Colour measurements for monitoring the conservation of contemporary artworks

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In this paper the data acquired by using Fibre Optic Reflectance Spectroscopy (FORS) and spectro-colorimetry on the mural *Tuttomondo* (1989) painted by Keith Haring (1958-1990) on the wall of the Church of Sant'Antonio Abate in Pisa (Italy) will be reported. *Tuttomondo* is one of a few extant Haring large murals worldwide. Although it was in a relatively good state of conservation, alterations and fading of the colours, yellowing and darkening of the white background, and losses in the black lines were observed. A diagnostic survey was begun in September 2011 to evaluate the state of conservation of the mural in order to support the conservation intervention which was focused on cleaning and the subsequent consolidation of the mural painting. The FORS data recorded on several spots (about 1.5-mm in diameter) of the mural before any conservation procedures provided useful information on the composition of the acrylic paints supplied to the artist by Caparol Italy GmbH & Co. In regards to the yellowing and darkening of the white background, as well as the fading of the colours, cleaning tests were carried out, using various materials (e.g. hard erasers, deionised water, wishab, and cleaning emulsions). For some of these tests it was decided to use spectrocolorimetres to monitor and document the colour variations caused by each cleaning test on selected areas both before and after the cleaning process. The colorimetric data supported the choice of the final cleaning procedure, which, to a great extent, enabled the recovery of the vivid original colours. The colorimetric measurements will be used to monitor the state of conservation of the mural on a regular basis

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Introduction

The primary importance of expressing the creative messages of contemporary artists' has often been considered more important than the preservation/conservation of their artworks. If contemporary outdoor mural paintings are taken into consideration, it is easy to understand why they tend to lose their original aesthetic characteristics, in particular their colour, over time. Therefore, for documentation and conservation purposes, it is very important to document/report the colorimetric values of artworks. For this reason, any studies and/or preservation/conservation procedures should also be programmed with preliminary and, in the course of any interventions, diagnostic measurements. In this way, the colorimetric data will make it possible to follow the conservation procedures applied to the artworks under treatment, to check the colour rendering of the inpainting or other restoration processes, and to monitor their behaviour during permanent and/or temporary exhibition events.

In this paper are reported the non-invasive data acquired in situ on the mural entitled Tuttomondo (1989), which was painted by Keith Haring on the wall of the Church of Sant'Antonio Abate in Pisa (Italy). Measurement were recorded by means of ultraviolet (UV), visible (Vis), and near-infrared (NIR) Fibre Optic Reflectance Spectroscopy (FORS) and colorimetric methodologies. Tuttomondo is one of the few existent large murals by Haring in the world. It covers an area of approximately 180 m2 and consists of 30 figures that represent the theme of "harmony and peace in the world", which suggest the variety of the aspects of human coexistence [1-5]. Twenty-two years after its creation, the mural was still in acceptable conditions, although not comparable to its original appearance. Indeed, the artwork presented a yellowing of the white preparation layer and a discoloration of the black colour in the outlines of the figures. The coloured areas also showed intense fading and their hues were uniformly lacking in saturation. In September 2011 a diagnostic survey was begun, which was supported by the COPAC Project (Preventive Conservation of Contemporary Art), which was sponsored by the Tuscan Region, by the City of Pisa and by the Friends of Heritage Preservation (USA).

The goal of the present study was to determine the chromatic values of the mural before, during and at the end of the conservation processes, in order to document and support the restoration procedures, which were focused on cleaning the surface of the painting and protecting it from the atmospheric events. The FORS analysis was mainly focussed on obtaining preliminary information on the composition, in terms of pigments and colorants, of the acrylic paints used by the artist. Colour measurements were used instead to document the colour variations caused by each cleaning test on selected areas both before and after the cleaning process, and to monitor the stability of the preservative intervention over the course of time.

Instrumentation

Reflectance spectra were recorded using two portable single-beam Zeiss spectroanalysers, model MC601 and model MC611 NIR 2.2WR, in the 350–2200 nm range. A voltage-stabilised tungsten-halogen lamp (20 W, model CLH600) was utilised. The data acquisition step was 0.8 nm/pixel and 6.0 nm/pixel for the 1024-element silicon photodiode array (MCS601) and for the 256-element InGaAs diode array (MCS611 NIR 2.2 WR) detectors, respectively. The spectroanalysers were equipped with a quartz optical fibre bundle connected to a probe-head designed for reflectance analysis. The geometry of the measurements was 8°/8°. A circle-shaped area with a 2 mm diameter was investigated. Calibration was performed by means of a 99% Labsphere Spectralon diffuse reflectance standard.

Colour measurements were acquired by using a Konica-Minolta spectro-colorimeter, model CM-700d. It was equipped with an integrating sphere, d/8° measurement geometry, and worked in the 400-700 nm spectral range with a 10 nm acquisition step. The light source and detector were, respectively a pulsed xenon lamp with UV cut filter and a silicon photodiodes array [6]. The instrument was provided with its own white reference (100% reflective) and a zero calibration box (0% reference).

Colour measurements were acquired using D65 illuminant, a 10° supplementary standard observer, and excluded the specular component of light. The data reported were based on an average of three measurements, and were calculated for the CIEL*a*b* 1976 colour space. For each measurement, the spectro-colorimeter was positioned in exactly the same spot (Ø 8 mm) of each area. Colour differences, Δ(L*a*b*) and ΔE, were calculated on average values.

Results and Discussion

Fibre Optic Reflectance Spectroscopy

FORS measurements were used to tentatively characterise the composition of the acrylic paints used by Keith Haring. This analysis made it possible to identify all the pigments (Table 1).

area	pigments*	resin	inert
white (background)	titanium white (rutile)	acrylic	---
burgundy	iron oxides	acrylic	kaolinite
red	quinacridone red	acrylic	kaolinite
pink	tetracene	acrylic	kaolinite
yellow	arylide yellow	acrylic	kaolinite
green	phthalocyanine green	acrylic	kaolinite
blue	phthalocyanine blue	acrylic	kaolinite
violet	carbazole dioxazine	acrylic	kaolinite
black	---	---	---

*****all coloured areas were mixed with titanium white (rutile)

Table 1: List of the materials detected with FORS analysis.

The reflectance spectra collected on the whitish background support revealed the presence of titanium dioxide (TiO_2) in the rutile crystalline form [7-8].

Rutile was also used by the artist in combinations with pure colours in order to paint the coloured areas.

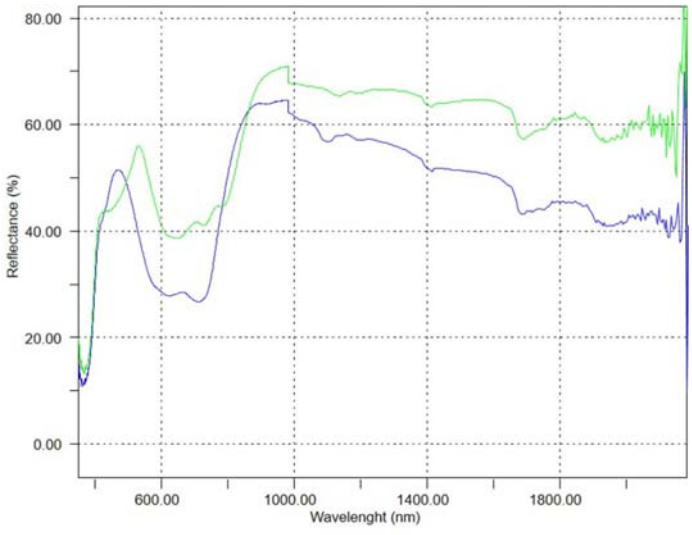

Figure 1: FORS spectra of the blue (blue line) and the green (green line) areas.

The burgundy, red and pink areas were obtained by using three different red pigments. In particular, the FORS spectra acquired on the burgundy area showed two absorption bands at about 530 nm and 865 nm, which are characteristic of iron oxides (hematite α-Fe_2O_3). The spectra collected on the red and pink areas presented the typical spectral shape of organic red dyes. In fact, two absorption bands at 520 nm and 556 nm, which could be attributed to the presence of a quinacridone

red [9] in the red paint, and two bands at 498 nm and 535 nm which were attributed to the presence of an orange dye (probably tetracene) in the pink area, were found. The spectra acquired on the yellow areas showed an inflection point at around 505 nm, which was probably due to the presence of an arylide yellow pigment. The green and blue areas showed the characteristic spectral features of phthalocyanine pigments. As regards the green area, absorption bands at 450 nm, 650 nm, 730 nm and 780 nm, were observed, that are imputable to a phthalo green pigment. A phthalo blue pigment was identified, in the blue area. Its presence was confirmed by two absorption bands at 620 nm and 715 nm, with a shoulder around 430 nm, and by two other bands at about 910 nm and 1100 nm (Figure 1) [10].

Lastly, the FORS spectra acquired on the violet areas showed three absorption bands at around 540 nm, 567 nm and 627 nm, which are due to the presence of a carbazole dioxazine violet dye [9].

UV-Vis-NIR reflectance spectra recorded on black lines did not provide any specific information on the chemical composition of the pigments used by the artist. This was due to the presence of a strong absorption band that covered the entire spectral range investigated.

The spectra of all the coloured areas also showed two absorption bands in the NIR region at 1394 nm and 1414 nm, which are due to the presence of kaolinite [11]. It can be assumed that kaolinite was used as a filler in the paint formulation of the pure colours, whereas its absorptions were not present in the spectra acquired on the white background.

Colorimetry

The entire mural surface, except for the black lines, was cleaned using a mixture of agar gel (concentration of 5%, warmed in demineralised water) and 1% disodium EDTA (pH 4.5) with the addition of 0.2% ammonium carbonate, in a quantity sufficient to obtain a pH value of 7-8 in the mixture.

Since the black lines, had a tendency to lose materials simply by soft contact, they were consolidated by using a microacrylic nanophase emulsion (Microacril® IMAR) diluted to 5% in water.

The colorimetric measurements were focused on the variations of colour values in each spot before and after cleaning in order to assess the relative effectiveness of the applied procedure. Analyses were repeated soon after the application of Hydrophase®, an alkyl alcoxysilane protective, and again one year later (Figure 2). The results are shown in Tables 2-3 and in Figure 3.

Figure 2: Tuttomondo by Keith Haring. Detail of the investigated areas.

All the colours became more saturated after cleaning, except for the white and red areas, which did not show significant changes in colour. The pink and violet areas showed the same behaviour after the cleaning procedure: both the a* and b* parameters increased, while the L* remained unchanged. For the burgundy spots, higher values of a* and b* were observed, but the colour was darker ($\Delta L^* \approx -2$) than before the cleaning treatment. In the case of the blue and green areas, all the three colorimetric coordinates decreased after cleaning. In particular, the most significant reductions were for b* in the blue area ($\Delta b^* \approx -11$) and for a* ($\Delta a^* \approx -8$) in the green one, resulting, as expected, in an increase in

the blueness and the greenness, respectively. The yellow area showed an increase in the b* coordinate ($\Delta b^* \approx 8$) and a slight reduction in the reddish component. The black lines became darker and more saturated after the consolidation treatment.

As regards the protection treatment, the colour variations were very small after the application of the Hydrophase® protective: ΔE was about 1 (violet, blue, yellow, black and pink areas) or 2 (green, white and burgundy areas). A $\Delta E \approx 5$ was registered only for the red area.

Furthermore, the colorimetric analysis repeated one year after the conservation procedure showed no significant changes, except in the red areas ($\Delta E \approx 7$). This anomalous behaviour will need to be further investigated in order to justify the colorimetric values.

area	colour	t_0 before cleaning			t_1 after cleaning			t_2 after protection			t_3 after 1 year		
		L*	a*	b*	L*	a*	b*	L*	a*	b*	L*	a*	b*
A	violet	73.8	1.7	-3.2	73.1	3.8	-12.3	72.6	3.9	-11.9	72.7	3.7	-11.1
B	blue	62.6	-9.5	-15.5	57.5	-15.4	-26.8	56.8	-15.6	-26.4	56.1	-15.4	-26.2
C	yellow	81.9	2.7	28.4	83.1	1.7	35.9	83.1	2.0	36.3	81.9	1.8	35.2
	black	28.8	0.5	0.2	25.1	0.5	-0.2	24.5	0.5	-0.1	24.3	0.5	0.0
	pink	74.5	18.1	13.5	73.9	23.2	15.4	73.1	24.1	16.1	72.9	23.9	16.3
D	green	70.4	-14.4	4.8	67.7	-22.8	0.8	66.6	-21.8	1.6	66.7	-22.0	1.5
	white	78.1	0.9	11.0	78.2	1.0	10.2	79.6	0.8	9.7	79.3	0.9	9.7
	burgundy	54.7	17.4	7.7	52.4	21.4	9.3	50.7	20.1	8.8	51.1	20.4	9.4
E	red	64.9	32.0	10.7	65.0	31.9	10.0	62.7	35.7	11.3	57.7	39.9	12.6

Table 2: Average colorimetric values (L, a*, b*) for each coloured area before (t_0), during (t_1 and t_2) and after the restoration (t_3).*

area	colour	ΔE (t_1-t_0) cleaning	ΔE (t_2-t_1) protection	ΔE (t_3-t_2) after 1 year
A	violet	9.4	0.6	0.9
B	blue	13.7	0.7	0.8
C	yellow	7.7	0.4	1.7
	black	3.8	0.6	0.2
	pink	5.5	1.4	0.4
D	green	9.7	1.7	0.3
	white	0.8	1.6	0.3
	burgundy	4.8	2.2	0.8
E	red	0.7	4.6	6.6

Table 3: Average ΔE colour differences.

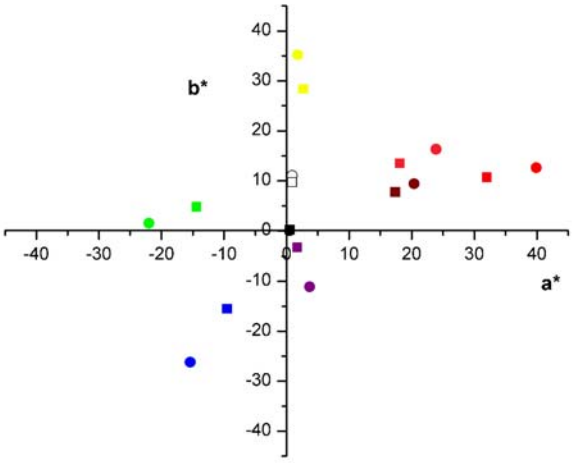

Figure 3: Diagram of the investigated areas before (square) and after (circle) the conservation treatment (t_3-t_0) showing the shifts of their a and b* coordinates. The colour of each point corresponds to the one of the investigated area.*

Conclusions

Within the conservation project of the *Tuttomondo* mural by Keith Haring, colorimetric and spectroscopic investigations were carried out in order to:

- identify the pigments in the acrylic paints used by the artist;
- check the chromaticity coordinates before, during, and after the cleaning process of the coloured areas and the consolidation of the black lines;
- check for any changes in the chromaticity coordinates as a result of the protective treatment;
- monitor the efficiency of the protective treatment over the course of time.

The FORS results allowed to make a tentative characterisation of the artist's palette. Secondly, the colorimetric measurements enabled us to choose the best cleaning procedure, in terms of hue and saturation variations. Moreover, by means of further analysis it was found that the cleaning treatment was very effective, and that induced a significant colorimetric change over the entire surface. In fact, all the colours of the painting, which had faded after twenty years of environmental exposure, appeared more brighter and saturated after their conservation. The protective treatment, instead, did not induce significant changes in the colour surface, except for the red area, thus confirming the reported characteristic (good transparency) of the product.

One year after the conservation procedure, the mural has not undergone any significant changes, thus confirming the effectiveness of the selected treatment.

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