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Cerebral perception and appreciation of real paintings and sculptures by neuroelectric imaging

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Abstract.

It was reported as the observation of fine arts artifacts displayed on a screen or even in real art galleries produced stable neuroelectrical patterns in humans. In this paper, we report the results from the measurements of the cerebral activity of a group of subjects during the observation of several real paintings of Titian. Furthermore, we reported here also the cerebral and emotional reactions of a group of persons during the observation of the real Michelangelo's Moses sculpture. We collected the cerebral activity by a portable EEG devices, while the collection of EKG and GSR will return information about the emotional states of the subject. In addition, an eyetracker device was used for the collection of eyegazes during the fine art experience. Neurometric indexes related to the Approach Withdrawal (AWI) and Emotional Index (EI) were used. Results showed that in the case of the examined paintings the AW index was significant higher during the observation of portraits than during the observation of the religious ones. Results from the sculpture observations showed that cerebral activity of the subjects varied significantly across the different point of views for the sculpture's observations. Taken together, such results suggested that the perception of the sculpture depends critically by the point of view since it can produce separate emotional and cerebral responses. In addition, results also highlights the appreciation of observed portraits. Neurometric indexes returns then important information on the quality of the appreciation of fine arts artifacts.

Keywords: Neuroaesthetics; EEG; HR; GSR; Eyetracking

Introduction

The study of the cerebral perceptions related to fine art experiences has been started more than a decade ago by Zeki [Zeki, 1999]. To now, the major part of the studies related to the neuroaesthetic discipline have been performed by using the hemodynamic correlates of brain activity through the functional Magnetic Resonance Imaging (fMRI), as reviewed in [Di Dio and Gallese, 2009]. Only few studies have been performed by using the neuroelectrical correlates of brain activity during the fine arts perception [Cela-Conde et al.,2009; Umilta' et al., 2012]. Many of them put the subjects in front to a reproduction of the fine arts picture or sculptures on a computer screen, while only few are using real masterpieces. However, nowadays the use of mobile EEG and eyetracker devices could allow to record brain activity during the real experience of visiting a fine art gallery. Recent studies have been showed as the perception of real or displayed masterpieces by ancient or modern painters generate stable neuroelectrical correlates in humans [Di Dio and Gallese, 2009; Babiloni et al., 2013]. The interest for such study relies on the fact that the fruition of volumetric information introduces a further degree of freedom to the observer's perception that is not present in the observation of paintings on a screen. To understand whether the point of observations plays a role in the cerebral and emotional fruition of architectonical artifacts and sculptures it was decided to analyze the cerebral reactions of a group of subjects during an observation of the Michelangelo's Moses sculpture. Such sculpture is located in the ancient church of San Pietro in Vincoli in Rome, and it presents the interesting feature that the Moses face has the orientation not toward the observer but rather tilted toward the right side of him/her. If Moses was a paint, there will be no other available information available. However, since it is a sculpture it is then possible to collect the different cerebral and emotional reactions to its observation from different points of views. Thus, it has been decided to collect both neurometric and emotional responses of the observers during the contemplation of the sculpture from different points of views that are significant for the gathering of different details related to the sculpture.

Furthermore, the other goal of this work is to analyze the neuroelectrical cerebral signatures of the appreciation or rejection of the paintings of Tiziano Vecellio (known as Titian), in a group of 27 healthy subjects. Such paintings were exposed in a main art gallery in Rome, named "Scuderie del Quirinale", for a period of several months. We were interested to understand how the cognitive appreciations or rejection of such Titian's pictures and observation of Michelangelo's Moses sculpture, Cerebral activity linked to the appreciation or rejection of sensory inflow related to the picture's observation has been indexed in literature by the unbalance of the EEG power spectra (EEG PSD) in the alpha band over the prefrontal areas [Davidson, 1995]. In particular, it has been suggested as the approach-withdrawal behavior could be indexed by the different activities of the left and right prefrontal cortices in humans. In fact, a greater left prefrontal activity suggest a propensity to an engage with the sensory stimulus provided while a relatively greater right prefrontal activity suggest a modality of disengage from the stimulus proposed [Demaree, et al., 2005]. While the EEG activity over the prefrontal cortices returns effectively a stable index of the approach-withdrawal attitudes of the subject in front to the stimuli, the information about the modality of the picture exploration are not easily determined unless an eye-tracking device is used, as in the present case. In addition to the EEG, also the Heart Rate (HR) and the Galvanic Skin Response (GSR) were collected simultaneously to assess the emotional engage of the investigated population. The indexes employed to assess emotional and cognitive appreciation during the observation of those masterpieces have been previously defined in literature [Davidson, 1995; Vecchiato et al., 2011]. By recording the eye-movements of the participants during the observation of the pictures we were interested in the analysis of their scanning pattern during the observation of pictures they like when compared to the pictures they do not like.

Material and Methods

2.1 Experimental design

Two experiments were performed in order to evaluate cerebral and, in one case, also visual perception of art masterpieces. The experiments were conducted following the principles outlined in the Declaration of Helsinki of 1975, as revised in 2000.

Experiment 1: The first experiment has been performed in one of the finest church in Rome, "San Pietro in Vincoli", in which the Michelangelo's Moses sculpture is located. Twenty normal subjects (27.3 ± 1.5 years, half males) were involved in the experiment. In particular, during the whole experimental session, each subject was guided through the church by an experimenter bringing her/him in front to the Michelangelo's Moses in three different points of observation (POV) adopted. The entire experimental procedure consisted in a 1 minute resting sequence of open eyes before the visit, 1 minute baseline sequence observing a white wall within the church before the visit, 1 minute of observation in each one of the points of view considered. Fig.1 showed the position of the subject in the different points of view in front of the Michelangelo's Moses.

Figure 1. The three point of view (POV) in the front of the sculpture.

Then, the experimenter asks the subject to start the naturalistic vision of the sculpture. Sixty seconds of free vision of the Moses was then performed by the subject, without any pronounced words. 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 point of view of the Moses sculpture. Three different point of views have been employed. The position of the subjects in those three points of view is presented in the Fig 1. In particular, the point of view #2 is located on the right side of the sculpture, directly in front of the Moses face (POV#2). The point of view #3 (POV#3) was instead located about 10 mt from the Moses face, in front of the sculpture . The distance of the subjects with respect to the Moses face was roughly the same for the POV#1 and POV#2 (e.g. about 5 mt) while was the double for the POV#3. The entire visit was repeated two times, one with the observation of the sculpture with the natural light, and the other with the observation of the sculpture with the artificial light available from the church. The sequence of artificial and natural light was randomized across the subjects. The visits of all the subjects were performed at noon in a series of days characterized by good weather and stable condition of light within the church. The comparison between these two conditions was made to analyze the effect of the artificial illumination over the sculpture appreciation.

Experiment 2: The second experiment has been performed at the "Scuderie del Quirinale", which is one of the major art gallery in Rome. The gallery hosted a collection of pictures from Titian (1488 – 1576). Twenty pictures were then selected as stimuli for the subjects, 10 related to portraits and 10 related to religious matter. During the experiment the gallery was closed to visitors. Twenty seven healthy subjects (37.04±9 years, 14 males) were involved in the experiment. All the subjects are subjected to the same experimental procedure: a) 1 minute resting sequence of open eyes; b) 1 minute baseline sequence observing a text explaining the content of the exposition; c) successively in the visit they performed 1 minute of observation for each one of the selected paintings. Each subject was conducted along the gallery by an experimenter that brings her/him in front of each one of the selected painting. Such procedure was adopted in order to assure that all the subjects observed in the same temporal sequence the pictures. The naturalistic vision of the picture was performed in silence by the subjects, which were also asked to minimize their movements in front to it. Fig. 2 shows the typical setup of the EEG and the eye-tracking recording performed.

Figure 2. Gathering of the brain activity during the aesthetic observation of the painting "Annunciazione" by Titian. 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 portable bag.

After the 1 minute of free vision, the experimenter asked the subject to rate the painting observed according to his/her perceived pleasantness (ranging from 1, ugly, to 10, beautiful) and then guided him/her to the next picture.

2.2. EEG, HR and GSR recordings and signal processing

The electroencephalographic (EEG) activity were recorded, together with the acquisition of their heart rate (HR) and the Galvanic Skin Conductance (GSR). 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. The 10-20 international system were used as guide for the electrode placement. The Fpz channel has been used as reference. Electrode impedances were below 5kΩ. Independent Component Analysis (ICA) was applied to the EEG to detect and remove components due to eye movements, blinks and muscular artefacts. 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 [Klimesch, 1999]. EEG traces were then segmented to extract the time period related to the observation of the selected paintings. The AW index was defined using the EEG data from the electrodes F7, F3, Fp1, Fp2, F4, F8 of the 10-20 international system. 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; [Lehmann and Skrandies, 1980]) 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 pleasantness [Davidson, 2004 ; Usakli et al., 2009]. We reversed the GFP waveform in order to have the activity of de-synchronization pointing up. 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 AW cerebral index has been estimated for each seconds and then averaged for all the duration of the observation in each POV. 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 index was then standardized according to the baseline EEG activity acquired at rest within the church, before the starting of the visit. The AW evaluation was also estimated by taking into account the EEG data from the first 20 seconds as well as the data for the entire time period (1 minute).

The HR and GSR information was taken by using the NEXUS-4 system by Mindbrain BV, The Netherland). Autonomic information were taken by collecting HR and GSR and by composing the emotional index EI [Vecchiato et al., 2011]. Both AW and EI were referred to the mean and standard values of them obtained during the baseline acquisition, by realizing a z-score transformation of the indexes.

In the *Experiment 2* performed at the "Scuderie del Quirinale" gallery, also Eye Tracking recording were performed on the subjects by the means of a wearable eye-tracker (ASL Mobile Eye) with a sampling frequency of 30 Hz, enough to calculate fixations of the eye on the paintings. The eye-tracker device returned information about the displacement of the eye gaze for each subjects during the observation of the 20 pictures analyzed. In particular, it was taken as an index of the scanning behavior of the subject the number of fixations that were generated during the picture observation. In fact, a fixation is defined when the eye gaze of the subject remains stable for a period of about 200-280 ms during a scene viewing. Fixations were calculated with an I-DT algorithm (Identification by Dispersion Threshold) [Salvucci and Goldberg, 2000] for each subject and for all the pictures during the first 5, 10 seconds and for the entire duration of the observation allowed (60 seconds), with a spatial threshold of 1° of visual angle and a temporal one of 200ms [Rayner, 1998].

For the evaluation of the eye-tracking data, the number of fixations related to the picture that received the best verbal score was compared to the number of fixations related to the picture that received the lowest score for each subject. Such comparisons were made by using a t-paired Student test. The tests were performed for the number of fixations gathered during the first 5, 10 and 60 seconds of the pictures observation.

3. Results

3.1. Behavioral data

Experiment 1:The performed ANOVA for the verbal scores revealed a statistical significant effect for the factor POV (F=6.8510, p=0.02357), with the POV#2 having the higher score reported (9.66 on a scale of 10). The factor LIGHT also was significant for the verbal judgments (F=12.129, p=0.03939), with an increase value of the scores for the condition with the artificial light than the natural.

3.2. Brain activity

Experiment 1: Analysis of variance (ANOVA) was applied on the cerebral variable Approach/Withdrawal and to the autonomic variable Emotional Index with the factor Point of View (POV) with three levels (POV#1, POV#2, POV#3) and the factor LIGHT with two levels (natural, artificial). Duncan post hoc test was used at a p<0.05 level of significance. ANOVA results returned a significant increase of the AW index related to the interaction of POV x LIGHT factors (p<0,04). The successive Duncan's post hoc tests suggested how the cerebral appreciation of the subjects are increased for the POV#2 and POV#3 over the other conditions of observation. The POV#3 revealed also a statistically significant increase of the cerebral approach activity in both conditions of light (natural and artificial) when compared to the other points of view but POV#2. The AW cerebral index is then maximum in the POV#3 with the artificial light. The cerebral appreciation of the POV#3 is just tied with the appreciation of POV#2 in a natural light.

Experiment 2: Analysis of variance (ANOVA) with factors CONTENT (two levels; Portrait, Religious) x PICTURE (ten levels, one for each picture of portrait and religious matter) has been performed to assess significant differences about the AW index estimated in the investigated subjects. Duncan's test was used for post-hoc comparisons.

The average AW index estimated in all the subjects for the 20 paintings selected has 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 investigated group for the particular picture observed, while vice-versa when negative. The number on the abscissa of Fig. 3 represents the progressive number of the picture observed in the visit.

The ANOVA performed on AW index values returned a significant value for the factor CONTENT (F = 9,95; p<0,005) and for the interaction CONTENT x PICTURE (F = 2,64; p<0,007), being then the AW values of the Portrait level greater than the Religious level.

The AW index was also estimated for all the pictures with the EEG data relative to the first 20 seconds of the free observation (AW20). Then, it was estimated the AW index for the EEG data relative for the last part of the observation (from 20 seconds to one minute; AW60). Finally, the correlation between the AW20 and AW60 indexes across all the 20 selected pictures was performed. Such correlation between AW20 and AW60 indexes was quite high (r = 0,82) and statistically significant (p < 0,0001), suggesting that the pleasantness perceived in the first 20 second for each picture does not change too much during the observation time.

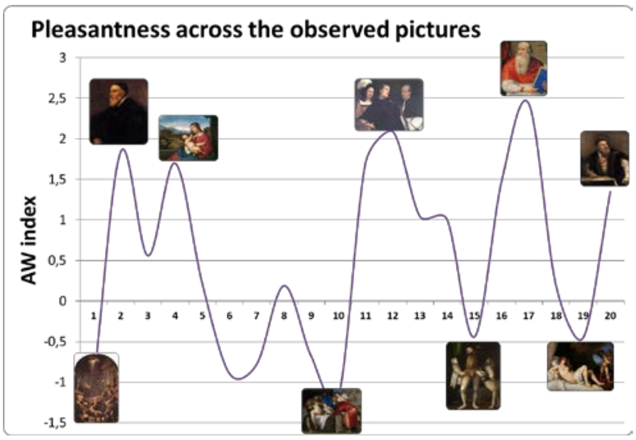

Figure 3. Variation of the Approach/Withdrawal index along the gallery visit. The X abscisse numbers represent the number of the painting encountered along the experiment. Y values are related to the z-score computed for the unbalancing of the EEG power spectra over the prefrontal cortex Maximum value of the AW index is reached for the observation of the painting number 17.

3.3. Emotional Index

Experiment 1: ANOVA performed on the Emotional Index, derived from the measurements of the HR and GSR, revealed that the factors POV is significant ($p<0.025$) but not the factor LIGHT ($p = 0.38$). It can be appreciated that the maximum of the Emotional index has been gathered for the lateral point of view #2 when compared with the others point of observations ($p<0.0022$).

3.4. Eye-Tracking analysis

Experiment 2: The analysis of the number of fixations gathered by the eye-tracker device during the gallery visit has been performed with the use of the t-paired Student. An higher number of fixations within the first 5 seconds have been given by all the subjects for the pictures that the subjects like most when compared to the fixations given to the pictures that the same subjects did not like (t-paired test, $p < 0{,}0483$). The same result was also obtained by comparing the number of fixations generated by all the subjects within the first 10 seconds of the scanning of the pictures. In fact, also in this case the pictures the subjects like most received a major number of fixations than the pictures the subject did not like in the first 10 seconds ($p < 0{,}018$). Interestingly, this statistical difference in the number of fixations between pleasant and less pleasant pictures vanished when the time period allowed for the observation of the picture reached one minute ($p = 0{,}54$). In this condition there is no difference between the number of fixations received by the pictures that the subjects like or reject most.

4. Discussion

Those experiments provide 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 the real Michelangelo's Moses sculpture from different point of views in the church of S. Pietro in Vincoli in Rome and observation of several real paintings of Titian.

Such findings are in agreement with the observations provided by several studies which used hemodynamic measurements and suggested that the medial orbitofrontal cortex is deeply involved in the perception of beauty [Di Dio and Gallese, 2009]. Interestingly, in *Experiment 1* we observed a dissociation between the cortical appreciation of the sculpture (maxima at the POV#3) and the emotions perceived from such observation, maxima at POV#2. An intriguing interpretation of this dissociation is proposed as follows: the POV#2 generate a direct face-to-face interaction between the Moses sculpture and the observer (as shown in Fig.1). This interaction has an high emotional content, since the face observation is associated with the interaction with the other human or animal beings and thus has an high importance for us. On the other hand, the cortical appreciation of an structure has been generated from a POV which allows to detect all the sculpture in its general details. The POV#3 allows to the observers to get all the information from the sculpture of the Moses as well as from the other sculptures associated with it since it is located relatively far from the sculpture when compared to the other POVs (Fig 1). By collecting the emotional and cortical responses during the observation of a real sculpture we observed such dissociations of the cerebral signals linked to the different modalities of fruition of the same sculpture. We believe that the observations could be used in a future to generate specialized paths across the museums to induce different emotions and perception of sculptures and artworks in the general public. This will be made possible by the possibility to collect reliable measurements of brain and heart activity not only in the neurophysiology laboratories [Usakli et al., 2009; Babiloni et al., 2002] but rather in a challenging environment such as museums, art gallery, churches and archeological sites.

Experiment 2 provide evidences of the cerebral prefrontal cortical activity correlated not to a general sensory or motor stimuli as in [Babiloni et al., 2000; Babiloni et al. 2002] but rather to the evaluation of a series of real paintings by Titian during a visit in an art gallery. Such finding is in agreement with previous observations stating the involvement of medial orbitofrontal cortex as assessed by hemodynamic and neuroelectric measurements in art perception [Di Dio and Gallese, 2009; Babiloni et al., 2013].

Interestingly, the AW index estimated in the first 20 second of the free observations of the pictures is highly correlated with the value of the AW estimated during the second part of the observations ($r=0{,}82$). This result could be interpreted as the fact that the "prefrontal" evaluation of the pictures by the subjects is quite fast and does not change across the entire time of the allowed vision. Such result could be also correlated with the evidences from the eye-tracking device, that have returned a significant different number of eye fixations for the pictures the subjects liked most when compared to the number of eye fixations for the picture the subjects did not like. In fact, such evidences held also for the comparisons performed within the first 10 second of the observation of the pictures, while vanishing after. Taken together, these results suggest that the "internal" appreciation or rejection of the pictures is a relatively quick process. In fact, it appears to be supported by a high fixation process in the first 5-10 seconds of the observation of the picture, also sustained by the formation of a stable prefrontal activity in the first 20 seconds of the free view of the picture. The eye gaze scanning pattern during the picture observation became statistically similar after those 20 seconds, while instead the cortical activity remains similar to the previous values. Such flow of event could be tested in a successive experiments in a near future, related on how and when we formed inside our head the judgment about the beauty perceived by a fine arts picture.

5. Conclusions

The two experiment performed highlighted the importance of prefrontal cortex in fine art evaluation and, with the support of both EEG and eye-tracker device we saw that the pleasantnes of a picture is perceived very fast during the observation in the first 10 – 20 seconds. Neurometric indexes can than returns then important information on the quality of the appreciation of fine arts artifacts.

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