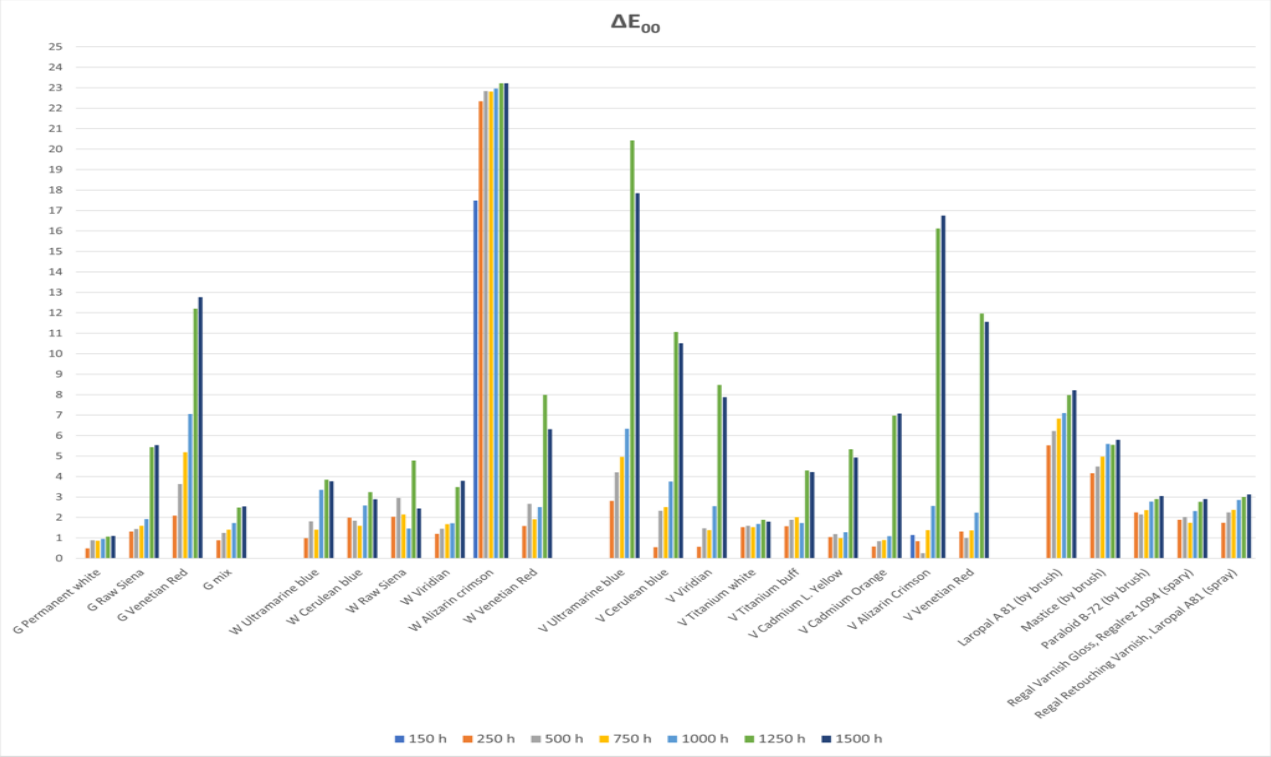

Fig. 8. ΔE00 calculated for each ageing step compared to time zero (G= gouaches; W = watercolour; V= varnish colour).

By observing the graph it is possible to confirm that alizarin watercolour is the material that undergoes the most relevant chromatic alteration, showing ΔE00 values up to approximately 23. The additional measurement at 150h was useful to confirm that, already after this early step, it exhibits a very high ΔE00 value, resulting in visible fading. After 500 h of accelerated ageing, the lacquer has completely disappeared, and the ΔE00 value remains stable until the end of ageing process. On the other hand, alizarin varnish colour showed good resistance up to 750 hours, and then a significant deterioration is observed after 1250 hours.

Among other materials, the one showing the lowest lightfastness is the ultramarine blue varnish colour, which undergoes considerable alteration after 1250 hours. Both Venetian red watercolor and gouache colour underwent alteration, but it is more evident in the latter, with a moderate alteration up to 500 hours and a serious colour change at 1250 hours. Interestingly, the color mix constituting the tempera base of the first set of multilayer samplesswas very stable, likely due to the doses used to create it. Indeed, it contains a significant amount of permanent white compared to the other two colours.

In general, a significant deterioration of values is observed beyond 1000/1250 hours of ageing for most retouching materials. Between the varnishes, Regalrez 1094 shows the best performance, along with Paraloid B72 and the ready-to-use Laropal A81-based. The mastice also visually exhibits noticeable yellowing, and when illuminated with ultraviolet light, strong fluorescence is observed. The Laropal A81 paint also shows a colour difference, likely related to a different mode of absorption into the prepared canvas during brush application of the product (**Fig. 9**).

As mentioned earlier, the first set of mock-ups showed a general chromatic alteration visible at naked eye. Indeed, each group of combination shown ΔE00 value higher than 1, which is the threshold value above which the change in hue becomes perceptible to the human eye. Among all the groups, Group C was the one with the lowest values

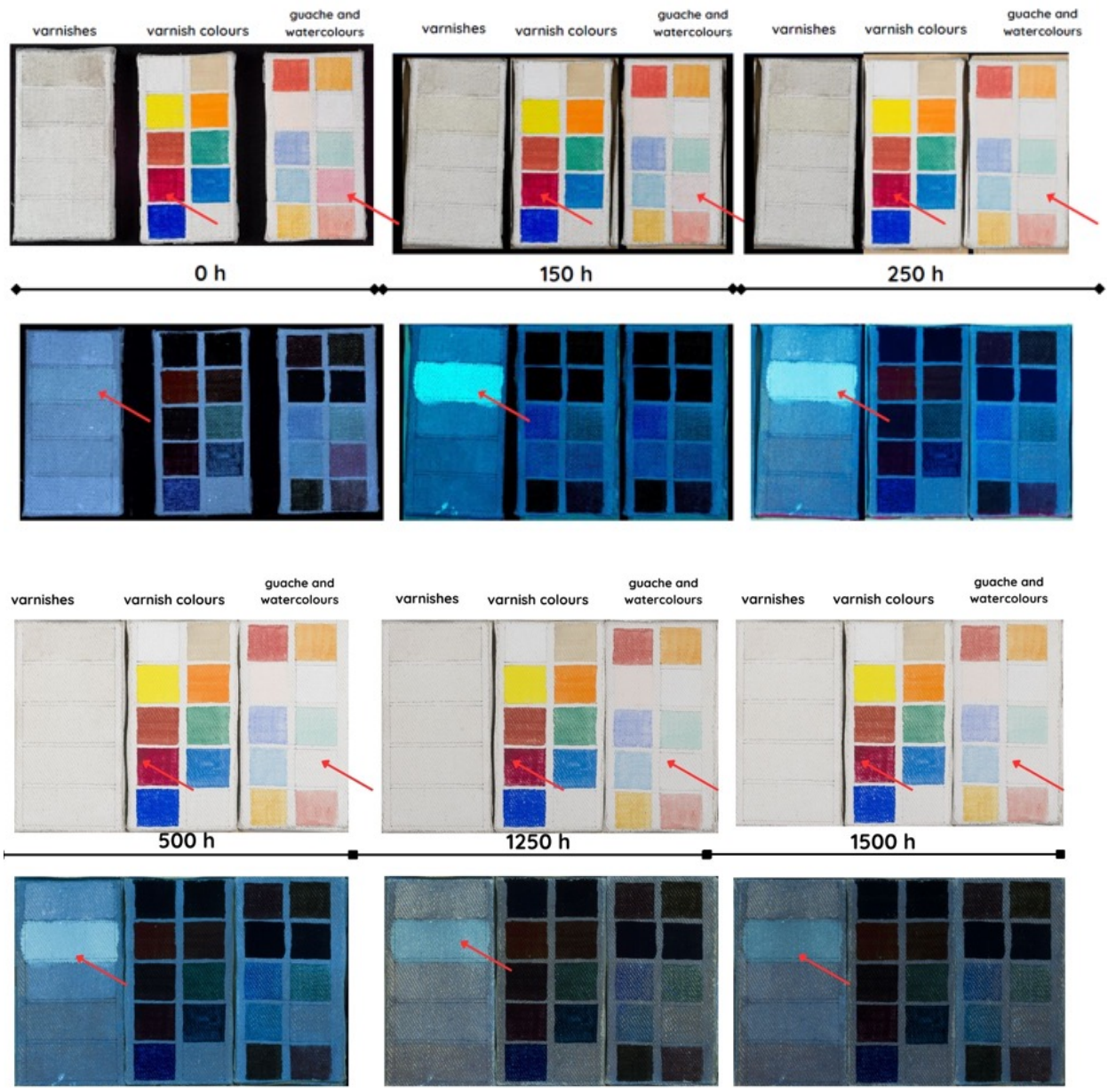

Fig. 9. Visible photos and UV photos of some significant steps.

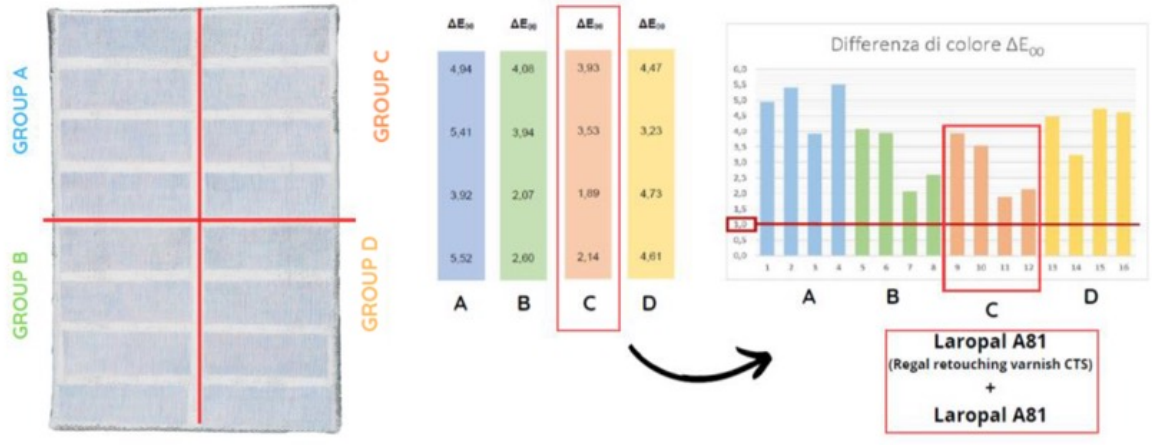

Fig. 10. ΔE00 values of every group.

(Fig. 10). In this case Laropal®A81 is present as a binder for the varnish colours and as a varnish in both applications, by brush and sprayed on top. Therefore, we can assume that the alteration is mainly caused by the pigments.

Conclusions

Our results show that it's better not to use alizarin in both watercolour and varnish colour, because it is a very photosensitive pigment. It fades in a very short period of time, and it means that in conservation treatments, the stability of the chromatic reintegration will likely last less than 10 years, requiring further revisions and interventions. This behavior is independent of the presence or absence of varnish overlap. If we don't use alizarin, we can include the red component using more venetian red and taking advantage from the gouache base. Also, this type of gouache base seems to be very stable to ageing and it doesn't entail any alteration of the pictorial integration. Among the varnishes the mastice was the one showing the worst performance because it started to turn yellow after only 250h while Laropal®A81 was the best one. Thus, the most stable to aging group of mock-ups was the one having Laropal A81 being present in the three outer layers.

Although the mock-ups of Group C resulted those having the best performance (lowest ΔE00 after accelerated aging), in our case we had to take into account also the reversibility of the layers, meaning the ability to remove individual layers without affecting that underneath.

Therefore, we decided to use the Laropal A81 varnish for the first layer of varnish applied by brush and a different low molecular weight aliphatic resin for the final coating in order to later permit a selective removal of the material without interfering with the varnish colours and the other varnish beneath.

On the basis of the above mentioned considerations, we finally selected the A mock-up group which include the use of Regal ®Varnish Gloss CTS as final coating. Regalrez 1094 is very stable to ageing and it is extremely soluble in apolar solvents.

Those materials were eventually used in the conservation treatment on the oil on canvas painting Ingresso di Vittorio Emanuele a Venezia by Pierre-Paul Comba, after the structural operations. The tear was mended using the thread-by-thread methodology introduced by Winfried Heiber in the 80s. This method allowed us to reestablish the weave and flatten the canvas surface. The areas with preparation losses were infilled with gypsum and treated to match the surrounding texture. Then, the surface was ready for the retouching process. According to the ownership, it was decided to use the "tratteggio" technique to make it recognizable and it was performed by the selected products (Fig. 11).

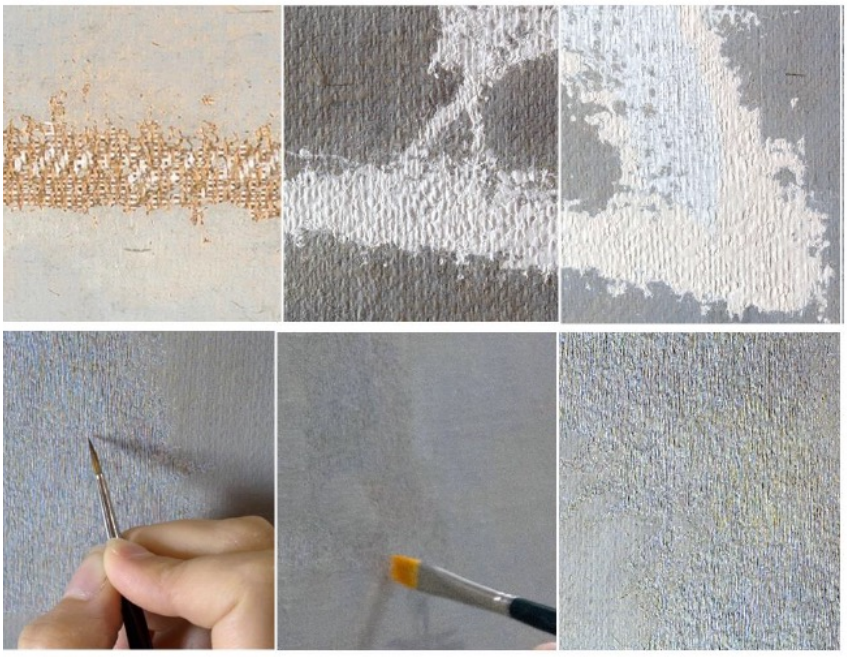

Fig. 11. Phases of the conservation treatment.

A precise comparison of the data resulting from the experimentation conducted during the master's thesis project with those reported in the literature has been difficulted by the unclear and incomplete available information. Some articles lack essential data related to ageing conditions (lamp, filters, irradiance, temperature, and humidity values), impeding a comparative evaluation of sample exposure in the solar simulator. In addition, often incomplete information about the acquisition of colour measurement is included within the text.

The stratigraphic mock-ups simulate a specific retouching scenario for the analyzed case study, which is indeed real. However, the environmental conditions of each artwork's storage location (lighting and environmental factors) may lead to slight variations compared to the reported data.

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