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All articles submitted to the "Color Culture and Science Journal" are peer-reviewed according to the following procedure:

First review level
The Associate Editors evaluate each article in order to determine if the topic and content are of interest to the journal. Once the article passes the initial review, the Associate Editors select several referees from the Editorial Board based on their expertise in a particular subject area or topic.

Second review level
Each article is reviewed by two or three referees and submitted to a double-blind peer review process where both the authors and the reviewers are kept anonymous. Referees are asked to evaluate the manuscript based on the following criteria:
- Originality
- Relevance to journal's aims and scope
- Technical merit and/or validity
- Soundness of methodology
- Completeness of the reported work
- Conclusions supported by the data
- Correct acknowledgment of the work of others through reference
- Effectiveness of the manuscript (organization and writing)
- Clarity of tables, graphs, and illustrations
- Importance to color researchers
- Relevance to color practices

If the article is accepted with major revisions by the referees, the author(s) are asked to improve the article according to the suggestions of the referees. The revised article will then be submitted to a further review.
After collecting the referees' reports, the Associate Editors make a recommendation on the acceptability of the article to the Editor-in-Chief.

TOPICS
The CCSJ accept papers on a wide range of topics on color, including and not limited to the following:
1. Color and Measurement/Instrumentation. Colorimetry, photometry and color atlas: method, theory and instrumentation; quality control and food coloring, dyes, organic and sustainable color.
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6. Color and Production. Food and beverages, agriculture, textiles, plastic materials, ceramics, paints, gemology, color in the food industry.
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8. Color and Environment. Representation and drawing, urban planning, project of color, architecture, interior design, landscapes & horticulture, color and architectural syntax, territorial identities, biodiversity.
9. Color and Design. Furniture, CMF design, fashion, textiles, textures, cosmetics, food design, museography.
10. Color and Culture. Arts and crafts, history, philosophy, aesthetics, ethno-anthropology, graffiti, geology, sociology, lexicology, semantics, anthropology of vision, food culture and heritage, color naming.
11. Color and Education. Pedagogy, didactics of color, aesthetic education, artistic education.
12. Color and Communication/Marketing. Graphics, communication, packaging, lettering, exposure, advertising.

Table of Contents

Editorial

Dear Readers, with vol 12 n. 2 we close the seventh year of CCSJ. Since 2019 the CCSJ website is available via the Open Journal System. This allows a better indexing of the published articles and will guarantee the compatibility with Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH). In 2020, despite the severe Covid19 crisis, we continued with the publishing activities and we refined our archiving policy to guarantee long-term access of our issues, making agreements with the Biblioteca Nazionale Centrale di Firenze. Since 2014 we have published 12 volumes for a total of 14 issues. Since 2015 we have applied the double blind peer review and since 2016 we have applied the DOI system. It is also useful to recall the importance of the concept of “diamond open access” under which our journal is published: the journal is completely free for both readers and authors. This is possible thanks to the voluntary support of the members of the "Associazione Italiana Colore" who work in the editorial committee, thanks to the associate editors, thanks to the deputy editor Alessandro Rizzi and the President of Associazione Italiana Colore Marcello Picollo. A special thanks goes to Chiara Storti of the Biblioteca Nazionale Centrale di Firenze (BNCF) the main official library of Italy, to Filippo Cherubini of IFAC-CNR who manages the Open Journal System, to Veronica Marchiafava, the secretary of our association, for the management of DOI database and to Andrea Sinicalco, the vice-president of our association, for the graphic support. Many of these people are also involved in the organizing committee of the important meeting in 2021: the AIC 14th Congress that will be held for the first time in Italy organized by the Associazione Italiana Colore (www.aic2021.org).

The peculiarity of our journal, also written in the statute of our publisher, the Associazione Italiana Colore, is to collect papers on color and related areas in a multidisciplinary way. This basically means that in our peer review process we could have papers ranging from the science of colorimetry to the culture of color in the history of art. Moreover, these papers have very different styles and ways of writing, as diverse is the group of the peer reviewers that constitutes our editorial board. The CCSJ accept papers on a wide range of topics on color, including and not limited to the following:

1. Color and Measurement/Instrumentation. Colorimetry, photometry and color atlas: method, theory and instrumentation; quality control and food coloring, dyes, organic and sustainable color.
2. Color and Digital. Reproduction, management, digital color correction, image processing, graphics, photography, film and video production, printmaking and 3D print, artificial vision, virtual reality, multispectral imaging, data visualization. Light field imaging. Multi-sensor fusion. Color localization, recognition, HDR imaging, ADAS systems.
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In an era in which sectoral super-specialisation has reached extreme limits, having a multidisciplinary journal, on a multidisciplinary theme such as color, favors the development of problem solving skills that are based on the psychological methodologies of lateral thinking.

July, 2020
The Editor-in-Chief
Maurizio Rossi
Full professor of Lighting Design and Design Methods
Politecnico di Milano

Color segmentation and neural networks for automatic graphic relief of the state of conservation of artworks

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ABSTRACT

This paper proposes a semi-automated methodology based on a sequence of analysis processes performed on multispectral images of artworks and aimed at the extraction of vector maps regarding their state of conservation. The graphic relief of the artwork represents the main instrument of communication and synthesis of information and data acquired on cultural heritage during restoration. Despite the widespread use of informatics tools, currently, these operations are still extremely subjective and require high execution times and costs. In some cases, manual execution is particularly complicated and almost impossible to carry out. The methodology proposed here allows supervised, partial automation of these procedures avoids approximations and drastically reduces the work times, as it makes a vector drawing by extracting the areas directly from the raster images. We propose a procedure for color segmentation based on principal/independent component analysis (PCA/ICA) and SOM neural networks and, as a case study, present the results obtained on a set of multispectral reproductions of a painting on canvas.

KEYWORDS Multispectral images, Segmentation algorithms, Image analysis, Shape representation and analysis, Cultural heritage, Raster to vector, Neural networks

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1. Introduction

All the disciplines connected to restoration have always shown a deep need to achieve an extensive understanding of the object of interest, in order to develop a greater awareness of the actions needed and to perform them in the full respect of the object features. This knowledge can only be acquired through the study of the artwork's artistic and conservative history and the techniques and materials used for its realization. Several factors contribute to the realization of a restoration project, involving theory and methodology based on the relevant regulations (in Italy, issued by the Central Cataloging and Documentation Institute, iccd.beniculturali.it). Based on these regulations, all restoration interventions must be preceded and accompanied by documentation to create a sort of "medical record" of the artwork, within which all the collected data must be transcribed and archived in different forms and standard and geometrically correct modalities (The Venice Charter 1964) (Sacco 2002). At this cognitive stage, an important role is played by the transcription in graphics drawings of all the information obtained on the artwork. These graphics drawings, called *graphic relief* or *thematic maps*, are the primary tool for communication and synthesis of the collected data and are structured in categories and subcategories. The thematic maps are formed by two graphically distinct models using different textures and colors and associated with a legend: 1. *The artwork model* is the graphic representation of the shape of the artwork and its figurative symbology; 2. *The information model* is the graphical description of the information regarding conservative historical data (Sacco 2002). It is worth observing that currently, the graphic transcription of the data is performed manually by the restorer, and the multispectral images used for the localization of the information, are inspected only visually, or at most are optimized through a preprocessing by the experts (Dyer, J. et al. 2013). The level of detail of each graphic relief is different from any other, and the edges of the areas that contain the information of interest are often very complex to be transcribed. The restorers often rely on architects for the architectural graphic relief or use commercial software without a standard methodology. In 2003, the web-based information system SICaR was created for the georeferenced documentation within the network of the Italian restoration sites (sicar.beniculturali.it). Unfortunately, no image analysis tools are included in this software. This means that the graphic reliefs are performed by manually tracing the relevant areas with drawing tools, no image analysis strategy can be used to extract the relevant information, and no interaction is possible between the raster images and the vector graphics to help compile the thematic maps. In cultural heritage, the interest has focused recently on 3D modeling operations, image processing and artificial vision (Apollonio et al. 2017) (Tonazzini et al. 2019a, b) (Grifoni et al. 2019) (Vallet, J.M. et al. 2012) (Grilli, E. (2019). However, the authorities in charge of the conservation of cultural heritage (the Italian Ministry of Cultural Heritage, for example) still require graphic reliefs based on photographs. This motivates the quest we are pursuing for a standardizable methodology to separate and extract the relevant areas of interest from the raster images (photographs, *etc.*), then vectorize their boundaries and synthesize the results in the documents required by the authorities. A number of suitable image analysis methodologies must be selected that can solve, at least in part, the problems of reading and transcribing data. Besides avoiding results that are prone to personal biases, a partial automatization of this process can also reduce significantly the burden associated with the most time-consuming tasks. The method we are proposing here is based on our consolidated toolbox for the analysis of multispectral images. Spectrally discernable areas in the artwork image can be separated through statistical techniques such as principal component analysis or independent component analysis, and with the help of dedicated neural networks. With the essential contribution of the human expert, the areas relevant to the documentation are then recognized and segmented with the help of a dedicated image analysis process. The latter extracts semi-automatically the areas, separating them into different regions of interest (ROI), each corresponding to specific information attributable to the executive, restoration, and conservation history of the painting. The ROIs are then vectorized and used in graphic relief. This process is more objective and repeatable than any manual solution, and also enable the user better to perform geometric and statistical measurements on the resulting drawing.

2. Case study

The procedure described above has proved to be effective in different cases and with different restoration objectives. We demonstrate it here as applied to a canvas depicting queen Cleopatra, attributed to Donato Creti (Fig 1 a). This *opera* was donated to a private family by Pope Leo XII on 27 August 1827. Its last restoration intervention was executed in 2019 when the restorers discovered several pictorials *pentimenti* [1] executed by the author and several mimetic pictorials retouched executed after his death by unknown artists or restorers. Donato Creti used to repaint the subjects: his contemporary painter, the art historian Giampietro

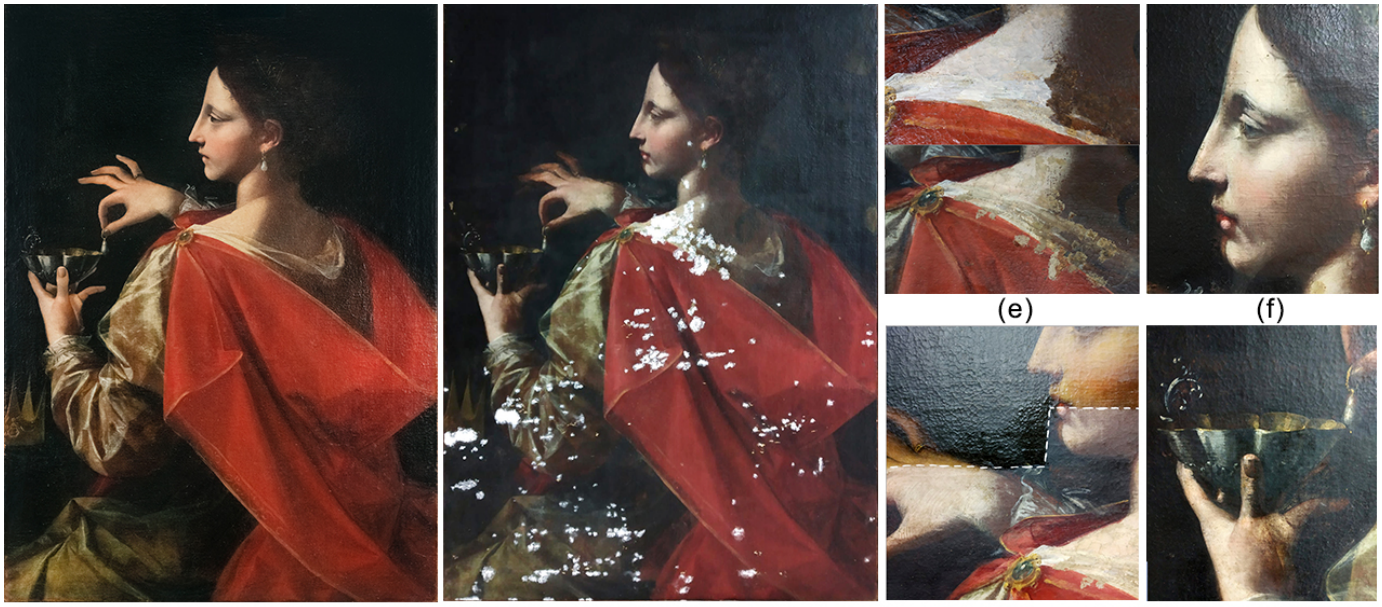

Fig 1 (a) Cleopatra by Donato Creti (Cremona 1671, Bologna 1749), oil on canvas, 100×77 cm. Standard RGB; after the restoration intervention, (b) image captured during the restoration. Gaps covered by white stucco in 2019; (c) Removal of old varnish; (e) Old gaps from previous restorations and retouches not performed by the original artist. (f) (d) Pictorial pentimenti make by the artist in profile and left hand.

Zanotti, says that – *"for his profession, he always studies, he sighs, he is anxious about the desire he has of perfection, and glory, and he never tires of finishing and finishing his work"* (Riccomi 2012). The *pentimenti* painted by Donato Creti concern the profile, the eye, and the hands of Cleopatra (Fig.1 f, d). Also, the canvas has several stuccoes (gaps filled with stucco, Fig.1 b), made in old restorations, and several mimetic retouches, especially evident in the neck area and on the shoulder (Fig.1 e).

3. Methodology

The ROIs to be separated can be classified into three categories: pentimenti of the artist, old restoration interventions, restoration interventions carried out in 2019. Our purpose is to highlight and separate the different regions through image analysis.

3.1. *Image dataset*

The input image dataset has been captured in different modalities: under visible light illumination, with two Nitraphot 500W diffuse-light projectors and a Macbeth Color Checker used as the reference, an RGB image was captured by a Nikon D800 camera. An infrared image (IR) at 1050 nm (Fig.2b), with a high dynamic range (16 bits), has been acquired through a multispectral system based on Morovian G2-8300 (CCD KAF 8300 18.1 × 13.7 mm pixels 5,4 × 5,4 μm). The sensor is cooled to reduce the electronic noise during acquisition. The spectral resolution is obtained through interferential filters with ± 25 nm passbands around the central wavelengths 450, 500, 550, 600, and 650 nm in the visible range and 850, 950, and 1050 nm in the near-infrared. This choice ensures complete and continuous coverage of the visible range plus three infrared channels.

3.2. *Image analysis through blind source separation*

A painting can be seen as the combination of *M* different spectral components, namely, the colors of the pigments and other materials used to produce the original painting and the restoration interventions. These *M* spectral components represent the hyperspectral input data cube. Each of the *M* image channels shows a combination of the emissivities of the different materials at a given waveband. The simplest model to describe this combination is the linear, instantaneous one (Hyvärinen et al. 2001)

$$x(t) = As(t), t = 1,2,\dots,L \qquad (1)$$

where t is a pixel index, and L is the number of pixels in the input image, x is an *M*-vector representing the spectral samples captured at each pixel, s is an *N*-vector quantifying the presence of the different components at each pixel, and *A* is an *N*x*M* mixing matrix whose element a_{ij} represents the emissivity of component *j* at the *i-th band*. In this scenario, if we are able to extract vector s from the observed vector x, we can estimate the *N* individual component maps. Since we assume that each region of interest has an approximately uniform spectral appearance, the *N* estimated component maps could be inspected visually

to locate the regions of interest. Usually, we know neither the total number *N* of components nor the emissivity spectra *A*. The techniques used to estimate s from x alone are called of *blind* source separation - BSS (Cardoso 1998) since they solve system (1) with no knowledge of matrix *A*. Some additional assumption must replace this missing knowledge. By the Independent Component Analysis (ICA) principle (Hyvärinen et al. 2001), if *A* is a tall, full-rank matrix and the components are independent and non-gaussian, a copy of vector s can be estimated from x. Other approaches, such as Principal Component Analysis (PCA) and symmetric whitening (SW, see Cichocki et al. 2002, Tonazzini et al. 2007), in some cases, produce equally useful results by simply assuming uncorrelation between the components. Thus, if the number *N* of spectrally discernable components in the images is not larger than *M*, we can solve the BSS problem by ICA or PCA. If the components are more than the image's channels (*M)*, some of the output channels will still contain mixtures of different components, possibly preventing the ROIs from being recognized. This is a very likely situation because each artwork presents many different components related to materials and techniques used in her conservative history, which are not always simple to separate spectrally.

For this reason, we often have different components mixed in the same output channel. In this situation, the only solution that has proved to be useful is the restorer's inescapable judgment. Indeed, it is always necessary to inspect the outputs channels to choose the ones that better highlight specific components in regions of interest (ROIs). Due to the impending judgment of the restorer, our methodology is defined as semi-automatic. The automatism is present in the segmentation of the *N* separated components, the extraction of the binary mask and the raster-to-vector conversion of the highlighted areas. The recognition and classification of the components are always up to the judgment of the restorer. In this case study of the methodology helped the restorer to locate the ROI and extract them from the image domain. We assume the nine channels in Fig. 2 as our input data and apply the three processing strategies mentioned above, each assuming 9 components, thus obtaining 27 output images, from which we try to locate the regions of interest related to the artist's *pentimenti*, to the old restoration, and to the 2019 restoration. Figure 3 reports the three output channels chosen, all resulting from the application of an ICA algorithm called FastICA (Hyvärinen et al. 2000), from which the three regions of interest can easily be recognized by the restorer and extracted by any existing thresholding algorithm.

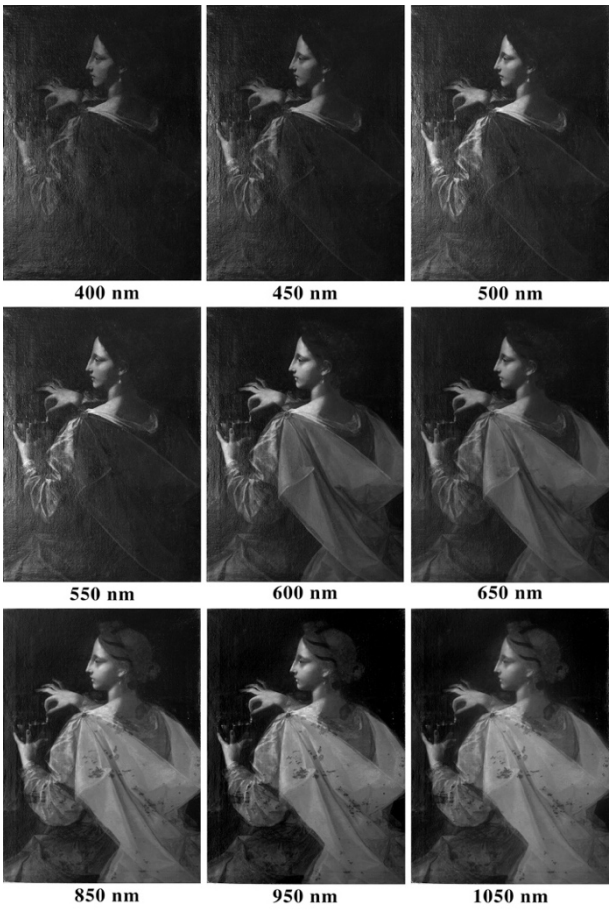

Fig.2 Cleopatra by Donato Creti. A representative set of multispectral image capture by Vincenzo Palleschi.

3.3. Self-organizing map segmentation

The Kohonen self-organizing map (SOM) is a particular kind of neural network based on competitive training algorithms (Kohonen 1998) (Rumelhart et al. 1985). Its advantage over other neural networks is the capability to preserve the topological properties of the input images (Uriarte et al. 2005) (Yeo 2005). SOMs have long been used to segment different types of images due to their characteristic of learning to respond in the same way to the same inputs (Kon et al. 1995). In this work, the SOM neural network has been applied, using as inputs the output images of the statistical preprocessing performed through ICA, PCA, and SW, with the intention of testing whether we can obtain a further improvement in ROI extraction. In the worst case, we can get output maps similar to the inputs; in the best case, we can get outputs in which different ROIs appear in different maps. The SOM outputs are binary maps, thus, besides improving the segmentation, they can also allow for a straightforward production of the contours of both the ROIs and the represented figures, without the need of applying any threshold. In figure 4, we show some examples of the results.

(a) (b) (c)

Fig.3 Some output channels of the FastICA algorithm from the multispectral set input. (a) Channel 1: here, the darkest regions correspond to the pictorial reintegration performed in 2019, especially in the face and shoulder. (b) Channel 3: the darkest regions in this ICA output correspond to the old pictorial reintegration. These regions are particularly visible on the profile of the forehead, nose and neck, the hand, and the red tunic. The numerous gaps also correspond to very dark pixels. (c) Channel 4: This output contains much information on the different restoration works; the gray levels represent the thickness of the color used. Black represents a dense color layer of color, whereas progressively light gray levels represent thinner color layers.

(a) (b) (c) (d)

Fig.4 Some SOM outputs with FastICA and PCA inputs. (a)(b) SOM output from FastICA: These two binary masks classify the different restoration interventions and the different types of a mixture of white pigments; (c) (d) SOM output from PCA: contours of the figure. This image was used to draw the Model of the Artwork in thematic maps.

4. Results: feature extraction, vectorization, and final graphic documentation

After visually analyzed the outputs of all the elaborations, the restorer chooses those where the regions appear more clearly. In our case, we have manually drawn only the *Artwork Model*, helping ourselves, when possible, with the raster to vector conversion of the SOM outputs, which in some cases delineate the edges of the figure with high precision. Two *Artwork Models* have been created: the first, from the RGB image (Fig.3 a), it is the outline of the painting in its current state; the second, from the 1050 nm channel (Fig.3 b) and the Output SOM from PCA (Fig. 4 d), is the outline of the earliest version of the artwork. Overlapping these two drawings is possible to see the difference between the two versions and the artist's *pentimenti* (Fig.5 c). Instead, the *Information Model* (Fig. 4) was exclusively created with automatic procedures, starting from the three outputs of FastICA (channels 1, 3 and 4), with an automatic raster to vector conversion of the region of the areas identified, resulting into the extraction of edges and areas of the regions of interest ROIs. Each channel was processed individually through the different values of threshold, thus obtaining various binary masks. The extraction can be performed in two ways, both present in many commercial tools: by thresholding or by selecting the value of the pixel of interest through slicing algorithms (Mabrouk 2013). Each channel was processed individually through the different values of threshold, thus obtaining various binary masks. An enhancement step is essential here because the FastICA outputs contain backgrounds of different intensity, and this might confuse. A morphological filtering algorithm has been applied to the areas of FastICA to reduce noise and maintain linear edges (Zhao 2008). Subsequently, two vector drawings have been created through raster to vector conversion. All the operations used can be performed through different software tools. In our case, we used MatLab for image analysis (ICA, PCA, SW, SOM) and QGIS 3.6 for thresholding, raster to vector conversion, classification, and characterization of the ROIs, and to set the graphic relief (*thematic maps)*. It is essential to specify that the polygons extracted with this method can be read by other commercial tools widely used in the documentation for cultural heritage, such as AutoCAD and SICAR.

5. Conclusion

The present work describes the first steps towards the development of an integrated methodology that uses new digital technologies to support graphical documentation in Cultural Heritage. Algorithms of image segmentation and neural networks have never been used in this field, and our work demonstrates their potentiality in reducing subjectivity and speeding up the entire process. However, it is necessary to specify that the final result depends on the type of artwork and the quality of images used as input to these methods. In this respect, it is possible to create a guiding model and give

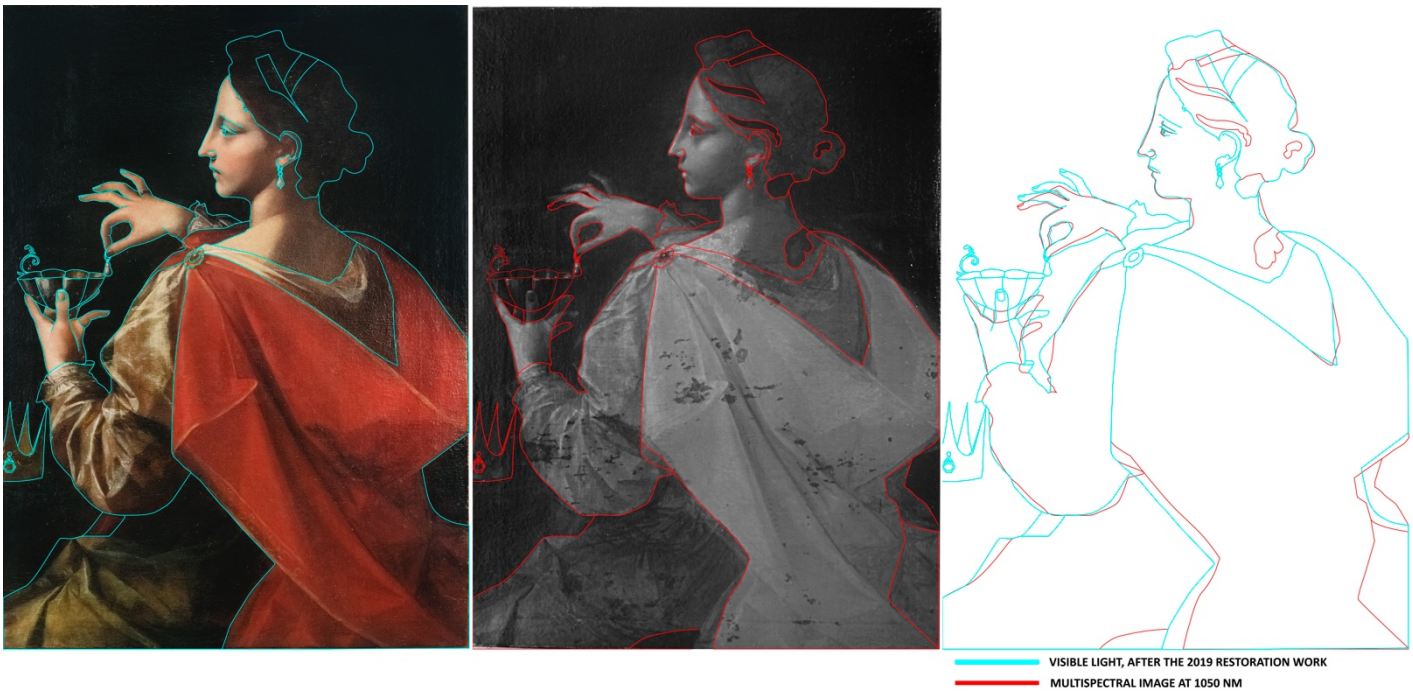

Fig.5 Two Artwork Models (a) image in visual range RGB, the final version of the figure, (b) First version of the figure visible in the multispectral image at 1050 nm. (c) Overlap of two Models, the difference between the first version and the final version with the pictorial pentimenti executed by the artist.

Fig.6 The two thematic maps obtained from the automatic extraction of the regions of interest from the raster outputs of the ICA are shown. For each information, a specific color has been assigned.

specific indications on the quality of the images to be used. For example, high resolution and limited noise and light reflections could be required. In this case study, the methodology has integrated and supported the planning process of restoration intervention, we have identified three distinct moments in the history of our case-study artwork and have been able to map and document the results much more quickly and accurately than any current manual graphic documentation. We are planning to implement this methodology in open-source GIS software to combine all operations into an easy tool for restorers. Moreover, implementing this methodology in a GIS system allows us to obtain a quantitative evaluation of the surface degradation, by applying the zonal statistical analysis tools to the polygons representing the ROIs.

6. Conflict of interest declaration

The authors declare that nothing affected their objectivity or independence and original work. Therefore, no conflict of interest exists.

7. Funding source declaration

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8. Acknowledgment

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9. A short biography of the authors

Annamaria Amura is a Ph.D. Candidate in Computer Science at the University of Urbino. She holds a BS degree in Technology for the Conservation and Restoration of Cultural Heritage, Class 41, and an M.Sc. degree in Graphics of Images, LM12, Documentation, and Photography for Cultural Heritage. Her research interests include digital photography, image analysis,

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Notes

[1] *Pentimenti* is an Italian term that identifies the painting modification performed by the same author during the creation of the painting.

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Περὶ χρωμάτων (*Peri chrōmatōn*): Colour formation and investigation method.

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ABSTRACT

In this essay, the attention is focused on the method used to investigate colours, as produced in nature. This method was proposed by the author of the treatise *Peri chrōmatōn*, which has become part of the *Corpus Aristotelicum*. The colours are first divided into two large categories, simple and mixed, in accordance with other scientific and philosophical approaches. Simple (primary) colours are considered to be white and yellow, and are associated with the elements (air, water, earth, and fire/sun); black is also associated with the elements as they transform into one another. This division is new in comparison with previous theories based on two or four fundamental colours. The endless range of colours seen in objects, plants and animals, is connected to the mechanisms of mixing different qualities and quantities, inherent in what it comes into contact with, and in the consequent changes, in conditions and states of matter, in the incidence of light, qualitatively and quantitatively different. The heuristic reference scheme and the analogical model are represented by the dyeing process. The essentially phenomenological treatise contains historically significant insights: no colour can be seen in its purity; the reciprocal interaction of colours; the variability of conditions that determine the chromatic impression; light as a component of mixtures, and its diversity depending on the source; and the chromatic value of shade. In it, we can also see the formation of a classification of colours and a nomenclature, founded on the relationship of distinct chromatic notations with light and darkness.

KEYWORDS colours and elements, lights and pigments, shadow and darkness, *physis and technē*, dyers and painters.

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1. Introduction

The topic of perception, classification and naming of colours in Greek culture is at the centre of a lively debate, which started as early as antiquity. The bibliography on the subject is vast and includes studies in various fields (philological, anthropological, sociological, psychological, philosophical, artistic) and stimulating comparative investigations (Ferrini 1999; 2008; 2010; 2019; Gage 2001; Tiverios and Tsiafakis 2002; Cleland and Stears 2004; Rouveret *et alii* 2006; Carastro 2009; Grand-Clément 2011).

An essential work to capture some of the most salient aspects of Greek speculation on colour is Περὶ χρωμάτων incorporated in the *Corpus Aristotelicum*: this treatise is the only ancient work dedicated exclusively to colours (observed in objects, plants and animals) and has been preserved in its entirety, despite some textual corruptions.

2. Simple colours

In *Peri chrōmatōn*, colours are divided into two large groups, simple and mixed, in accordance with other scientific and philosophical treatises. These demonstrate the close link, in Greece, between the investigation of the cosmos and the origin of the existing, and the theory of colour. Simple colours (which we would call primary) are regarded as white (τὸ λευκόν) and yellow (τὸ ξανθόν): these are associated with the elements (air, water, earth, fire/sun); black (τὸ μέλαν), as a colour, is also associated with the elements, although when they change into each other: «Simple are those colours that are associated with the elements, i.e. fire, air, water, earth: air and water are white by nature, fire and sun are yellow. The earth is also white by nature but appears to be various colours because it is tinted. [...] The colour black is associated with the elements when they are transformed into one another. Other colours derive from these, as can easily be seen, by combining and mixing with each other. Darkness, in the end, is due to the lack of light» [1]. Defining black as a colour that is connected with the elements in their respective transformation has original characteristics in Greek literature; it derives from the observation of the phenomena described from time to time, in which processes that imply gradual changes over time take place: the appearance of black occurs *over time*. Furthermore, black is not only a colour but also a state of darkness or semi-darkness. It is particularly significant and original the passage which examines the three ways black can appear: as a positive colour, associated with the elements, and as a negative colour, in that it is the total *or* partial lack or absence of light, and is connected with a visual weakness or insufficiency. The black of black objects is distinguished from the black that is shown when an object reflects no or little light. In addition, terms connected with the noun that indicates shadow (σκιά, distinct from darkness, σκότος, which is deprivation of light) are used for the first time with a specifically chromatic value ('shadow colour'): «In three ways black appears to the eye. In general, what we do not see is black by nature (because all objects of this colour reflect like blacklight), or those objects from which no light reaches the eyes are black: what we do not see if the surrounding space is visible, determines the appearance of black; or, finally, all those objects from which light reflects poorly and very faintly appear black. This is why even shadows appear black; and so also does water, when it is disturbed, as when the sea ripples: since, due to the agitation of the surface, few rays fall on it and the light is diffused, what is in shadow appears black. The cloud also appears black for this same reason, whenever it is very dense. The same happens to water and air when light does not penetrate it completely [...]. It is not difficult to understand from many factors that darkness is not a colour, but deprivation of light, in particular from the lack of perception of how great the darkness is, and what its form may be, as is possible for other visible objects» [2]. Black, therefore, occupies a very special place: it is the only colour which, while having the function of a primary colour, can be produced and manifest itself over time. Even the definition of white and yellow as simple colours has new features compared to other and previous theories, in which white and black are considered simple, explicitly or implicitly, or four colours, white, black, red and yellow/green: red is the salient colour par excellence, while yellow and green are additional colours in many cultures, being able to integrate a triadic base, consisting of white, red, and black/blue. The four-colour painting, of which there is evidence in some ancient sources, is a matter of debate; in any case, it may have been influenced by conceptions of the cosmos and the elements. The relationship between colours and elements is theoretically investigated in other Greek sources, while in *Peri chrōmatōn* it is an accepted fact, instrumental to the discussion and a constant point of reference: each physical element is associated by its nature with a colour, as its inherent and characteristic, distinctive quality. Secondary and tertiary colours are obtained by mixing and in certain quantitative and qualitative [3] ratios. Few other colours are listed as ingredients in addition to the primary colours, while light and sun rays appear as fundamental components, quantitatively and qualitatively marked in their various gradations, intensities, and inclinations. Observations on light constitute one of the most significant aspects of this treatise. Even its opposite, darkness, has direct and concrete effects on the production and appearance of colours, as well as shadow, which has a chromatic value, and which can vary in intensity and be a

component of the mixture from which colours originate. These observations seem very important, if one thinks of the history of painting from antiquity to the present, the problem of the representation of shadow and the function attributed to it in theoretical speculation and practice.

3. The infinite variety of colours and the investigation method

The variety of colours is linked to mixing mechanisms of different qualities and quantities, which are inherent to what comes into contact, and to the consequent changes, to conditions and states of matter, to the incidence of light: «The multi-faceted aspect and the infinite variety of colours must not escape attention, no matter for how many reasons this may happen. We will discover the cause, either in their unequal and discontinuous reception of light and shadows [...], or in the fact that the mixed colours differ in quantity and vividness of the components, or that they do not have the same proportions. Violet, red, white and any other colour differ greatly according to the plus and minus, by the respective combination and purity. The colour mixed according to whether it is bright or shiny, or on the contrary dull and opaque, contributes to the difference. The brightness is nothing if not continuity and density of light; in fact, the colour gold shines when the yellow of the sun's light, which is very concentrated, shines through. Consequently, the neck of pigeons and droplets of water also appears gold-coloured if there is a reflection of light» [4].

3.1 *Reference Models*

Both the heuristic reference scheme and the analogical model are shown by the fabric dyeing process, extending to other phenomena. Each body is as if immersed in a dye: the image of a liquid flowing through the material is frequently used, conveying its chromatic qualities, spreading out along its path and permeating the parts that are porous enough to absorb it. To carry out the process, the following is necessary: a dye that penetrates the pores of the object to be dyed, water as a medium and heat. In particular, the development of different colours when dyeing with the murex illustrates what happens with fruits, which take on various colours, depending on their ripening stages: «When they crush the murex and drain the moisture away, and then it is poured into pots and boiled, initially no colour is distinguishable in the dyeing bath. This is because each of these colours gradually varies in many different ways; the more the liquid boils, the more the colours that remain are combined: you have black, white, brown, blue-grey, and then all the colours become violet once they have been boiled together, so that none of the other colours is distinguishable by itself, due to the mixture» [5]. Dyeing practices are used as experimental evidence and as an explanatory model of what happens in nature, according to parallels traditionally established between natural processes and *technē* procedures, and helpful for reasoning as the latter are useful for understanding and interpreting the former. Therefore, art can represent a model for the analysis of nature. However, in *Peri chrōmatōn*, it is noted that while the dyeing technique performs this function, the mixture of pigments by painters is not considered methodically valid for the investigation of colours. It is, in fact, the dyers who imitate nature, not the painters. On the contrary, the dyeing bath of fabrics soaked in the dyeing substance resembles how the liquids present in plants and animals affect and colour their various parts.

3.2 *Colour mixing in nature*

The author of *Peri chrōmatōn* proposes a method of investigation of colours, just as they are produced in nature, referring repeatedly to certain criteria that essentially derived from a series of observations arranged and supported by rules, from specialised knowledge, and based on the conviction that in nature lights and not pigments are mixed. «We must examine all this without mixing these colours as painters do, but by comparing the rays that are reflected by the colours we have been talking about: this is the best way to investigate the mixtures of colours according to nature. Also, the evidence and basis for comparison must be derived from cases where the origin of the colours will be clear. This is particularly true of sunlight and firelight, air and water: their mixture in greater or lesser proportion gives rise to almost all colours. […]. Other colours must then be observed in the processes of ripening since they are produced in plants, fruits, hair, feathers and so on».[6] The skill of painters, who mix pigments, is opposed to the recommended research method, which is to observe colours in nature. The emphasis is placed on the concept expressed by the nexus *kata physin theōrēsai* [7]. The passage was usually compared with the statement of Aristotle, in the *Meteorologica* (372a 5 ff.), about the three main colours (red - φοινικοῦν, green - πράσινον, violet - ἀλουργόν) of the rainbow, which cannot be artificially produced by painters: in both cases, it seems that the authors distinguish between two systems, which we define respectively as an additive, where coloured lights are mixed, and subtractive, where pigments are mixed.

3.3 *Origin and change of colours*

Careful observation and correlation of the phenomena would be more fruitful in cases where colours' origin is clear (those in which sunlight and fire, air and water interact): then they can be valid as proof and as a basis for comparison. The reference to a colour of clear origin, the

comparison of reflected rays and the effects of light on different objects, the transition from one colour to another, and again (as the author says in the section on the formation of colours in the vegetable and animal world) the connection between colour in living organisms and ripening represent the basis for the study and understanding of chromatic phenomena. In this way, everything can have a permanent colour and a transitory colour, an original colour and a colour that is formed over time, again starting from the original, linked to the element of which a substance is predominantly made up. The only distinction that the author invites us to make is between the colour based on observation, or presupposition, and the colour that occurs in successive phases of growth (plants and animals reach their own colour as they *mature*), or in dyeing processes, or following mechanical phenomena, for example, the rubbing of stones and metals, physical (and chemical) actions due to light and heat. We can, therefore, observe initial colours, intermediate colours, final colours; light is a fundamental variable for their formation and their manifestation, even transitory. There is a colour naturally linked to things, as they are mainly formed by an element, but we do not always see it; therefore analysis and interpretation focus on the visible and very mutable colour, on the colour that appears at the beginning of a process, for example, green in plants. The evidence (πίστις) that proves and confirms the validity of the statements once again comes from observation and experience. The simultaneous reference both to arguments that can be adduced as evidence and to a criterion by which relationships between things are identified (the criterion of similarity) is significant. In collecting data, attention is paid to the analogy of the phenomena and the causes that produce them. The necessity to observe and correlate the phenomena, underlined many times, is associated with an attempt at experimentation in the passage in which reference is made to the iridescent neck of the pigeons, an example that is added to the chromatic changes of the air and water, due to the different incidence of light on a surface: «[...] the air sometimes takes on a purple tint to the east and west, when the sun rises and sets: then its particularly weak rays hit the dark air. The sea also tends towards the purple when the waves rise and the part of the wave that arches is in shadow, for the sun's rays strike this inclined part lightly, and cause the violet colour to appear. This is also observed in the plumage of birds: under a certain angle of light, it has a violet colour. If a lesser amount of light hits it, it is of that dull colour which is called brown; whereas plenty of light, mixed with the original black, produces red. If it is bright and glittering, the colour changes into the red of the flame» [8]. The orientation of the feathers in the direction of the light, almost skimming, has several effects that depend not only on the quantity and quality of the incident light but also on the angle of incidence. It is significant that the plumage of birds, traditionally a symbol of colour variation, is colouristically defined as the iridescent seawater. The iridescent colour of pigeons' neck, in the sun, was one of the well-known arguments in favour of relativism of knowledge and optical illusions (today we would speak of colouring by interference). Each qualitative and quantitative change corresponds to a change of colour and a step to characteristics that from time to time are opposite or intermediate, with respect to the completion of a process and the time it takes. The processes and actions that influence the various production of colours are heating, combustion, liquefaction, melting, boiling (in the case of artificial dyeing, for example), cooling, maturation/cotion (in plants and animals), correlated with nutrition and assimilation. Precise qualities, positions and dispositions, characteristics and states of matter are just some of the variables that determine colour: density and compactness, rarefaction and thinness, porosity or continuity, smoothness or roughness. Different conditions related to light and shadow, depth, distance, surface or interior vision, direct or through a medium, permanence or movement, space or time, add to the list of factors to which reference is made several times. The various causes of colour change are therefore attributable to physical (or chemical, in some cases, from our point of view) characteristics and processes, and to optical phenomena of light reflection, sometimes superimposed.

3.4 *No colour is seen in its purity*

Attention is constantly drawn to the infinite variety of colours [9]: this part is extremely interesting for its modernity. There is a clear awareness of characteristics, colour attributes, distinctions and phenomena, to which we give precise names (hue, saturation, brightness, contrast of tone, simultaneous contrast of colours, influence of the field) and which we define with different parameters, based on acquisitions and new settings, methodical experimentation and instrumental measurements, but in their intuitive essence are present in the mind of our author. No colour can be seen in its purity: all are to some extent modified by mixing if not with other colours, certainly with light and shadow. In fact, light and shadow appear to be the main factors of chromatic alteration: they can vary in intensity, quantity, regularity and interact differently with things that have a different composition, structure, consistency, surface, position, exposure and inclination: «We do not see any colour in its purity, as it is in reality, but all mixed with others: and even when they are not mixed with another colour, they are at least mixed with the rays of light and shadows; so they appear different, and not as they are. For the same reason, the same objects appear to us of a different colour when observed in the

shadow, in the light, when there is the sun, under intense or dim light, according to inclinations and different positions, and other different factors. The same happens with objects exposed to the light of a fire, the moon, or lanterns because each of these lights is different; and again in the case of the combination of colours, because they acquire their colour as one passes through the other. When light, falling on something, is coloured, and becomes, for example, red or grass green, and then the reflection falls on another colour, it takes on a different chromatic mixture as a result of this new intermingling. Undergoing these continuous but imperceptible modifications, the light sometimes reaches the eyes already mixed with many colours, but in such a way as to determine, among the prevailing colours, the perception of only one. This is why objects observed underwater come closer to the appearance of water, and objects observed in mirrors have similar colours to those of the mirrors themselves. The same must be thought to happen with the air. In conclusion, all colours are a combination of three components: light, the medium through which it is seen, for example water or air, and finally, the basic colours from which light is reflected. » [10].

4. Conclusion

There are many historically significant findings in this treatise, which is essentially phenomenological: no colour can be seen in its purity; the mutual interaction of colours; the variability of conditions that determine the chromatic impression; light as a component of mixtures, and its diversity depending on the source; the chromatic value of shade. Likewise, the attempt at a classification of colours and nomenclature, based on the relationship of distinct chromatic notations with light and darkness, emerges in it.

5. Conflict of interest declaration

No potential conflict of interest

6. Funding source declaration

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7. Short biography of the author

Maria Fernanda Ferrini is Associate Professor of Greek Language and Literature at the University of Macerata. Her principal monographies are focused on the technical and scientific treatises of the *Corpus Aristotelicum* (*De coloribus, Problemata, Physiognomonica, De audibilibus, Mechanica, De plantis, Rhetorica ad Alexandrum*). Among her most recent publications is ΧΡΩΜΑΤΑ *(Chrōmata). Lessico dei termini greci di colore. I: alpha* (2019)

Notes

[1] Col. (= De coloribus) 791a 1-12. The Greek text of the treatise is quoted according to my edition (Ferrini 1999), for which I revised the manuscripts collated by Bekker (1831) and by Prantl (1881), and I used other manuscripts that were not examined by the other two editors.
[2] Col. 791a 13-b 6.
[3] Col. 792a 4-5; 792 a 32-b 2. For some derivatives colours, components and quantity are given, but this is only vaguely indicated with 'a lot' and with 'a little', 'more' and 'less'; in every case, the author does not give formulae (his treatise is not an investigation for practical purposes) which we find in a list of instructions for the composition of colours, destined for painters and dyers, which was very common from late antiquity until the modern age, as a jealously guarded secret of every workshop, painting school, and alchemy and weaving studio.
[4] Col. 792b 33-793a 16.
[5] Col. 795b 11-21; cfr. 797a 3-8.
[6] Col. 792b 16-32.
[7] Col. 792b 20 κατὰ φύσιν θεωρῆσαι, 'investigate according to nature'. The method proposed is the best and most effective for explaining the variety of colours, even according to the more general principle, typical of ancient science, of studying phenomena as they appear in nature.
[8] Col. 792a 17-29.
[9] Col. 792b 33-34: τὸ πολυειδὲς καὶ τὸ ἄπειρον τῶν χρωμάτων.
[10] Col. 793b 12-794a 2.

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Graphical interpolation of Munsell data

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ABSTRACT

This paper analyzes the problem of converting Munsell color notations (hue, value and chroma) into CIE 1931 Yxy coordinates using the graphical method outlined in 1943 by the Optical Society of America (OSA). Various software programs can now perform this task, running on computers or color control instruments. Nonetheless, the OSA graphical technique remains the reference procedure to transform Munsell notations into CIE coordinates. The ASTM "Standard Practice for Specifying Color by the Munsell System" provides the data and charts needed to perform such conversion. Accordingly, Munsell value can be easily transformed into CIE luminance Y through a search in a data table. However, a guided procedure to graphically convert hue and chroma into CIE chromaticity coordinates is not available yet. To fill this gap, this paper proposes a graphical technique, which can use simple drawing computer programs such as PowerPoint, or more sophisticated tools for Computer Aided Design or Graphic Design, such as SolidWork or Adobe Illustrator. As an example, the proposed procedure is applied to a set of Munsell color chips from the Munsell Book of Colors, with nominal Munsell notations, but unknown CIE coordinates. The CIE Yxy coordinates of the analyzed chips are then digitally obtained by two ad hoc software conversion programs, and by instrumental measurements performed with a commercial spectrophotometer. Finally, a detailed comparison of the graphically and digitally interpolated data and of the instrumental measurements is provided and discussed.

KEYWORDS Munsell Color System, CIE coordinates, Visual interpolation, Color measurement

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1. Introduction

It is a truth universally acknowledged that specifying, matching or communicating colors in an objective way is a difficult task, even for expert practitioners endowed with sophisticated equipment. On the other hand, this unpleasant aspect of colorimetry can shed some light on the long-lasting interest of industry, academia and standard bodies for the Munsell Color System (MCS) and its companion, the Munsell Book of Colors (MBC) (Cochrane 2014).

The MCS was proposed by Albert Munsell in 1905, with the aim of defining a perceptually uniform color space (Newhall 1940) (Newhall et al. 1943). Based on a huge number of visual judgments by human observers, the MCS characterizes colors by three independent parameters - hue, value and chroma, representing tint (e.g. red, yellow, or green), lightness, and difference from neutral grey, respectively (ASTM Standard D 1535-14 2014).

The MBC, conversely, consists of a collection of uniformly distributed reference colors, printed on removable paper chips. Released in 1915 and commercialized in 1929, the MBC was finally updated after 1943 (Cochrane 2014), based on the studies of an ad hoc subcommittee of the Optical Society of America (OSA). The final OSA results, published at first in (Newhall et al. 1943), are now included in the international standard (ASTM Standard D 1535-14 2014).

The MBC chips originate a regular tridimensional grid in the Munsell color space (Newhall et al. 1943). They span 40 hues at constant steps of 2.5, integer values from 1 to 9, and even chroma from 2 towards the Mac Adam limit, i.e. the maximum chroma theoretically achievable by any object color of given hue and value (Wyszecki and Stiles 2000).

Using the MBC, one can obtain the Munsell specification of an object color: to this end, (ASTM Standard D 1535-14 2014) recommends selecting (by direct visual comparison) the perceptually closest MBC chips and linearly interpolating their Munsell notations.

For various reasons (some of which will be briefly discussed in the following), the MCS and the MBC are still adopted today in many color application fields, such as fashion and design, soil analysis, food control, forensic pathology, color education, and many others (Cochrane 2014).

The practical use of the MCS, however, very often brings about the consequent need to convert the Munsell notations into CIE 1931, CIELAB, or RGB coordinates (Wyszecki and Stiles 2000), in particular when the obtained color data require further processing (Paglierani and Valan 2018).

In the literature, the problem of transforming CIE 1931 coordinates into Munsell notations has received greater attention than the opposite conversion, from MCS to CIE – see, for instance, (Rheinboldt and Menard 1960), (Simon and Frost 1987), (Smith et al. 1990), (Mahyar et al. 2008). From the 60's up to nowadays, in fact, most of the efforts in this field have aimed at converting by digital means instrumental colorimetric data (i.e. the CIE coordinates evaluated by suitably processing measured reflectance spectra) into Munsell notations – which should indeed be the result of a perceptual judgment by a human observer (Newhall 1940), (Wyszecki and Stiles 2000).

As a result, low cost, portable measuring devices with user-friendly interfaces are now available on the market, which can provide not only CIE or CIELAB data, but are also capable to digitally provide perceptual Munsell notations from instrumental spectrophotometric measurements – see, for instance (Konica Minolta 2014).

Digital techniques and color-control instrumentation can be extremely useful when a large amount of colors must be characterized (Centore 2011). On the other hand, their practical use can be problematic in certain color control applications, specifically when the specimen under test is liquid or semi-liquid (e.g. beers, icecream or sauces in food control), non-compact (such as sand, in soil analysis, or hair, in hair dyeing control), or visually complex (e.g. diamonds or other gems) (Munsell Color 2020). In these cases, the use of the MBC chips still prevails, owing to their practical effectiveness and easy applicability.

Furthermore, various industrial or commercial recommendations issued by national or international standard bodies still adopt the MCS and ad hoc versions of the MBC to specify colors; two interesting examples are the Brazilian System for Soil Classification (De Souza 2020) or the United States Standards for Grades of Frozen French-Fried Potatoes, (Munsell Color 2020).

Thus, either for the reasons summarized above or just because they prefer relying on the human color vision rather than on electronic devices, many color professionals still use the MCS and the MBC in their work. To support such practitioners, this paper will focus on the Munsell to CIE conversion problem. Thus, for the sake of brevity, CIE to Munsell conversion techniques will not be considered in the following.

(Newhall et al. 1943) gave a fundamental contribution to the Munsell to CIE conversion problem, by providing the Munsell Renotation Data (MRD) - i.e a collection of reference Munsell notations with the corresponding CIE Yxy coordinates, and outlining a graphical conversion

procedure based on specific MRD charts available in (ASTM Standard D 1535-14 2014).

One relevant limitation of the MRD (and, consequently, of the MRD charts) is the fact that the provided reference colors are only expressed as Munsell notations and CIE 1931 Yxy specifications; hence, the MRD charts are available only in the CIE xy chromaticity plane (Newhall et al. 1943). As a consequence, their application can be extended to other color spaces only by means of a successive transformation, from CIE to the target color space. For instance, once a Munsell notation has been graphically turned to CIE coordinates using the MRD charts, the corresponding CIELAB data can only be evaluated by applying sequentially the well-known algebraic expressions for the CIE to CIELAB conversion (Wyszecki and Stiles 2000).

A direct transformation between the MCS and the CIELAB color spaces by means of digital techniques has been analyzed in (Mahyar et al. 2008), where the conversion from CIELAB coordinates to Munsell hue is investigated. Conversely, graphical techniques between CIELAB (or any other color space) and MCS are not known to the authors.

The higher uniformity of the more recent CIELAB space (or of other color spaces) with respect to the CIE 1931 color system system could be exploited to improve the accuracy of the conversion process (Wyszecki and Stiles 2000). In fact, as will be highlighted in the following, the low uniformity exhibited by the CIE 1931 xy chromaticity plane is a critical aspect in the OSA graphical conversion. Nonetheless, this paper will focus only on the use of the MRD charts for the Munsell to CIE 1931 conversion procedure. The analysis of the impact of the low uniformity of the CIE 1931 color space on the conversion process, and its extension to other color spaces, can represent further steps of the research activity presented in this paper.

Another drawback of the OSA graphical procedure is that it can be quite complex and time consuming. For this reason, various software programs have been proposed, which can perform the Munsell to CIE conversion (BabelColor 2018), (Centore 2011), (Paglierani and Valan 2018, Conference Paper). Such programs are usually based on linear, linear and radial (Centore 2011), or spline interpolation techniques (Paglierani and Valan 2018, Conference Paper). Neural network conversion techniques have also been investigated (Kang et al 2009) (Tominaga 1993). To the best of the authors' knowledge, however, these techniques are not used in practical applications yet.

A partial comparison of the results provided by linear, linear and radial, or spline interpolation techniques is given in (Paglierani and Valan 2018, Conference Paper), where the lack of a suitable set of reference colors outside the MRD was highlighted as a major problem in performance analysis activities.

This paper aims to contribute to this topic, by providing common guidelines and a simplified procedure to obtain reference MCS and CIE 1931 data outside the MRD. In fact, as clearly stated in (ASTM Standard D 1535-14 2014), the graphical approach is the reference conversion technique that should be used to determine the accuracy of any computer program performing the Munsell-to-CIE conversion.

In the Munsell to CIE conversion, the Munsell value can be simply transformed into CIE luminance through a search in a data table (ASTM Standard D 1535-14 2014).

On the contrary, graphically transforming Munsell hue and chroma into the CIE chromaticity coordinates xy can be more complex (Centore 2011). Moreover, a detailed guided procedure to systematically perform such task, to the best of the authors' knowledge, is not available yet.

To fill this gap, this paper proposes a graphical Munsell to CIE conversion technique based on the MRD charts and supported by simple and popular computer programs for drawing, e.g. PowerPoint (Microsoft Powerpoint 2020) or LibreOfficeDraw (LibreOffice Draw 2020), or by more complex Computer Aided Design or Graphical Design applications, such as Solid Work (Solidwork 2020) or Adobe Illustrator (Adobe Illustrator 2020).

The paper demonstrates the use of such tools in the Munsell to CIE conversion through practical examples, and verifies its reproducibility by comparing the results achieved by independent operators using different tools.

The proposed procedure is then applied to a set of Munsell color chips included in the MBC - hence, with nominal Munsell notations, but of unknown CIE coordinates (intermediate MBC chips).

In the paper, the CIE Yxy coordinates of the intermediate MBC chips are also obtained by two computer programs, i.e. (Centore 2011) and (Paglierani and Valan 2018, Conference Paper). Moreover, they are directly evaluated from instrumental spectrophotometric measurements obtained with a commercial instrument (Konica Minolta 2014), (Wyszecki and Stiles 2000).

Finally, the CIE coordinates obtained by graphical or digital conversion of Munsell notations and the ones directly evaluated from spectrophotometric measurements are thoroughly compared and discussed.

The procedure presented in this paper can be used by researchers who need to validate a novel digital conversion algorithm, or compare the accuracy performance of different conversion techniques. The proposed procedure can also provide a systematic way for independent researchers to produce reference color data.

Furthermore, this paper can be considered a tutorial for all those color practitioners who wish to acquire a deeper understanding about MCS and MBC.

The structure of the paper is as follows. The next section briefly introduces the MCS, the MBC and the MRD. Section 3 presents and discusses the proposed graphical conversion procedure, and the experimental use of different digital tools. Section 4 summarizes the conversion algorithms proposed in (Centore 2011), (Paglierani and Valan 2018, Conference paper). Finally, the graphical conversion results, the digital conversion results and the obtained measurements are described, compared and discussed.

2. The Munsell Color System

The MCS associates colors to points in a tridimensional space, so that equal perceptual differences between colors imply equal Euclidean distances between the corresponding points (ASTM Standard D 1535-14 2014) (Newhall et al. 1943).

In MCS the color attributes, hue value and chroma, are represented by cylindrical coordinates: hue is the angle about the neutral axis, value is to the distance from the plane containing the black point, and chroma is the radial distance from the neutral axis.

A Munsell notation is a combination of letters and numbers, written in the form *pHV*/*C*, which defines the color of an opaque object with respect to the Munsell hue *pH*, the Munsell value *V*, and Munsell chroma *C*.

In this notation, *p* is a real number in (0,10] and *H* a letter in {*R*,*YR*,*Y*,*GY*,*G*,*BG*,*B*,*PB*,*P*,*RP*} (ASTM Standard D 1535-14 2014). The value *V* is a real number in [0,10]; 0 corresponds to ideal black and 10 to ideal white. The chroma *C* is real and non-negative. Examples of Munsell notations are 8.75G3.8/2 or 6PB3/5.5. In some cases, it may be convenient to use the all-number notation (see fig. 1), in which the hue is a real number in (0,100] or in (0,10] (The Munsell and Kubelka-Munk toolbox 2019).

The MRD are a collection of 2734 Munsell specifications, whose corresponding CIE Yxy coordinates (relative to Illuminant C) are given in (ASTM Standard D 1535-14 2014) and (Newhall et al. 1943); they are available in digital format at (Munsell Renotation Data 2019).

Fig.2 shows the subset of MRD points with Munsell value equal to 5, on the CIE xy plane: one can see the manually drawn curves representing the constant-chroma and constant-hue loci of the MRD (Newhall et al. 1943). The MRD points lie at the intersections between ovoids and radial curves. As an example, the red arc in fig.2 is the constant-chroma arc between the MRD notations 7.5R 5/12 and 10R 5/12.

The MRD and the MRD charts are the basic elements for the Munsell conversion procedures, be they graphical or purely digital. However, before analyzing the different types of procedures, we first need to define the Munsell to CIE conversion problem.

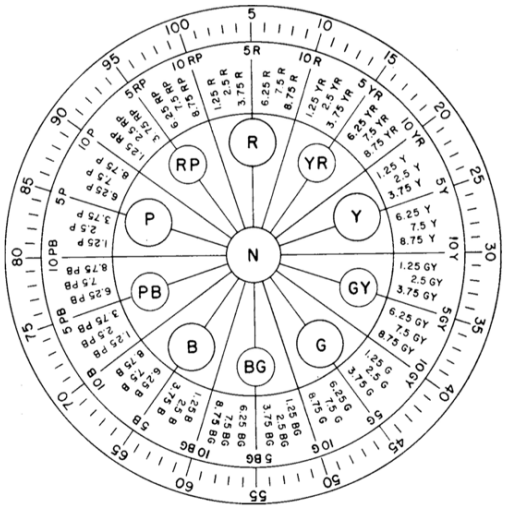

Fig. 1. Designation Systems for Munsell Hue, from (ASTM Standard D 1535-14 2014).

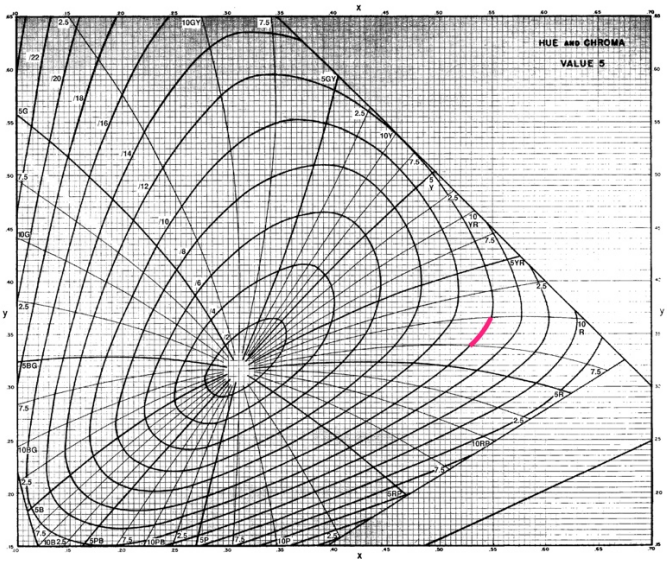

Fig 2 Munsell Renotation Data with Munsell Value 5 from (ASTM Standard D 1535-14 2014). In red the constant chroma arc between 7.5R 5/12 and 10R 5/12.

3. The Munsell to CIE conversion problem

The Munsell to CIE conversion problem can be stated as follows: given a Munsell notation with hue *pH*, value *V* and chroma *C*, find the corresponding CIE Yxy coordinates (Centore 2011):

$$\begin{aligned} Y &= f_1(pH, V, C) \\ x &= f_2(pH, V, C) \\ y &= f_3(pH, V, C). \end{aligned} \tag{1}$$

If the Munsell notation belongs to the MRD, the conversion can be easily carried out by an exhaustive search in the MRD database. Conversely, for a generic Munsell notation outside the MRD, it is necessary to rely on (1) to find the corresponding CIE coordinates.

The luminous reflectance factor *Y* depends only on the value *V*; hence, one can write $Y = f_1(V)$. A conversion table to directly obtain *Y* from *V* is available in (ASTM Standard D 1535-14 2014).

Unfortunately, useful approximations of the functions f_2 and f_3 in (1) are not available (Centore 2011). Thus, there are two possible ways to convert hue and chroma to the CIE xy parameters.

One approach is the graphical procedure outlined in (Newhall et al. 1943) and recommended by (ASTM Standard D 1535-14 2014).

The second one consists in a tri-dimensional search and interpolation process based on the MRD, digitally implemented by a computer program (Centore 2011).

When converting a generic Munsell notation, any available procedure (be it graphical or software-based) necessarily starts by transforming the closest adjacent Munsell notations having multiple-of-two chroma and integer value: for a detailed discussion of this aspect, see (ASTM Standard D 1535-14 2014), (Centore 2011), (Paglierani and Valan 2018, Conference Paper).

Once such adjacent Munsell notations have been converted, their CIE coordinates can be easily interpolated, so as to obtain the coordinates of the generic Munsell notation to convert (ASTM Standard D 1535-14 2014).

As a consequence, in the following, we will only consider (without loss of generality) the conversion of Munsell notations lying on the constant-chroma ovoids (at multiple-of-two chroma) drawn in the integer-value planes shown in the MRD charts (Centore 2011).

3.1 *The graphic conversion procedure*

The first step in the graphic conversion procedure consists in determining the chart (identified by an integer value from 1 to 9) and the ovoid in that chart (determined by a multiple of two chroma) on which the Munsell notation to convert lies. Then, one must find the arc containing such Munsell specification, delimited by the two closest MRD notations (Centore 2011).

As an example, we will consider the problem of determining the CIE coordinates of the Munsell notation 8.75R5/12, which is an intermediate color sample physically available in some editions of the MBC.

The MRD notations closest to 8.75R5/12 and with the same value and chroma are 7.5R5/12 and 10R5/12, as one can see in the zoomed chart (value 5) shown in fig.3.

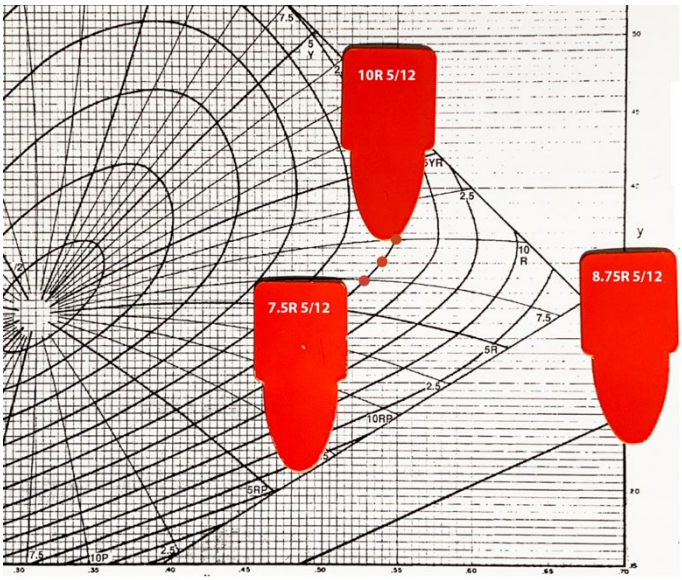

Fig 3. Munsell notation to convert (8.75R 5/12) and the two closest MRD notations with the same value and chroma.

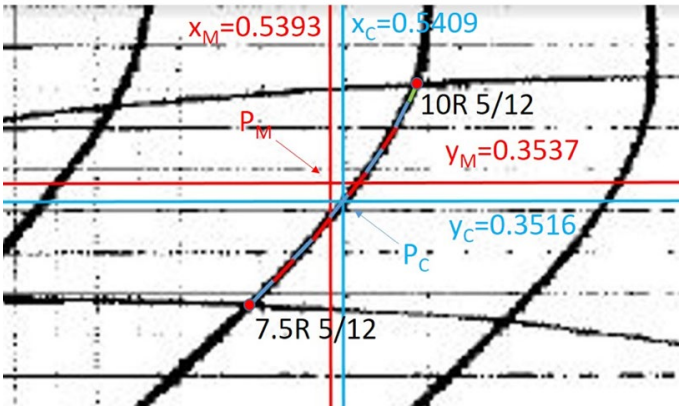

Fig 4. Graphical interpolation of the Munsell specification 8.75R5/12 obtained with PowerPoint.

Once the position of 8.75R5/12 on the arc between 7.5R5/12 and 10R5/12 is known, its xy coordinates can be straightforwardly obtained on a paper print of the chart, or digitally on a Personal Computer, e.g. using a drawing program such as PowerPoint. The searched xy values are the coordinates of the point corresponding to 8.75R5/12, read on the x and y axis of the chart.

However, determining the accurate position of such a point on the arc is less trivial. To overcome this difficulty, we need to assume a linear relationship between arc lengths in the CIE xy plane and numeric hues.

From an operating point of view, this assumption is fundamental to locate the color position in the CIE xy plane, and proceed with the interpolation process. On the other hand, the non uniformity of the CIE xy plane is well-known (Wyszecki and Stiles 2000); hence, assuming a linear relationship between hue and arc length in the CIE xy plane could give rise to observable non-linear effects, if a statistical analysis of the converted data were performed.

Nonetheless, this type of statistical analysis is out of the scope of this paper. Thus, in the following, we will accept the linearity assumption discussed above as a necessary working hypothesis, and postpone this type of investigation (together with its extension to more recent, approximately uniform color spaces such as CIELAB) to the next steps of this research work.

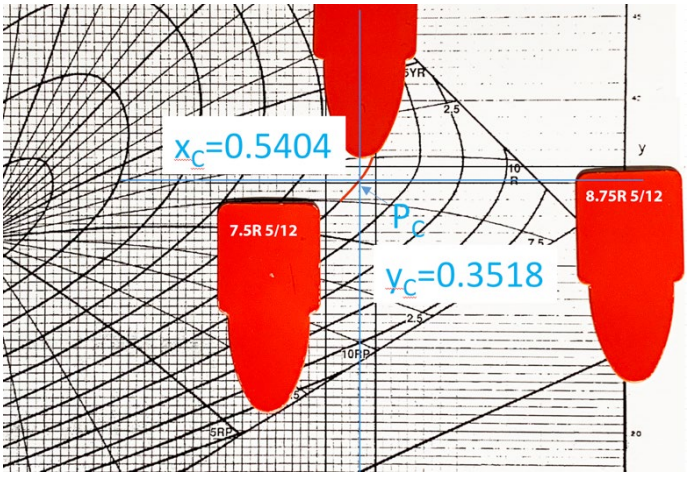

Fig. 5. Graphical interpolation of the Munsell specification 8.75R5/12 obtained with Adobe Illustrator.

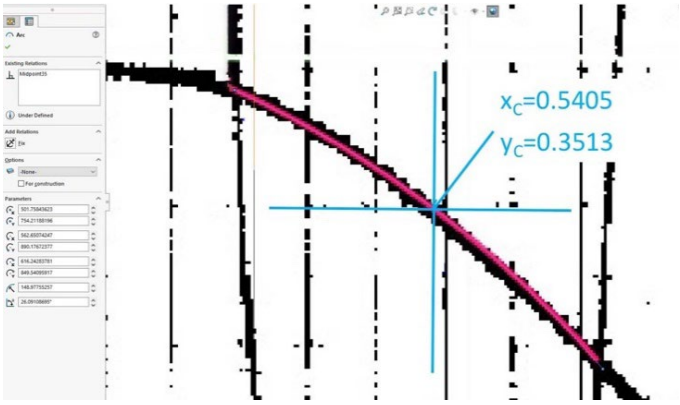

Fig. 6. Graphical interpolation of the Munsell specification 8.75R5/12 obtained with SolidWork

In the considered conversion example, the hue of 8.75R5/12 is exactly intermediate between 7.5R and 10R; hence, the searched point on the chart divides in two equal parts the arc between 7.5R and 10R.

In general, if *Hx* is the hue of the Munsell notation to convert, *H1* and *H2* the hues (*H2* > *H1*) of the adjacent MRD notations, and *L* the length of the arc between *H1* and *H2*, the semi-arc length *Lx* from *H1* to *Hx* can be evaluated as:

$$Lx = \frac{Hx-H1}{H2-H1}L. \qquad (2)$$

To evaluate (2), the length *L* of the entire arc from *H1* to *H2* is needed. Such a value can be obtained by approximating the arc as a sequence of linear segments of fixed length *Lu*. Fig.4 shows an example of arc approximation with a sequence of juxtaposed linear segments (in red and blue) of constant length *Lu*, superimposed to the arc in the MRD chart. In this case, the length *L* was obtained with Power Point. Notice that the final segment (in green) has a shorter length than *Lu*, to adjust the sequence of approximating segments to the arc. The length *Lx* of the semi-arc can be obtained in the same way.

To verify the reproducibility of the proposed graphical approach, a second operator independently (i.e. without any information coming from the previous PowerPoint-based conversion experiment) transformed the Munsell notation 8.75R 5/12 to CIE coordinates using the Adobe graphic design tool Illustrator. The output of the procedure is summarized in fig. 5.

Finally, a third operator independently performed the same conversion, using a Computer Aided Design tool, i.e. SolidWork. In this case, the lengths *L* and *Lx* were obtained by approximating the arc as a circle, by means of the built-in functionalities provided by SolidWork. The

circular curve interpolating the arc and the obtained results are shown in fig.6.

As one can easily verify, even if performed with different tools and carried out by different independent operators, the results of the three conversions are very close.

3.2 *Liner/radial digital interpolation*

The MKT algorithm extends the purely linear interpolation technique suggested in (Rheinboldt and Menard 1960) by using radial interpolation where the MRD constant-chroma ovoids exhibit a higher curvature (Centore 2011).

The MKT is open source, available in Python (Colour Science for Python 2019) or Matlab (The Munsell and Kubelka-Munk toolbox 2019). Its details are thoroughly described and discussed in (Centore 2011).

The algorithm mimics the graphical procedure described in the previous paragraph by digital means, using the two MRD samples, *p1H1V/C* and *p2H2V/C*, adjacent to *pHxV/C*, and their coordinates (*x1*,*y1*) and (*x2*,*y2*).

To decide if linear or radial interpolation should be applied, a lookup table is used (Centore 2011). If linear interpolation applies, the algorithm transforms the hues into real number in the range (0,10]. The searched coordinates are calculated as:

$$(x, y) = \frac{H2-Hx}{H2-H1}(x1, y1) + \frac{Hx-H1}{H2-H1}(x2, y2)$$

For radial interpolation, the xy coordinates (*x1*,*y1*) and (*x2*,*y2*) of *p1H1V/C* and *p2H2V/C* must be first transformed into polar coordinates (*θ1*,*ρ1*) and (*θ2*,*ρ2*), with respect to the Illuminant C neutral point. Moreover, MKT transforms hues in Temporary Hue Angles, *TH*. The polar coordinates of *pHxV/C* are finally obtained as:

$$(\theta, \rho) = \frac{TH2-THx}{TH2-TH1}(\theta 1, \rho 1) + \frac{THx-TH1}{TH2-TH1}(\theta 2, \rho 2)$$

and then transformed in xy coordinates.

3.3 *Spline interpolation*

The spline interpolation technique is described in (Paglierani and Valan 2018, Conference Paper). While the MKT algorithm uses only the adjacent points to interpolate a notation, the spline technique can use all the points belonging to a constant chroma ovoid (or even to constant-hue radial lines). The basic idea behind this algorithm is to express any MRD chart ovoid, identified by constant integer value *V* and multiple-of-two chroma *C*, by approximate mathematical formulas, which can be expressed in parametric form as:

$$x = g_1(H), \qquad y = g_2(H) \tag{3}$$

To evaluate the xy coordinates, we substitute in (3) the unknown functions g_1, g_2 with their approximations $\hat{g}_1$and $\hat{g}_2$, obtained by applying spline interpolation to the subset of MRD points lying on the found ovoid (Press et al. 2007). To this end, one must collect the xy coordinates (*xi*,*yi*) and numeric Munsell Hues *Hi* of the MRD points lying on the identified ovoid in the vectors *x*=[*x1*,…*xN*]T, y=[*y1*,…*yN*], and *H*=[*H1*,…*HN*]. The desired xy coordinates are:

$$x = \hat{g}_1(H), y = \hat{g}_2(H)$$

where:

$$\hat{g}_1 = spline(H, x), \hat{g}_2 = spline(H, y),$$

while:

$$q = spline(t, z)$$

represents the cubic spline interpolant polynomial *q* of the data values *z*, at data sites *t* (Press et al. 2007).

Since the ovoids are closed curves, it is necessary to extend and wrap the vectors *x*, *y* and *H*, repeating the initial and final values (Paglierani and Valan 2018 Conference paper). The interpolation procedure is finally performed by (6)-(7), with the extended vectors *x*', *y*' and *H*' taking the place of *x*, *y* and *H*.

4 Numerical and experimental results

To analyze the performance of the considered graphical and digital interpolation techniques, a set of intermediate MBC color chips were used. Such sequence of Munsell specifications is reported in the first column of Table I; for the sake of simplicity, they all have value equal to 5 and chroma equal to 12.

For each Munsell specification, the corresponding CIE xy coordinates were obtained by applying the graphical procedure described in Section 3.1, using PowerPoint. The results are shown in the second column of Table I, while the third and fourth columns report the corresponding digitally interpolated values provided by the MKT and the Spline algorithms, respectively. Finally, the fifth column contains the results of the measurements performed on the physical chips of the MBC, obtained by using the Konica-Minolta spectrophotometer CM-2600d (Konica Minolta 2014).

Preliminary tests showed a high repeatability of the CIE coordinate measurements. For this reason, the measurement process was repeated four times for each physical chip; the fifth column in Table I shows the average measured coordinates. The standard deviations obtained from all the performed measurements resulted very similar for the *x* and *y* coordinates, close to σx = σy = σ = 0.0001.

As an example, the CIE coordinates obtained by the graphical procedure and the averaged coordinates

provided by the Konica Minolta instrument are shown in fig.4, in light blue and red, respectively.

From Tab. 1, it was possible to evaluate the geometric distance between the CIE coordinates provided by the different approaches. The final results are reported in Tab. 2. As one can immediately notice, the maximum geometric distance occurs between graphical interpolation data and instrumental measurements. Conversely, the data obtained by the two digital algorithms achieve the minimum distance. Finally, one can observe that, quite surprisingly, the digital interpolation techniques, though based on the MRD, provide data closer to the spectral measurements than to the graphical interpolation results.

5. Conclusions

This paper has presented a graphical technique, based on digital drawing tools, to perform Munsell to CIE data conversion. The procedure has been described through a practical example, in which a Munsell notation has been transformed to CIE coordinates by three independent operators using different digital tools, so as to verify its reproducibility.

The procedure has also been applied to a set of color chips available in some editions of the Munsell Color Book, whose CIE coordinates are not known. Moreover, instrumental measurements of the chip CIE coordinates have been performed, using a Konica Minolta CM-2600d spectrophotometer.

The obtained data have been analyzed and discussed. The interpolation results provided by the two digital interpolation techniques result quite close. The maximum geometric distance is observed between graphical interpolation data and instrumental measurements. The results of the digital algorithms are closer to the instrumental measurements than to the graphical interpolation results.

The presented procedure can be used to assess the conversion performance achieved by computer programs, and to further analyze the relationship between Munsell notations and CIE coordinates as enforced by the Munsell Renotation Data.

Further steps in this research activity can be observer tests to assess the linearity of interpolated data in terms of appearance, the main characteristics of the Munsell Book of Colors, and investigating the possible use of other color spaces to improve the conversion process of the Munsell notations.

Munsell Spec	**Graphical interpolation** (x,y)	**MKT interpolation** (x,y)	**Spline Interpolation** (x,y)	**Spectral Measurements** (x,y)
8.75R 5/12	0.5409, 0.3516	0.5384, 0.3519	0.5395, 0.3520	0.5393, 0.3537
1.25YR 5/12	0.5442, 0.3613	0.5485, 0.3784	0.5502, 0.3789	0.5467, 0.3786
3.75YR 5/12	0.5464, 0.4027	0.5455, 0.4025	0.5454, 0.4025	0.5487, 0.4021
1.25G 5/12	0.2694, 0.5421	0.2616, 0.5431	0.2650, 0.5431	0.2644, 0.5360
3.75PB 5/12	0.1875, 0.1852	0.1856, 0.1875	0.1847, 0.1874	0.1849, 0.1899
6.25PB 5/12	0.2016, 0.1837	0.2039, 0.1839	0.2029, 0.1840	0.2082, 0.1933
3.75RP 5/12	0.3829, 0.2422	0.3831, 0.2424	0.3829, 0.2424	0.3817, 0.2399
6.25RP 5/12	0.4166, 0.2600	0.4172, 0.2602	0.4163, 0.2599	0.4202, 0.2607

Tab. 1. Simulation and Experimental Data

	Graphical interpolation	MKT interpolation	Spline Interpolation	Spectral Measurements
Graphical Interpolation	x	0.0070	0.0069	0.0084
MKT Interpolation	0.0070	X	0.0015	0.0051
Spline Interpolation	0.0069	0.0015	x	0.0053
Spectral Measurements	0.0084	0.0051	0.0053	x

Tab. 2. Interpolation technique comparison via geometric distance

6. Conflict of interest declaration

The authors certify that they have no affiliations with or involvement in any organization or entity with any financial or non-financial interest in the subject matter or materials discussed in this manuscript. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors

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Simone Liberini - • Received his MS degree in Biomedical Engineering at Polytechnic University of Milan. He worked as a research fellow at IBFM, Milan, where he contributed to an image-based frame of assessment of parotid glands shrinkage in head-and-neck cancer patients. He is currently external researcher at University of Milan, where he is involved in quantitative and perceptual analysis of applications of the Munsell Colour System

Alessandro Rizzi - • Is Full Professor at the Department of Computer Science at the University of Milan, teaching Multimedia and Colorimetry.

He is doing research since 1990 in the field of digital imaging with a particular interest on color, visualization, photography, HDR, VR and on the perceptual issues related to digital imaging, interfaces and lighting. He is the head of the MIPS Lab at the Department of Computer Science. He has been one of the founders of the Italian Color Group, Secretary of CIE Division 8, IS&T Fellow and Vice President. In 2015 he received the Davies medal from the Royal Photographic Society.

He is co-chair of the IS&T Conference “Color Imaging: Displaying, Processing, Hardcopy and Applications”, Topical Editor for “Applied Color Science” of the Journal of Optical Society of America, Associate Editor of Journal of Electronic Imaging, member of several program committees of conferences related to color and digital imaging, and author of more than 300 scientific works.

Francesca Valan - • Industrial designer, specialized in the design of colors, materials, and finishes (CMF Design). She graduated in Industrial Design at IED in Milan in 1989 and received her Master in Surface Quality in 1990. She lives and works in Milan, where she founded her studio in 1998. As an Industrial Designer, her activity consists in defining Product Identity. Her CMF projects range from elevators to office furniture, from home appliances to sport

items, pens, glasses etc. She has collaborated with De Longhi Group, Lechler, Samsung, Telecom Italia, LG, Hitachi, Olivetti, Atomic, Technogym, Fila, Campari, and many others. She is a teacher in university and master courses in color design technology. She developed a method of prediction of trends based on historical and statistical analysis of color by market sector, which exploits the periodicity of color preferences and the duration of cycles for product type.

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Francesco Algarotti explains Newton's prism experiment to Ladies

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ABSTRACT

In the 18th century, a "new science" flowed in Europe. One of the primary elements of Enlightenment was the rise of the public sphere excluding women and lower classes. *Les Philosophes* introduced the public to many scientific theories, in particular–Newtonianism by Voltaire and Émilie du Châtelet. Some works are more formal, but the popular works were written in a discursive style. Articles on scientific topics appeared in popular women's magazines and books designed to introduce women to scientific disciplines. Noted examples of this popular new genre include Francesco Algarotti's *Newtonianism for Ladies or Dialogues on light and colours*. This book was an 18th century best seller and was one of the main channels through which Newtonian ideas reached the public in continental Europe. The text explained the principles of Newton's *Opticks* while avoiding much of the mathematical rigor of the work in favour of a more "agreeable" text. Algarotti presented Newton as a follower of the Galilean tradition and the first modern philosopher. The description of some of Newton's experiments on the nature of light and colours in the form of a gentle dialogue has great educational value, because it does not demand any geometrical or algebraic knowledge.
In this article, the authors want to underline the importance of Algarotti's book for the dissemination of Newton's ideas that until then had been shared only by scholars.
Algarotti's book today is testimony to women's interest in science during 18th century.

KEYWORDS Optics, Colour, Enlightenment, Algarotti

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1. Introduction

In the 18th century, Enlightenment's principles inspired a new genre of painting, music and the "new science" flowed in Europe. One of the primary elements of the culture of Enlightenment was the rise of the public sphere. The word "public" implies the highest level of inclusivity – the public sphere should be open to all. However, this sphere was only public to relative degrees. Additionally, most institutions of the public sphere excluded both women and lower classes. An important development was the popularization of science among an increasingly literate population.

Les Philosophes (Philosophers) introduced the public to many scientific theories, most notably through the Encyclopédie and the popularization of Newtonianism by Voltaire and Émilie du Châtelet.

Some works were more formal and included explanations of scientific theories for individuals lacking the educational background to comprehend the original scientific text. The popular works were written in a discursive style, which was laid out much more clearly for the reader than the complicated articles or treatises. Articles on scientific topics appeared in popular women's magazines and books designed to introduce women to scientific disciplines. Noted examples of this popular new genre include Francesco Algarotti's *Newtonianism for Ladies or Dialogues on Light and Colours* (1737). This book was an 18th century best seller and was one of the main channels through which Newtonian ideas reached the public, not only women, in continental Europe.

The widespread use of the book was also due to the fact that Algarotti was well introduced in the English and French as well as in the Italian cultural circles.

Algarotti frequented the salon of Elisabeth Montagu where he met Elizabeth Carter who translated the *Dialogues.* Later, Algarotti became a great friend of Frederick the Great.

The book brings together both groups of women, the amateur and the learned scientists. Algarotti illustrated the book with an engraving of Émilie du Châtelet and himself set in a bucolic scene. The text explained the principles of Newton's *Opticks* while avoiding much of the mathematical rigor of the work in favour of a more "agreeable" text. In the book, Algarotti presented Newton as a follower of the Galilean tradition and the first modern philosopher. The distinguishing feature of the book is that he presents the theory about the nature of light and colours by means of Newton's experiments. He shares. with Galileo and Locke, the same idea about the scientific value of experience, in antithesis with the Cartesian method. The description of some of Newton's experiments on the nature of light and colours in the form of a gentle dialogue has great educational value, because it does not demand any knowledge of geometry or algebra. From this point of view, the literary quotes are always totally justified and meaningful. Algarotti writes the verses in the beginning "o, of the golden sevenfold light the myriad ardent, mixed and glorious colours," in honour of Laura Bassi, professor of Philosophy and Physics at the University of Bologna. This quote shows his attention to the Experimental Method and recalls the period in which Algarotti himself studied Physics at the University of Bologna.

In this article, the authors want to underline the importance of Algarotti's book for the dissemination of Newton's ideas that up to that time had been shared only by scholars. In the 18th century, as pointed out, the salons where literature and science conversations were held were also very important. The conversations were held also by women, despite not being able to attend schools, who had to know and talk about the latest discoveries.

So, Algarotti's book explains Newton's theory in a simpler and less formal way with rhetorical figures and literary verses. Therefore, Algarotti's book is witness to women's interest in science in 18th century.

2. Importance of Decomposition of White Light in Eighteenth Century

In 18th century there is a reassessment of the connections between practical techniques, philosophical ideas and the cultures in which they resided. The production of dyes, pigments and glazes were well established industries. Colour was a subject of systematic experimental and theoretical investigations in the sciences. Colour brought philosophical ideas close to everyday experience. In books and lectures directed at popular audiences, colour was used to illustrate connections between methods and theories, emphasizing the familiarity and practicality of colour making techniques. The characterization of Chemistry in eighteenth century as under fledged in comparison to Physics meant that mainly Mathematics, Mechanics, Optics and Dioptrics were present in discussions of colour practices. Reference to Newton, Descartes, Gassendi and even Aristotle were obligatory in practical writing intended for publication. Colour was part of a developing art or tangential to science.

The expanded place of the sciences in public and private life explains the interest in learning the book of nature, that the sciences provided with exemplary systems, visible or invisible as the laws of motion or mathematics. There were many strategies for disseminating information. The transfer could be purely verbal, as in *Conversazioni* or lectures, or by means of a combination of verbal and visual strategies (Fig.1). Colour was a topic with clear connection to science. It suggested visible and tangible opportunities to join theories and practice, providing a unitary focus for systematic conjecture and experiment. (Lowengard, 2005).

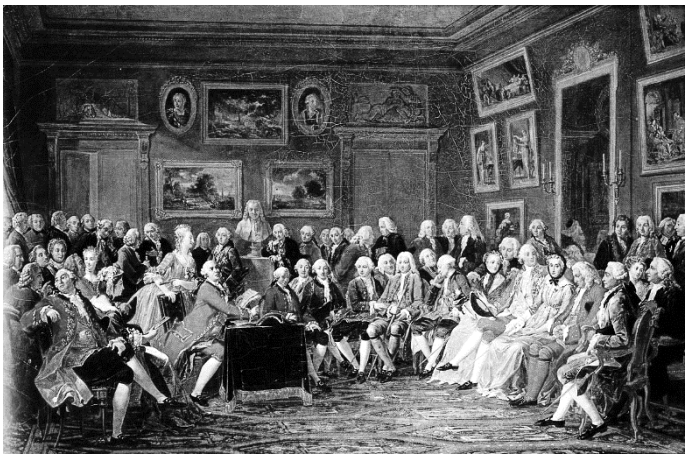

Fig. 1. Conversazioni or lectures

3. Newton Prism Experiment

Between 1665 and 1666, Isaac Newton realized a series of experiments with the prism that radically transformed traditional ideas about the nature of light and colours. He made a small hole in the window of his perfectly darkened room. He caused a prism to intercept the ray of light that penetrated from the small opening, projecting the image onto a wall several meters away, on which he observed a non-circular, but elongated spectrum in which all the colours of the iris were revealed. Newton also showed the reversibility of the experiment: by projecting the polychrome spectrum on a converging lens, the white light beam was in fact regenerated. From these experiments he deduced that the colours were not, as Descartes had assumed from Aristotle, accidental modifications of white light. The latter no longer appeared as an elementary but heterogeneous substance: the product, that is, of mixing different colours. Newton correctly stated that the spectrum appeared elongated because the various colours have different indices of refraction. He derived from this discovery the idea of the reflecting telescope, capable of considerably attenuating the annoying effects of chromatic aberration. The results of this research were published by Newton in the Philosophical Transactions of the Royal Society in 1672 and 1675. The Newtonian theory of light and colour stirred lively debate. The comparison with the wave theory of light supported by Huygens was particularly lively.

Experiment's description (Newton, 1704)
Place a prism (whose angle *fbd* is about 60°) in a dark room in which the Sun passes only through a small round hole *k* and holding it near the hole *k* so that the rays being equally refracted in *n* and in *h*, project *rstv* colours on the opposite wall (Fig. 2).
The colours are refracted forming an oblong shape bounded in the sides *r* and *s* by straight lines. The amplitude *rs* is 2 1/3 inches, their length about 7 or 8 inches and the distance of the centres of red and blue (*p* and *q*) are about 3 inches. The distance of the *rstv* wall from the prism is 260 inches (about 6.70 meters).[1]
In another experiment, Newton took a prism on a face of which he placed a sheet of paper with different bands parallel to the edges of the prism and placed at a regular distance.
Passing through these cracks, the sunlight, collected on a screen near the prism, produced a coloured line at each slot. However, as soon as the screen moved away, white formed in the central part of the spectrum. If the screen was placed at an even greater distance, the whole spectrum reappeared.

Fig. 2 - Newton's experiment drawing (drawing by authors of this text)

4. Francesco Algarotti: a Venetian Polymath

Count Francesco Algarotti (1712–1764) was an eclectic scholar: philosopher, poet, essayist, art critic and art collector. He was a man of broad knowledge, an expert in Newtonianism, architecture, music and a friend of most of the leading authors of his age. Voltaire, Jean-Baptiste de Boyer, Pierre-Louis de Maupertuis, Lord Chesterfield, Thomas Gray, Metastasio, Benedict XIV and Heinrich von

Brühl were among his correspondents. Algarotti was born in Venice as the son of a rich merchant. Unlike his older brother Bonomo, he did not step into the company, but decided to become an author. Francesco studied natural sciences and mathematics in Bologna under Francesco Maria Zanotti and in 1728 he experimented with optics.

At the age of twenty, he went to Paris, where he became friendly with Voltaire and Émilie du Châtelet.
The first French introduction to Newtonianism and the *Principia* was *Eléments de la philosophie de Newton*, published by Voltaire in 1738.
Émilie du Châtelet's translation of the *Principia*, published after her death in 1756, helped to spread Newton's theories beyond scientific academies and the university. Bernard de Fontenelle's *Conversations on the Plurality of Worlds* (1686) was the first significant work that expressed scientific theory and knowledge expressly for the laity, in vernacular and with the entertainment of readers in mind. The book was produced specifically for women with an interest in scientific writing and it inspired a variety of similar works and pushed Algarotti to write his book about Newton's Optics during his stay in Cirey, guest of Voltaire and du Châtelet.
When he was in London, he was made a fellow of the Royal Society and joined the friends' circle of Lady Mary Wortley Montagu.
Among them there was Elisabeth Carter, the poet, linguist and polymath, who later translated his book. In 1737, Algarotti left for Italy and finished *Neutonianismo per le dame* (Newtonianism for Ladies), dedicated to Bernard le Bovier de Fontenelle, a work intended for the popularization of Newtonian philosophy and addressed to women.
Algarotti wrote *Il Newtonianesimo per le dame, ovvero Dialoghi sopra la Luce e i Colori* as a series of six dialogues.
First dialogue: Introduction; a general Idea of Physics, and an Explanation of the most remarkable Hypothesis concerning Light and Colours.
Second dialogue: That Qualities, such as Light, Colours, and the like, are not really in Bodies. Metaphysical Doubts concerning our Sensations of them. Explication of the general Principles of Optics.
Third dialogue: Several Particulars relating to Vision, Discoveries in Optics, and a Confutation of the Cartesian System
Fourth dialogue: Encomium on Experimental Philosophy, and an Exposition of the Newtonian System of Optics
Fifth dialogue: Exposition of the Newtonian Philosophy continued
Sixth dialogue: Exposition of the Newtonian universal Principle of Attractions and Application of this Principle to Optics. (Algarotti, 1737)

5. Newtonianism for Ladies

Algarotti began his book with the following sentence

I am putting the last touches to my Dialoghi, which have found grace in the eyes of the belle Émilie and the savant Voltaire. I try, when near them, to acquire those choice terms, that charming turn of speech with which I should like to embellish my work.

Algarotti illustrated the book with an engraving of Émilie and himself set in a bucolic scene, which represented the Cirey gardens with the château on the right.


IL NEWTONIANISMO
PER LE DAME
OVVERO
DIALOGHI
SOPRA
LA LUCE E I COLORI.
——— quæ legat ipsa Lycoris.
Virg. Egl. X.
IN NAPOLI
MDCCXXXVII

Fig. 3. source Linda Hall Library of Science, Engineering & Technology

The marquise was highly flattered at being placed at the head of the work to represent "*wit, grace, imagination, and science*." The book was published with a title that did not refer to women, leading some to believe that the female branding of the book was a ploy to avoid censorship. Algarotti had to make changes, certainly not improving the text, in the most famous editions following the first. The changes are both in the content and in the expressive form, in order to avoid a further condemnation, or the accusation of harmful work to morals of young people. He eliminated any reference to sensationalist gnoseology and praise of experimental philosophy, every positive judgement of ancient atomism, and every expression deemed excessively free and polemical. The "tone" of research, of direct investigation, the language so close to the daily use of the things, which we find in the first edition of the "Dialogues", is less in the following ones. The civil tension and the true will of renewal, which is easy to detect in the first edition—emphasizes experimental philosophy as a methodology valid in every field, from natural research to political practice—which are lost in a "neutral" dissemination of the only scientific results of Newton.

Condemned by decree of April 1739, the book appeared in the 1744 edition of the *Index Librorum Prohibitorum* (List of Prohibited Books). From 1746, the new prints presented a revised title (the last was *Dialogue on the Neutonian Optics*) and significant variations. Algarotti added a new dialogue, which he envisages to happen several years after the others, and an appendix containing some scientific dissertations. From 1750, Algarotti replaced the Proemio, originally dedicated to Fontenelle, with another dedicated to Frederick II, King of Prussia in which his literary style became more austere and academic. (Salvadé, 2010)

The distinguishing feature of *Newtonianism for Ladies* was that Algarotti presented theory about the nature of light and colours according to Newton's experiments. Algarotti shares, with Galileo and Locke, the same idea about the scientific value of experience, in antithesis with the Cartesian method. In the book, he presented Newton as a follower of the Galilean tradition and the first modern philosopher.

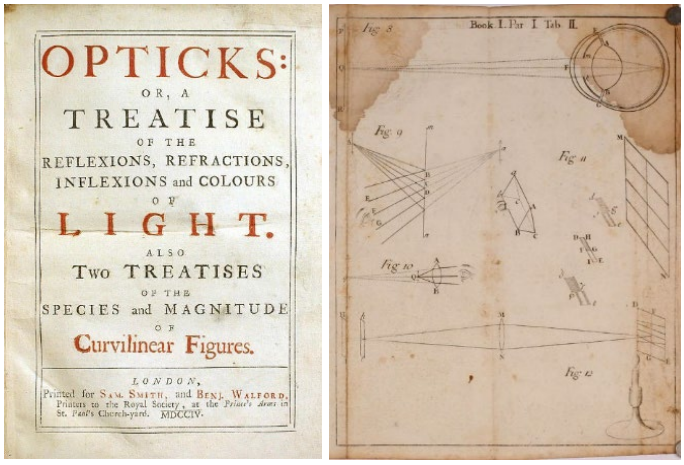

Fig. 4. Newton's Opticks

The description of some of Newton's experiments on the nature of light and colours in the form of a genteel dialogue has great educational value, because it does not demand any geometrical or algebraic knowledge. From this point of view, the literary quotes are totally justified and meaningful.

At the beginning of the first dialogue, Algarotti turns to the Marquise declaiming the following verses:

The sevenfold light
Whence ev'ry pleasing charm of colour springs,
And forms the gay variety of things

From the composition of these seven colours in a direct ray from the Sun arises the white or rather golden colour of Light: that if this direct Ray from the Sun is refracted by a certain Glass called a Prism, these rays of which is composed differing in colour and differ also in degrees of refrangibility.

In fact, Algarotti intends to speak about Optics and in particular wants to explain to the Marquise how light, according to Newton's opinion, is not simple and pure but like each ray of sun is a bundle composed of red rays, some orange colour, yellow, green, indigo and violet.

Algarotti then also explains reflexion and refraction. Reflexion happens by a collision of the globules of light with the solid part of bodies, these globules are repelled back again as a ball rebounds when it is struck against the Earth.

Refraction is caused when the globules of light passing through air, water, glass, meet with the pores and cavities of these bodies, so that the ray, which is only a chain of globules, breaks and turns out of its proper path and takes a different direction from what it had before.

He tells the Lady to think she is in a room, completely in the dark except for a narrow, round glimmer from which a ray of sunshine comes.

At a certain distance from the glimmer, there is a glass prism, which receives through it that glimmer of light.

The prism must be situated so that a face is looking at the ceiling of the room, another face at the glimmer and the third face at the wall facing the glimmer. One of the edges must face the floor.

The ray of the sun, which penetrates the face that looks at the glimmer, comes out of the face that looks at the wall so that the prism refracts it and sends it straight over the wall of the room that faces the glimmer.

The luminous trace is no longer that which the straight beam impressed on the floor.

The trace is white and almost round, while the second is five times longer than the width, it is four-sided and rounded at the ends and the light is broken down into seven colours.

The colours are arranged as follows: first red, then orange, then yellow, green, blue and indigo and finally purple.

Turning the prism, a little around itself the ray of sun becomes more or less oblique to the face on which it falls. Thus, the order of refraction can be changed and the coloured image can be seen rising or falling from the wall. Stop the prism when the emitting ray is equally inclined to the faces of the prism. Then the colours are even more beautiful and bright.

Né il superbo pavon si vago in mostra,
spiega la pompa dell'occhiute piume,
né l'iride si bella indora e innostra.
Il curvo grembo e rugiadoso al lume [2]

6. Conclusion

In Italy, Francesco Algarotti was the first author of a text popularizing Newton's theories. Following the Principles of

Enlightenment, Algarotti, by literary quotes or his own verses, achieved the purpose of disclosing scientific culture to women and lower classes.The civil tension and the true will of renewal, which is easy to detect in the first edition—emphasizes experimental philosophy as a methodology valid in every field, from natural research to political practice—which are lost in a "neutral" dissemination of the only scientific results of Newton. Even today, Algarotti's method of dissemination could help pupils to understand principles of Newton's physics.

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9. Short biography of the authors

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Notes

[1] 1 inch=38 centimeters.

[2] Neither the superb peacock wanders in the exhibition, explains the pomp of the eyed feathers, nor the iris is beautiful and gilds it with its own. The curved womb is dewy by the light

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Light and Colour at the Theatre in Paolo Bini's Works for Francesco De Gregori

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ABSTRACT

In March 2019, the Italian singer-songwriter Francesco De Gregori sang at the Teatro Garbatella in Rome in front of an audience of 230 spectators, according to a choice that has privileged aspects of intimacy and listening. This stage offered the artist Paolo Bini an experimental place for the study of an original and unusual set design. In fact, the environment work *Cromatismo emozionale in ritmo variabile* (Emotional Chromatism in Variable Rhythm), enhanced the involvement of the spectators and free expression of emotions, using bright and iridescent colours.

This contribution is an evidence of how contemporary art - exploiting certain technical rules of theatre performance, through the colour that interacts with light - has cooperated in theatrical communication by enhancing music and sound. More and more in recent years, the sets of concerts are a meeting place between various forms of art and techniques, between music and visual art and where set designers have more and more space to express themselves by appealing to the use of technology. In this case, Bini has not resorted to any technological support, simply leaving to the work/backdrop of a stage the task of creating dynamism to the entire show. Finally, aspects related to the artist's research were also highlighted, placing him in continuity with the history of art and the abstract poetics of the twentieth century.

KEYWORDS Francesco De Gregori, Paolo Bini, Garbatella, Colour, Chromatism, Painting, Abstractism

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1. Introduction

From 27 February to 28 March 2019, the Italian singer-songwriter **Francesco De Gregori** sang at the Garbatella Theatre in Rome in front of an audience of only 230 spectators, according to a choice, desired and sought after by De Gregori himself, who privileged intimacy and listening. This choice concentrated the tone of "confidentiality" that characterizes the twenty concerts in the programme in its title *Off The Record*. The concerts were not recorded and were therefore transformed into a series of unique and unrepeatable moments: “Here lies one whose name was writ in water, said John Keats. Well, these concerts are written on the water”, said Francesco De Gregori who, with his band formed by Guido Guglielminetti on bass and double bass, Paolo Giovenchi on guitars, Alessandro Valle on pedal steel guitar, mandolin and guitars, and Carlo Gaudiello on piano and keyboards, evening after evening played an ever-changing lineup. In addition to his most famous mainstream songs (*La leva calcistica della classe ’68*, *Titanic*, *Alice*, *La Donna Cannone*), he proposed a repertoire of rarely performed songs such as *Festival*, *I Matti*, *Quattro Cani*, as well as *San Lorenzo* or *A Pà* dedicated to Pier Paolo Pasolini. This stage and this concept were offered to the artist **Paolo Bini** as an experimental place for the study of a set design, an original and unusual site-specific environment work. In fact, if normally for a musical concert at the theatre the tendency is to enhance the few instrumentalists on stage and the singer, through colour differences between the mixture of mainly gray and blue light shades, the environment work *Cromatismo emozionale in ritmo variabile* has enhanced the involvement of the public and free expression of emotions in the use of bright and changing colours. Distinctive bright and iridescent colours are in the work of the Italian artist who, since the beginning, has been interested in a research between matter, light, and colour, where the landscape is the subject and privileged object of his work and is reorganised by virtue of the expressive-abstract dictation, which is typical of the experiences of twentieth century art, according to a current and contemporary vision. This vision never disregards the value of painting as an infinitely living language, let alone a "doing" that unwinds in a typically traditional action - if you like.

This contribution is proposed as part of the 15th Conference of Colour, held from 5 to 7 September 2019 at the Academy of Fine Arts in Macerata, and is therefore an evidence to how contemporary art, using certain technical rules of show performance, has cooperated in theatre communication enhancing music and sound with great simplicity and naturalness, in this specific case, although for the lighting of a stage space there are not always valid scientific precepts, through the colour that interacts with the light.

2. Paolo Bini. The landscape, colour, and environment work Cromatismo emozionale in ritmo variabile in the interaction between light and colour

Paolo Bini was born in Battipaglia, in the province of Salerno, in 1984. He studied set design, graduating from the Academy of Fine Arts in Naples in this discipline, and in 2007 he joined the set designer Gerardo Viggiano at the Cinespettacolo del Grancia in Brindisi Montagna, as his assistant. From the very first steps in the world of art, the theme of landscape and colour are at the centre of his interests, investigated first of all from the observation of both environmental and urban nature, and both in terms of landscape and view, to extrapolate, and then emphasize, the colour entities that make it unique and extraordinary, but also particularly attractive to man. As is well known, the landscape in Western artistic culture became a subject of specific interest from the seventeenth century onwards. Think, for example, of extraordinary works on the ideal and classical landscape such as *The Flight into Egypt* by Annibale Carracci, or those by Nicolas Poussin and Claude Lorrain, although previous examples of interest for this iconography - however never the subject - can be found in artists such as Leonardo da Vinci, to whom we certainly owe, with the study of the nuance, one of the first investigations on the nature and perception of colour. Still, think of how nature and colour have always been evaluated by artists as an indissoluble pair, in the proofs of the natural sublime, or in categories such as picturesque, peculiar to the eighteenth century. Finally, consider the Impressionist nineteenth century totally dedicated to the study of light, up to the first experiences of expressionist and then abstract avant-garde, which we can summarize by citing names such as Vasilij Vasil'evič Kandinskij, Paul Klee, Kazimir Malevič, or Piet Mondrian when he says: “Nature (and what I see) inspires me”. About colour, we cannot but remember Matisse, one of the first artists to claim that it was the relationship between colours, in a painting, not forms, that gave it a structure: “Composition is the art of arranging the various elements available to the painter in a decorative manner to express the painter’s feelings... The main aim of colour should be to serve expression as well as possible” [1]. This expressiveness is not so much deduced from the theories of colour, but instead from observation and feeling, unlike other artists who, in the same period of time, took into account primarily the novelties introduced by science. Think of Gaetano Previati who, in 1906, published *Princìpi scientifici del Divisionismo* [2] (Scientific Principles of

Divisionism), a text that certainly influenced the entire Futurist movement and in particular the research of Umberto Boccioni. Think of Delaunay, of the Orphism and his studies on Chévreul, but especially look at the already mentioned Paul Klee, works such as *La luce e molto altro ancora* (The Light and Much More) of 1931, where the main interest of investigation of the artist is clear. It is no coincidence that Klee found himself with Vasilij Vasil'evič Kandinskij, who was undoubtedly a pioneer in his studies of light, form and colour, and in his research into the constant comparison of music and painting, to teach at the Bauhaus where, together, they codified a concept of art that was not only synaesthetic but also symbolic. With a leap through the twentieth century, the abstract approach with the real, with the world, and again with the landscape, is found in the new wind of the Informal and in the very origin of expressive action, and then again, in those experiences, so-called analytical painting, that developed from the 1970s where, having abandoned the discourse on nature, everything focuses on the analysis of the material components of painting, first of all the colour, which thus loses the last referentiality with reality and expressiveness. Paolo Bini faced all this heritage of research and poetry and carried out his own artistic path along the links of expressionism and lyrical abstractionism to finally arrive at the codification of his own personal language which, as we have just said, starts from the initial observation of the landscape, or more precisely from the horizon. This also gives rise to a reflection on the compositional structure of his paintings. Bini visualizes this reflection in the synthesis of vertical or horizontal lines, a sort of grid, in essence, which becomes in his poetics the rhythm of real narrative spaces, intervals characterized only by colour aimed, not only to suggest the residual colours of the landscape, but to solicit empathy and emotional experiences in the viewer. This research was carried out as a result thanks to a first experience in South Africa in 2013, the place where a new consciousness of nature and colour matures, has now become its distinctive feature, but also the ground for a continuous evolution that, in the most recent works, has been pushed into ever more daring and spectacular chromatic experimentations. Although always faithful to his own system of verticals and horizontals, the recent flexion towards thinner lines and the use of fluorescent and brighter colours, is leading the artist to new frontiers of research. On the one hand, the image itself is exasperated and the idea that it is formed according to the unity of the pixel is exaggerated; on the other hand, the increasingly obsessive concentration on colour, on its psychology and on the reactions of people to chromatic frequencies, makes his work something extremely contemporary. The interest of the critics in his work is shown by the numerous and important personal and collective exhibitions and awards that enrich his career. Among the most prestigious awards in 2016 is the Cairo Prize, 17th Edition, while his works are kept in Italy at the Fondazione Donna Regina Museo MADRE in Naples, in the Collection of the Cairo Prize in Milan, and in the collection of the Luigi Di Sarro Centre in Rome. Abroad, at the Leeu Collection of Franshhoek in South Africa and in the same country, at the Public Works Collection of Cape Town. Finally, the performative work *Trovo Luce* was presented in July 2019. This work was created for a public space and as part of an exhibition dedicated to the artist's performance at ISCP - International Studio & Curatorial Program in New York, confirming the artist's interest in the search for light-colour interaction.

Fig. 1. Paolo Bini, Astrazione introspettiva con varco centrale, 2017. Acrilico su nastro carta su tela, cm. 120x120.Ph. © Carlo Ferrara.

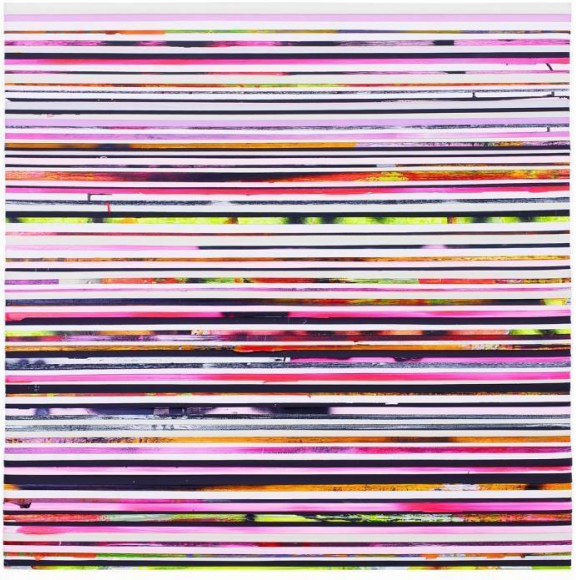

Fig. 2. Paolo Bini, Eden, 2017. Acrilico su nastro carta su tela, cm. 120x120.Ph. © Carlo Ferrara.

The environment work *Cromatismo emozionale in ritmo variabile*, a set backdrop created for the concerts of Francesco De Gregori's Garbatella in Rome, held between February and March 2019, is based on these concepts, in perfect continuity and consistency with the artist's own poetics. However, the artist has challenged himself with this work, not only because it is a large work, but also with the concreteness of a real set backdrop consisting of one cotton cloth of the size of 496 x 950 cm, as well as with the specific needs of a theatre and a specific music performance, deliberately arranged by Francesco De Gregori to create an intimate and confidential atmosphere with the spectators. Past experiences, similar but not equal, of environmental works are not unusual to Paolo Bini. Here we recall, for example, the large wall painting created for the exhibition *Left Behind* at the Royal Palace of Caserta in 2016, a real example of installation painting and with purely scenic sequels where, however, the artist acted directly on the wall. *Cromatismo emozionale in ritmo variabile* imagined by Bini, whose general poetics, as already mentioned, moves essentially around the concepts of emotion and sensation that generate colour, has found, at the Garbatella in Rome, first of all, a semantic correspondence with the concept of the show itself designed by Francesco De Gregori, to be configured, later, not as a traditional work, but as a series of elements capable of embracing the spectators.

The work/backdrop, made with acrylic painting, was therefore crossed by vertical coloured segments of abstract mould that, in the alternation between white and various mostly fluorescent colours with an iridescent character, however affected by black spots, with a wide chromatic scale including red, orange, pink, green and fluorescent yellow, reacted in an extremely pervasive way in the interaction with the stage lights.

Fig. 3. Paolo Bini, Cromatismo in ritmo variabile, 2019, Teatro Garbatella Roma.

More and more in recent years, the sets of concerts are a meeting place between various forms of art and techniques, between music and visual art and where set designers have more and more space to express

themselves by appealing to the use of technology. In this case, Bini has not resorted to any technological support, simply leaving the task of creating dynamism for the entire show to the painting and the scanning of coloured vertical segments hit by light beams.

Taking into consideration some of the possibilities underlying the role played by the lights, i.e. visibility, revelation of forms, vision and creation of an atmosphere, *Cromatismo emozionale in ritmo variabile* has shown itself properly in its form of a painting, supporting the same proscenium but managing at the same time to subvert the traditional set relationships and frontality with the spectators. In fact, the possible degree of flattening of the scene has been cancelled out by the performance characteristics inherent in the work, thus contributing in the interaction between colour and light, to restore depth to the place of action, generating three-dimensionality also to the stage presence of the musicians and to space.

As can be seen from the sketches - renderings that describe the three-dimensional scene, in *Cromatismo emozionale in ritmo variabile*, Paolo Bini has composed a sequence of very precise colours, taking into account the background because horizon, or the infinite where the eye and imagination move. All this, harmonizing and dialoguing with the lighting design by Andrea Coppini, light designer of Francesco De Gregori who, at Garbatella in Rome, used mainly lead lights from above, so as to obtain a strong contrast, albeit with some compression effect, side lights to enhance the shadows of the musicians on stage, so as to rebalance the effect of crushing and encourage a sort of three-dimensional modelling but also encourage an emotional atmosphere, and grazing lights, or beams very tangent to the subjects, in order to enhance their presence. In addition, sometimes to support the silhouette effect and return a fascinating halo in the contours and depth of the scene, a light from behind was used to help detach the subject from the background. Finally, to meet specific theatrical needs, warm and cold lights were used, once again to give prominence to the objects and create enveloping atmospheres or to make the contours - in this case of the musicians - clear and precise, taking into account, in the final analysis, the fixity and the very few moments of mobility by the nature of this show. It is precisely in the interaction between the lights and coloured backdrop that we have obtained an even more spectacular emphasis than that which the lights alone or a black backdrop would normally have given back. Through light, in fact, *Cromatismo emozionale in ritmo variabile* is activated. Under conditions of natural radiation, in fact, the work has the characteristics of a classic painting of the artist, but it is in the reaction to light of fluorescent colours that it changes features, amplifying every aspect of the atmosphere and environment. *Cromatismo emozionale in ritmo variabile* reacted to the presence of white lights by showing its dominant colours, obviously as a result of reflection and crossing, to that of coloured lights (blue, green, purple, red) absorbing and intensifying the dominant colour of the light itself. Consequently, the lights produced by point sources, in meeting the environment work of Paolo Bini, due to the effect of reverberation, have transformed it into its own source of light. A diffused and soft light source where the chromatic surface responds to opaque hues, mirrored where there is a dominance of fluorescent colours and which, in their combination, have chromatically influenced all the space around, including the floor.

The artistic literature on colour, and that on colour and light, as is well known, is vast. It is certainly to it that Paolo Bini looks, and it is through it that one can see the motives behind his research and consequently those of *Cromatismo emozionale in ritmo variabile*. Certainly, the use of colours by the artist makes in any work, so the intense introspective value he assigns to it, becomes an interpretative of a "rhythm" or an "out of rhythm" mirroring that which accompanies the individual throughout his life. His works, in general, are always portions of space that welcome the lights and shadows of the surrounding, but it is in an environmental dimension, such as that of the Teatro La Garbatella precisely, in the study of colours to the reactions of theatrical lights, then and in this case, in the interpretation of a show, which shows how this research, like contemporary art, can be a convincing grammar at the service of music and emotions. Bearing in mind that light is communication, since in a performance it is that element capable of mediating the relationship between space and the spectator's perception, it could be said that, by interacting with *Cromatismo emozionale in ritmo variabile*, it behaves, in this case, more than like a brush. This environment work, which never loses its pictorial character, precisely because of this shows the full potential of how different knowledge and languages, respect and amplify the symbolic matrix that has always accompanied the theatre. *Cromatismo emozionale in ritmo variabile*, therefore, highlights this aspect, suggesting how tradition can be innovative despite a future marked by virtuality.

Fig.4. Paolo Bini, Cromatismo in ritmo variabile, 2019, Teatro Garbatella Roma. Ph. © Daniele Barraco

3. Conflict of interest declaration

The undersigned Maria Letizia Paiato declares that the contribution Luce e colore a teatro nell'opera di Paolo Bini per Francesco De Gregori of which she is the author is not subject to any actual or potential conflict of interest, including financial, personal or other relationships with other persons or organizations within three years from the beginning of the work presented and that it could influence inappropriately or be perceived to influence their work. Nothing has affected my objectivity. Therefore, there are no potential conflicts.

4. Funding source declaration

The undersigned Maria Letizia Paiato declares that no funding or research grants have been received in the course of study, research or collection of the manuscript nor to have received any financial support for the conduct of the research and/or preparation of the article.

5. Short biography of the author

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Notes

[1] The citation is from Barr Jr A.H., *Matisse: His Art and His Public*, New York 1951, p. 119.

[2] Previati G., *Princìpi scientifici del Divisionismo*, Fratelli Bocca Editori, Turin 1906.

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Floral decorations and colours in Naples. The case of Villa Pappone in Posillipo

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ABSTRACT

The contribution investigates some examples of the architectural heritage developed in Naples with the expansion and regeneration plan of the city between the late nineteenth and early twentieth centuries, with particular reference to villa Pappone in Posillipo, identifying the decorative features of the Art Nouveau that have given expressiveness to architecture. The typological innovation of the so-called Floral style spreads in Naples mainly in the newly urbanized districts of Vomero, Posillipo, Parco Margherita, and Chiaia, through the construction of villas and palaces that strongly characterize the urban context; some of these examples are also isolated in some urban areas or overwhelmed by successive buildings.

The Liberty in Naples is linked to the works of Adolfo Avena, Giulio Ulisse Arata and Gregorio Botta, who operate an integration between ancient and modern through the new architectural language, which finds its maximum expression in the use of glass surfaces, made with refined decorations and chromatic variations, capable of creating interesting colour reflections and suggestive effects in the diffusion of light. The villa designed by Gregorio Botta in 1912 for Francesco Pappone in Posillipo is an emblematic example of the Neapolitan Liberty, which refers to the models in vogue in the countries of central Europe. The contribution proposes a distribution scheme of the decorative elements of the main facade of the villa classified according to the material used, and their graphic restitution through image-based modelling techniques, in particular of the distinctive entrance canopy made by ornate ironwork and polychrome glasses and the hand-painted majolica tiles bands that run through the building on various levels.

KEYWORDS Floreale Napoli, Polychrome stained glass design, Colour representation, Structure from motion, Facade drawing, Villa Pappone Posillipo, Image-based modelling

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1. Introduction

The production of the Floral Style in Naples spreads in association with the expansion and regeneration plan of the city of 1885 and with the 25 July 1912 law issued for the completion of the plan [Alisio 1987]. It is in the newly urbanized district of the Vomero, Posillipo, and Chiaia hills that the typological and formal innovation of a new architectural language spreads in Naples, which, as is known, developed in Europe between 1880 and 1910 with different names and expressive features according to the countries involved. In France and Belgium, the new architectural language is called *Art Nouveau*, *Modern Style* in Great Britain, *Modernisme* in Spain, *Jugendstil* in Germany, *Sezessionstil* in Austria, *Floreale - Floral Style* or *Liberty* in Italy, named after the London department store of Arthur Lasenby Liberty.

In Naples, the Floreale relates to the works of numerous architects including Adolfo Avena, Giulio Ulisse Arata, and Gregorio Botta who, intervening in compliance with the new building regulations, become the spokesman for a more modern architectural culture that sees an integration of architecture and decorative arts with the abandonment of all axiality and symmetries both in plan and in elevation [Martone and Giugliano 2019]. Floral motifs, delicate ribs, vegetable designs define mouldings, windows, entrances, string courses using new materials, such as glass, iron, and majolica, bearing a set of colours characterizing each component [De Fusco 1959].

2. The Floreale in Naples

In Naples, as well as in other European cities, the Applied Arts movement preceded the Floral style building. With the patronage of Prince Filangieri, the Industrial Artistic Museum was established, whose didactic-industrial activities were highly appreciated for their efficiency and modernity by foreign scholars and art masters. Next to the museum, that collected works of local and foreign tradition, were also born ceramic workshops as well as cupboards, bronze casting, and lithography, including the Southern Artistic Figulina, founded in 1902 by Giovanni Tesorone, which represented the first artistic-industrial initiative linked to the development of the Liberty in Naples.

The Venice Exposition of 1903 was one of the most important events. Under the direction of Ernesto Basile, a leading figure in modern Italian architecture, the Sale del Mezzogiorno were set up, which displayed Neapolitan and Sicilian products. The large turnout to the international Venetian exhibitions, as well as contacts with Basile, determined the success of the Neapolitan Floreale. Not surprisingly, the first Art Nouveau works were internal arrangements for nineteenth-century buildings, such as the windows of the Grand Hotel de Londres and Santa Lucia furnished with floral elements by the architect Giovan Battista Comencini [De Fusco 1959].

The first area interested by Floral settlements in Naples is the Posillipo hill, which separates the gulfs of Naples and Pozzuoli. Characterized by significant orographic differences in height and very suggestive for the views it offers on the Gulf of Naples, the hill was part of the expansion program of Naples designed within the 1914 Town Plan by Francesco De Simone, also the author of some buildings of the Floreale. De Simone defined the new building area, which included the western and eastern declivities of the Posillipo hill up to the slopes of the Vomero, as "the garden city of the West", in which small residential settlements developed along the connection routes to the Vomero. A large and panoramic residential park, called Carrelli, initially distinguished by Floral style architectures, was built along a serpentine road which, only after many years from its construction, was connected to the above Via Petrarca, undergoing significant alterations. Outside the Carrelli park, along the Salita di Casale di Posillipo, which connects to Via Manzoni, we find the elegant Villa Pappone and a little further on Villa delle Rose, significant examples of the Floral style in Naples.

The second area in which the Floral building industry develops is the Chiaia hill, a central-western area between Via dei Mille, piazza Amedeo and Via Parco Margherita, included between Corso Vittorio Emanuele and the ancient "*Real Passeggio di Chiaia*". Here too, the design of the new district shows an "organic" layout due to the orographic nature of the area, not suitable for a nineteenth-century checkerboard-like design like those in the lower city.

Each of these streets differs from the others, thanks to the presence of different building types. This is the case, for example, of Via del Parco Margherita, the Liberty street by definition, along which there are villas and buildings of inestimable architectural value with colourful canopies and majolica decorations. On Via dei Mille and Via Filangieri, however, the floral arrangement is present with massive and imposing buildings, such as the case of Palazzo Mannajuolo.

Another area involved in the expansion plan of the city was the one consisting of the plateau and the slopes of the Vomero hill, where the new constructions follow the canons of the new Floral language. Although on the Vomerese plateau it was possible to create a new settlement with a checkerboard-like layout, on the

southern slope of the hill, the new road system built respected the landscape and the orography of the place.

Along Via Luigia Sanfelice, Via Gioacchino Toma, and Via Filippo Palizzi there is a more significant presence and continuity of Art Nouveau buildings, some of which designed with a double entrance; a first entrance towards the valley and a second one towards the mountain with a particular bridge structure to adapt to the level irregularities of the site [De Seta 1999] (Fig. 1).

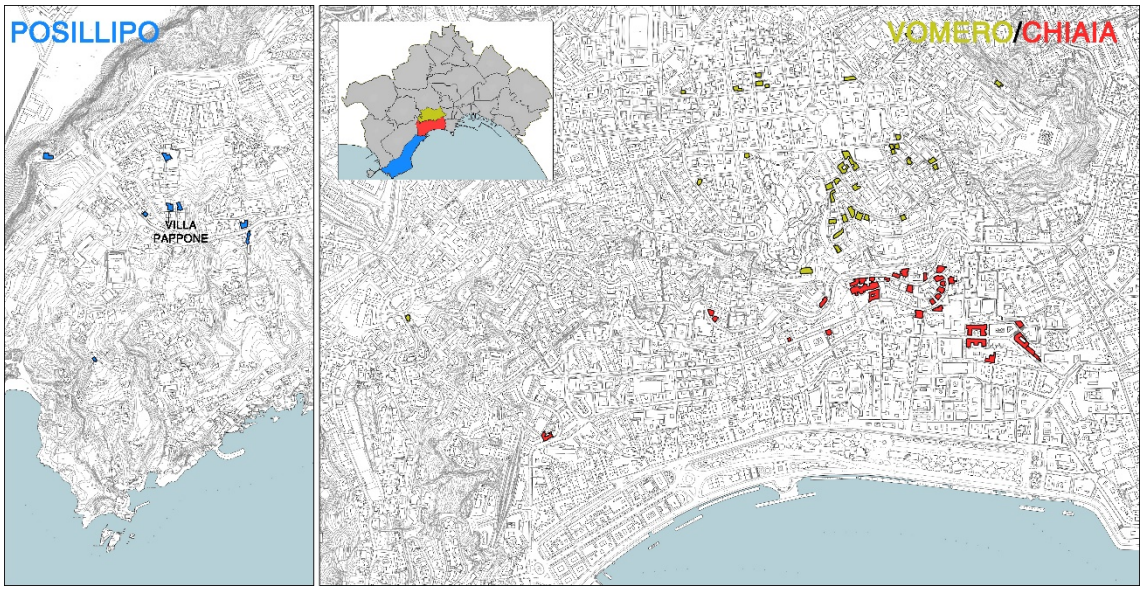

Fig. 1. Cartographic map of the Posillipo, Chiaia, and Vomero districts with an indication of the most significative Floral style buildings in Naples.

3. Light effects through coloured windows and majolica surfaces

The Liberty/Floral style finds in architecture one of its most eloquent expressions with the creation of external surfaces in majolica or made by ironwork and glass, almost exclusively opaque. Entrance canopies, verandas, and windows of villas and buildings manufactured using the stained-glass technique, show refined decorations and chromatic variations able to create interesting plays of coloured reflections and suggestive effects in the light diffusion interacting with the external environment of the street. The glossy surface of the majolica of polychrome decorations that cover numerous Floral palaces in Naples makes the colours bright, producing unusual chromatic effects.

In Naples, it is possible to observe many examples in which both surface treatments coexist, such as the facade of the former Grand Hotel Eden, today Villa Maria, designed by Angelo Trevisan, admirable from Piazza Amedeo, in which chromatic contrasts underlined by a careful choice of materials such as brick, glass, and majolica, contribute to give a suggestive oriental appearance to the building (Fig. 2a/b). Another example of liberty with oriental features is the salmon pink building in Via del Parco Margherita 57, in which polychrome majolica panels in green and yellow pastel colours surmount single-lancet and double-lancet windows with a low arch. At the same time, a blue-green string course at the ground floor wraps around the entrance porch with a balcony above. On the main and side facades open polychrome verandas in metal and glass, in which simple geometrical patterns recur (Fig. 2c/d).

Of classic shapes is a colourful iron and glass canopy that covers the entrance of the baroque building at number 38 in Via Parco Margherita. The formal rigor of the canopy design, based on a combination of squares, rectangles, and semicircles, also reflects in the rigorous choice of primary colours, yellow, red, and blue, which create a harmonious primary contrast based on a quantitative correlation. The predominance, in fact, of the yellow glass with the red in the middle, emphasised by an elongated shape, ending with two semicircles, increases the brightness on the entrance area of the building. The small window layout, in which each geometric figure is highlighted by the band of the binder between the plates, shows an explicit reference to Mondrian. In contrast to the schematic design of the glass, it is a rich wrought-iron decoration that runs along the contour of the canopy with a succession of small palmettes that echo the acroteria of ancient temples (Fig. 2e/f).

An emblematic example of the production of the Floral style in Naples is the Cassa Armonica, a bandstand built in 1877 to a design by Enrico Alvino in the Villa Comunale, where the city's musical band once performed [The Italian illustration 1878]. An elegant cast-iron structure with a circular plan is covered by a dome with triangular segments, each composed of rectangular strips of opaque white glass, which rests on a polygonal lattice tholobate, supported by slender columns on which round arches open. A coloured bichrome perimetral canopy, formed by the alternation of blue and yellow glass, complements the design of the polygonal structure, protruding from the volume of the bandstand. The coloured crown, a diaphragm towards the outside, enhances the white of the cuspid dome, which becomes an incandescent source of light when brightened by the sun. A recent renovation has restored the original colours of Alvino's project, and the entire structure in its lightness continues to be a strongly characterizing element of the surrounding environment (Fig. 2g/h/i).

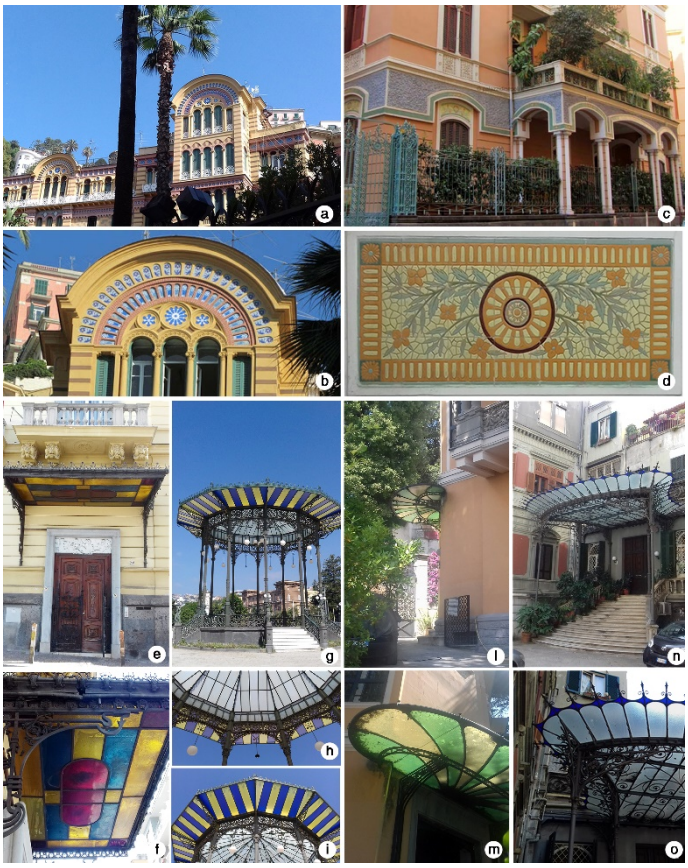

Fig. 2. From above: Villa Maria, ex Hotel Eden (a, b); below: building in Via Parco Margherita 57 (c, d). Below: the canopy of the building at number 38 in Parco Margherita (e, f); the Cassa Armonica in the Villa Comunale (g, h, i); canopy of the entrance of Villa Irene, formerly Villa Ascarelli (l, m); entrance canopy of Palazzo Bile (n, o). During the photographic survey, the pictures were taken with a reflex digital camera with colour temperature control in automatic mode.

Villa Irene, formerly Villa Ascariello, is full of floral friezes that surround the entire volume of the yellow straw building, built in 1913 on a project by Adolfo Avena on the slopes of the Vomero hill, along the hairpin bends of Via Palizzi, at number 41 and 43. A distinctive curved canopy in iron and glass, manufactured with sinuous green and yellow segments, opens onto the entrance allowing the light to penetrate, which conveys green-yellow reflections in continuity with the colours of the surrounding garden [Mautone et al. 2011] (Fig. 2l/m).

Majestic in structure and shape is the stunning liberty canopy in white and blue glass that distinguishes the internal elevation of Palazzo Bile located in vico della Cavallerizza 38, full of floral decorations on a neo-Renaissance structure. Still within the internal courtyard, at the entrance, there is a large veranda in yellow and blue polychrome glass (Fig. 2n / o).

4. Villa Pappone in Posillipo

Representative of the new architectural language of the Neapolitan Liberty, Villa Pappone, designed by Gregorio Botta in 1912 on behalf of the Neapolitan merchant Francesco Pappone, is located on the Posillipo hill, at number 5 in Via del Casale. Referring to the models of the countries of central Europe, such as some buildings in Prague, the villa is characterized in the main facade by a distinctive canopy, in iron and white and green bichrome glass supported by bronze griffins [Palaces of Naples 2019].

Wrought iron balustrades reproduce floral motifs with different designs on each floor, also present in the decorations of the window mouldings and in the corbels that support the balconies. Original decorations such as the majolica string course will be proposed by other authors in some coeval constructions on the Vomero hill. The villa, built with a wealth of materials, represents a unique example in Neapolitan production, which still suffers from the influence of nineteenth-century eclecticism (Fig. 3) [De Fusco 1959].

In the following paragraph, we propose a critical analysis on the facade of the villa, which highlights the decorated majolica surfaces, those treated with wrought iron, and the entrance to the building. The latter, considered as a single element, is composed of the bichrome glass canopy, and a luxurious wrought iron frame, which starting from supporting the canopy, comes together in large volutes as a balustrade towards the marble steps arranged in a shell. A photogrammetric survey with accurate restitution of the

portal highlights the iconic curvilinear shape of the shelter, which finds a formal correspondent in the arrangement of the stairs and the texture of the railings.

Fig. 3. On the left: plan of Villa Pappone (Fusco 1959). Top right: photo gallery of the facade. Bottom right: the entrance and the large staircase.

4.1 Geometry and colour through the image-based survey of the decorative elements

To understand, capture, and represent the decorative elements of villa Pappone, we used an integrated survey methodology, with the use of both digital and direct tools [Cundari 2012].

The acquisition of metric data through Structure from Motion (SfM), performed with the software *Metashape*, as well as the direct survey, and the orthorectification technique, allowed the interpretation of the distribution scheme of the decorative elements of the facade, the modelling and the representation of the shelter entrance, up to the drawing, by way of example, of one of the majolica bands that characterize the elevation [Sardo et al. 2011].

Villa Pappone, one of the best preserved examples of Floral style in the city of Naples, is characterized by the luxury of the decorative elements, declined through thoughtful use of different materials, and by the attention to the design and the chromatic combinations, which not only concerns the outside part but it continues organically inside the building. The distribution scheme of the elevation offers a summary of the distribution and consistency of the decorative elements of the facade examined (Fig. 4).

We first analysed the decorative apparatus according to the material used- majolica, iron and glass - and subsequently mapped it according to the position on the facade. Besides the entrance glass canopy, single and strongly characterizing element of the main facade, the hand-painted majolica and the wrought iron balustrades are distributed in singular bands, characterized by a different design at each level, which run all over the building.

The orthophotos obtained through structure from motion, suitably scaled thanks to the data deriving from direct survey, provided the basis for the redesign of the shelter and of the entire iron structure, in plan and in elevation (Fig. 5).

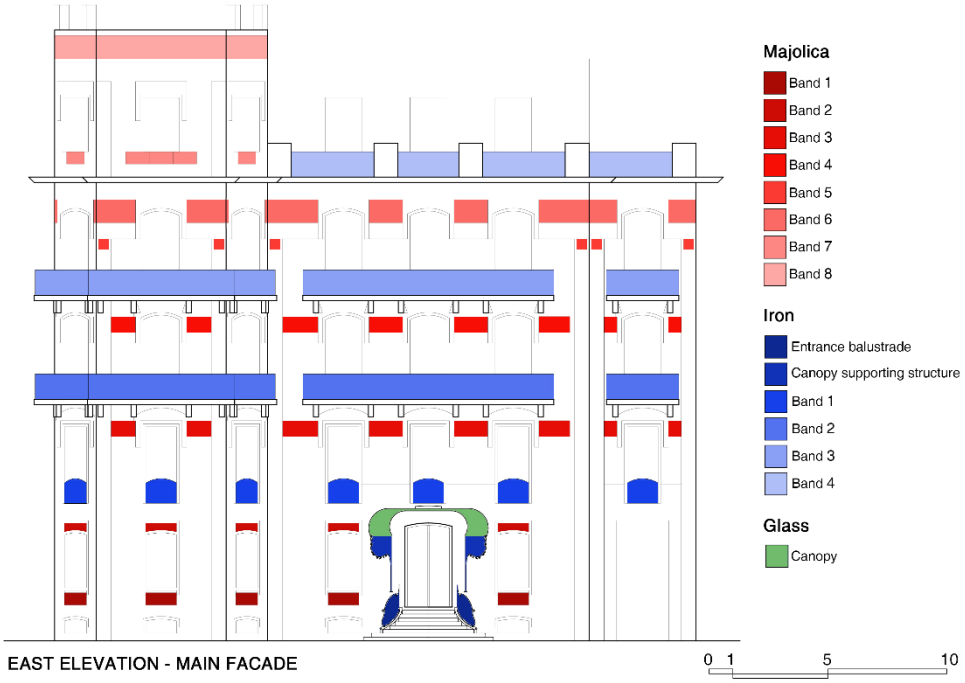

Fig. 4. Distribution scheme of the facade of Villa Pappone with indication and position of the decorative elements declined according to the material.

The shooting of the images used to create the image-based 3D model of the entrance with its rich canopy, with white and green opaque glass, required specific climatic conditions, in order to avoid light reflections, incompatible with Metashape difficulty in working with transparent objects, mirrored or reflective surfaces.

For the photos, we used a Nikon D5200 SLR, with an APS-C 23.6x15.7 mm sensor, which mounts Nikkor AF-S DX 18-55 mm lens, without using a tripod. We took about 50 shots by rotating 180 degrees around the object. The images have been aligned within the software with "ultra-high" accuracy [Foschi 2015].

We took the shots in overcast conditions, obtaining images with a uniform exposure, free of bright reflections, and drop shadows. Even so, several attempts were required, diversifying both the number and order of the shots, before being able to obtain the point cloud used to generate the mesh surface and the photographic texture, which, applied to the model, allowed to generate the orthogonal views.

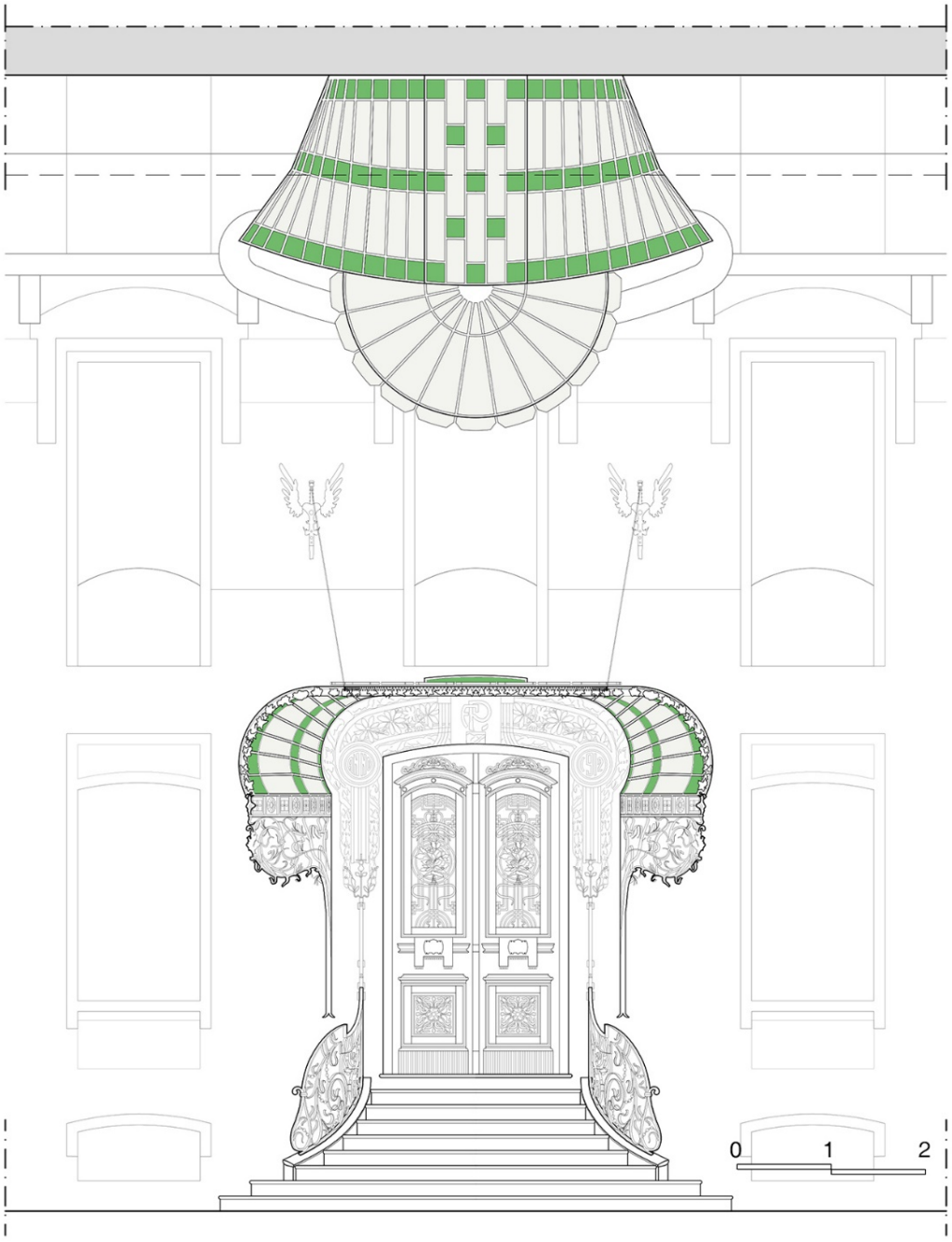

Fig. 5. Plan and elevation of the entrance portal with the wrought iron canopy with two-coloured glass, original scale 1:50.

One aspect that proved to be particularly interesting in this phase of the work was the comparison between the orthogonal view of the model obtained and a photograph of the object. (Fig. 6).

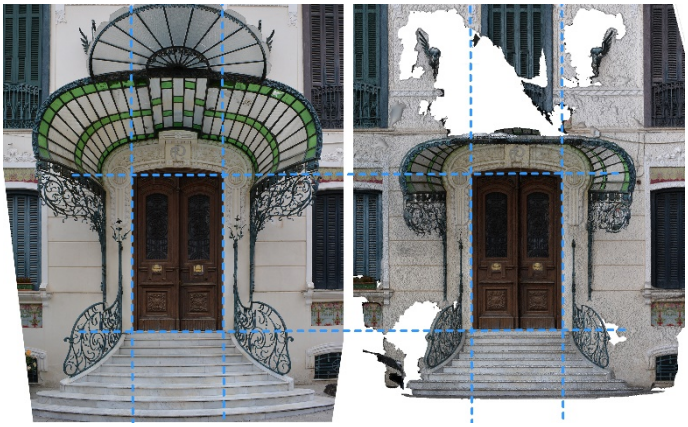

Fig. 6. Comparison between a perspective view from a photograph of the canopy and the orthogonal view of the textured model obtained with photogrammetry.

The 3D photogrammetric model highlighted the altered perception we have of the canopy. In the perspective view, the canopy appears more soaring and slenderer than the orthogonal view. This feature is stressed by the level of the entrance to the building, which is at a higher altitude than the observer; hence the canopy is perceived from a rather low point of view.

The use of the structure from motion has, therefore, allowed the representation of a very complex object and its peculiar characteristic, which would otherwise have been perceptible only thanks to the original project drawings, in orthogonal projections, or subsequent surveys.

Finally, we terminated the analysis of the decorative elements with the study of the majolica bands. We applied the adopted methodology to the band of the ground floor, but it could apply to all the other bands of the building, and, in general, to other decorative majolica elements on other buildings. The digital photographic survey with colour-temperature control allowed a reliable colour reproduction of the areas examined (Santopuoli and Seccia 2008).

The images were captured in RAW format with the same Nikon D5200 SLR camera. We used a calibration target (colour checker), which uses the NCS-Natural Colour System for radiometric references, which come in the form of colour boards. The use of the color checker allowed, in the post-production phase with the Adobe Lightroom software, to balance all the images created in the campaign phase and obtain a more faithful correspondence between the colours of the real object and the colours of the image.

The colours acquired using the color checker were used as a gold standard for experimentation on the use of low-cost equipment for the acquisition of colour. In parallel with the photographic survey, the sampled colours were also acquired through the use of Color Grab, an application for smartphones that allows the selection, capture, and recognition of colours through the camera of the mobile phone (Fig. 7).

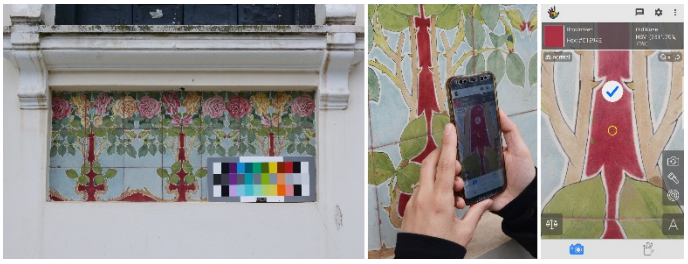

Fig. 7. The colour acquisition phase: on the left, the majolica band photographed with the colour checker; on the right, the experimentation carried out with the smartphone application.

For the re-drawing of the floral motif, we selected a high-resolution photo of the majolica band, which was orthorectified with the software RDF Didattica, using the metric data collected on-site.

All the data collected allowed the creation of a summary board (Fig. 8), in which it is possible to observe the results achieved. In particular, as regards the colour survey with the two described methods, the values of the areas selected for sampling are expressed in RGB, indicated with capital letters.

The synoptic board combines colour with photography and drawing, and could be used as a basis for a critical reading of the decorative apparatus in architecture useful for cataloguing, virtual applications, or reconstruction in case of loss.

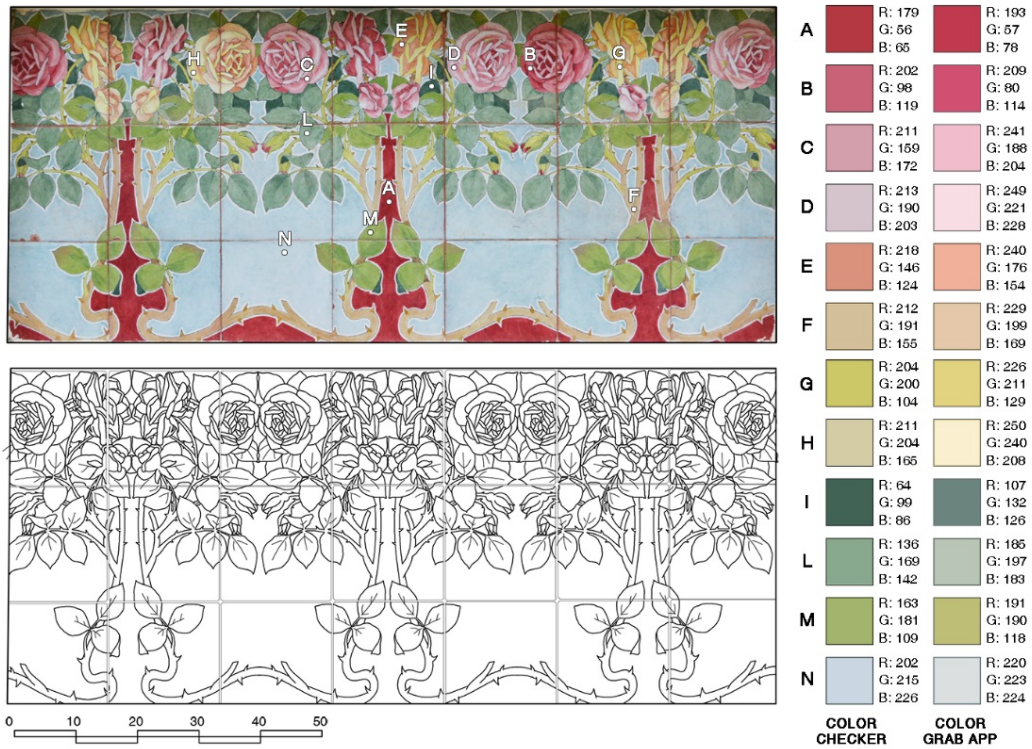

Fig. 8. Synoptic board of the study of the hand-painted majolica band of the first level. Above: orthorectified picture; below: graphic restitution; right: colour matrix. In the first column, the gold standards obtained with the digital photographic survey and the use of the colour checker, in the second the results obtained with the Color Grab application. Even if there is a great visual similarity, due to the automatic balance of brightness that the camera of the mobile phone implements, the second results are not perfectly responding to the reference data.

5. Conclusions

In addition to promoting the knowledge of an asset through the tools of survey and drawing, this study aims at projecting the architectural detail, analysed according to its geometric, formal and chromatic matrix, on the urban scale as an element that contributes to the creation of the image of an urban context. It is hoped that this investigation methodology will then be reflected in broader analyses always aimed at critical documentation for the conservation and protection of the architectural heritage.

6. Declaration on conflict of interest

The authors declare that there is no conflict of interest, real or potential, including financial or personal relationships with other people or organizations, in the three years since the presentation of this work, which could inappropriately influence the results of the research carried out.

7. Declaration on funding sources

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The contribution comes from a widely shared research work; however, paragraphs 1-3 and 5 and figures 2, 3 are by Maria Martone, while paragraph 4, the drawings, and figures 1, 4-7 are by Alessandra Marina Giugliano.

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Maria Martone - Architect, Researcher at the Department of History, Drawing and Restoration of Architecture, Sapienza University of Rome, aggregate professor of Architectural Drawing I with Laboratory and Digital Representation at the Faculty of Civil and Industrial Engineering of the Sapienza University of Rome, carries out her activity of research on the theme of the representation and documentation of architecture, the city, and the territory.

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communication of the results obtained through three-dimensional virtual models.

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Food waste: potential bioresource for the colour of polymers

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ABSTRACT

The paper proposes the results of the research carried out by the authors on the theme of sustainable product design starting from the material component. In this context, there is a significant link between bio-materials and their chromatic value, originated by the pigment of natural origin, which is mainly responsible for the aesthetic characterization of the product. To support this thesis, a methodological approach has been adopted, developed in two phases: the first is critical - analytical (desk) and identifies the framework of the research and the state of the art; the second is applicative - experimental (field) and proposes some original experiments that include both the definition of new polymeric materials, obtained by adding waste coffee and sea urchins, and the characterization of optical and chromatic qualities, also conducted through technical tests instrumental mechanical strength.

The results of the research arrive at hypotheses of mechanical and optical characterization, however the scalability of the results to the industry would require the use of appropriate instrumentation in the preparation phase of the materials (in this phase of study they were composed through an artisanal approach).

KEYWORDS Food waste, Organic colour, Bioresource, Sustainable product design, Digital manufacturing

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1. Introduction

The paper proposes the results of the research carried out by the authors on the theme of sustainable product design starting from the material component (Di Roma et al. 2019). This research was carried out in the Design_Kind research and teaching laboratory, with the collaboration of the company Crea 3D and the mechanical testing laboratory of the DMMM Department of the Politecnico di Bari. In the field of product design, there is a significant link between bio-materials and their chromatic value, originated by the pigment of natural origin, which is mainly responsible for the aesthetic characterization of the product. To support this thesis, a methodological approach has been adopted, developed in two phases: the first is critical - analytical (desk) and identifies the framework of the research and the state of the art; the second is applicative - experimental (field) and proposes some original experiments that include both the definition of new polymeric materials, obtained by adding waste coffee and sea urchins, and the characterization of optical and chromatic qualities, also conducted through technical tests instrumental mechanical strength.

The logical bases of the research are based on the need to offer a critical contribution to the reflection of design, which on the one hand is measured by the theme of environmental pollution associated with the production and use of synthetic dyes, on the other hand defines a new phase of material culture that is based on the (re)acquisition of an aesthetic sensitivity associated with natural materials, with particular reference to those obtained using waste from the food and non-food sectors of the agri-food (Scarcelli 2017).

With reference to the state of the art of the artistic industry, the paper shows how colour has always played a fundamental role in describing the link between the aesthetic sensitivity of a civilization and the technical means at its disposal (Kubler 1976): the culture of colour is the synthesis of scientific and technological innovation and the artistic sense of time. It is argued that in the "chain of time" that links colour to material culture, humanism and the first industrial revolution have impacted with profound changes.

With reference to the current scenario, the development of a new approach to the theme of color as a material that supports the growth of green chemistry through experimentation and self-production of bio-materials is highlighted.

2. Return to the origins of the material colour

In the history of art and artistic manufacture, colour takes on a primary role, since each civilisation, starting with the first representations on the rocky walls of the Lascaux caves, has been characterised by its own culture of colour. Scientific discoveries and technical innovations accompany the evolution of the chromatic world in art, translating into tastes and styles shared by the material culture in the most common objects of use, from pottery to clothing. Coloring the material means knowing how to masterfully manipulate pigments, tints and dyes; it means knowing ancient recipes and procedures to be skilfully adopted on different supports. In the ancient world, this science had a precise name, before becoming chemical: Alchemy.

Until the dawn of the fourteenth century, color was a priority in art, evident in the recognized expertise of the artist in the preparation of colored powders, like the craftsmen: the color was produced in the workshop, with processes of manufacturing of organic and inorganic materials made available by the local land.

"This is the why the grinding of a colored powder may affect its hue - a phenomenon exploited by the artists of the middle ages, who controlled the shade of a pigment by the degree of grinding" (Ball 2003).

Among the Guild of Arts and Crafts of Florence, in the '300 painters chose to join the Art of Medici and Speziali precisely because of the presence of pigments and dyes in their shops.

Humanism led to a separation of art from technique, of intellectual activity from manual activity, and this led to a greater attention of artists to the role of drawing at the expense of color, which remained an exclusive activity of craftsmen, especially ceramists, glassmakers, goldsmiths and tailors: the pigments were no longer processed by painters but purchased ready by traders, in increasingly wide color ranges. The advent of the Industrial Revolution, in addition to determining new market needs and new quantities to be satisfied in the consumption of goods of use, introduced the chemical industry of colorants into the artistic world, able to produce synthetically in the laboratory products cheaper, in practical tube packaging, and especially available in colors until then unimaginable. The colour naming, previously associated with the material origin, is identified by a number perfectly corresponding to its reproducibility according to artificial processes: red, for example, is no longer cinnabar, carmine or purple but, choosing the colour coordinates in CMYK, becomes 0-80-100-0, 0-75-42-1 and 30-100-100-0. In other colour systems it is possible to obtain other codes which, however, do not tell us anything about the colour or its history (Di Roma and Scarcelli 2017).

Another fundamental aspect of modernity is represented by the affirmation of the solid colour, which underlines the need to standardise and make constant the colour of a material in all its consistency, highlighting the artificial character of

the perfect industrial product against the inconstancy of the imperfect handmade product. "*La frequentazione dei linguaggi industriali comporta infatti che del colore oggi predichiamo prevalentemente la tinta… quando diciamo "tinta", diamo per scontato che sia unita. Insieme ai pigmenti sintetici, quest'idea di compattezza è forse la vera e più importante novità del mondo moderno*" (Falcinelli 2017).

3. Research Framework

The theme of colour associated with industrial products is fully integrated into the history of industrialism and identifies the area that has given rise to the development of the contemporary chemical and pharmaceutical industry.

"*Il maggior sforzo della chimica industriale fu quello di produrre tinte derivandole dalle scale coloriche di quelle naturali già selezionate dal gusto e dall'occhio, ma imponendo, infine, quelle prodotte come più convenienti ed eliminando di fatto quelle più rare, care e di difficile produzione*" (Brusatin 1999). As far as the development of the material is concerned, there is a progressive substitution of the raw materials of organic origin with the polymeric materials of fossil matrix and by chemical synthesis.

"*I coloranti sintetici, vengono facilmente inglobati nella massa plastica durante il processo di stampaggio; ciò fa si che il colore diventi il carattere distintivo del design del tempo, che dall'imitazione dei marmi e madreperle passa a sapienti "urli" cromatici che denunziano la loro artificialità, spesso ispirata all'uso ardito dei colori dei Fauves; agli inizi degli anni '30, la Catalin Corporation, la più importante ditta statunitense a produrre oggetti in resine fenoliche fuse, comprendeva 200 tinte, dai colori compatti e pastello a quelli traslucidi e perlati*" (Ferrara 2012).

On the other hand, today, the theme of sustainability applied to materials and products opens up a new phase of reflection in design that goes hand in hand with developments in the so-called green chemistry industry. In this context, the contribution of scientific research on bioplastics is of great importance: these, in fact, give back to the reflection of design the chromatic qualities of the material in its natural meaning. In particular, the "artisan" production of the product from the material defines a new field of experimental research and the self-production of the material (Rognoli et al. 2015) thus becomes an indispensable moment in the definition of the new product. A new dialectic is established between material and product: one influences language, the other influences the technical performance of the product. Below is a selection of case studies identified during the desk phase of the research that defines the framework of the proposed research: the main assumption is the aesthetic value of the bio-based polymer, rather then the technical performance, this in order to define and develop a new sensibility on color.

3.1. *Shellworks*

This is a project carried out by Ed Jones, Insiya Jafferjee, Amir Afshar and Andrew Edwards of the Royal College of Art and Imperial College of London that develops a system of machines and instrumentation suitable for the extraction of chitin from the exoskeleton of crustaceans. The aim is to produce biodegradable and recyclable disposable packaging from crustacean waste (Fig. 1). Chitin is a biological polymer that, when mixed with vinegar, produces a bio-plastic. The chromatic gradient obtained is the result of the different type of vinegar used and the different dosage of the components, which is also associated with a gradient referred to the optical clarity of the material and the different specific thickness.

Fig. 1. Shellworks (2019) at the Royal College of Art and Imperial College London by E. Jones, I. Jafferjee, A. Afshar and A. Edwards. Bioplastic based on vinegar and chitin extracted from the shell of crustaceans. Image courtesy: www.dezeen.com/2019/02/22/shellworks-bioplastic-lobster-shell-design)

From scientific literature it is evident the wide interest in chitin and its main derivatives (chitosan), because this new family of biological macromolecules shows excellent proprieties such as non – toxicity, ability to form film, biodegradability, biocompatibility. All this aspect as defined a wide field application: in the field of medicine, food, biotechnology, agriculture and cosmetic industry (Alabaraoye E. et al. 2017).

3.2. *AlgaeLab*

This is a laboratory that consists of a structure for the cultivation, harvesting and drying of algae for the production of starch suitable for the production of bioplastics (Fig. 2).

Fig. 2. AlgaeLab (2017) at the Luma Atelier in Arles by Erik Klarenbeek and Maartje Dros. Algae bioplastics and container production through rapid printing. (www.dezeen.com/2017/12/04/dutch-designers-eric-klarenbeek-maartje-dros-convert-algae-biopolymer-3d-printing-good-design-bad-world)

The project Algae Lab won the New Material Award in 2018. Klarenbeek & Dros have set up the Algae Lab in collaboration with Atelier Luma. Their project is based on the collaboration of a wide number of experts from various discipline that includes scientist of materials and designer. The definition of the new polymer is suitable to be used in the FDM technology systems, and actually the project is shifting from the small size to largest one trough a specific technological research on 3d printing system. This line of research aim at rising up the local economy and employment, giving evidenc about social inclusiveness potentiality of the project.

3.3. *That's It*

Austeja Platukyte, a student at the Vilnius Academy of Arts, developed the project for a bioplastic produced by the addition of agar, extracted from algae, with calcium carbonate, reinforced with an emulsifying wax (Fig. 3).

Fig. 3. That's It (2016) at the Academy of Arts in Vilnius of Arles by Austeja Platukyte. Bioplastic based on algar and calcium carbonate reinforced with emulsifying wax. (www.austejaplatukyte.com/project-15)

The produced material is lightweight and whaterproof, suitable both for packaging solution and product design, as well. After the primary use of the material it could be composted or used as fertilizer.

4. Coloring the material: Caffil and Echinmat

This section summarizes the results of the original research outcomes, conducted in the Design_Kind Laboratory at the Politecnico di Bari, which led to the development of physical samples, characterized by a double composition, as they consist of the basic polymer added with food waste: it is precisely the waste that gives new perceptive qualities to the plastic material, first of all the inhomogeneity of color. The chromatic characteristics of the inclusion powders mainly affect formal variations, based on the detection of the natural colour of the organic compound used, which can be distinguished in the various samples produced.

4.1. *Caffil*

In the first case, the material produced is the result of an experiment started in the didactic and research laboratory Design_Kind of the Politecnico di Bari coordinated by the authors together with the students Antonello Monitillo and Ivan Saccotelli of the CdL in Industrial Design, in collaboration with CREA 3D, a company specialized in 3D printing machines located in Ruvo di Puglia.

The result is Caffil, a PLA filament for rapid prototyping, characterized by an internal composition with a percentage of coffee powder, resulting from the post-production poses of bars and restaurants. The material is

100% biodegradable and compostable. The choice of the material comes from the reflection on the great quantity of food waste deriving from the bottom of coffee produced by every gastronomic activity, bar, restaurant in the Italian territory, which generally does not undergo a differentiation in the waste cycle, nor a diversification for recycling. The hypothesis of reuse of this waste has been supported by the state of the art verification of other experiences of material experimentation starting from the coffee waste, including Kaffeeform, Decafè, C2C coffee cup, NAT2 vegan, and others (Fig. 4).

Fig. 4. Examples of products made from coffee waste material. From left: Kaffeeform, Decafè, C2C coffee cup, NAT2 vegan.

What distinguishes Caffil from other experimented materials is the desire to define a new material class, rather than a defined and finished product, able to open infinite creative possibilities and to generate classes of products from new material qualities.

In general, coffee powder is obtained by grinding the seeds of some tropical tree species belonging to the Coffea genus: although it is not a typical dyeing plant, coffee is part of the Rubiacee botanical family, to which belongs, among others, the Robbia, a spontaneous plant from whose roots the famous garanza lacquer was extracted.

For the extrusion of the Caffil filament, an Italian experimental machine was used, the Felfil Evo, a plastic extruder capable of producing personalized filaments with a recycled base for 3D printers, starting from industrial pellets or plastic waste.

The preparation of the materials involved a drying process, in an electric oven for several hours at a constant temperature of 60°C, both for the coffee grounds and for the PLA pellets, in order to remove any water and humidity present. In addition, the coffee has been sieved to uniform the grain size of the compound.

To extrude a filament with PLA, the machine must reach a temperature of 187 °C, and then set a printing speed of 50-120 mm/s; once the temperature has been reached, the materials can be inserted in the upper pocket.

The extrusion temperature affects the color and strength of the material. When the temperature exceeds 190°C, the material enters a glassy phase, which increases its fragility: with the same dosage, the material tends to behave differently between 190°C and 200°C, passing from a plastic to a glassy state, before starting to carbonize at around 210°C. Even the coffee must remain roasted and must not carbonize, to avoid giving a dark color and increase the fragility of the material.

In the first phase, to understand the behaviour of the composite material, different doses of the elements, different temperatures and different times were tested in order to define a stable and repeatable recipe. In fact, following some preliminary tests, to optimize the production process the machine underwent some changes, including a track with side pockets equipped with cooling fans, so as to guide the wire quickly on the winding coil. In the end, a filament with a diameter of 1.75 mm was chosen, with three different percentages of coffee compared to the PLA, 8%, 10% and 20%; with this dosage different filament reels were made (Fig. 5).

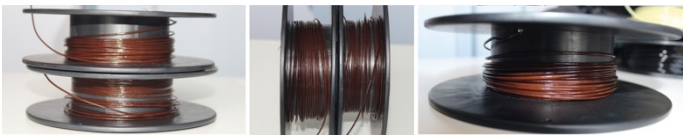


Fig. 5. Caffil Filament Reels, 8%, 10% and 20%.

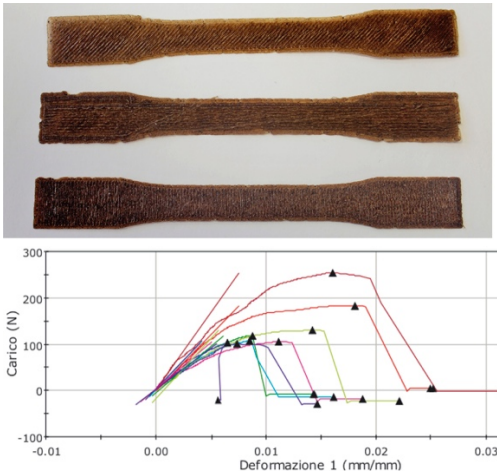
The experimentation continued with the technical verification of the material following 3D printing.

4.1.1. *Mechanical test*

For the mechanical stress test, 20 dog-bone test pieces were produced (Fig. 6), printed with the three different percentages of compound, according to three different extrusion directions, 0°, 45° and 90°, and different thicknesses.

Fig. 6. Samples of 3d -printed Caffil for the stress tests.

Mechanical analysis of the test pieces was carried out in accordance with the international ASTM D638-14 standard, which specifies the test conditions for determining the strength properties of unfilled and reinforced plastics. These properties include rupture, deformation at rupture and modulus of elasticity. The mechanical properties of plastics can change dramatically when some additives are incorporated into the formula, in particular strength and ductility. Tensile strength tests were carried out in the optical test laboratory of the Politecnico di Bari, using an INSTROM uniaxial loading machine with a maximum load cell of 1 k/N. The samples were analysed maintaining a constant traction speed, corresponding to 5 mm/min, to evaluate the variation of the load supported. Tensile tests have shown that the organic compound added to the PLA causes a decrease in the original elasticity of the material and therefore an increase in brittleness, with acceptable values up to a maximum percentage of dust of 20% (Fig. 7).



20%	E[MPa]	σrott
B1	1410,6	11,44
B2	113,3	13,94
B3	1360,2	8,90
B4	1171	8,04
B5	1321	7,95
B6	1069	8,56
B7	1220,3	9,77
B8	1120,9	7,71

Fig. 7. Samples dog-bone at 20%. Data table: transition point from elastic to plastic deformation and breaking point. Stress/strain graph tensile test.

4.1.2. *Optical test*

For the optical test, 9 square 70x70mm demonstrators were produced, printed with the three different percentages of compound and three progressive extrusion heights. In fact, to evaluate the yield of the printed filament in relation to light, the samples have a variation in thickness, one layer (0.3mm), two layers (0.6mm) and three layers (0.9mm). The test, of a subjective type, evaluated the chromatic qualities and the qualities of transparency of the material, lit directly from a natural and backlit source (Fig. 8).

The coffee powder is not soluble in PLA, and consequently does not "dye" the plastic compound, but has a significant effect on its colour rendering. The density of the inclusion material affects the degree of brightness of the sample, which has a darker shade as the percentage of coffee powder increases and as the layer thickness increases.

The particular mixture of the material gives each print a different texture, determined by an uneven distribution of the coffee in the PLA and therefore in the filament.

Fig. 8. Backlit Caffil samples for optical performance. From above, proceeding in rows: Coffee 8% (3 layers, 2 layers, 1 layer); Coffee 10% (3 layers, 2 layers, 1 layer); Coffee 20% (3 layers, 2 layers, 1 layer).

In order to obtain a correspondence of the colour value of the new material with conventional colour spaces, a colour measurement was carried out on the test specimens using an NCS reader.

Different colour variants were detected in each sample, determined by the variegated texture of the material. Therefore, it was not possible to assign a unique colour, but a palette of at least 4 different chromes. The figure 10 shows the matches of NCS values for each piece.

4.2. *Echinmat*

Again, the material produced is the result of a recent experimentation carried out by the authors in the Design_Kind Laboratory, in collaboration with some students of the CdL in Industrial Design, Federica Cardanobile and Flora Dell'Acqua.

Caffil 8% 3 layer	S6020 Y90R	S7010 R10B	S7010 Y50R	S8010 Y50R
Caffil 8% 2 layer	S3030 Y40R	S4020 Y60R	S5020 Y40R	S6020 Y70R
Caffil 8% 1 layer	S1505 Y30R	S2010 Y10R	S3010 Y40R	S3020 Y30R
Caffil 10% 3 layer	S8005 G80Y	S8010 Y50R	S8005 R20B	S8505 Y20R
Caffil 10% 2 layer	S5020 Y30R	S5030 Y70R	S6020 Y30R	S7010 Y50R
Caffil 10% 1 layer	S1515 G90Y	S2020 Y20R	S3020 Y60R	S4020 Y30R
Caffil 20% 3 layer	S7010 Y70R	S7010 R10B	S8010 Y50R	S8505 Y20R
Caffil 20% 2 layer	S7010 R10B	S8010 Y50R	S8505 Y20R	S8505 G80Y
Caffil 20% 1 layer	S5020 Y70R	S5030 Y50R	S6020 Y20R	S7010 Y50R

Fig. 9. Table of NCS colour palettes corresponding to the Caffil samples.

The food waste adopted in this experience was chosen by evaluating the traditional consumption of fish products in the Apulian territory. In particular, the sea urchin was selected for the formal quality of its shell and for its properties of reflection and chromatic variation when subjected to light radiation (Fig. 10).

Fig. 10. Sea urchin shells, chromatic variations obtained from exposure to light

An analysis of the data of the Coastal Conservatory shows that in Italian waters alone there is an annual withdrawal of about 32 million sea urchins, with an induced of about 9 million euros. However, although their shells are food waste, they are not differentiated and recovered, since the calcareous composition of calcium carbonate makes them waste of an inorganic nature, incompatible with the accelerated composting process. This aspect has encouraged the "ecological" aim of the project, which is to partially reduce waste for disposal and to return a material to the world for a second life.

The sea urchin is part of the species Paracentrotus lividus. The rigidity of the dermaskeleton is determined by the union of a series of limestone plates, externally characterized by a black or greenish color and purplish shades. The spines are also composed of calcite and organic matter, and have a pigment, the "chrome spine", which gives them a very intense and dark color ranging from purple to olive green, from brown to red, from yellow to black: these shades depend on the type of nutrition of the hedgehog.

With the rejection of the curl, reduced to powder of different granulometry (Fig. 11), polymeric binders of the epoxy and polyester types were tested to evaluate their technical and aesthetic characteristics.

The use of plastic resins for the development of material samples represents a starting phase of the study, justified by practical requirements of binder availability. The choice of a variable grain size, in any case greater than 0.5 mm, has led to mould casting processes, for which a resin is used as binder (in this case PLA is not suitable, because it requires a melting phase of the material at high temperatures). In a subsequent phase of experimentation, the use of bio-based matrix resins is expected, which will have a positive impact on the environmental sustainability of the new material. To date, in fact, the efforts of academic and industrial research are focused on the production of 'bio-based' polymeric materials, but currently there is little commercial availability. The bio-based nature of these materials derives from their origin from renewable and environmentally compatible raw materials, the most important of which are: starch, cellulose, lignin, furans, terpenes, natural rubber, waxes, vegetable oils, proteins.

Before each trial operation, the waste was carefully washed with water and ethyl alcohol to remove any organic residues and eliminate the characteristic odour: immersion in the compound for 24 hours was followed by a natural drying phase for another 24 hours.

Fig. 11. Sea urchin shells, different particle size variations adopted in the project

In order to obtain material samples, it was necessary to make moulds in which to pour the composite of curl and resin. Two series of square specimens of the size 50x50x10mm were made, obtained by varying exclusively the granulometry of the compound and the type of aggregating agent: the first series was obtained by mixing

an epoxy resin, the second a polyester resin, both transparent (Figs. 12-13).

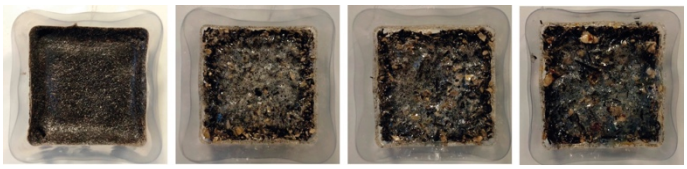


Fig. 12. Echimat: samples with epoxy resin based on different grain sizes of the sea urchin shells.

The same procedure was adopted for the production of the samples in the two series. After mixing the elements together and adding the catalyst, the compound was poured into the moulds. The main difference concerns the curing times, which are very short in the case of the polyester resin series.

Fig. 13. Echimat: samples with polyester resin based on different grain sizes of the sea urchin shells.

The tests carried out on the samples concerned the mechanical technical verification (drop test), in which the polyester samples showed greater resistance to impact, and the optical verification, through the microscopic vision of the different compounds, with a zoom of up to 10x. In this case, the polyester samples proved to be more compact and less porous than those with epoxy resin, where numerous air bubbles were visible. Moreover, the composition of the polyester resin highlights more the texture obtained from the different granulometric gradients, enhancing the chromatic variations present in it.

The tests therefore allowed the identification of the most suitable mixture for the final objective, the polyester resin compound, with which small demonstrators were made (Fig. 14), for the final verification on moulds with more complex geometries and more dimensionally consistent.

Fig. 14. Echimat: demonstrator

5. Conclusion

The paper proposes a concept referring to the color of the material through some experiments to verify the correctness of the theoretical assumptions.

The scalability of the research to the industrial fields of application is open, and in this the proposed study has the limits of an experimentation conducted 'by hand'. However, on the methodological level, a description of the steps has been offered, from experimentation to technical and performance verification, in order to enable scholars in the field to replicate the process. Among the expected effects, the project aims to enhance the socio-cultural context in which the history of color and the material culture to which it is associated is inserted, aiming at a redefinition of the aesthetic value "imperfect and inconsistent" of the chromatic quality of the pigment originating from the waste produced in the food and non-food sectors of the food industry.

6. Conflict of interest declaration

The authors declare that nothing affected their objectivity or independence and original work. Therefore, no conflict of interest exists.

7. Funding source declaration

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8. Acknowledgment

The contribution is the result of a common reflection of the Authors; nevertheless, paragraphs 3 and 4.2 are to be attributed to A. Di Roma, while paragraphs 2 and 4.1 are to be attributed to A. Scarcelli.

9. Short biography of the authors

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Alessandra Scarcelli - Architect and PhD, she is a research fellow and adjunct Professor of Industrial Design

at the Polytechnic of Bari (Italy). She is specialized in Lighting Design. The current research area combines the transversal areas of product design and information design, with particular reference to the socio-cultural aspects.

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The restoration of the Basilica Minore di Maria SS. Incaldana in Mondragone (northern Campania): the role of color

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ABSTRACT

The Basilica Minore di Maria SS. Incaldana, located in Mondragone (a city of Northern Campania), for many years was affected by many degradation pathologies.

So, its restoration have been divided in: consolidation and replacement of deteriorated plasters of internal walls; painting of the internal walls with new colors; removal of the plaster on the left and right pillars of the central nave to analyse and date its masonry characterizations; painting of the façade.

In the study phase we used a remote sensing thermographic camera to know its construction techniques and its pathologies in a non-invasive way.

KEYWORDS Restoration, Thermographic analysis, Stratigraphic analysis, Sacred architecture

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1. Introduction

The restoration of the Basilica Minore di Maria SS. Incaldana in Mondragone has made it possible to safeguard its interior and its external façade.

The interventions were three: consolidation and replacement of deteriorated plasters; new colors for the internal walls; removal of the plaster of the left and right pillars of the central nave near the transept, creating stratigraphic windows.

The restoration allowed to protect the church after many years of neglect and damage.

2. Historical-constructive analysis

The church was built by Carafa family at the end of the 16th century, on a pre-existing and smaller sacred structure. The presence of this church is shown by some circular pillars made of tufa, placed around the original presbytery, discovered during the recent restoration work.

The plant made by Carafa family was divided into three naves culminating with three semi-circular apses, introduced by a wide transept surmounted by a mighty drum dome and an eight-spindle vault.

The central nave was originally covered with a wooden structure, replaced over time by a barrel vault. Instead, the side naves were, like today, covered by cross vaults (Fig. 1).

Fig. 1. Basilica Minore di Maria SS. Incaldana, drone view before restoration work (Ph: Antonio Smirne).

The church revealed a basic project certainly drawn up by a master builder. The precise iconographic geometry of the sacred building wanted by the Carafa, typical of the late Gothic forms, is an expression of an art that is no longer spontaneous and popular, but desired by a wealthy client: the feudal lord. With the construction of the church, the three urban centers of the "Terra di Mondragone" in the early 17th century had four parish churches.

An interesting description of the church is in the list of Mondragone's feudal properties compiled by the engineers Galluccio and Ruggiano after the death of Prince Carafa di Stigliano (1690). However, this important historical document does not contain any information on its original colors.

In the twenties of the 18th century the new feudal lords, the Grillo of Clarafuentes, carried out an intervention of restructuring and expansion, which led the church to its current conformation.

Among the various interventions carried out, there was the replacement of the roof of the central nave and the realization of the barrel vault which replaced the pre-existing wooden roof.

3. Restoration work

Several pathologies of degradation, according to the recommendations of the "Ente Italiano di Unificazione" (UNI 11182/2006), have been found in the church and on its external facade, mostly related to capillary rising damp.

They are, for the internal environments: *detachment*, *missing part* (also found in other glossaries as *lacuna*), *discolouration* (also found in other glossaries as *chromatic alteration*), *efflorescence* (Fig. 2). On the external surfaces, on the other hand, the pathologies found may refer to *missing part*, *discolouration* and *crack*. Despite various analyzes of coloring and historical documents, no historicized colors were identified.

Fig. 2. Basilica Minore di Maria SS. Incaldana, left nave before restoration work.

In the church has also been identified the presence of various layers of colouring, not breathable, affixed in recent decades. Instead, on the external colourings it has still been possible to determine the shade, as the degradation has acted, as in most cases, on the intensity and saturation. In this way it was possible to reproduce the pre-existing chromatism of the external façade.

It should also be noted the presence of rainwater infiltrations in correspondence of the upper surfaces of the sacred structure, due to widespread disconnections of the bituminous sheath above. The result was an accurate macroscopic analysis of this area, carried out with a limited margin of error.

In the pre-intervention phase was used co called “remote sensing thermography”, for years the subject of great interest on the part of restoration operators, to detect the presence of any manifestations of moisture and/or lesions of plaster. It allows the visualization, in two dimensions, of the radiation measurement of the materials, using the thermal imaging camera, a device capable of detecting the temperatures of the bodies through the measurement of the intensity of infrared radiation emitted by them above absolute zero.

Thermography made it possible to visualize absolute values and temperature variations of the objects, to verify the presence of pathologies of the various stone elements (Fig. 3).

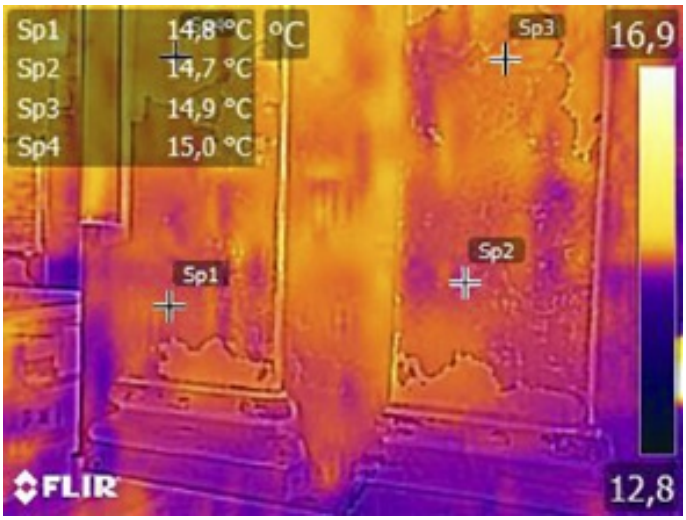

Fig. 3. Basilica Minore di Maria SS. Incaldana, thermographic analysis.

After identification of the deterioration phenomena, a series of interventions were carried out, outlined in accordance with the modern exercise of protection and the rules contained in the italian law called “Codice dei beni culturali e del paesaggio” (D. Lgs. 42/2004).

Restoration work was designed by architects Francesco Miraglia and Corrado Valente and directed by architect Francesco Miraglia.

Objectives of the interventions were: consolidation of the historicized plasters with integration of the compromised ones; redefinition of the colors, replacing the previous ones (dating back several decades and inadequate).

During all phases of the interventions, constant attention was paid to eliminate the problems related to the widespread presence - especially in indoor spaces - of capillary rising damp, responsible for the presence and multiplication of biodeteriogenic organisms, favoured by the use, over the years, of cement-based plasters and fillers.

Plasters based on certified lime and selected aggregates were chosen to give a material support to the new colourings, also based on lime, that could prevent - in the long term - oxidation or loss of adhesion. The plaster additions, which concerned a significant portion of the vertical surfaces, were made using three products, with various grain sizes (Fig. 4).

Fig. 4. Basilica Minore di Maria SS. Incaldana, right nave during restoration work.

Attention was also paid on the scientific analysis of the complex stratifications of the structure, through the creation of two stratigraphic windows on the pillars of the central nave, located in correspondence with the transept, to assume useful information on the presence of as many circular pillars in tufa, constituent of the original late 15th century church (Fig. 5, Fig. 6).

4. Choice of new colors

The new colors were chosen after having analysed the church from a historical point of view, assisted by the application of preliminary investigations and knowledge of construction techniques and constituent materials.

After unsuccessfully searching for any chromatic evidence, it was decided to choose new colors. The choice of new colors for the interiors is based on the observation of the absence of historicized colors (evidently eliminated during previous interventions); this allowed the choice of the colors in order to meet the renewed needs of the worship building.

Fig. 5. Basilica Minore di Maria SS. Incaldana, left nave, stratigraphic window.

Fig. 6. Basilica Minore di Maria SS. Incaldana, right nave, stratigraphic window.

The result was an overall analysis of the lighting criteria - both natural and artificial - of the interior spaces, in order to use softer and clearer colors. It was, therefore, aimed at making the sacred environment brighter, avoiding the previous visual context, which did not give back the right value to the membranes and finishes.

The new colors, approved by the Superintendence for Architectural Heritage and Landscape, were also chosen for their figure: starting from a neutral color (white), they became, in correspondence with the upper portions of the structure (arches and vaults) more lively (sand and indigo) (Fig. 7, Fig. 8).

Fig. 7. Basilica Minore di Maria SS. Incaldana, testing of the new colors for the superintendence approvation.

In order to restore the wide external front, instead, colors equal to the pre-existing ones have been identified, varying the brightness to make them softer. The white of the high overhanging pilasters, therefore, was interspersed with the yellow of the walls (Fig. 9).

5. Conclusions

The restoration work has made it possible to eliminate the pathologies of degradation of the church. In addition, they have made it possible to restore the sacred building to a more harmonious figural condition, eliminating the chromatic chaos especially in the interior, caused by decades of deplorable neglect and inadequate interventions.

Fig. 8. Basilica Minore di Maria SS. Incaldana, central nave after restoration work (Ph: Angelo Razzano).

6. Conflict of interest declaration

This research did not hold any conflict of interest.

7. Funding source declaration

This research did not receive any grant.

Fig. 9. Basilica Minore di Maria SS. Incaldana, external façade after restoration work (Ph: Angelo Razzano).

7. Funding source declaration

This research did not receive any grant.

8. Short biography of the author

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Archaeological digital anastylosis. From survey to lighting analysis

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ABSTRACT

The operational context is that of the ancient city of Stabiae, today not fully known and scarcely appreciated, and in particular of the complex of Villa San Marco and its representative spaces, in which there are figurative apparatuses both in wall paintings of the peristyle and in the stuccoes of the exedra at the bottom of the pool. The aim is to analyze the artifact in relation to the perceptive characterization - qualitative and quantitative - of its external and internal spaces, documenting some stages, related to the most thorough investigations with the targeted use of laser scanning techniques, to the analysis of photometric and colorimetric characteristics, and to the perceptive study of decorative apparatuses. Precisely this artistic repertoire, is believed to have characterized the use of the environments and, to date, it connotes spatial qualities. The focus is mainly on the area of the nymphaeum, characterized by a swimming pool and a bottom-closing exedra: for the two larger sides it is defined by suggestive arcades with decorated walls in the IV Style in which a figurative solution is adopted to subsequent panels. On this environment, the diaetae appear on opposite sides. They show, despite the structural symmetry, disparity in the chromatic and figurative treatment, presumably due to the different destination: representation on the east side, a more "domestic" use than the one located on the west side. The intention to test the variation of the simulated perception, within a digital reconstruction process, required a preliminary survey campaign, both for the metric acquisition of the artefact and the contextual lighting characteristics. In this preliminary study on a cultural heritage artefact with its own historical past we have highlighted the need for a concerted, multidisciplinary effort; these partial results should ensure future developments.

KEYWORDS Survey, Three-dimensional simulation, Lighting analysis

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1. Introduction

The study was carried out in the ancient city of Stabiae, still not fully explored and only marginally enhanced. Its objective was to analyse the Villa San Marco complex and the figurative decorations in its reception rooms: the wall paintings in the peristyle and the stuccoes in the exedra at the end of the swimming pool.

In addition, the study meticulously examined the characteristics of the building and qualitative and quantitative features of its external and internal spaces; it also documented several stages of a more in-depth assessment which included the use of laser scanning techniques, an analysis of its photometric and colourmetric characteristics, and a perceptive evaluation of its decorations.

The artistic repertoire is believed to have determined the use of the rooms and currently conveys its spatial qualities. Testing the changes in simulated perception as part of a digital reconstruction process required a preliminary surveying campaign and acquisition of the measurements of the building and lighting characteristics of the context.

2. The reference framework

Enhancement of archaeological artefacts is an extremely topical subject.

It has led to a merger between traditional enhancement methods and the most modern cognitive and communicative tools, appreciated by increasingly informed users especially when it is impossible to fully enjoy the sites included in national and international tourist itineraries.

The archaeological site of Stabiae is a case in point: the cognitive support tools present on site (primarily concise panels positioned near the most important excavated domus) fall short of visitors' expectations and the cultural interests perceptively sparked by the context (Fig. 1). All the villas brought to light so far were originally decorated and elegantly embellished with extremely expensive furnishings; unfortunately, ever since the initial eighteenth-century excavations they have been systematically removed in order to protect them (Papa et al. 2013, Papa et al. 2014). This raises two sets of problems: the first involves the difficulties inherent in the study of changes in local and territorial scenarios; the second is how to define and integrate the most effective cognitive and communicative strategies in order to generate greater fruition.

The experimentation illustrated in this contribution and presented as a progress report of the study in question chose Villa San Marco as a case study; it is one of the biggest architectural complexes in the Stabia area (a total of 49 hectares) located in the hilly south-east part of the Castellamare di Stabia municipality (Fig. 2).

Fig. 1. The area of the otium villas

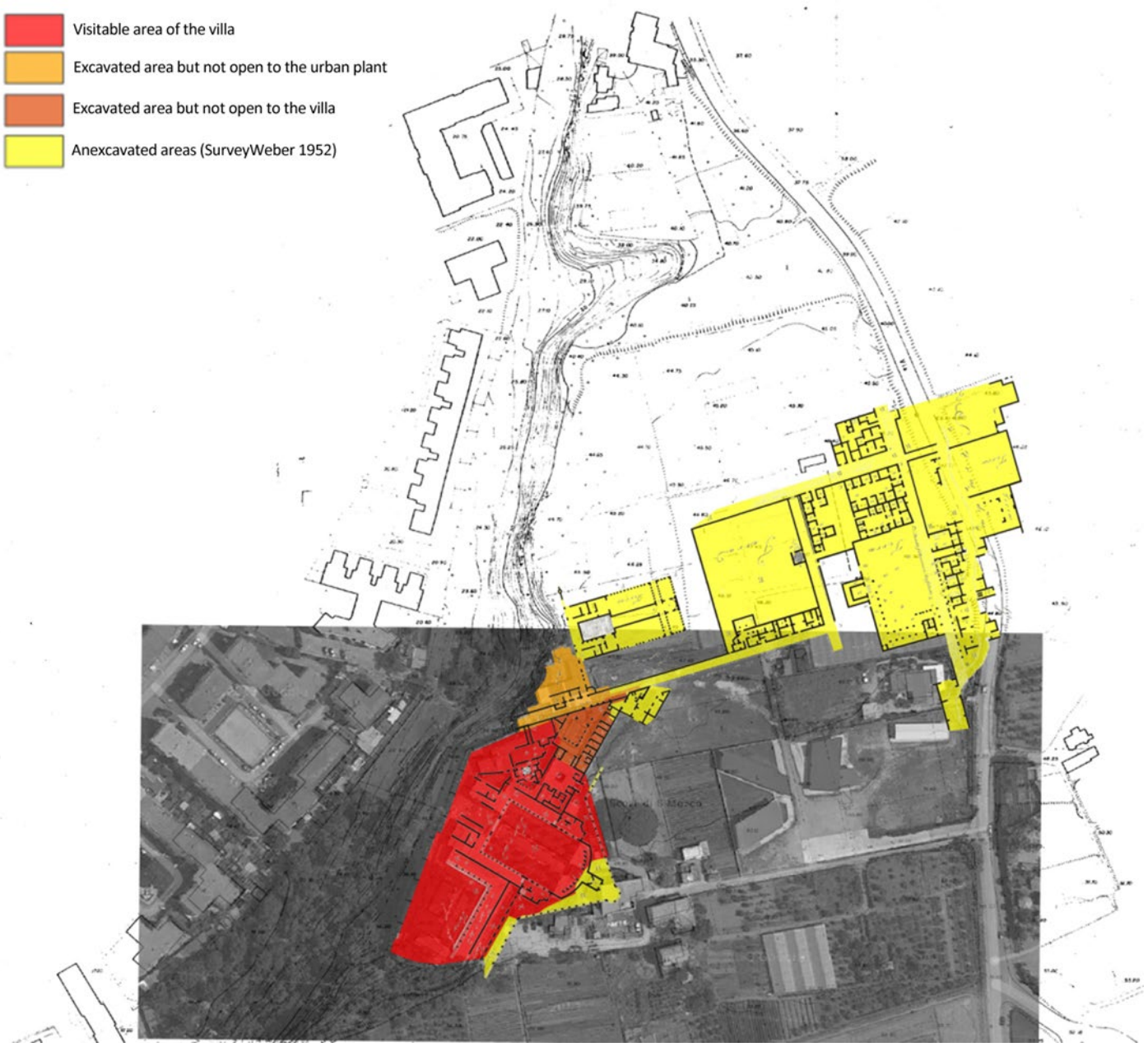

Fig. 2. Plan of old Stabiae showing Villa San Marco

The oldest part of the Villa was built under Augustus (from 27 BC to 14 AD), but the complex was enlarged under Claudius (41-54 AD). A spa area was built between the entrance to the complex and the edge of the hill as well as a big, shady garden and a decorated nymphaeum between the swimming pool and the hillside; the dietae panoramically opened onto the swimming pool. Most areas in the layout of the complex are positioned so as to adapt to the relief of the hillside on which it was built; the most representative rooms were originally positioned panoramically towards the sea. Instead the spa complex follows the orientation of the urban layout, as illustrated in the surveys performed by Karl Weber in 1759; these surveys will be compared with the results of the surveys we were necessarily required to perform to verify the position and extension of the buildings previously surveyed and later integrated.

3. Real space ad illusory space

The layout of the rooms in the Villa follows the privileged directions of the “San Marco terrace”; its conformation required the construction of imposing structures not only to solve the problem of the extremely steep slope between the terrace and the countryside below, but also to position the rooms in an east-west direction so that the design enhanced its panoramic position.

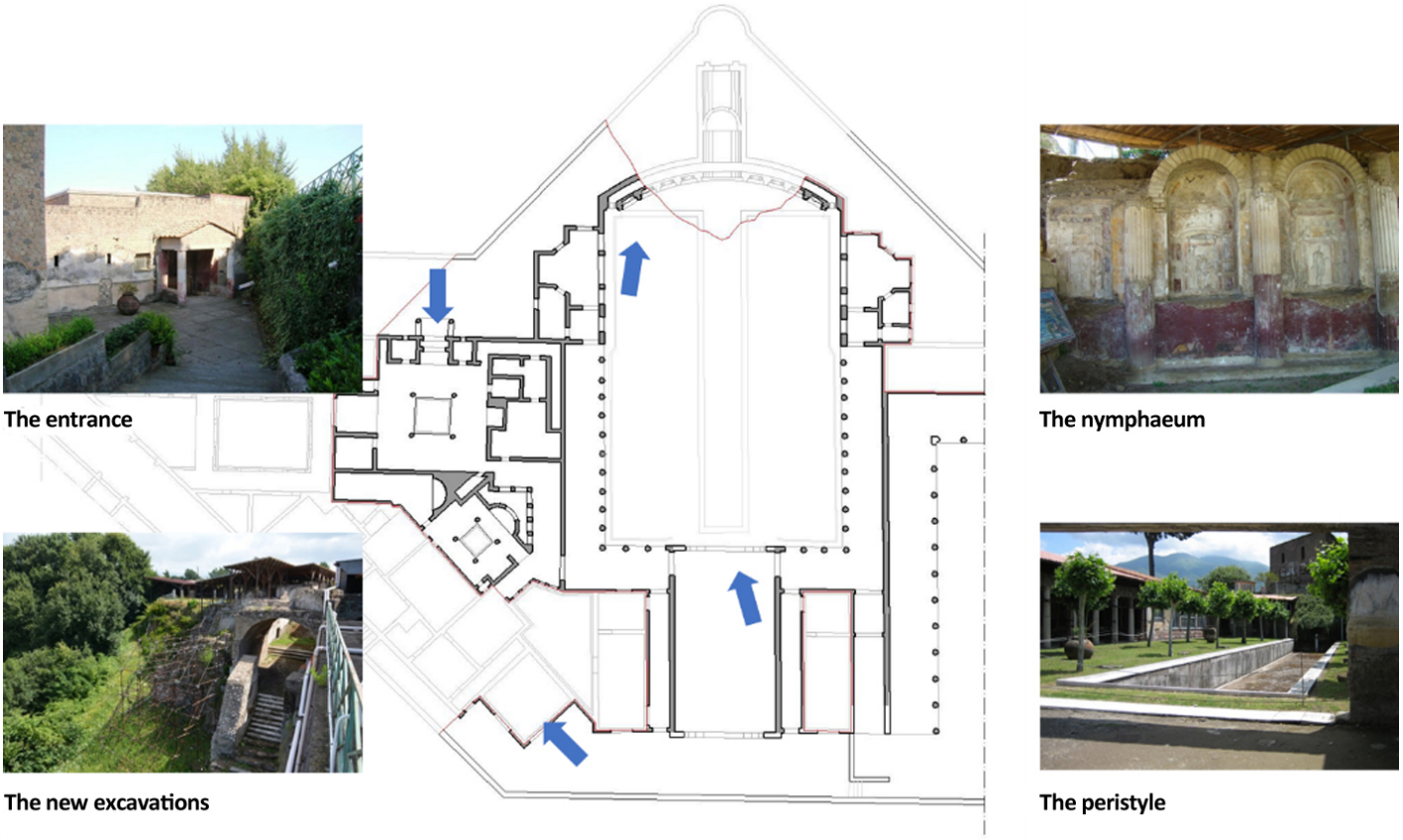

Fig. 3. Entrances to the villa: surveys and areas currently open to visitors

The villa's architecture and infrastructure influenced the decorations which, on the one hand, appear similar to the ones in other buildings in old Stabiae and, on the other, enable identification of the several construction phases of the Villa (Fig. 3). The built area developed around an older, initial layout that was reorganised during the first century CE. Evidence shows that the third rebuilding and reorganisation phase took place more or less when Vesuvius erupted in 79 CE.

The coherently executed decorations follow the logic of the temporal progression of the restructuring, but they also clearly characterise the rooms in which they are present. It is therefore possible to talk of a "decorative space" in which the use of unusual solutions boosts the quality of the architectural space by linking the rooms and turning them into an organic figurative narrative.

The oldest wall paintings are the ones in the spa rooms and hallway where the idea behind the albeit different decorations on the walls and floor was nevertheless similar; the tetrastyle hallway of Villa San Marco and the nymphaeum were particularly enhanced by decoratively varying the cabled white plaster coating and 8grooved plaster (also white). This was a common for open spaces in the alternation of lights and colors (Papa et al. 2014).

The nymphaeum, positioned along a longitudinal axis, faces the plain below where in the past the coastline was much closer to the hill, so much so that the water in the pool seemed to stretch seamlessly to the sea. The walls along its two longer sides have beautiful porticoes with IV Style of of Pompeiian wall-painting (datable to the second half of the first century) in successive panels. The main scene has a white background with small, framed figurative panels between the yellow and red painted areas. This pattern was quite common in the IV Style; due to its paratactic structure it was well-suited to decorations along long surfaces such as porticoes (Fig. 4a). The decorative effect is achieved by the studied, regular repetition of motifs and colours; the material continuity of the wall is only ostensibly broken insofar as the ensuing image is not fragmented but recomposed on a plane where colours, light and shadows create an illusory *continuum*.

4. The on-site architectural survey

The architectural survey campaign was performed using laser scanning techniques; it envisaged a series of recordings for a total of twenty-two stations covering approximately 2400 m^2, equal to roughly a third of the total excavated area.

This study was carried out on a relatively small portion of the Villa that was nevertheless emblematic for the articulation of the archaeological rests that were brought to light until then. Operating on the basis of a well-planned topographic framework, the scans were set up with the purpose of correlating the current survey campaign with future ones. In particular, a clear line of sight between current survey stations and potential future ones, to be located in other rooms, has been ensured. The ambulatory, the baths district and the kitchens are indeed adjacent to the scanned zones.

Thanks to this survey campaign, the overall perspective, offered by the processing of the obtained point cloud, led to some significant results since the very first observations. Once the campaign was finished, the images produced after processing the points clouds led to several initial results and observations. For example, the structural symmetry and chromatic and figurative differences of the dietae facing each side along the long sides of the garden are presumably due to their diverse function: the ones on the east side (Figs. 4b & 5) had a more representative function while the one on the west side played a more “domestic” role.

Fig. 4. Left (a), central view of the west wing of the major peristyle of the Villa; right (b), corner of the entrance of the west dietae towards the domestic area of the Villa.

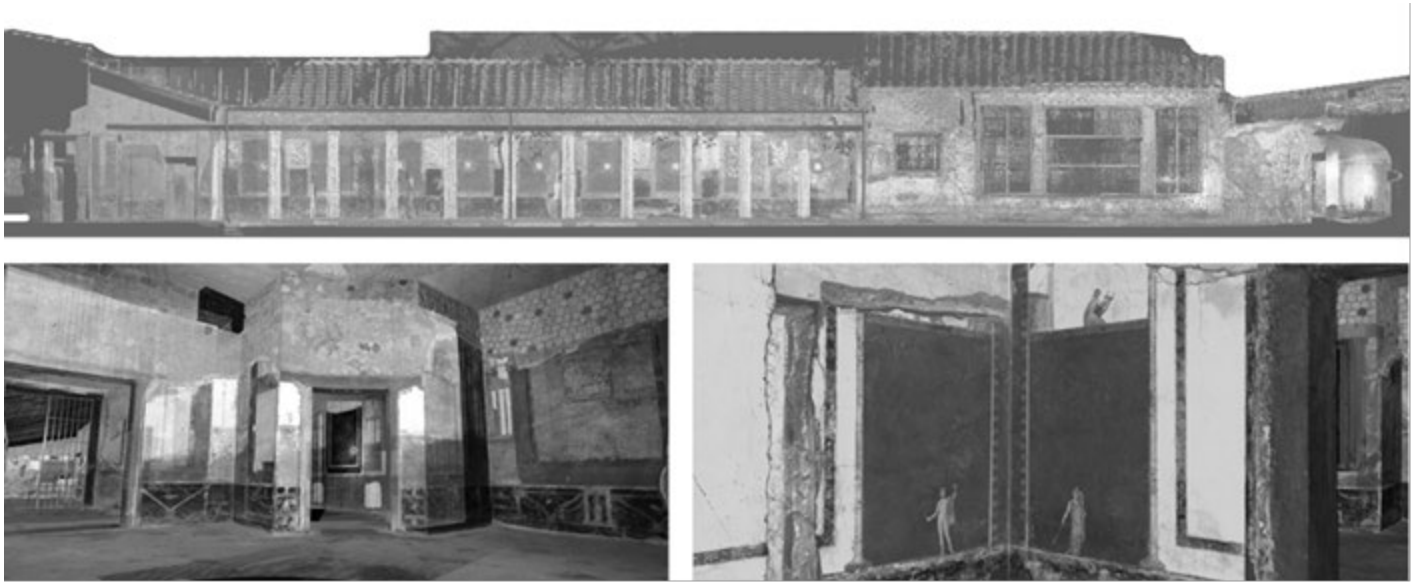

Fig. 5. Points cloud from the laser scansion of the peristyle and east dietae

Moreover, the structures in the former were drawn in perspective which, unlike the ones in the more famous sites of Pompeii and Herculaneum, appear to have less figurative embellishments but are in some cases more interesting due to their unusual position at the corners of the walls rather than in the middle of the walls which are, nevertheless, present. Likewise, the surveys of the exedra next to the pool and at the end of the partially inaccessible ambulacrum at the rear are equally fascinating from a disciplinary point of view. The perceptive study of the decorative devices is integrated with the in-depth analysis of the photometric and colorimetric characteristics to investigate the variation of the simulated perception, within a digital reconstruction process.

4.1. *Photometric and spectroradiometric surveys*

Lighting in the Villa is currently provided only by daylight and during the surveys it presented significant spatial and temporal variability. These differences are generally due not only to the daylight variability during time, but also to the different daylight availability in the rooms due to their architectural features, i.e. the presence or absence of openings, their orientation, the presence of external obstructions, etc. (Balocco and Calzolari 2008). The on-site survey, aimed at collecting illuminance and luminance measurements along the visit route, made it possible to evaluate the gradients occurring both in spatial and temporal dimensions (Bellia et al. 2018) (Fig. 6). In addition, by measuring the spectral reflectance of the building surfaces (both painted and non-painted) it will be possible to insert the measured data into a lighting simulation software in order to obtain useful information not only about light scenarios, but also about the annual (day)light exposure of the painted surfaces, necessary for evaluating the risk of damage (Cuttle 2000). Spectral reflectance values are also useful for performing the proper choices of the light sources' spectral power distribution so as to enhance the correct fruition of the spaces. Finally, by measuring spectral irradiance it was possible to assess how the intensity and spectrum of natural light is modified by the materials on the walls (especially the colored ones) inside the rooms.

The first survey campaign was performed on February the 28th 2018, starting from 14:20 to 15:00. The relatively short period of time and the fact that the sky was cloudy allowed us to acquire data in the rooms with the same outdoor lighting conditions; as a result, measured data for all the rooms were comparable. We focused in particular on the two dietae. We measured luminance and spectral irradiance, as well as the spectral reflectance of the interior surfaces. From the measurements of spectral irradiance, performed in several points and different orientations, it was possible to calculate illuminances and colour temperature of the incident radiation. Specifically, both interior and exterior horizontal surfaces were considered, in order to obtain information on how daylight entrance is at today controlled by the presence of the current window systems. Vertical illuminances at the eye level (1.60 m from the floor), in several points of view along the visit route were also collected. In this way it was possible to detect if the visual conditions along the visit route are affected or not by strong gradients.

In fig.7 the points where measurements were performed are reported. It's important to notice that the illuminance value at the eye's level can be assumed as proportional to the average luminance in the field of view of the observer, by applying the relationship $Lav = E/\pi$. The average luminance, in its turn, can be considered as the "adaptation luminance", i.e. the luminance value corresponding to a specific condition of adaptation by the visual system. Consequently, when illuminance values at the eyes' level are affected by strong variations along the visit route, it means that visitors will not be able to adapt their visual system to the changing levels of lighting. The result will be an incorrect visual fruition of the spaces, especially in perceiving colors when passing from brighter to darker conditions.

Table 1 reports the results obtained by processing the spectral irradiance values. As it can be inferred by analyzing the vertical illuminances and the corresponding average luminances, even in the same room, values are strongly different. For example, in the "Pavilion left", average luminance ranges from 20 to 590 cd/m^2, whereas in both the cubicula illuminance assumes insufficient values in order to allow a proper environmental perception. This effect is enhanced by the fact that visitors reach the cubicula by previously passing through much more bright rooms (the pavillons). Given the overcast sky conditions during the survey, it is possible to assume that in general, even in other days or hours, illuminance and luminance distributions attain similar values than the measured ones, proportional to the outdoor external values on horizontal surfaces. In table 1, correlated colour temperatures (Tc) related to the spectral irradiances are also reported. They represent the "colour" of the light striking on the considered planes. As it can be noticed, outdoor values are always higher than the indoor ones. In particular, considering that outdoor values are around 6000K (6282K and 5866K in the points EXT/1 and EXT/2 respectively), in rooms as the cubicula, these values are much lower, reaching the minimum at around 3700K (3718K in the "Cubiculum left" and 3741K in the "Cubiculum right").

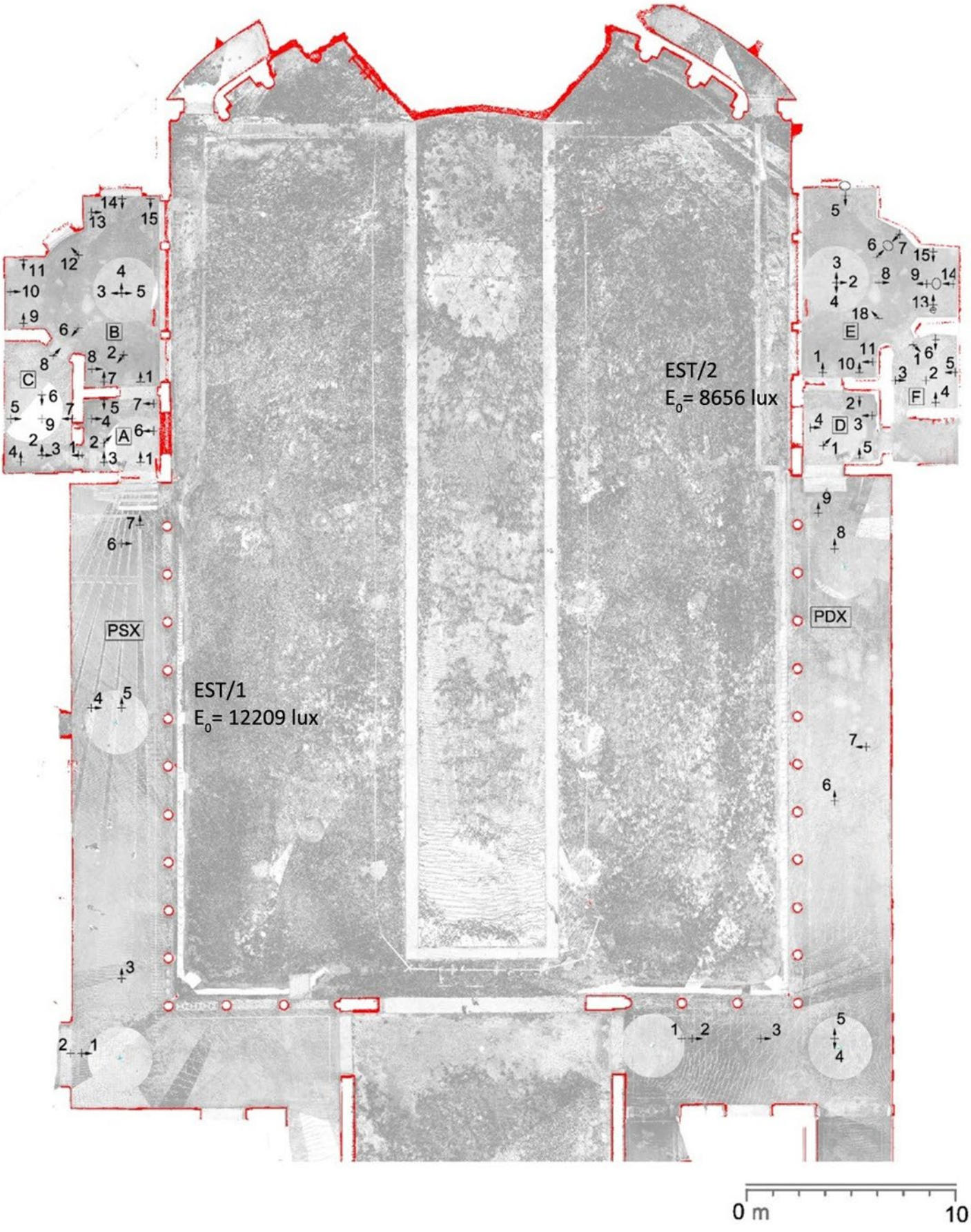

Fig. 6. Laser survey plan of the peristyle and dietae showing the irradiance measurement point

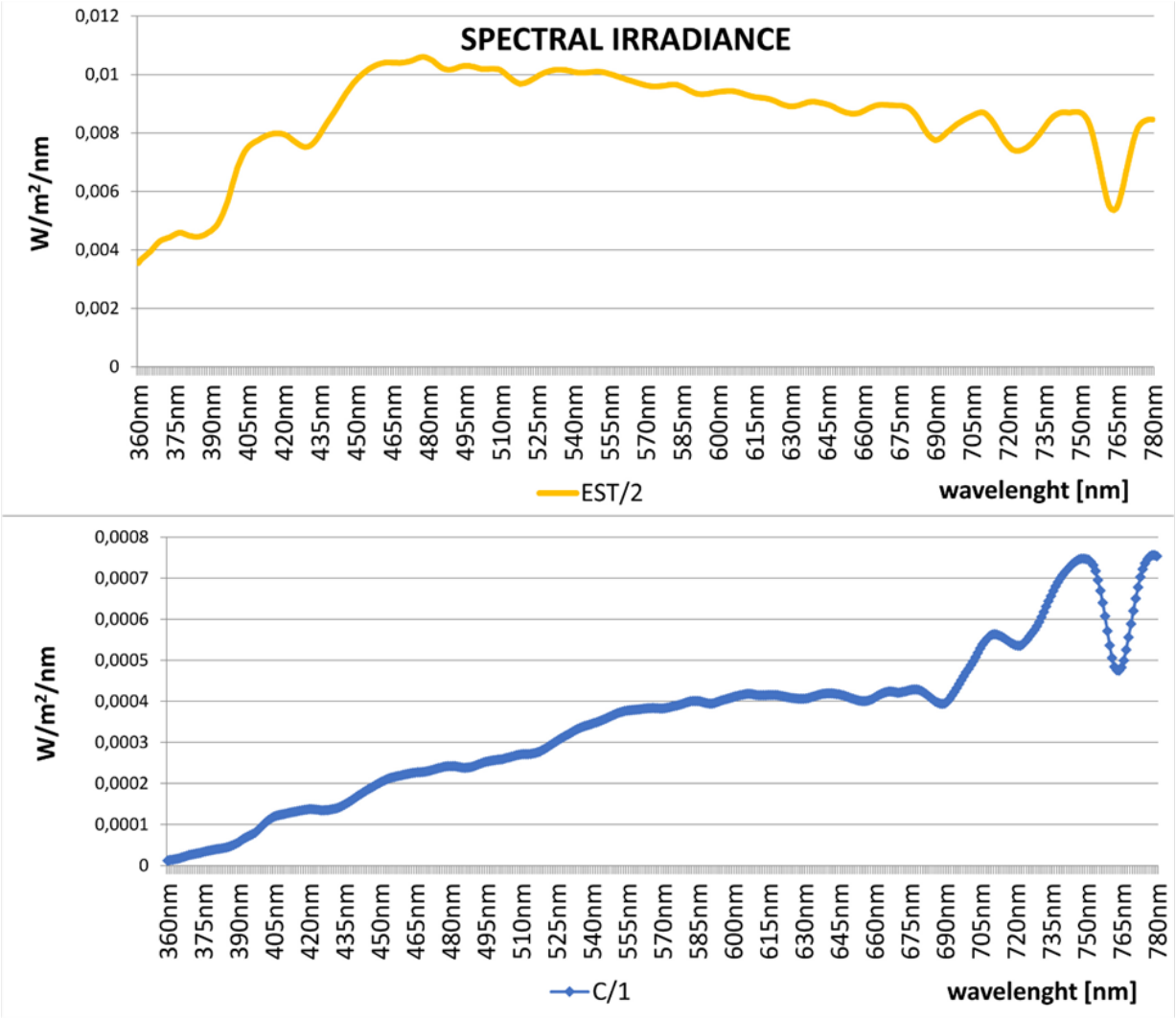

Fig. 7. Daylight spectral irradiance of the two extreme cases, EXT/2 (outdoor) and C/1 (indoor) regarding colour temperature.

Code	Position	E [lux]	L_{av} [cd/m²]	Tc [K]	Code	Position	E [lux]	L_{eq} [cd/m²]	Tc [K]
OUTSIDE					OUTSIDE				
EXT/1	horizontal	12209..4		**5866**	**EXT/2**	horizontal	8656.0		**6282**
PORCH LEFT					PORCH RIGHT				
PSX/1	vertical	711.6	226.6	5645	**PDX/1**	horizontal	1239.5		5024
PSX/2	vertical	375.8	119.7	4515	**PDX/2**	vertical	576.8	183.7	4923
PSX/3	vertical	1209.9	385.3	4775	**PDX/3**	vertical	255.7	81.4	5288
PSX/4	vertical	991.1	315.6	4719	**PDX/4**	vertical	626.7	199.6	5035
PSX/5	vertical	1106.2	352.3	4853	**PDX/5**	vertical	859.9	273.9	5078
PSX/6	vertical	3016.8	960.8	5295	**PDX/6**	vertical	1158.0	368.8	5206
PSX/7	vertical	1006.3	320.5	5086	**PDX/7**	vertical	808.3	257.4	5311
ENTRANCE LEFT					**PDX/8**	vertical	706.8	225.1	5419
A/1	vertical	264.1	84.1	4762	**PDX/9**	vertical	85.6	27.3	4467
A/2	vertical	192.2	61.2	4638	ENTRANCE RIGHT				
A/3	vertical	139.5	44.4	4475	**D/1**	vertical	203.6	64.8	4908
A/4	vertical	226.5	72.1	4765	**D/2**	vertical	300.1	95.6	5069
A/5	vertical	155.0	49.4	4537	**D/3**	vertical	100.3	31.9	4710
A/6	vertical	91.3	29.1	3916	**D/4**	vertical	77.9	24.8	4281
A/7	vertical	118.4	37.7	4042	**D/5**	vertical	206.2	65.7	5592
PAVILION LEFT					PAVILION RIGHT				
B/1	vertical	801.1	255.1	5076	**E/1**	vertical	674.3	214.8	5985
B/2	vertical	165.9	52.8	3942	**E/2**	vertical	124.2	39.5	4721
B/3	vertical	205.0	65.3	4587	**E/3**	vertical	167.2	53.2	5134
B/4	vertical	665.3	211.9	5023	**E/4**	vertical	938.9	299.0	5564
B/5	vertical	1845.8	587.8	5317	**E/5**	vertical	294.4	93.8	5418
B/6	vertical	115.1	36.7	4858	**E/6**	vertical	170.5	54.3	5226

B/7	vertical	661.0	210.5	5045	**E/7**	vertical	248.7	79.2	5237
B/8	vertical	816.0	259.9	5297	**E/8**	vertical	347.4	110.6	5100
B/9	vertical	143.9	45.8	4596	**E/9**	vertical	257.9	82.1	5178
B/10	vertical	229.4	73.1	4984	**E/10**	vertical	131.0	41.7	5094
B/11	vertical	62.9	20.0	4111	**E/11**	vertical	238.5	76.0	5348
B/12	vertical	324.1	103.2	5128	**E/12**	vertical	217.3	69.2	5146
B/13	vertical	625.3	199.2	5492	**E/13**	vertical	104.5	33.3	4879
B/14	vertical	461.1	146.8	5253	**E/14**	vertical	186.0	59.3	5077
B/15	vertical	600.0	191.1	5514	**E/15**	vertical	112.6	35.8	4817
CUBICULUM LEFT					CUBICULUM RIGHT				
C/1	vertical	26.1	8.3	**3718**	**F/1**	vertical	78.1	24.9	5059
C/2	vertical	32.2	10.2	4129	**F/2**	horizontal.	22.5		3677
C/3	vertical	31.9	10.2	4104	**F/3**	vertical	269.2	85.7	5004
C/4	vertical	25.0	8.0	4021	**F/4**	vertical	29.7	9.4	4072
C/5	vertical	34.5	11.0	4033	**F/5**	vertical	48.2	15.4	4546
C/6	vertical	32.4	10.3	4088	**F/6**	vertical	20.4	6.5	**3741**
C/7	vertical	141.0	44.9	5376					
C/8	vertical	407.3	129.7	4969					
C/9	horiziontal	28.7		4256					

Table 1. Illuminance, equivalent luminance and colour temperature of spectral irradiance measurements points

This effect is due to the optical properties of the painted indoor surfaces and precisely to their spectral reflectance. In order to evaluate how daylight spectral distribution is modified by the spectral reflectance of the surfaces, in Fig.7, diagrams of spectral irradiances measured in the two extreme cases are reported. So, in order to better investigate about this effect, by means of the spectrophotometer CM-2600d (Konica Minolta) the spectral reflectance of 16 samples including plasters, floors, coatings and decorations were collected, so as to describe the optical behaviour of nearly all the materials and pigments characterizing the surfaces. In Fig.8 the considered samples are shown, and in Fig.9 the spectral reflectance diagrams for eight of the sixteen samples are reported. As it can be observed, for all materials, spectral reflectance diagrams show an increasing trend with the wavelength, confirming that shorter wavelengths are generally absorbed more than longer wavelengths. This explains the fact that indoor daylight is characterized by lower correlated colour temperatures values (warmer light) rather than outdoor daylight. By processing spectral reflectance, it was possible to obtain the total reflectance under the Standard Illuminants A and D65. These are reported in Table 2. It is interesting to notice that, for all the samples, the reflectance related to the Illuminant. A always assume higher or equal values than those related to the illuminant D65. Equal values are attained for black surfaces (almost neutral). This is due to the already mentioned characteristic of all the analysed surfaces to absorb mostly short wavelengths of the visible range. The survey included luminance measurements as well. By means of a video luminance meter (Bellia et.al 2002; Bellia et al. 2003), luminance maps were obtained in correspondence of several points of view. Indeed, besides the already mentioned gradients of the adaptation luminance along the visit route, it must be noticed that, especially in presence of windows, for most of the considered positions of the observer, very high luminance contrasts occur. These conditions produce visual discomfort. Specifically, 21 luminance maps were analysed, the results of 12 of which are reported in Figs. 10 and 11. For each luminance pattern, the average luminance Lav was calculated by weighting the measured values according to the apparent areas; then the maximum value Lmax was considered and the ratio Lmax/Lav. This ratio is particularly significant because it represents how much the maximum luminance value, in the visual field, exceeds the average one, considering that, on increasing this ratio, the discomfort effects increase.

Fig.8. Pictures of the samples taken into consideration

Num.	Sample Name	ρ(A)	ρ(D65)
1	YELLOW 1	37	33
2	RED 1	10	9
3	BLACK 1	10	9
4	WHITE	65	63
5	BROWN	17	16
6	BLACK 2	5	5
7	RED 2	12	11
8	BLACK 3	8	8
9	PINK	21	19
10	RED 3	14	12
11	YELLOW 2	24	21
12	RED 4	12	10
13	WHITE FLOOR	43	42
14	RED DECORATION	19	16
15	BLACK FLOOR	13	13
16	WHITE COLUMN CLADDING	56	54

Table 2. Total reflectance factors

Assuming that in indoor spaces, for comfort purposes it is generally suggested not to exceed luminance ratio of 10:1, from the analyses reported in Figs. 10 and 11, it appears evident how most of the values are higher than 30 and in five cases they are higher than 100, demonstrating the presence of very critical visual conditions. Figure 12 shows the detailed luminance maps, represented in false colours, for the main room of the left dieta (view 1) and one of its cubicula (view 4). Both of them present an excessive luminance range and reveal the necessity of specific interventions for a correct and comfortable perception.

5. Discussion and Conclusions

This contribution was written to illustrate the methodological approach used to enhance the archaeological site of Villa San Marco in Castellammare di Stabia. From the photometric and spectroradiometric surveys it came out that currently, without any lighting installation in this archeological site, many problems occur. Indeed, the main issues are related to the illuminance and luminance gradients that, in many cases assume excessive values and compromise the correct perception of the spaces and their work of arts. More in detail, it can be observed that some rooms, as the cubicula, receive insufficient daylight whereas other spaces, as in the porches and in the dietae, are characterized by excessive illuminance values and contrasts.

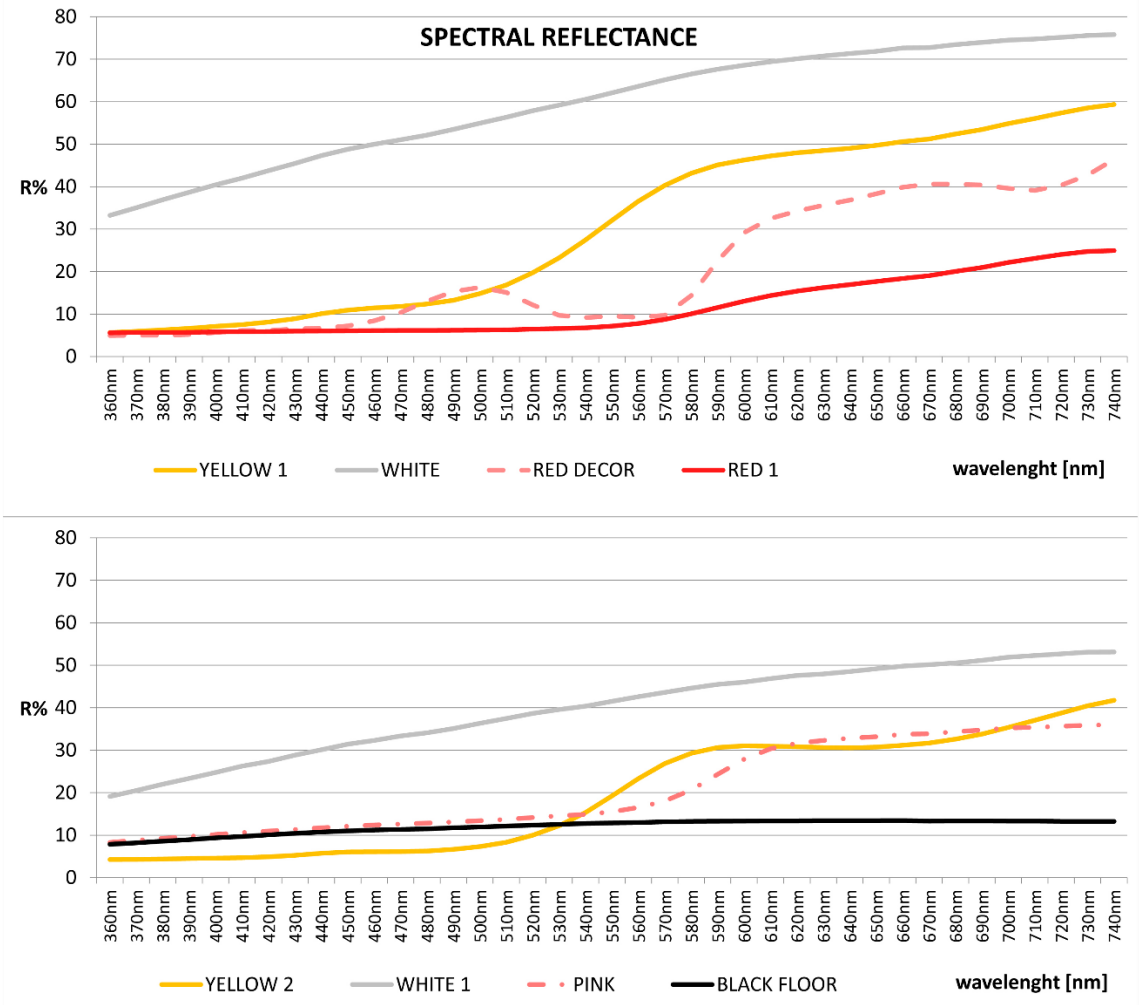

Fig. 9. Spectral reflectances of eight of the sixteen samples

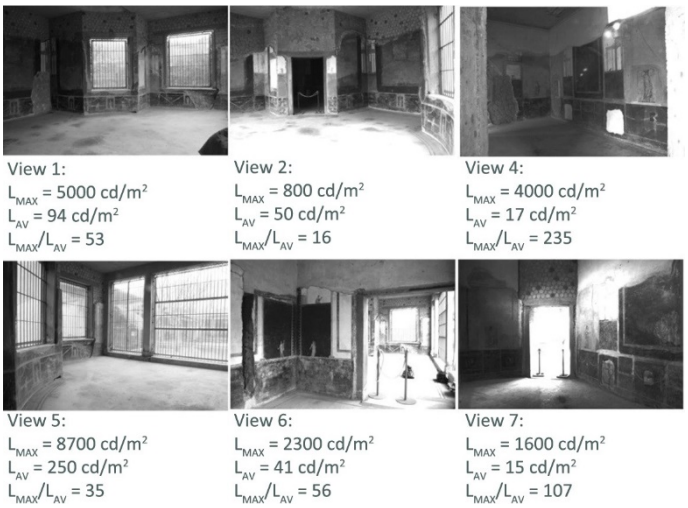

Fig. 10. Images of some views with luminance data and ratios (left spaces)

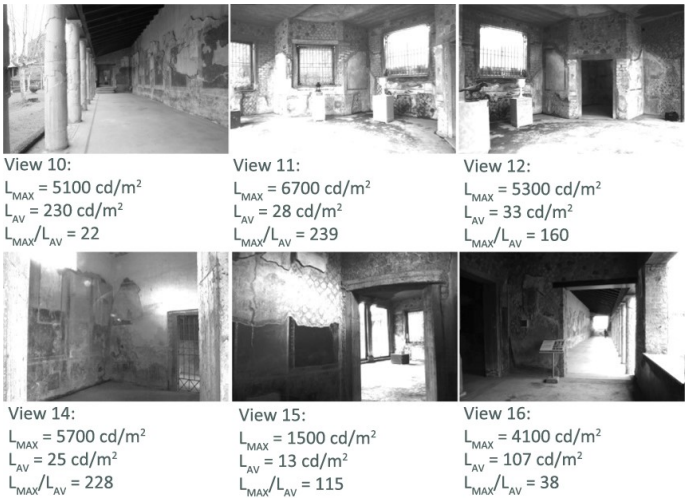

Fig. 11. Images of some views with luminance data and ratios (right spaces)

From the obtained results, the necessity of a proposal of intervention outcomes, both for limiting the daylight access in some spaces and for integrating the insufficient light in others. The former aim can be addressed by installing proper shading systems, while the latter by installing proper lighting systems. Both of them should be removable, flexible and well-integrated in the archeological context.

However, considering the daylight variability during time, in order to propose the most effective solution, further research is required. Indeed results obtained by the measurements survey will be useful to calibrate input parameters for lighting calculation software and to validate the model, in order to perform dynamic and static daylight simulations (Reinhart et al, 2006; Nabil and Mardaljevich, 2006). Results from dynamic daylight simulation will be useful for the assessment of the potential damage to the paintings produced by radiation (especially the direct sunlight), for the choice of the most effective light control strategies (lighting and shading fixtures) and also for the evaluation of energy consumption due to electric light. On the other hand, static simulations, performed in different typical conditions will be useful to help light designers in making the most proper choices in integrating daylight and electric light for a perfect fruition of the site. Furthermore, spectral reflectance of materials will be necessary for the design of the most appropriate Spectral Power Distribution of the light sources, considering also the daylight contribution when present (Schanda et al. 2015; Di Salvo S., 2014).

In conclusion, our dual goal was to not only enhance the heritage of frescoes and improve perception and fruition by tourists, but also safeguard the original chromatic features and ultimately protect them from direct sunlight, where necessary. After this experimental study on part of the site and the acquisition of data from just one instrumental lighting survey – which obviously requires further research – any further developments will provide visitors with a variety of scenarios in an archaeological context which, although ready to be compared with contemporary, adjacent sites and situations, presents its own unique characteristics that deserve a much broader cultural focus based on solid technical and scientific knowledge.

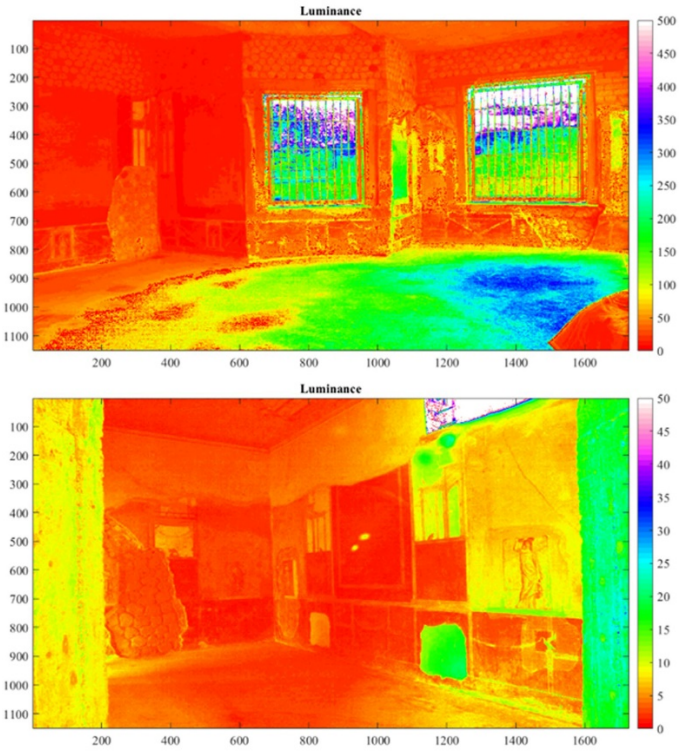

Fig. 12. Luminance maps in false colours referring to view 1 (above) and view 4 (below)

6. Conflict of interest declaration

The authors declare that there is no conflict of interest with other people or organizations.

7. Funding source declaration

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Pierpaolo D'Agostino - Engineer, is associate professor at University of Naples Federico II, involved in investigations concerning design, survey and digital representation in architectural, urban and environmental issues. He is author of over forty scientific papers, many of which signed, often autonomously, in several national and international editorial publishers. He is also author of monographic work about, above all, solar shading design in architecture and railway stations.

Gennaro Spada - MSc in Mechanical Engineering on 27/11/2000, PhD in Thermal-Mechanical Systems in 2004, his final dissertation dealt with videography applied to luminance measurements. At present he is technical responsible of the Photometry and Lighting Laboratory at the Department of Industrial Engineering of the University of Naples Federico II. He performs scientific and educational activities related to lighting.

Giuseppe Antuono - Engineer, PhD in History, Design and Restoration of Architecture (XXX Ciclo, Curriculum Design, SSD ICAR/17), carries out research at the Department of Civil, Construction and Environmental Engineering in the field of architectural survey and documentation complex of historical, urban and environmental interest, with integrated methodologies and with attention to the management and implementation of geographic information systems. Participate in national and international conferences with written contributions and communications.

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Transmitted light imaging in VIS and IR, in the study of paintings: a brief report on the behavior of the main historical pigments

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ABSTRACT

The aim of this paper is to evaluate the behavior of 50 historical pigments in the two spectrum ranges VIS and IR, by using transmitted light. For this study, pigments were bound with oil and were applied in several layers over underlying lines, drawn with different media. The purpose of this study was to evaluate the behavior of pigments in the two spectrum ranges, comparing visible and infrared photographs with the respective images taken with transmitted light. The main idea is to compare the optical properties of each pigment in visible (VIS), transmitted light (TL), infrared (IR) and infrared transmitted (IRT). This was achieved by assessing visible and infrared photographs in incident and in transmitted light. The ultimate goal is to understand aspects such as transparency and opacity as well as the ability to block light. Finally, the intention is to classify the pigments by their behavior noting their similarities and differences, considering the aforementioned factors. Since photographic techniques are very common in the study of painting, this study has been considered useful to classify patterns of behavior, which will allow greater systematization of these types of imaging.

KEYWORDS Transmitted light, Transradiation, Infrared, Multiband, Pigments, Art diagnostics, Painting

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1. Introduction: transmitted light imaging techniques in the study of paintings

In the last decades, the study of paintings with non-invasive methodologies has been continuously growing as a respectful practice towards heritage, and nowadays with the spreading of low-cost methods, many art historians, conservators or restorers use imaging as a starting point in the meta-formal research on paintings (Poldi and Villa 2006). In fact, for the diagnostic study of paintings, it is very common to use basic technical photography (TP) in order to observe the surface and the possible alterations affecting the works of art (Matteini and Moles 2001). When dealing with panels, in addition to visible photography (VIS), raking light (RL) is used. For the study of canvases and other translucent surfaces (parchment, cloths, paper, etc.) transmitted light (TL) becomes a helpful tool (Riley and Berger 1971). These latter techniques are generally carried out by the restorers to evaluate the conditions of paintings since, as it is known, the altered varnishes, cracks, and other types of alterations of the support or the pictorial layers can be easily recognizable with such imaging tests (Cardinali et al. 2002); (Cucci et al. 2012); (Dupont 1977); (Moutsatsou et al. 2011). Infrared transmitted imaging (IRT) is a commonly used infrared photographic technique, which reaches up to 1100 nm and is performed with the characteristic TL backlighting conditions (Kushel 1983). For some years, it has been considered a non suitable technique for the study of paintings, (due to the effect of heating of IR radiation, which is pernicious for paintings). However, digital photography has allowed it to be considered again due to the short time of exposure to the light that there is needed to take the IR image (Cucci et al. 2012).

Table 1: Applications and results of transmitted light techniques in painting studies

	VIS	TL	IR	IRT
Ductus /Brush-strokes				
Pentimenti				
Underdrawing				
Pigments visual identification				
Inner condition				
Superficial condition				
Inpainting				

Very good to excellent results mainly
Medium to good results on average
Poor to fair results in many cases
Very poor results (only in very few cases)

Table 1 indicates the suitability of each technique depending on the scope of the research.

When TL and IRT are used together with VIS and IR respectively, an interesting range of data about the way the painting has been made can be extracted, as well as about the materials that had been used. That happens, specially, if the results in such images are compared with one another. Thus, they provide much more information, covering subjects either about its own materiality, or about the execution process, in addition to their contribution to the collection of data regarding the state of conservation (Table 1).

Especially useful for the procedural study are TL and IRT (Vervat et al, 2005); (Cucci et al. 2012). The reason is that they allow the observation of brushstrokes, giving also information on the thickness of the pictorial layer. They also report on the ability of materials (especially pigments) to absorb or reflect the light, while they also allow highlighting the hidden elements, the *pentimenti* and any other modifications made to the painting. (Herrero-Cortell et al 2018). Furthermore, when the two types of transmitted light techniques are performed together and the results can be compared, important differences in pigment behavior can be appreciated, as these are images obtained in two different regions of the spectrum.

2. Scope and methodology

The main objective of this paper is to describe some differences in the visual behavior of historical pigments, when confronting, VIS, IR, TL and IRT. The purpose is to summarize the general characteristics of the main common pigments when transmitted light techniques are chosen for the study of paintings. Specifically, the paper proposes an experimental approach regarding the observation through TL and IRT of the behavior of 50 pigments and historical lacquers, mainly produced by KREMER® (although some others have been manufactured by the authors following the indications of historical recipe books). Nevertheless, in order to permit the comparisons VIS and IR standard imaging have also been considered.

The pigments and lakes were applied using a rectified linseed oil as a binder, on a cloth prepared with a layer of gesso (rabbit glue with carbonate and calcium sulfate). The area painted with each pigment was divided into four strips, corresponding to the number of layers, starting from one layer up to four levels, thus producing a crescendo of glazes thicknesses. Furthermore, in order to evaluate the behavior of the underlying design through the transmitted light techniques (in addition to its interaction with pigments), lines were drawn using different mediums. In this way, it was thus possible to evaluate the transparency and opacity properties of the pigments. Line 1 corresponds

to charcoal; the line 2 to the black pencil Conté; line 3 is graphite line; line 4 is sanguine; line 5 is metallogallic ink; line 6 is metallogallic ink in a 50% aqueous solution, and finally line 7 is sepia-colored ink.

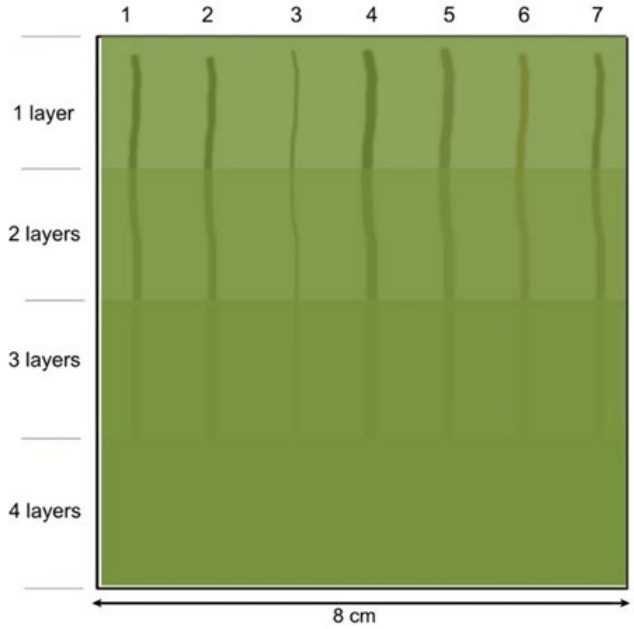

Fig. 1. Diagram showing how pigments were applied over underlying lines, in four layers.

VIS, IR, and IRT were carried out using a *Nikon® D7200 DSLR* (24 MP, CMOS sensor) digital camera modified "full spectrum" (sensitivity between about 360 and 1100nm), coupled with *Nikkon Nikkor®* 50mm lens. The following filters were used: X-Nite CC1 for Visible (VIS), Transmitted Light photography (TL); Heliopan RG1000b for Infrared (IR), and Infrared Transmitted (IRT) (Cosentino, 2014); (Herrero-Cortell et al. 2018). Two halogen lamps (1250W) were used for VIS and IR imaging, while for TL and IRT only one lamp was set perpendicularly at the back of the canvas at a distance of 2m. To keep the canvas in a vertical position of 180º from the ground, a special easel was constructed. It is an aluminum structure that holds the stretcher by its sides with two sliding clamp rails. In order to avoid light pollution, the reflected light was removed by using a parasol, which fitted the back of the canvas while mounted in the easel (figure 2). The American Institute of Conservation Photo Documentation (AIC PhD) target was used for calibration images. The images were shot in RAW mode and then color corrected, balancing white by using the N8 neutral grey patch in the AIC target5. They were also exposure corrected: N8 patch 150 +/- 5 for VIS. The same patch was also used for correcting IR images: 100 +/- 5 for IR and IRT. The purpose of this study was to evaluate the behavior of pigments in the two spectrum ranges, comparing visible and infrared photographs with the respective images taken with transmitted light. The ultimate goal is to understand aspects such as transparency and opacity as well as the ability to block light, highlighting factors that will allow greater systematization of this type of imaging.

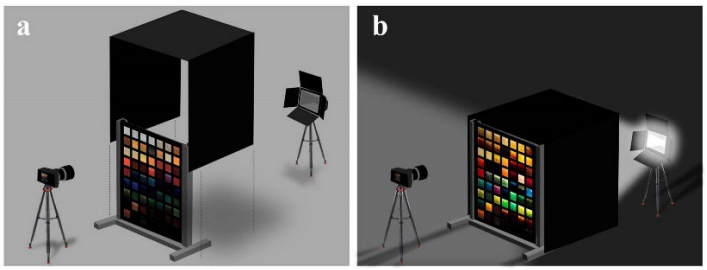

Fig. 2. Disposition of the camera, the canvas and the light for the imaging techniques in which transmitted light is used TL and IRT. A special easel was constructed to hold the canvas allowing a proper back lighting.

3. Results and discussion

Once the TL and IRT photographs were taken the results considered were compared with the VIS and in the IR. This work became very important in order to appreciate how the behavior of each pigment changed by carrying out the different techniques, considering whether it was opaque, semitransparent or transparent. In the same way, it could be demonstrated how the superposition of the various layers of each pigment sometimes generates a graduated tonal effect in some of the techniques. With this term, we refer to the ability to absorb more or less the light according to the thickness of the layers. For example, if the application is very thin the color can be very light, while in the areas where there is an overlap of layers the color increases becomes deeper proportionately, and thus its tonality becomes darker. It must be considered that some pigments show graduated tonal scales both in the visible and in the infrared range, either with reflected or transmitted light. Other pigments show these tonal scales only in VIS, being perfectly homogenous in IR. Finally, some others appear like flat colors in VIS, while they can show graduated tonal scales in TL, IR, or IRT. In order to understand their main differences, they have been organized in families by their color, confronting, thus, their VIS, TL, IR and IRT appearances.

3.1 *Yellow pigments*

Unlike other families, such as whites, the behavior of yellows is quite heterogeneous (figure 3). Gold ocher and raw Sienna (figure 3, samples 1 and 2) present a medium hiding power, being sienna slightly opaque. They both tend to slightly block the light if the layer is very thin, so

they can be perceived in IR and IRT as a medium gray scale. They both show a graduated tonal scale in all the technical images. On the other hand, orpiment (figure 3, sample 3) and Naples yellow (figure 3, sample 4) suffer great variations in their opacity depending on their application: while with thin layers the passage of light can be total, the thicker layers tend to block the light. Nevertheless, they are semitransparent in VIS while they are both transparent and present graduated scales in IR and IRT. Lead-tin yellow (figure 3, sample 5) and chrome yellow (figure 3, sample 6) behave uniformly, regardless of the thickness of the application, allowing more light to pass through. They are both semitransparent in VIS and have homogenous gray level in IR. However, much more translucent are those of cadmium (figure 3, sample 8) and cobalt (figure 3, sample 9), whose light blocking capacity is as low as that of arzica lake (figure 3, sample 7). Not even the greater hiding power of cadmium yellow provides any type of luminous block in IRT, thus all three yellows are perceived as very light whites or grays.

3.2. *Red pigments*

Many reds are known for their transparency in IR techniques (figure 4), although that is not true for all pigments. Cinnabar and vermilion (figure 4, samples10, 11) are known for their high hiding power in VIS (although cinnabar tends to be slightly more translucent than its artificial version). Generally, they both usually are quite flat, allowing little transparence, even if the application is not very thick. They also tend to block light in TL. Instead, in IR the thickness is a key factor to visualize a hypothetical underlying design, allowing to see the underdrawings traces only if the pictorial layer is thin. The lead red (minium) (figure 4, sample 13) is, on average, much more transparent in all the techniques, showing little variations even if the application is more or less thin, and thus is not a graduated tonal scale pigment. In IRT, it behaves like a uniform light gray, which allows us to see any underlying trace, including the sepia dye, which is often invisible in many pigments. The red lakes (figure 4, samples 16, 17, 19), show a predictable transparency,

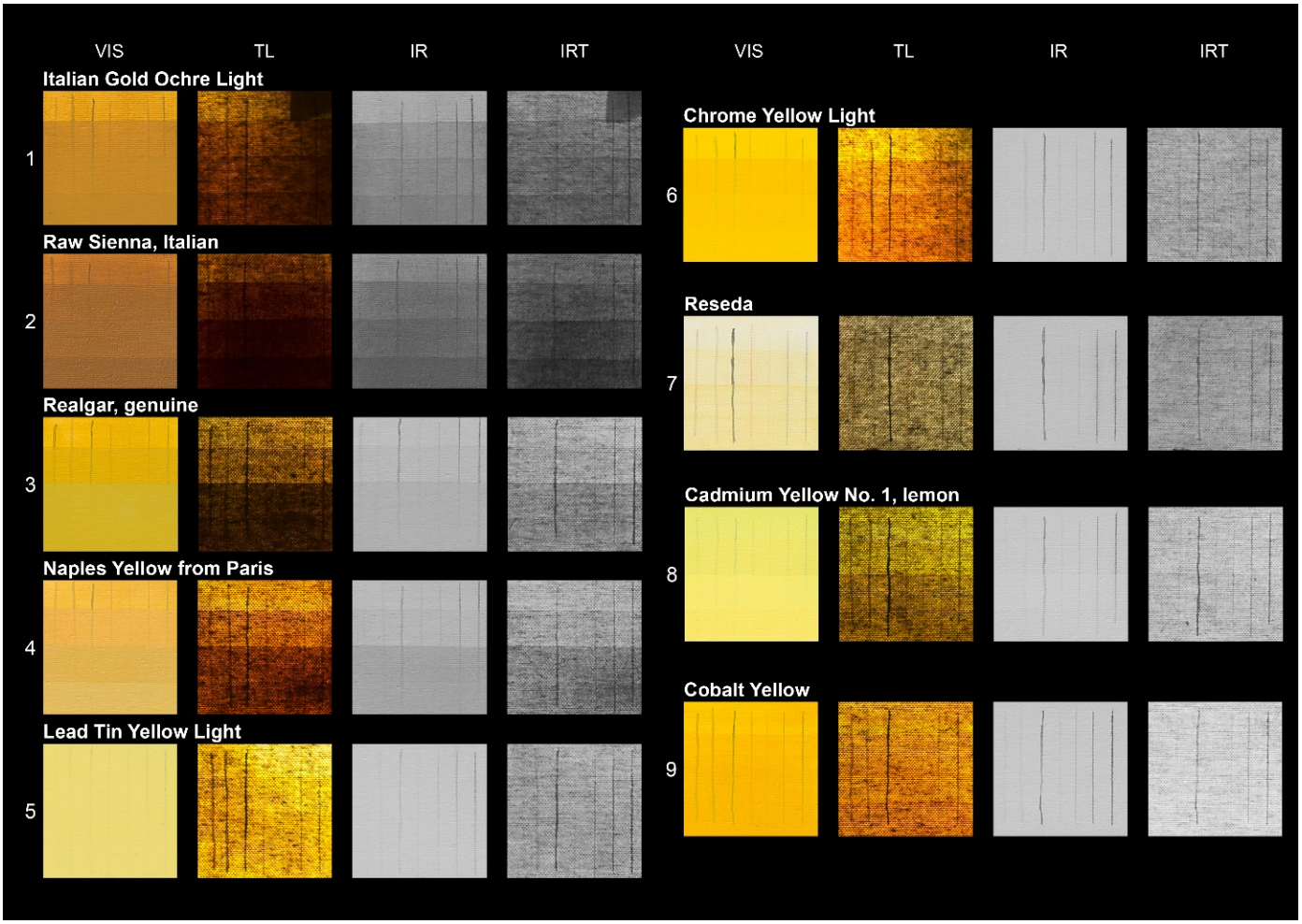

Fig. 3. Yellow pigments observed in VIS, TL, IR and IRT.

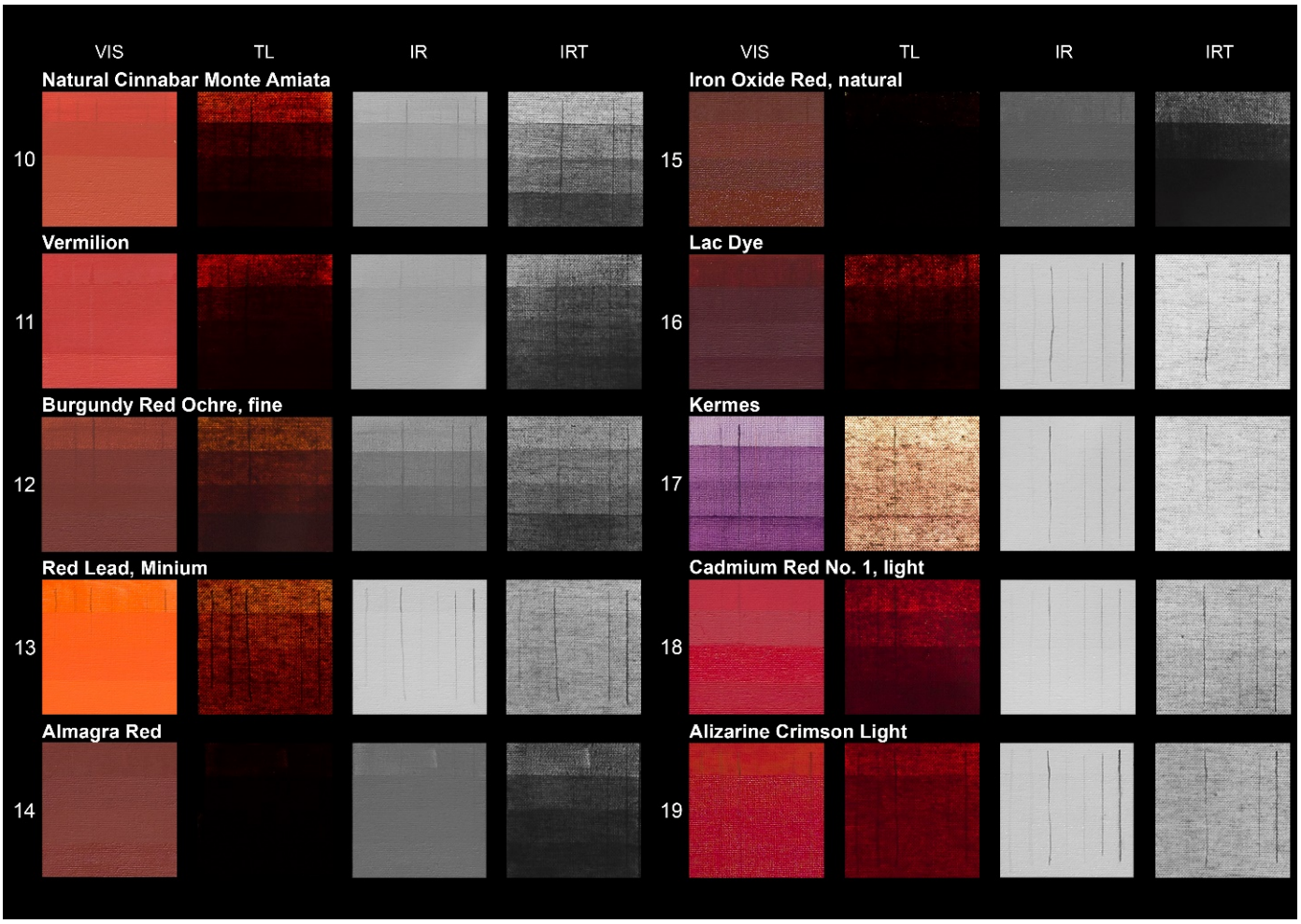

Fig. 4. Red pigments observed in VIS, TL, IR and IRT

both in visible and in IR, so in IRT the light block is very low. Only lac dye (figure 4, sample 16) is relatively more opaque in VIS, while all the others are very translucent. Cadmium red (figure 4, sample 18), which presents a high hiding power in VIS, shows graduated scale in TL, while is as transparent as lakes in IR techniques. The iron reds, burgundy red ocher, almagra and iron oxide (hematite) (figure 4, samples 12, 14, 15), despite all of them being in the category of earthen pigments, exhibit some differences among them. While almagra and iron oxide (figure 4, samples 14, 15) have a high opacity in IR which does not allow the visualization of the underlying lines, burgundy is more translucent. Their respective behavior in TL and IRT is similar. Almagra and hematite can perfectly block the light even if sometimes they are able to form dark gray graduated scales. Instead, burgundy (figure 4, sample 12) is quite more transparent.

3.3. Blue and purple pigments

Lapis lazuli, azurite, and blue bice (Figure 5, samples 20-22) exhibit similar behaviors in IR and IRT, while in TL lapis presents a higher light-blocking power, while bice is the most translucent. All of them are sensitive to the thickness of the application, becoming medium or dark gray if the application is very thick. In general, only the charcoal and the metallogallic ink lines can be partially perceivable in IR, so for the best visualization of any underdrawings an IRR device with a greater penetration strength is required. Prussian blue (figure 5, sample 23) has a very specific pattern of behavior. Although in the VIS it can be partially transparent, favoring an identification of the underlying lines if the application is not very thick, both in IR and in IRT it behaves like a highly opaque pigment that does not allow identification of any underdrawings. In fact, in IRT, if the application is thick, it forms an impenetrable dark spot, as it happens in TL. Like azurite, only the IRR image is able to reduce some opacity. Indigo (figure 5, sample 24) and smalt (figure 5, sample 25), even if they present tonal scales, are clearly transparent in the IR band. However, their behavior is not identical. Indigo is the most transparent of them, and therefore in IR it can be very sensitive to the thickness of the application while in IRT the light passes through it homogeneously. If the application is thick, it can eventually block the light. Smalt, instead, is very transparent in all the bands.

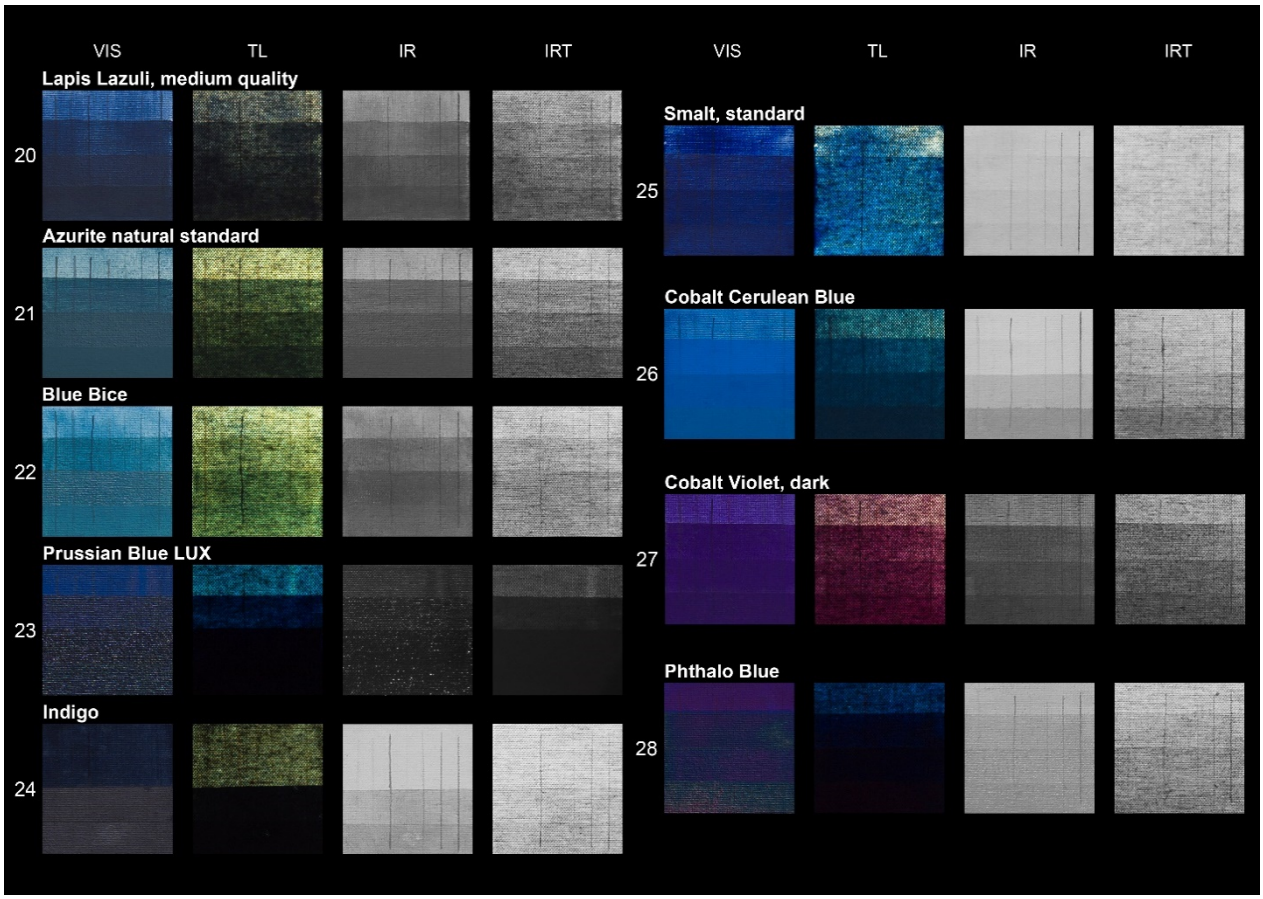

Fig. 5. Blue pigments observed in VIS, TL, IR and IRT.

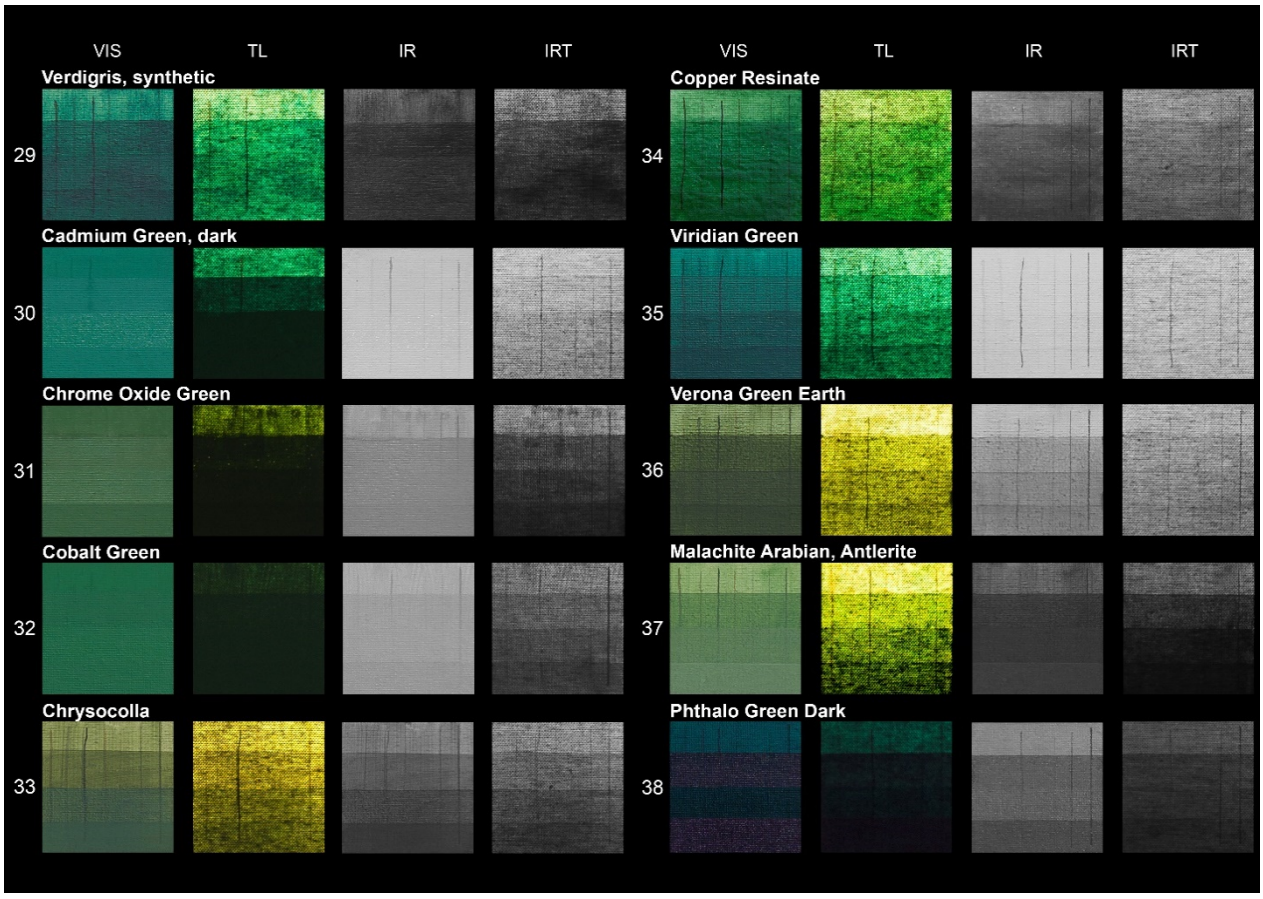

Fig. 6. Green pigments observed in VIS, TL, IR and IRT.

Phthalocyanine blue (figure 5, sample 28) has a similar response in TL, IR and IRT to that of indigo, although it is slightly less transparent. Finally, cerulean blue and cobalt violet (figure 5, samples 26, 27) exhibit very different behaviors. Therefore, they show significant differences in VIS and IR depending on the thickness of the layers. In

general, the response of the cerulean blue in IR is in the form of light gray, with high transparency, which allows the identification of the carbon lines and the metallogallic ink. Instead, the cobalt violet is darker in both IR and IRT, which makes difficult to perceive any underdrawings line.

3.4. Green pigments

As it happens with other color families, the different nature of greens creates varied behavior patterns (Figure 6). Sometimes, some greens based on the same element can react very differently. A good example is chromium oxide green (figure 6, sample 31) and viridian (figure 6, sample 35), a chromium oxide dihydrate green. Chromium oxide green is one of the pigments with greater hiding power in VIS and in the TL blocking the incident light. Indeed, in IR it manifests itself as a quite opaque pigment, of medium gray. It only allows you to guess some of the underlying lines if the application is very thin. In IR, in fact, the difference in thickness between the different layers is not perceptible, while in IRT it responds with a graduated pattern, being quite more translucent, despite displaying a medium-dark grey scale. Being of the same family, viridian (figure 6, sample 35) is a translucent pigment both in the visible and in the TL, a feature that allows the observation of underlying lines. Likewise, in the IR range it behaves like a transparent pigment, regardless of the thickness of its application. Cadmium green (figure 6, sample 30) shows a similar behavior of viridian in IR and IRT despite being less transparent than viridian. However, in the visible range, cadmium green is a pigment whose transparency directly depends on the thickness of the application, and while its appearance in VIS tends to be quite homogenous it is capable of forming graduated scales in TL. The copper greens, verdigris, chrysocolla, resinate and malachite (figure 6, samples 29, 33, 34, 37), are also a good example of materials with a common matrix (copper) exhibiting different behaviors. While verdigris and resinate, which have similar compositions based on copper acetate, malachite and chrysocolla are copper based carbonate and silicate minerals, respectively. They have something in common, being very translucent in VIS, and only the natural pigments have some hiding power in thick applications. Even in TL they behave like pigments that allow the light to pass permitting the observation of underlying lines, even if they show graduated scales. However, the main differences are observed in the IR band. Although generally the response of copper greens is always dark, especially deeper in verdigris and malachite, but, definitely it can be lighter or darker depending on the thickness of the application or the number of layers. In IRT these colors are always semitransparent, however the reading of the underlying lines becomes practically impossible. Verona green earth (figure 6, sample 36) shows a quite transparent behavior in all the ranges, presenting a light medium gray in the IR and forming graduated tonal scales in all the techniques with the exception of IRT in which it tends to form a quite flat gray tone, although significant changes in the thickness of the pictorial film could eventually respond with graduated scales. Cadmium green (figure 6, sample 30) has great hiding power and its behavior is very similar to that of cobalt green (figure 6, sample 32) in all the considered spectral ranges. Their ability to block light in TL is very high, while in IRT they are much more translucent. In IR they respond like a very light gray although they still have some power to hide the underlying lines. Finally, phthalocyanine green (38) is a very intense color, which does not permit the complete vision of the underdrawings. Both in IR and IRT, it forms graduated scale and shows a translucent appearance.

3.5. Brown, White and Black pigments

Earthen browns are very heterogeneous pigments: they present hundreds of shades and hues; some of them tend to be quite translucent while others are very opaque. Only deep browns have been chosen here, and those closer to ochers or red earths have been discarded (figure 7). However, in general, they share many characteristics with ochers and earth reds. Umber pigments (figure 7, samples 39, 40) are semitransparent and form strong graduated scales in all set of measurements. They both block the light in TL and IRT, unless they are applied in very thin layers. Burnt Sienna earth (figure 7, sample 41), is very opaque and shows little gray variations except in IRT. Its ability to block the light is very significant, as it was described for iron oxide pigments (hematite and almagra red).

White colors are a quite homogeneous family. They display the main differences in VIS, where, some of them are quite transparent while others tend to be opaque. Titanium dioxide, rutile (figure 7, sample 42), and lithopone present a high hiding power. They have quite similar patterns of behavior in all the ranges. Despite their opacity, in general, the behavior of whites in TL and IRT regarding the ability to let light pass through them is reasonably good and, in fact, their light blocking response is very low. Only titanium (figure 7, sample 42), and lithopone (figure 7, sample 44) are able to slightly block the light in TL when the layer is quite thick. That happens especially with titanium, which also presents a characteristic tonal scale. Zinc white (figure 7, sample 45) proves to be very transparent to the passage of light in all tests. Something very similar happens with the chalk of Bologna (figure 7, sample 46), whose uses as pigment are very limited when oil is chosen as a binder. (Doerner, 1998).

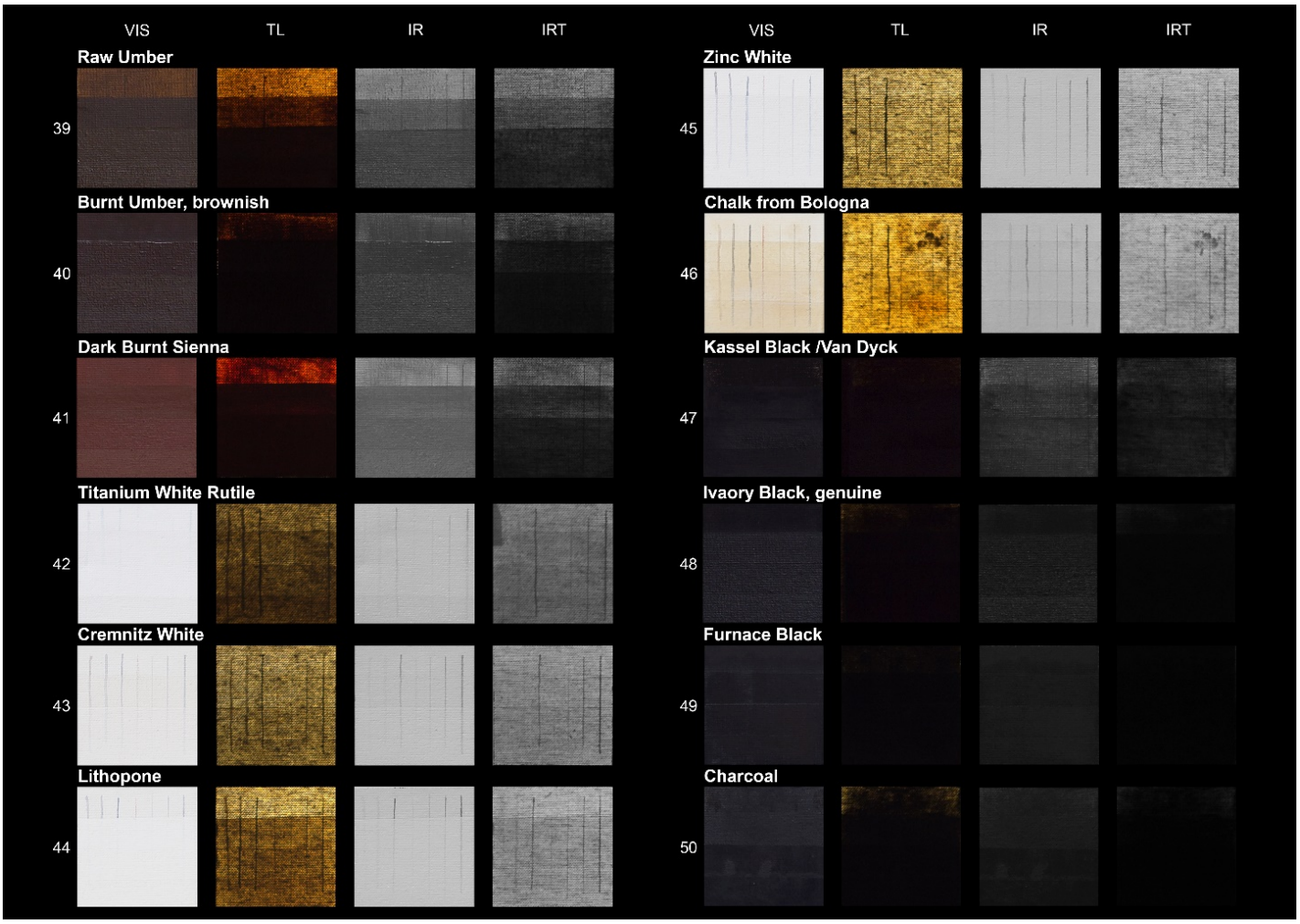

Fig. 7. Brown, white and black pigments observed in VIS, TL, IR and IRT

A high opacity in the VIS, TL, IR and IRT is the common characteristic among all Black pigments (figure 7, samples 47-50). They tend to have a high hiding power, and thus their ability to block light is also very high, being the Kassel Black (figure 7, sample 58), the only one that permits a bit the light to pass through it, although this fact has little application due to the darkness and hue of the color, which does not permit to read underdrawings.

4. Conclusions

Along this paper it was highlighted that the pigments respond differently to the passage of light in the visible and infrared bands. Although a relatively constant behavior is observed in some pigments, some others have disparities between their own behavior, depending on the chosen technique. A table containing all the pigments and colorants used in this study has been made in order to classify their respective behaviors in VIS, TL, IR and IRT (Table 2).

The light, passing through the brush strokes can finally allow to preliminary guess which pigments could have been used in a painting, by considering the palette and the period of the artwork (even if other analysis methods must therefore verify the hypothesis). The data obtained can contribute to a greater readability of the results of painting when performing TL and IRT imaging. This paper therefore intends to be a contribution to the proper interpretation of such light transmitted techniques performed on paintings with translucent supports. Finally, the selection of pigments covers the main historical specimens from antiquity until the twentieth century. For this reason, we hope that this experiment will be of help to conservators, restorers, art technicians, dealing with artworks and even art historians.

			VIS				TL				IR				IRT			
Nº	PIGMENT	REF	O	S.T	T	C	O	S.T	T	C	O	S.T	T	C	O	S.T	T	C
1	Italian Gold Ochre Light	K 40220		■		■			■	■			■	■			■	■
2	Raw Sienna, Italian	K 40400		■		■			■	■			■	■			■	■
3	Realgar, genuine	K 10800	■			■			■	■		■		■			■	■
4	Naples Yellow from Paris	K 10130		■		■			■	■		■		■			■	■
5	Lead Tin Yellow Light	K 10100		■					■				■				■	
6	Chrome Yellow Light	S 549		■		■			■				■				■	
7	Reseda	(S/N)			■	■			■				■				■	
8	Cadmium Yellow No. 1, lemon	K 21010		■					■	■			■				■	
9	Cobalt Yellow	K 43500			■	■			■				■				■	
10	Natural Cinnabar Monte Amiata	K 10610	■					■		■		■		■			■	■
11	Vermilion	K 42000	■					■		■	■			■			■	■
12	Burgundy Red Ochre, fine	K 11574	■					■		■		■		■			■	■
13	Red Lead, Minium	K 42500		■					■	■			■				■	
14	Almagra Red	K 40545	■				■				■					■		■
15	Iron Oxide Red, natural	K 48600	■				■				■			■		■		■
16	Lac Dye	K 36020	■					■		■			■				■	
17	Kermes	K 36045			■	■			■				■					
18	Cadmium Red No. 1, light	K 21120	■						■	■			■				■	
19	Alizarine Crimson Light	K 23600		■					■				■				■	
20	Lapis Lazuli, medium quality	K 10510		■		■			■	■		■		■			■	■
21	Azurite natural standard	K 10200		■		■			■	■		■		■			■	■
22	Blue Bice	K 10184			■	■			■	■		■		■			■	■
23	Prussian Blue LUX	K 45202		■		■		■		■	■			■	■			
24	Indigo	K 36007		■				■		■			■	■			■	■
25	Smalt, standard	K 10000			■				■				■				■	
26	Cobalt Cerulean Blue	K 45730	■						■	■			■	■			■	■
27	Cobalt Violet, dark	K 45800		■		■			■	■		■		■			■	■
28	Phthalo Blue	K 23050	■				■					■		■			■	
29	Verdigris, synthetic	K 44450			■	■			■	■	■			■		■		■
30	Cadmium Green, dark	K 44510	■					■		■		■					■	■
31	Chrome Oxide Green	K 44200	■				■				■					■		■
32	Cobalt Green	K 44100	■				■					■		■			■	■
33	Chrysocolla	K 10350			■	■			■				■	■			■	■
34	Copper Resinate	K 12200			■				■				■				■	
35	Viridian Green	K 44250			■	■			■	■			■				■	
36	Verona Green Earth	K 41700			■	■			■	■			■	■			■	
37	Malachite Arabian, Antlerite	K 103700		■		■			■	■	■			■		■		■
38	Phthalo Green Dark	K 23000a		■					■	■			■	■			■	■
39	Raw Umber	K 40610	■					■		■		■		■			■	■
40	Burnt Umber, brownish	K 40710	■				■				■					■		■
41	Dark Burnt Sienna	K 40430	■				■					■		■		■		■
42	Titanium White Rutile	K 46200	■						■	■		■				■	■	
43	Cremnitz White	K 46000			■				■			■					■	
44	Lithopone	K 46100	■						■				■				■	
45	Zinc White	K 46300			■				■				■				■	
46	Chalk from Bologna	K 58100			■				■				■				■	
47	Kassel Black /Van Dyck	K 41000	■				■					■		■		■		■
48	Ivaory Black, genuine	K 12000	■				■				■			■	■			
49	Furnace Black	K 47250	■				■				■			■	■			
50	Charcoal	(S/N)	■				■				■			■	■			

Table 2 lists the fifty pigments that have been used in this study, including their main behavior characteristics in VIS, TL IR and IRT. Aspects like opacity (o), semi-translucency (s.t), translucency, (t) or graduated tonal scale response (C) have been considered for each imaging technique.

5. Conflict of interest declaration

The authors wish to state that no financial or personal interests have affected the objectivity of the study, and that no conflicts of interest exist.

6. Funding source declaration

Authors wish to state that no external funding has been involved for this study.

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8. Short biography of the authors

Miquel Herrero-Cortell - He holds a PhD in Art History. He has a degree in Fine Arts from the Polytechnic University of Valencia (UPV) and a degree in Art History from the University of Valencia (UV). He holds a Master's Degree in Conservation and Restoration of Cultural Heritage and a Master's Degree in Artistic Production. He has developed his work as a researcher focusing on the field of materials and painting techniques, as well as on painting diagnosis. He is currently teaching at the Universitat Politécnica de València.

Paola Artoni - She holds a PhD in Beni Culturali. From 1999 to 2009 she worked for Ministero per i Beni e le Attività Culturali in the Museum of the Ducal Palace in Mantua. Since 2010 she's Functionary technical responsible of the Centre Laniac (Laboratorio di Analisi Non Invasive per l'Arte Antica, Moderna e Contemporanea), in Dipartimento di Culture e Civiltà, (University of Verona). She held courses for introducing non-invasive diagnostics applied to cultural heritage in the same university, from 2011 up to now.

Marta Raïch - She has a degree in Audiovisual Communication by the University of Lleida (Spain). She is a Technician in Image Production. She is specialized in scientific photography applied to works of art, as well as artistic diagnosis. She is currently developing her research and work as a technician at the Centre d'Art d'Època Moderna (CAEM) of the UdL where she carries out technical and scientific imaging, while she also develops design and layout tasks.

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BOOK REVIEW: L'anima e la magia dei COLORI. Uso consapevole dei colori nella vita

Renata Pompas

Samya Ilaria Di Donato: L'anima e la magia dei COLORI. Uso consapevole dei colori nella vita. LE DUE TORRI, Bologna, 2017.

Samya Ilaria Di Donato is a colour researcher and consultant. Previously a country manager for a multinational company and president of the Italian Association of Image Consultants, careers that she left (after a health problem which changed her existential perspective) to dedicate herself entirely to colour. Today she organises colour training and consultancy for leading companies, is a business counsellor, trainer in chromo-disciplines, talent consultant as well as creator of colour-related events.

Of her many publications, I started with this book - *L'anima e la magia dei COLORI* - and it allowed me to gain an overview of her research, to be explored more deeply in the other texts. It is a particular and unusual approach, based on diverse spiritual and holistic disciplines and, as the author explains, it is divided into four levels: physical, mental, emotional and spiritual.

In the introduction, the relationships established between the source, the object and the observer as well as their influence on the body are examined. Then Di Donato looks at the significance and function of colours through myths, rituals, alchemy, and holistic therapies, with the aim of evoking a "journey" of knowledge.

The **significance of colours** represents the main aspects.

Alchemy - myth or a real pre-chemistry discipline that has fascinated scientists like Isaac Newton, and philosophers like John Locke and whom psychoanalysts such as Carl Jung and James Hillman have written about - describes the different corresponding colours of *nigredo (the blackening or melanosis)*, *albedo (the whitening or leucosis)*, *citrinitas (the yellowing or xanthosis)* and *rubedo (the reddening, purpling, or iosis)* which mark the different phases necessary to achieve philosophical gold.

Religion illustrates how different religious denominations use colours to express mystical notions - of which I list a few examples. In addition to the traditional colours of the castes (varna = colour), *Hinduism* explores the seven "chakras" (energy centres) with their seven colours - each one connected to meaning, an element, a function, a planet - marking the path to asceticism. The author explains *Judaism's* ten "Sĕfirōt" (emanations through which the divine is manifested, also connected to the practical and emotional circumstances experienced by each individual in daily life) with their colours and features. From *Christianity,* she examines the liturgical colours together with those of the Archangels whose colours symbolise the functions. *Buddhism's* five primary colours ("Pancha-Varna") are also discussed.

So-called "natural" **Chromotherapy** provides a concise overview: *Chromotherapy*, which uses colours to restore the body's balance. *Crystal Therapy* uses crystals, stones and minerals of varied shapes and colours for the same purpose. The *Family Constellations*, which apply the colours of the "chakras" to the systems psychology technique devised by German psychologist Bert Hellinger. *Art Therapy*, which cures several psychological disorders through drawing and colouring. *Ayurveda* (the science of longevity) expresses its three "doshas" (vital energies) with colours. *Aura Soma* which heals through contact with coloured bottles filled with an infusion of herbs, essential oils, plant extracts, buds, crystals and water. *Reiki*, the Japanese practice that conveys healing energies through the placing of hands, applied by the author using the colours of the "chakras".

Beyond the discussion on the science and effectiveness of these practices (around which there is a debate which is not appropriate to mention in this context) I thought it was very interesting to see how they all turn to colour as both diagnosis and cure, as well as all the myths, rites, religious confessions, esoteric practices that the author describes - zodiac signs, tarot cards, enneagram, etc. - all of which are not only a question of science and efficacy. - signs, tarots, enneagram, etc., which give the colour symbolic, signifying, active and transformative properties.

In conclusion Di Donato in the twelve chapters of the book presents a wide and diverse outline of the various fields of knowledge in which colour is the protagonist, quick and essential points in which the content stirs the comparison between cultures and applications, searching for similarities and differences. For more information: https://samyadeicolori.it/.

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