Driven by Caravaggio Through His Painting

An Eye-Tracking Study

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Abstract— **Thanks to eye-tracking technology, we observe and measure the eye behavior of two samples of volunteers interacting with two Caravaggio's paintings in different contexts of use, in order to test the artist's ability to guide the reader through a visual pathway. According to our preliminary results, the context strongly influences the fruition pathway designed by the author. It is the first time that art perception is investigated in an ecological environment.**

Keywords-eye-tracker; art; Caravaggio; visual perception.

I. INTRODUCTION

Since ancient times, we wonder how the human brain acquires and processes images of the outside world.

Aristotle, in "De Anima," said that the mind creates an inner world of images in which there is correspondence to the outer world [1]. Cognitive psychology explains the same phenomenon through embodied simulation: the ability to build a representation of the outside world to which our visual experiences is related [2].

The experience of artistic fruition is so complex that the cognitive disciplines have begun to investigate it with growing interest. As art critics say, the viewer does not have the simple mechanical role of recording visual stimulation provided by the work of art, but the fundamental task of giving meaning to it [3]. For semiotics, the reader has in fact a cooperative role in the interpretation of any text, be it a painting, a story, etc. [4]. Some artists are clearly representative of this cooperation because they attempted to build spatial organization in their paintings, which are structures for both contemplation and interpretation, and are exploited by the viewer upon reception [5].

The Italian painter Michelangelo Merisi, known as Caravaggio, creator of important paintings such as *Sette Opere di Misericordia* (Seven Acts of Mercy) and *La Flagellazione di Cristo* (The Flagellation of Christ), is one of the most representative painters in this sense. It says that he, at the end of the sixteenth century, probably skillfully manipulated an early but deep understanding of the field of optical sciences and visual perception to construct his paintings, thus guiding fruition through a specific path [5][6]. Research on the Galilean lenses, studies of Della Porta and Kepler on perception, feed the cultural patchwork around the painter [5].

How these ideas were used by the artist to picture his subjects has been the focus of numerous studies, evidence of how interesting the manner is in which the painter translated the optical sciences into painting practice, using for example a hole in the ceiling of his studio as a prototype of the camera obscura [6]. Indeed, in the seventeenth century, science was investigating vision with particular attention.

Eye tracking is a useful methodology for the experimental validation of the hypothesis that the pictorial technique of Caravaggio individuates in each painting a precise visual pathway passing through precise areas of interest.

In this paper, we compare the ocular behaviors of two groups of volunteers dealing with two original works by Caravaggio: the first group observed the altarpiece *Sette Opere di Misericordia* (Fig.1) from the church of Pio Monte della Misericordia in Naples; the second group observed the painting *La Flagellazione di Cristo* (Fig.2), exhibited in the Museum of Capodimonte.

The collected data show different fruition strategies: the visual scan path among the subjects belonging to the first group was almost always the same. Instead, among the subjects in the second group it was not possible to find any recurring pattern of fruition.

The article is structured as follows: in Section II, we enumerate the studies related to artistic fruition performed to date. In Section III, we highlight the experimental hypothesis and in Section IV, we describe the experiment we carried out. The methodology used in compiling the data for the two samples of subjects is explained in Section V, and the procedures in Section VI. In Section VII, we compare the data collected and carry out a first analysis that leads us to the preliminary conclusion (Section VIII).

II. PRIOR ART

The eye-tracking devices for the analysis of the cognitive processes activated during artistic fruition have been used in several recent studies. The project started by the research group led by David Massaro of the Catholic University of Milan [7], like the study conducted by Rodrigo Quian Quiroga and Carlos Pedreira (respectively belonging to the University of Leicester and University of Magdeburg [8]), studied the perception of paintings using a digital version. Both studies investigated, through fixed eye-tracking devices, the neurocognitive processes that govern the way we see art.

In these studies the paintings are measured primarily through their formal components. In addition, the study

 ISBN: 978-1-61208-462-6

performed by Quiroga and Pedreira addressed the topic that has always guided the studies on artistic perception: how to establish the judgment of a work of art, based on the question *"is this beautiful?"* Neither of the two studies focused on the visual pathway of observation.

An example of a study of artistic fruition inside a museum itself, using the original painting, is that conducted at the Museum of Arts of Indianapolis in 2011 regarding the contemplation of *Hotel Lobby* by Edward Hopper. In this case, the eye-tracking device used was a fixed type which forced contemplation from a fixed position; distance and observation time were imposed by the conductors of the experiment and strongly influenced the viewing experience. For these reasons the experiment cannot be considered ecological.

Another important experience is the one organized in 2000 during the exhibition *Telling Time* at the National Gallery in London [9] in which museum visitors were invited to sit in a cubicle equipped with a fixed eye-tracker device inside and to watch some paintings on a screen. Participants' visual scanning paths were projected outside the cubicle. The installation was aimed at enhancing the content of the museum with the use of new technologies.

The experiments previously described aimed to validate the cognitive process of the subject and they did not take into consideration the painter's perspective and intention. Moreover, they use paintings in a non-original context and often in a digital copy: these reasons have led us to initiate a series of new experiments on artistic fruition in ecological environments.

III. THE EXPERIMENT

Is there a narrative path in the works of Caravaggio that the painter consciously constructed and which has endured through the centuries? What are the elements that influence this visual pathway? Does the *formant light*, to which the art critic and historian Cesare Brandi refers, have a role in the *revelation* of Caravaggio's paintings – either on the aesthetic level or on the level of the semiotics? [10]. In the following, we describe the experiments we performed.

Two groups volunteered in the experiment. *Group 1* composed of 40 participants, with the same number of men and women, all aged between 17 and 70 years; *Group 2* composed of 28 participants randomly picked from the visitors of the museum, men and women of varying age between 18 and 65 years. They came from all over the world and had normal or corrected-to-normal vision; none of them received any remuneration.

The painting *Sette Opere di Misericordia* portrays the Seven Acts of Mercy of the New Testament (Fig.1). The scenes on the painting are illuminated by a beam of light that follows the course of the scenes in the moment in which they take place: Pero on the right is nursing her father Cimone through the bars of the prison (corresponds to the two acts of mercy: to visit the imprisoned and to feed the hungry); behind her a bearer of the dead, called a "monatto" carries a deceased person (to bury the dead); at their feet Saint Martin gives half of his cloak to a sick, naked man (to care for the sick and to clothe the naked); a traveler (Saint James of Compostella) asks for hospitality (to shelter the homeless); in the shadow Samson is drinking from the jawbone of a donkey (to give drink to the thirsty).

The painting looks crowded and very difficult to understand, however, it was painted in the century that gave rise to the Baroque style, characterized by multiple perspectives, both eccentric and oblique [11].

The painting is located in the church of Pio Monte della Misericordia in Naples, the original location planned by the painter, where the painting has been preserved since 1607.

Figure 1. The painting *Sette Opere di Misericordia* by Caravaggio.

La Flagellazione di Cristo is a less complex painting in terms of spatial organization (Fig.2). The center of the canvas is occupied by the figure of Christ suffering at the hands of two torturers intent on tying him to the column, the place of immolation. A third torturer, called "Scherano", is bent down to pick up the branches they are going to use in the torture. As in the *Sette Atti*, a beam of light is striking the forms and the action, leaving large areas of the scene in the shadow.

The painting is now located in the Museum of Capodimonte, in a little room where the visitor is forced to admire it from very close and from a different height than in the original location. However, it was commissioned for the De Franchis chapel in San Domenico Maggiore Church (Naples) where it was placed on the altar, about one meter above the ground and and viewed on a diagonal from two meters away.

 ISBN: 978-1-61208-462-6

Figure 2. The painting *La Flagellazione* by Caravaggio.

In both paintings, a light beam illuminates the most important areas of the scene to look at, and it seems to merge them into one path. Our study aims to confirm this insight in a scientific way.

A. Methods

Eye-tracking devices are able to record the movements of the eye and some behaviors of the eyes related to cognitive activity.

In the two experiments described in this paper, we used the Tobii eye-tracker wearable glasses [12]. Tobii glasses are able to record data at a frequency of 30 HZ; the acquired data can be analyzed using the software Tobii Studio. The characteristics that make Tobii glasses a device particularly suited to our purpose are the following: the *portability*, i.e., the device is integral with the head of the observer, the observer can conduct its normal viewing experience without the feeling of participating in an experiment; the *independence*, i.e., the participant does not need to be accompanied by the researcher during the visit; the *understandability of data*, i.e., thanks to Tobii Studio software you can easy overlap the visual scan path with the corresponding stimulus.

The methodology used was validated using a control group [13].

B. Procedure

The experiment included two procedures, named A and B in the following:

1) Procedure A

The first phase of the experiment was conducted over a span of three days at the church of Pio Monte della Misericordia. Participants were randomly selected from among the visitors of the museum. All participants said that they had normal or corrected vision (with contact lenses or eyeglasses). Participants were asked if they had seen the painting before (from a picture or in real life).

A calibration phase is necessary for the device to recognize the coordinates of convergence of the gaze unique to each test subject. Once calibrated, the subjects were able to start their visit. Each participant wore Tobii glasses for three minutes.

2) Procedure B

The second part of the experiment lasted a whole day at Capodimonte Museum. The procedure we used was the same described in *Procedure A*. Participants, chosen at random from among the visitors of the museum, were asked if they had seen the painting before (from a book or in real life) and to wear Tobii glasses during a three-minute visit.

IV. RESULTS AND ANALYSIS

The following metrics are obtained through the Tobii glasses recordings (*Visit duration:* 3 minutes): *Number of gazes:* i.e., the number of times that the eye stops on the different parts of the work, and *Number of fixations:* the number of micro-movements of the fovea (part of the pupil) occurring during the path of fruition. This is a synthetic element, obtained through an algorithm to measure processes of attention. It can be considered an indicator of the intensity in which a visual stimulus is processed. Also measured are *Time to first gaze* and *Time to first fixation* (expressed in seconds)*:* these measures allow us to know the exact moment when the eye of the subject stops on a precise region of the painting and the moment when the cognitive processes for the interpretation of the stimulus are activated.

The *Areas of interest* (AOI) of the two images are defined with the program Tobii Studio. The AOI we activate are the regions with the highest number of visits (*Visit Count)*. We obtain the visual pathway executed by each subject by extracting the *Time to first fixation* (expressed in seconds) of each participant in each of the AOI.

1) Results for procedure A

With the metrics described above, we are able to define the visual pathway of the subjects. In particular we discover that each participant focus their attention on the same AOI. In fact the data aggregation allow us to identify five areas of interest, namely the regions on which subjects' attention is targeted on the basis of the *Fixation Count* and visualized by the program in a *heatmap* (Fig 3).

We also notice that the AOI correspond to the illuminated areas: *Pero nursing Cimone* (a); *The bare back of the sick man on the ground*, (b); *The torch* (c); the *Virgin and Child* (d); *Samson while drinking* (e).

 ISBN: 978-1-61208-462-6

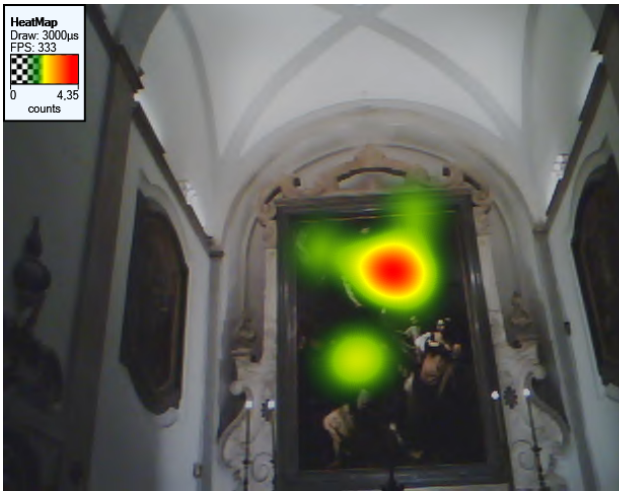

Figure 3. Heatmap by Tobii Studio software vizualizes in real time the intensity in the observation of the picture (Fixation Count).

Moreover, the *Time to first fixation*, corresponding to the precise moment when the visitor observes actively each portion of the painting, allows us to recognize not only when the gaze is resting on each of the scenes of the composition, but also when the visitor starts the cognitive process of understanding.

The *GazePlot* obtained with Tobii Studio (Fig.4) confirms that the visual pathway of the participants moves from the figure of the *Virgin* (or *Pero* sometimes), then goes to the *torch*, than *Samson* and the area occupied by *the sick man* at the end.

Figure 4. GazePlot from Procedure A corresponding to Pattern 1.

The two recurring visual patterns we find (*Pattern A, B*) are described in TABLE I.

TABLE I. RECURRING VISUAL PATTERN IN PROCEDURE A.

	AOI					
Pattern 1	*d*	*a*	*c*	*e*	*b*	*(for 18 subjects)*
Pattern 2	*a*	*d*	*c*	*e*	*b*	*(for 4 subjects)*
No Common Pattern						*(for 18 subjects)*

The behavior of the subjects who participated in the experiment is not dependent on gender, age, country of origin, or prior knowledge of the painting.

2) Results for procedure B

The collected data allow us to define the AOI and the visual pathway of the visitors. Also in this case, we identify the bright regions of the painting corresponding to: *The shoulder of Scherano* (a); *The hand of Scherano* (b); *The chest of Christ* (c); *The head of Christ* (d); *The face of the torturer on the right* (e); *The face of the torturer on the left* (f); *The calf muscle of the torturer on right* (g).

Using the *Time to first fixation* it is not possible to find a common pathway among the 22 participants in the experiment. In fact, 20 different patterns are identified.

In order to compare the variability of the pathways in the two different scenes, we define a Pathway Variability Index (PVI):

PVI = number of distinct pathways / number of subjects.

This PVI tends to 0 when there are very few distinct pathways (i.e., low variability - several subjects performing the same pathway) and tends to 1 when the number of distinct pathways tends to the number of the subjects (i.e., high variability - each subject performing a different pathway). We obtain a PVI of 0.35 in the first scenario and a of 0.90 in the second one, much higher than the previous case.

V. CONCLUSION AND FUTURE STEPS

There is growing evidence that Caravaggio was aware of the phenomena of perception of images and optical studies in vogue between 1500 and 1600, and used this knowledge to direct the construction of his paintings so that this control is still valid after several centuries.

The eye-tracking methodologies allowed us to verify the validity of this hypothesis observing the visual pathway of the visitors of Pio Monte della Misericordia, where the painting *Sette Opere di Misericordia* is preserved in original condition.

Data collected from a group of 40 visitors allowed us to notice that people follows a consistent pattern when observing the painting. However, we could not find a common pattern among the visitors of the painting *La Flagellazione di Cristo*, on exhibit in different physical conditions from those originally foreseen when the work was created. Although the AOI were common to most visitors, the order (visual pathway) was different for each of the participants.

Using a Pathway Variability Index of the patterns, ranged between 0 and 1 (0 is the minimum variation and 1 the maximum), in the case of the *Sette Opere di Misericordia* the index is 0.35 while in the case of *La Flagellazione di Cristo* the index is 0,90.

The results of the two experiments have convinced us to go forward with the study, collecting and comparing the

 ISBN: 978-1-61208-462-6

fruition of other paintings by Caravaggio in the expected context or not in the original position.

In the future we aim to identify the formal elements with the function of guiding the reader through the works of the painter.

We intend to apply the technique of Caravaggio to other visual supports, with the aim of increasing the effectiveness of images. Furthermore, we hope to improve museum fruition and appreciation of works of art through the feedback from visitors.

ACKNOWLEDGMENT

We want to thank the Museum of Pio Monte della Misericordia for the opportunity to carry out our research, and the Museum of Capodimonte for hosting the experiment on the *La Flagellazione* painting on the occasion of Caravaggio's birthday.

Also: Roberta Presta for her valuable contribution, Rosa Strozzillo, Edvige Bruno, Vittorio Sarnelli, Virginia Santoro and Emanuele Garzia for the support, and all participants in the experiment for their willingness.

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 ISBN: 978-1-61208-462-6