35th Annual International Conference of the IEEE EMBS
Osaka, Japan, 3 - 7 July, 2013

Neuroelectric brain imaging during a real visit of a fine arts gallery: a neuroaesthetic study of XVII century Dutch painters

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Abstract— **Neuroaesthetic is a scientific discipline founded more than a decade ago and it refers to the study of the neural bases of beauty perception in art. The aim of this paper is to investigate the neuroelectrical correlates of brain activity of the observation of real paintings showed in a national fine arts gallery (Scuderie del Quirinale) in Rome, Italy. In fact, the present study was designed to examine how motivational factors as indexed by EEG asymmetry over the prefrontal cortex (relative activity of the left and right hemispheres) could be related to the experience of viewing a series of figurative paintings. The fine arts gallery was visited by a group of 25 subjects during an exhibition of the XVII century Dutch painters. Results suggested a strict correlation of the estimated EEG asymmetry with the verbal pleasantness scores reported by the subjects ($p<0,05$) and an inverse correlation of the perceived pleasantness with the observed painting's surface dimensions ($p<0,002$).**

I. Introduction

Neuroaesthetic is a scientific discipline founded by S. Zeki more than a decade ago [1] and it refers to the study of the neural bases of beauty perception in art. Such study are usually performed recording the cerebral hemodynamic responses (with functional magnetic resonance imaging; fMRI) to the observation of computer screen reproductions of paintings or sculptures (reviewed in [2]). Neuroelectrical and neuromagnetic correlates of such brain activity were also addressed by few authors by using magneto-encephalography (MEG; [3]) and electroencephalography (EEG; [4, 5]) brain imaging modalities. However, in all the published scientific reports related to the study of brain activity with fMRI, MEG or EEG modalities, the fruition of the paintings or the sculptures were made possible to the subjects through a presentation on a screen of a series of images of such fine arts works. This was due to the fact that both fMRI and MEG technologies are not portable. On the other hand, modern EEG technologies allow to record the brain activity in different environment and mobile conditions. However, although EEG technology is portable, to our knowledge the recordings of brain activity during the observation of a real paintings or a real sculptures was not yet performed. Thus, it appears now possible to record the brain activity during the fruition of real masterpieces in a fine arts gallery environment, where they are usually observed by visitors.

The aim of this paper is then to investigate the neuroelectrical correlates of brain activity during the observation of a series of real paintings during a visit of a real fine arts gallery (named "Scuderie del Quirinale") in Rome, Italy. Such fine arts gallery was visited by a group of 25 subjects during an ongoing exhibition of the XVII century Dutch's painters, including J. Vermeer (1632-1675). Of special interest for this study was to examine how the emotional and motivational factors as indexed by EEG asymmetry over the prefrontal cortex (relative activity of the left and right hemispheres) could be related to the experience of viewing a series of figurative paintings. In fact, it is known as an important model for the approach withdrawal motivational model of emotion suggests as the left- and right-anterior brain regions are part of two separate neural systems underlying approach and withdrawal motivation, respectively [6]. Relatively greater left frontal activity, either as trait or a state, indicates a propensity to approach or engage a stimulus, while relatively greater right frontal activity indicates a propensity to withdraw or disengage from a stimulus (see for a review [7]). To our knowledge, this is the first study facing the collection of brain activity during the observation of real masterpieces in a real national art gallery.

II. Methods

A. Experimental design.

The experiment has been performed in one of the most prestigious national fine arts gallery in Rome, the "Scuderie del Quirinale". In this occasion, the gallery hosted a collection of several masterpieces from J. Veermer (1632-1675) and his contemporary Dutch painters (such as Vosmaer, de Hooch, Dou, Metsu and many others). Sixteen masterpieces by J. Veermer (8 paintings) and his colleagues (8 paintings) were then selected as stimuli for the subjects. During the experiment the gallery was closed to visitors.

Twenty five normal subjects (34.04±10.61 years, 12 males) were involved in the experiment. For all of them the

*Research supported by BrainSigns srl.

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EEG activity were recorded while for 6 out of 25 the eye movements during the observation of the paintings were also acquired with a eye-tracker device. The experimental procedure consisted in a 1 minute resting sequence of open eyes, 1 minute baseline sequence observing a text explaining the content of the exposition, 1 minute of observation for each one of the selected painting, 1 minute of observation of two perspectives of the gallery (first and second floor, respectively), 1 minute of observation of the Rome panorama located at the end of the gallery (EEG data related to architectonic areas will be not discussed here for lacking of space). During the whole recording session, each subject was guided through the gallery by an experimenter bringing her/him in front of each one of the selected painting. Thus, all the subjects moved through the same sequence of paintings, as in a guided visit. This was done in order to avoid confound related to the order of visit between subjects. Then, the experimenter asks the subject to start the naturalistic vision of the masterpiece. Sixty seconds of free vision of the masterpiece was then performed by the subject, without any pronounced words. During the painting observation, subjects were asked to minimize their facial and gestural movements (Fig.1). At the end of the stimulation, the experimenter asked the subject to rate the painting according to his/her perceived pleasantness (ranging from 1, ugly, to 10, beautiful) and then guided him/her to the next stimulus. Hence, the experimenter noted the time of the beginning and the end of each stimulus as well as the related pleasantness score pronounced by the subjects. At the end of the recording session, subjects were then interviewed with a structured questionnaire. First, they had to recognized the images of the 16 paintings they observed among the representation of other 32 distractors paintings presented to them in a random order. The images of the "distractor" paintings are works taken by the same historical and artistic period of J. Vermeer (e.g. XVII century). When the subjects recognized a picture of a proposed stimulus, they re-scored again it, with a score from 1 ("ugly") to 10 ("beautiful") as during the visit. This was done since at the interview moment the subjects completed the view of all the selected paintings. Afterwards, subjects were asked about their familiarity with the paintings of the Vermeer's historical period. Finally, they complete a psychological questionnaire about the cognitive closure (not discussed in the following for lack of space).

B. EEG recordings and signal processing

The EEG activity was recorded by means of a portable 24-channel system (BEmicro, EBneuro, Italy). Informed consent was obtained from each subject after the explanation of the study, which was approved by the local institutional ethic committee. Electrodes were disposed according to the 10-20 international system. The Fpz channel has been used as reference. The impedances were kept below 5kΩ and the signals have been acquired at a sampling rate of 256 Hz. Raw EEG traces were first band pass filtered (hp=2 Hz; lp=30 Hz) and the Independent Component Analysis (ICA) was then applied to detect and remove components due to eye movements, blinks, and muscular artefacts. The EEG signals have been transformed by means of the Common Average Reference (CAR) and the Individual Alpha Frequency (IAF) has been calculated for each subject in order to define the frequency bands of interest according to the method suggested in the scientific literature [8]. In particular, we defined the following two frequency bands: theta (IAF-6, IAF-4), i.e. theta ranges between IAF-6 and IAF-4 Hz, and alpha (IAF-4, IAF+2). EEG traces were then segmented to extract and analyse the cerebral activity during the observation of the selected paintings. Each EEG trace has been band pass filtered in order to isolate the spectral components in the theta and alpha band from the whole EEG spectrum. The filtered traces have been used to calculate the Global Field Power (GFP; [9]) that was computed by using information from electrodes placed on frontal areas of the subjects. This because the several studies in literature describing the prefrontal cortex as a central areas in the analysis of (8,10-11). In order to summarize the properties of the cerebral activation for the analysed paintings we used the theta and the alpha bands to define the Attention and the Approach/Withdrawal indexes, respectively [8]. Particularly, we used electrodes F7, F3, Fp1, Fz, Fp2, F4, F8 to calculate the Attention Index (AI) and the homologous channels F7, F3, Fp1 to evaluate the Approach/Withdrawal Index (AW index). As to the Attention Index, we reversed the GFP waveform in order to have the activity of de-synchronization pointing up. As far as concern the AW index, it has been defined by taking into account the frontal EEG asymmetry's theory by Davidson [11] as already investigated in a previous study [12]. Hence, the formula defining the AW index is the following:

$$AW = GFP_{\alpha\_right} - GFP_{\alpha\_left} \qquad (1)$$

where the GFP_{α_right} and GFP_{α_left} stand for the GFP calculated among right (Fp2, F4, F8) and left (F7, F3, Fp1) electrodes, in the alpha band, respectively. The waveform of each cerebral index has been averaged second by second to finally obtain a signal consisting of 60 points. Then, the AW signals of each subject have been averaged to obtain a mean waveform and statistical analyses will be performed by using the z-score transformation. The AW and the attention indexes were standardized according to the baseline EEG activity acquired at rest.

C. Statistical analysis

The Pearson correlation has been used to correlate the explicit ratings of pleasantness, given by the experimental subjects immediately after the observation of the paintings, with the one expressed during the final interview at the end of the visit. Analysis of variance (ANOVA) with factors AUTHOR (two levels; Vermeer, Others) x PAINTINGS (eight levels; couple of paintings 1, 2, 3, 4, 5, 6, 7, 8) has been performed to assess significant differences about the pleasantness ratings. Duncan's test was also used for post-hoc comparisons, while Student t-test has been used for the analysis of pleasantness of the observed paintings. Neurometric and verbal score in response to two very similar paintings (by F.Ficherelli and J. Vermeer) both representing a saint, "Santa Prassede" (Fig. 2) were also computed.

III. RESULTS

A. Behavioral data

The Pearson's correlation analysis revealed that the two verbal judgments expressed by subjects during the visit and successively in the post-visit interviews are significantly and remarkably similar, with a high correlation ($p<0.00001$). Hence, in the following analysis we take into account only the verbal rates given by the subjects during the visit of the gallery. All subjects correctly recognized (100%) the observed paintings during the gallery visit in the successive interview. The t-test between the two paintings with the identical represented saint ("Santa Prassede") returned a significant increase of the verbal reported pleasantness score ($p<0.008$) for the Vermeer work (7.27±1.20) against the one by Ficherelli (6.77±1.12). The performed ANOVA for the verbal scores revealed a significant difference in the interaction AUTHOR x PAINT [$F(7, 161)=6.99$; $p=.000001$]. Vermeer paintings were generally best scored than others ($p<0.001$). The best verbal judged paintings were the Vermeer's "Woman with a red hat" (average score 8.01) at the number 8 in the progressive visit of the gallery and the Metsu's painting "Gentleman that writes a letter", (score 8.16) at the number 15 of the same gallery visit. However, such paintings did not statistically differed for the reported scores.

Figure 1. Gathering of the brain activity during the aesthetic observation of the painting "Young woman to the harpsicord" by G. Dou (1613-1675) at the art gallery "Scuderie del Quirinale" in Rome. Note the EEG cap and the eye-tracking device mounted on the cap for the monitoring of the eye movements. EEG and eye tracking data were stored on the portable devices brought by the subjects in a little bag near their hip.

B. Brain activity related to the paintings observation

The estimation of the average AW index for all the subjects along the visit of the 16 paintings in the fine arts gallery returned the profile showed in Fig. 3. The AW index is expressed as a z-score normalized value; when positive, it suggests an appreciation of the group investigated for the particular painting observed, while viceversa when negative. Values of AW index greater than 2.0 suggested a statistically significant increase of the approach/appreciation when compared to the considered baseline ($p<0,05$). The data of Fig. 3 are relative to the average values of the each individual z-score for the AW index computed for each one of the 25 subjects that participated to the gallery visit. The abscissa represents the progressive number of visit assigned to each one of the observed painting in the gallery by the collected group. A total of 16 paintings were observed during the collection of the EEG activity in the performed experiment. Almost all the paintings received an appreciation substantially greater than the baseline ($p<0.05$). It is also possible to note that the maximum value of the z-score (10.3) for the AW index is reached in occurrence of the painting number 8 of the visit, related to the J. Vermeer's "Woman with a red hat". Such painting was also rated as one of the best from the verbal judgments provided by the considered population. The other painting who received a very high verbal judgment by the analyzed group (the Metsu's "Gentlemen that writes a letter" at the number 14 of the visit) received a statistically lower value of the AW index (4.57) when compared to the Vermeer's best score (10.3). In Figure 3 it can be also appreciated as the comparison between the two paintings related to an identical subject (the saint "Santa Prassede") reported a value of AW index for the Vermeer's work (at the number 5 of the visit) statistically significantly greater than the AW index related to the Ficherelli's painting (e.g. z-score=3.25 for the Vermeer's work against the z-score=1.5 for the Ficherelli's work). Such evaluation was in agreement with the verbal judgments obtained in the analyzed population. The Pearson correlation between the verbal judgments provided by the sample considered and the values of the AW index was 0.505, that was indeed statistically significant ($p<0.05$). The lower evaluation for the AW index occurred to the last painting of the gallery visit, the J. Veermer's "Allegory of the faith", at the number 16. The same painting received also one of the most low score in verbal judgments but not as the worst one.

Figure. 2. The picture shows two paintings both representing the same subject, a saint (Santa Prassede). The left painting was performed by J. Veermer (blue panel) while the right painting was performed by F. Ficherelli (green panel, right). It is interesting to note that J. Veermer made a copy of the Ficherelli's painting. All the analyzed subjects viewed both paintings in the same order during the gallery visit.

The average values of AW index for the Vermeer's paintings (z-score=4,59) was statistically higher ($p<0,02$) with respect to the average AW indexes for the other authors presented in the gallery (z-score=1,87). This preference has not showed up in the verbal judgments of the sample (e.g. it results 7.24 for Vermeer's work against the 7.32 as the average score for the other paintings). A statistical significant correlation was found between the AW index and the dimension of the proposed paintings to the analyzed sample. In particular, an inverse significant correlation between the values of the AW index and the surface of the examined paintings, expressed in

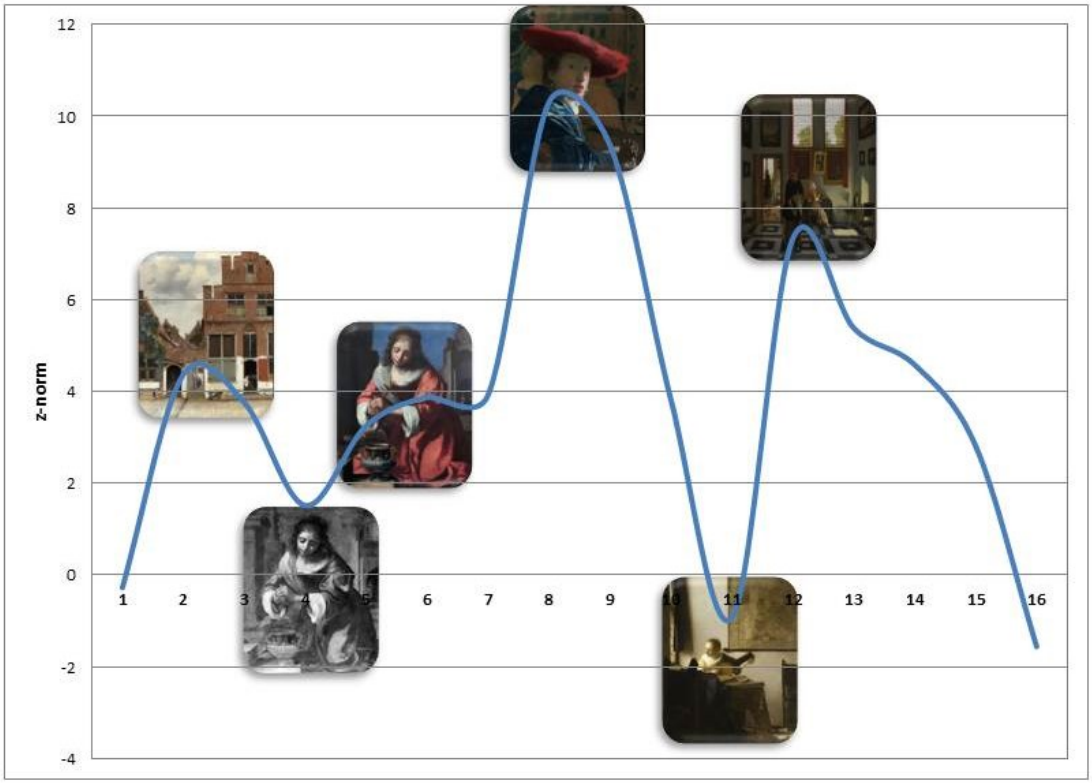

Figure 3. Variation of the Approach/Withdrawal index along the gallery visit. The X abscisse numbers represent the number of the painting encountered along the experiment. The paintings related to particular numbers are superimposed to the AW index fluctuations. Y values are related to the z-score computed for the unbalancing of the EEG power spectra over the prefrontal cortex as evaluated in agreement with the Methods description. Maximum value of the AW index is reached for the observation of the painting number 9 by J. Vermeer "The woman with a red hat".

squared centimeters, was also found (r =-0,72; p<.0020). The Attention index, that returns information about the degree of attention produced by the subjects during the visit to the gallery, showed values of z-scores greater than 2 for the most part of the visit for all the analyzed sample. This suggests a significant effort of attention performed by the analyzed group when compared to the baseline condition during the gallery visit.

IV. Discussion

This paper provided neuroelectrical evidences of the activity of the prefrontal cortical areas in occurrence of the evaluation of a succession of aesthetic stimuli, as provided by the observation of real paintings in a fine arts gallery. Such finding is in agreement with the observations provided by several studies performed by hemodynamic measurements that suggested as the medial orbitofrontal cortex is deeply involved in the perception of beauty [reviewed in 2]. Here, values of the prefrontal cortices activity (as indexed by AW) occurred in agreement with the maximum verbal judgments of the analyzed population. It was also observed a significant inverse correlation between the painting dimension and the score of pleasantness perception (p<0.002). It is now technically possible to measure in a challenging environment statistically robust signs of brain activity related to the art perception. This fact paves the way to a new seasons of brain activity measurements in fine arts galleries and museums for the assessment of the brain activity in front of real masterpieces of art.

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