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Journal of Clinical Trials

Research Article

Neuroaesthetics of Art Vision: An Experimental Approach to the Sense of Beauty

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ABSTRACT

Objective: NEVArt research aims to study the correlation between a set of neurophysiological/emotional reactions and the level of aesthetic appreciation of around 500 experimental subjects, during the observation of 18 different paintings from the XVI-XVIII century, in a real museum context.

Methods: Several bio-signals have been recorded to evaluate the participants' reactions during the observation of paintings. Among them: (a) neurovegetative, motor and emotional biosignals were recorded using wearable tools for EEG (electroencephalogram), ECG (electrocardiogram) and EDA (electrodermal activity); (b) gaze pattern during the observation of art works, while (c) data of the participants (age, gender, education, familiarity with art, etc.) and their explicit judgments about paintings have been obtained.

Participants were invited to respond during the observation of paintings, reporting the degree of pleasantness, perceived movement and familiarity with the painted subject.

Results: Each recorded bio-signal will be correlated with the explicit evaluations obtained by participants during the museum experience. These results may contribute to enlarge the theoretical framework on the physiological, cognitive and emotional responses of people when viewing pictorial artworks.

Conclusion: The NEVArt research, both in term of technical skills and upgrade in neuroscientific awareness, can be the basis to proceed with a set of further research topics in the near future. Ground-breaking and statistically significant observations can be derived from the present research, mainly at the biological, medical and didactical point of view, by paving the way for many other multidisciplinary research developments on art exhibit, architecture, etc.

Keywords: Neuroaesthetics; Art vision; Sense of beauty; EEG; ECG; EDA; Eyetracking

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Received date: February 27, 2020; **Accepted date:** March 12, 2020; **Published date:** March 18, 2020

Citation: Coccagna M, Avanzini P, Portera M, Vecchiato G, Destro MF, Sironi AV, et al. (2020) Neuroaesthetics of Art Vision: An Experimental Approach to the Sense of Beauty. J Clin Trials 10:404. doi: 10.35248/2167-0870.20.10.404

INTRODUCTION

Theoretical premises

Research carried out over the past few years within the field of empirical aesthetics, whether descriptive in approach (as to be found in the first works by Semir Zeki; cfr. Chatterjee, Vartanian 2016) or truly experimental, has contributed not only to revive the conceptual debate in philosophical aesthetics but also to substantially rethink of the aims, epistemological approaches and methods that have traditionally characterized this field of research.

Speculations on what has to be considered beautiful or artistic have always stimulated human thought. The foundation of aesthetics as a separate philosophical discipline only took place towards the middle of the XVIII century, thanks to A.G. Baumgarten [1-3]. Successively, this field was given a comprehensive framework through Immanuel Kant's Critique of the Power of Judgment, which exerted a great influence by establishing it as a study of reflexive-subjective judgments of "taste".

Before Kant and more or less during the same years as Baumgarten's aesthetic thought, investigations of an empirical and philosophical nature on experiences of beauty were being carried out (from which both Kant and Baumgarten were to distance themselves even if for different theoretical reasons): examples being reflections on what is beautiful and what is sublime by David Hume (1757) and Edmund Burke (1757,1759).

The first complete and systematic empirical approach to issues concerning what is beautiful or what is art did not, come about until the nineteenth century, in the context of the new positivism. The main role in this process was played by Gustav Fechner, the founder of experimental aesthetics and originator of a specific line of research.

Through the Elemente der Physcophysik, in 1860, Fechner created a bridge between physics (i.e. objective characteristics of physical stimuli) and psychology (i.e. the study of sensations produced in the subject by those stimuli). By applying this model to art, Fechner aimed to study which physical characteristics of objects produces a reaction of aesthetic preference in the subject. His contributions to empirical aesthetics are closely linked to the process of establishing experimental psychology as a separate discipline (the first laboratory of experimental psychology dates back to Wilhelm Wundt in 1879) and to the institutionalization of the research area of the Psychology of Art (the scientific study of artistic emotions, phenomena of empathy, sympathy, communication of feelings, etc.).

In his work, Fechner put forward a distinction between 'outer' psychophysics (i.e. the relationship between stimulus and sensation) and "inner" psychophysics, which concerned the relationship between the sensation (in the viewer) and the neural structure of his/her brain. Unfortunately, the lack of technical tools at Fechner's disposal greatly limited his study of inner psychophysics. Today, contemporary neuroaesthetics (or empirical aesthetics), starting from the pioneering studies by Semir Zeki up to the revolutionary studies being carried out in many European and international research centres, may be considered the natural evolution of Fechner intuitions.

As stated by Semir Zeki, who was the first to use the term 'neuroaesthetics' at the end of the Nineties and is the founder of Neuroaesthetics (www.neuroaesthetics.net), research on the neural correlates of aesthetics and art would not have been possible before the Seventies, when scientists had the technological know-how to record several processes of the brain.

Neuroaesthetics wants to deepen the neurophysiological bases to perceive an artwork as 'appreciated' or not, 'pleasant' or 'unpleasant', analysing the effects on the body and brain of the emotions that make up our personal aesthetic judgment.

Semir Zeki focused his studies on art implication, starting from the hypothesis that the objectives of art should be an extension of brain functions. Therefore, through the study of how people perceive art, we can understand something more about how our brain works. Zeki highlighted the debt of scientists to artists: indeed, these latter, although without any specific knowledge about the brain, intuitively anticipated a lot of recent discoveries about how we perceive colours, distances, perspective, shapes, etc.

Zeki's neuroaesthetics aim to programmatically provide a novel 'biology-based aesthetic theory' which allows us "to understand the neurological basis of aesthetic experience" [4-22]. It is an ambitious goal, which involves the participation of various areas of knowledge (theoretic, but also more 'technical' in nature) which give rise to truly interdisciplinary research.

In brief, Zeki's neuroaesthetics involves two fundamental principles:

1) The 'theory of functional specialization', presuming that "various attributes of the visual scene are managed in topographically different areas of the visual cortex" and that "there are different processing systems for the different attributes of the scene itself" [23-26].

2) The 'modularity principle', that balance the idea that "the brain processes the various features of the visual scene in different sub-areas" (that is to say there is a relative independence of the sub-systems) with a "vision [...] organized in accordance with a parallel modular system" [27-30].

Starting from Zeki's first works, published at the end of the 1990s, great progress has been made in the fields of neuroaesthetics and empirical aesthetics [31-38], often – it should be emphasized - in an attempt to overcome the limitations of Zeki's pioneering approach.

State of the art

The first studies in empirical aesthetics or neuroaesthetics (including those by Zeki) reflected the influence of general experimental psychology, in which specific features of the stimulus were systematically manipulated to quantify their effect on the experience. The aim was to identify a finite set of universal laws related to the subject's aesthetic interactions with objects. The results obtained were evaluated in accordance with the classical vision of cognitive science, which considers the brain as a machine that can process stimuli in a hierarchical way at different stages of complexity. This vision has led scientists to search for the area of the brain involved in processing beauty and aesthetics.

The most recent experiments, however, have shown that the cerebral correlates of aesthetic experience are distributed throughout the brain [7,8]. Therefore, there is no single area exclusively devoted to aesthetics, rather a set of cortical and subcortical areas which form a triad of circuits implicated in evaluation of emotions and significance/knowledge and sensory-motor processing [38-46].

Through brain scanning techniques, Semir Zeki highlighted at least two different brain areas "responsible" for beauty: on the one hand, there is a "feeling" of beauty, found in the cingulate gyrus, typical of romantic love, maternal feeling, and musical appreciation; on the other hand, there is a "vision" of beauty, related to the activity in the parietal cortex. Along with the aforementioned brain regions, the orbitofrontal cortex has a tardive development and it is involved in the elaboration of interior mental processes, referred to the self or to moral/social judgments. In particular, Zeki suggests that the orbitofrontal cortex, implicated in the reward system and emotional processing, plays an important role in the aesthetic experience. What is, however, the specific difference between art-derived pleasure and other types of pleasure (sex or food, as an example) in which the orbital-frontal cortex also takes part? [47-54].

Existing studies underline how emotions attending experience of art have specific connotations but with several relations, both in term of quality and quantity of psychological response, with daily emotions [16].

The research approach

NEVArt focuses on the processes through which people appreciate artworks. Following the experience of naturalistic researchers, it is targeted on analysing the 'real context' to discuss the existing theoretical hypothesis, as a possible way to contribute to the evolution/upgrade of our knowledge about perceptions and pleasure.

The research, moving from previous researches in neuroaesthetics, tries to overcome three main existing boundaries: the lack of information about the experience of people in a real context (outside the laboratory, using an ecological view) and the comparison between different neuro-biological tools, both in terms of target and technological affordability.

One important experience has been made at the New York University, using pictures of paintings and analysing the response of sixteen participants, using fMRI patterns, in terms of pleasantness; the results indicated an increase in neural activity but with an extremely moving response between a set of brain regions [4].

At now, technical limitations include the scarce number of research samples, the 'noise' in the environment and the difficulty in triggering significant events. Furthermore, practical limitations are mainly related to the availability of 'real contexts" (e.g. a museum or exhibition) and to time/technicians to conduct long term evaluations. That is way there is a great demand for a reliable quantification of neurophysiological activity, to describes the aesthetic experience in a real scenario, by introducing a more controlled experimental setting.

Same attempts have been made to correlate the neural activity with the explicit satisfaction, during a visit to the Scuderie Palace of the Quirinale in Rome [2] and the Museum of Contemporary Art (MARCO) in Monterrey, Mexico [20]. The electrophysiological approach was used to deduce preference (among different points of view) when looking at Michelangelo's Moses in the Basilica St. Peter in Chains in Rome [1]. At the University of Vienna, the EVA Lab, spearheaded by Helmut Leder, has carried out field research in important museums like the Kunsthistorisches Museum of Wien and the Belvedere Art Gallery.

Unfortunately, the state of art in neuroaesthetics and empirical aesthetics concerns the size of the statistical sample that each study has considered which is limited to groups whose numbers range from a few tens to around a hundred of participants, sometimes scarcely randomized, noticeably less than the sample of around 500 people expected with the NEVArt research.

Zeki's analysis, as well as some other scientists, was generally limited to the use of functional magnetic resonance imaging to identify the neural correlates of aesthetics. fMRI is not, however, the best candidate tool for the research in empirical aesthetics, in particular within and ecological experience; the use of alternative or additional neurophysiological methods can indeed provide a measurement during the 'real' aesthetic experience.

Studies using functional imaging have correlated the electro-dermal activity to specific brain areas, namely, the ventro-medial prefrontal cortex, orbitofrontal cortex, primary motor cortex and anterior and posterior cingulate, which have been shown to be associated with emotional and motivational behavior [9]. Moreover, several contributions report how HRV is connected to the emotional valence of a stimulus, for example, the positive or negative component of emotion [29].

As signs of the autonomic nervous system, the galvanic response of the skin (EDA) and the variability in heart rate (HRV) are two neurophysiologic factors often used to describe variations in emotional states, in terms of stimulation and valence [49]. EDA is indeed considered a sensitive and useful tool in the indexation of changes in sympathetic stimulation associated with emotion, thought and attention.

The measure of EEG, ECG and EDA is today possible through the combination of different devices, all of them with specific fields of application, in order to improve our knowledge in neuroaesthetics research.

A limit strictly connected to the use of these devices in the 'real context', derives from the presence of artefacts, due to movement, noise, crowding, etc, that are usually controlled in a laboratory setting.

To overcome these limits, the inclusion of a huge number of subjects as expected in NEVArt and the application of sophisticated analysis on the data to disentangle the brain activity to the noise, could guarantee the reliability of results.

METHODS AND DESIGN

Aim of the research

The purpose of NEVART is to provide, through a broad statistical basis, a picture of the emotional, physiological, neurological and cognitive reactions of people, looking for a connection between our experience (of art) and the pleasantness we feel. The project objectives are:

A) To obtain a neurobiological validation of aesthetic experience, with particular reference to the involvement of body and mind when facing an artwork, both implicit (EEG, ECG, EDA, eye tracking) and explicit (survey);

B) To quantify and compare the recorded signals, in a real museum context, according to different device settings (Scenario A and B);

C) To create a significant scale to represent the physical, emotional, cognitive responses during the art vision.

The research is not intended to determine aesthetic preferences over a range of people, but to provide a framework of people's physiological, neurological and cognitive-emotional reactions during the vision of art, possibly enlarging the research field with the observation of sculpture, architecture, perfumes, etc.

Study design

The study involves people of different ages, gender, education, customary visits (or not) to art museums, etc.

NEVArt analyses the explicit and implicit reactions of participants, using different kinds of sensors, during their visit to the exhibition "Painting affections: sacred painting in Ferrara between the '500 and the ‘700”, set up at the Estense Castle in Ferrara from the 26th of January to the 26th of December 2019. The Municipality of Ferrara gave us great support, opening free of charge the exhibition and the Estense Castle to the volunteers.

NEVArt project has been developed by CIAS, a research centre of the University of Ferrara, thanks to the collaboration of CESPEB Neuroaesthetics Laboratory of Milan and Neuroscience Institute of CNR of Parma.

The research has been managed according to the CIAS research method, which is exploiting new scientific challenges using a multidisciplinary approach and communicating all the research stages and analysis to the community. The research team includes many other experts, as neurologists, philosophers, engineers, architects, psychologists, ICT and art experts.

A group of fifteen students of the Ludovico Ariosto High School in Ferrara (selected from three different courses: from scientific to humanistic) followed the project through a specific internship, based on lessons deepening the research features (from theoretical to technical) and on research experience, accompanying the investigators during the summer stages. Furthermore, several university trainees in different disciplines were involved on the use of sensors and on the development of protocols and measurement.

The sample group people of different nationality, sex, age and level of education, thus ensuring a broad set of data for analysis and comparison. The form is available in Italian, English, and French. The identity data of each subject has been anonymized, in order to remove personally identifiable information.

The NEVArt study is based on the comparison of the data collected through an explicit evaluation by the visitor when observing the artworks and the bio-signals recorded using different tools: electroencephalography (EEG), electrocardiography (ECG), electro-dermal activity (EDA), gaze exploration (eye-tracking).

The NEVArt survey includes information about the setting of each test (number of visitors and thermal conditions), personal non-sensitive and anonymous data of the volunteer (age, gender, schooling, habit of attending exhibitions, possible performed art, music or sport activities, etc.), habits (coffee, alcohol and smoke in the last 3 hours) and finally the evaluation of each of the 18 selected paintings. The assessment of each artwork include three parameters, pleasure, perceived movement, familiarity with the painting, using a Visual Analog Scale (VAS) scale [35].

At the end of the visit, the participant may express a final wide judgement of all paintings, selecting from 0 to at least 5 artworks, giving them priorities, through a deck of cards picturing the 18 selected samples. This last assessment is intended to examine emotional memory of a subset of paintings, typically experienced at the end of the visit of real exhibitions.

NEVArt is structured considering different levels of analysis: the comparison between different bio-signals recorded during the observation of single painting and the association between the experience by all visitors and their background.

A series of pre-test has been conducted in order to understand the better experimental procedures. The pre-stages, made at the beginning of 2019, indicated the time needed to install and calibrate the devices for each participant (around 20’ in the A scenario and 10’ for the B one). Furthermore, the exposure of subjects to the visual stimuli (paintings) was fixed at 60”, a minimum timing to record all bio-signals, for each painting; the duration of experiment was then around 30’.

Painting selection

Between the 54 sacred paintings of the exhibition, 18 artworks have been chosen, starting from three main exclusion criteria: nothing too small (to avoid the risk that the distance from the observer may affect the wide perception), no damaged paintings (because the observer may overlook some elements disconnected with art) and no painting related to a series (because people may have difficulties in sorting each single artwork).

All paintings have been also ranked using an external panel, to give a first assessment of their features, according to: ‘movement’ and ‘static’ perception, with a particular focus on ‘portraits’ (including 6 samples for each category).

Painting will be assessed by participants using three scales of judgement: pleasantness (how much you like it), perceived movement (e.g. the Decapitation of St. John the Baptist by Bastarolo has a real explicit motor action) and familiarity with the subject, that may convey implicit messages (e.g. St. Rose of Lima who is receiving the baby Jesus from the Blessed Virgin).

To be able to analyse the movement perception as a possible part of the emotional activity related to paintings, the external panel selected the 18 samples by means of a preliminary behavioural experiment, made using a printed version of paintings.

Twenty subjects observed a copy printed on an A4 paper of all the 53 paintings included in the exhibition. Each painting was rated by a Visual Analogue Scale (VAS), according to the self-reported degree of perceived movement. The corresponding raw scores were then transformed in z-scores, whose analyses guided the selection of the experimental stimuli. In particular, 6 paintings have been identified with a z-score >1 and this category is labelled 'high movement': this was characterized by an average number of characters in the scene equal to 13.2. On the other side, the 6 paintings with z-score< -1 correspond to 'portraits', therefore with a number of characters always equal to 1. In order to control the variability in the number of characters, it has been added the category 'low movement', with an average z-score of -0.32 and by an average number of characters of 9. This criterion will allow analysing the corresponding neurophysiological activity related to the perception of three kinds of paintings, namely 'high movement', 'low movement' and 'portraits'.

Research scenarios

According to the research purposes, investigators defined two main experimental scenarios using two different sets of tools. The base of the experimentation remains the same: choice of participants, use of the NEVArt form to analyse the subjective characteristics and response of volunteers, collection of the same ECG and EDA data and the eye tracker signal about real-time gaze and pupil data.

The eye tracking is made using the headset of Pupil Core (2 monocular and 2 binocular tools). All sensors are connected with Surface laptops, used also to run the NEVArt form, through a touch VAS assessment.

The choice between two different scenarios is mainly related to the need of testing various kinds of tools, also trying to use each tool in ways that are as close as possible to its optimal/most usual application field.

In the scenario A, volunteers wear EEG caps with 64 dry touch-electrodes (ANT Eego sports), specifically developed to test EEG in dynamic conditions. With the ANT system also ECG and EDA signals have been collected (sensors were placed on the arms). To minimize the contamination of bio-signals recording with artefacts associated to movements and sweating, participants were asked to seat on a wheelchair. One investigator was in charge of guiding the participant though the exhibition, thus controlling the proper timing of the experimental procedure, whiles a second one supports the tablet, verifying the proper functioning of the devices.

In the scenario B, more ecological, volunteers wear Myndplay headsets, managed through Open Vibe software, tested in similar research with EEG sensors, using a Neurosky mindset configuration. For ECG and EDA measures the BITalino has been chosen, a versatile and scalable hardware platform for bio-signals acquisition and wireless transmission in real-time. All tools have been connected to a Surface Go laptop, optimised to manage Bluetooth signals. In this scenario, people may move freely, accompanied by an investigator that supports the tablet and checks the functioning of the equipment.

All recorded data will be periodically analyzed, statistically re-elaborated by the research group, relating objective data (collected with sensors) and subjective information, (entered by the volunteers and the experimenter).

A computer software designed during the research helps in managing and analysing all the collected data (an average of 20 Mb for each acquisition), though different functions:

Sorting and coupling all data related to the same run for each participant;

Synchronizing the onset and offset of painting observation onto the recorded signals;

Processing the spectral analysis of EEG signal, managing the personal data of volunteers (age, gender, etc.), together with their painting evaluation and recorded bio-signal.

Statistical analysis

The EEG and the autonomic signals, such as EDA and ECG, will be first analysed according to the grouping described above. Specifically, the EEG Power Spectral Density (PSD) related to the observation of each painting (60 seconds) will be computed across all electrodes and compared across experimental conditions by means of multiple paired t-tests. Similarly, the average values of ECG and EDA will be tested.

These neurophysiological variables will be later correlated with the explicit judgements provided by the subjects after the observation of each painting.

These ratings correspond to the amount of movement perceived in the painting, the overall pleasantness, and the level of familiarity with the content of the stimulus. Each of these scores will be correlated with the EEG PSD and with the autonomic parameters.

Finally, a third level of analysis will be performed based on the eye tracker data. In particular, the eye gaze collected during the observation of each painting will be analysed to investigate the scanning behavior in several regions of interest. These regions will correspond to portions of the paintings related to specific body cues, such as faces and arms, which will be disentangled from the background.

This analysis will allow to analyses the neurophysiological variables according to the perception of these specific regions of interest.

DISCUSSION

Leaving to the results of NEVArt any further consideration about the interplay of cognition, explicit aesthetic judgment and emotions in the visual experience of artworks, the selection of paintings was based on their content, leading to the identification of three categories: high-movement, low-movement and portraits.

Starting from previous empirical evidence related to the reactivity of the EEG sensory-motor rhythm during the observation of stimuli with motor content, in NEVArt we expect to find a differential involvement of this visuo-motor feature across the three experimental categories.

The case of portraits is also interesting, because it affects the work of our brain in recognizing, understanding the feelings expressed by the character and activating empathy with the painted person. Face recognition is essential for our functioning as social creatures and it develops at the earliest stages of life. A few neurological disorders are related to the inability to pay attention, understand, and look at the human face, as an example the autism spectrum disorders.

Taking advantage of a broad statistical basis, NEVArt aims at contributing to several ongoing debates at the interface between art, perception and neuroscience:

What happens in our brain and in our body when we feel aesthetic pleasure?

How does context (e.g. museum/laboratory) impact on the level of aesthetic appreciation?

Is it possible to identify neurophysiological invariants of the aesthetic perception regardless factors such as expertise, age, gender, familiarity, and previous knowledge of the painting?

Comparing the outcomes of this research with some existing trials involving art-experts and museum visitors will give a contribution to other open points:

How is that, that different people, with different backgrounds, consider the same artwork as pleasant?

Is it possible to dissociate the personal aesthetic appreciation of an artwork from the judgement of a recognized masterpiece?

Is beauty a matter of intensity of pleasure, or there is something else to be taken into account?

Why and in which sense have the concepts of art and beauty changed over the centuries and what about the historical shifts of taste and of the feeling of pleasure?

CONCLUSION

The NEVArt research, both in term of technical skills and upgrade in neuroscientific awareness, can be the basis to proceed with a set of further research topics in the near future. Ground-breaking and statistically significant observations can be derived from the present research:

From the perspective of biology, NEVArt allows the exploration of the relationship between the 'sense of beauty' in the animal world and the human aesthetic sense in the light of Darwin's theory of evolution, and consequent implications in the fields of philosophy and psychology.

From the educational/exhibit point of view, these investigative procedures and the ensuing new data can be used to improve the teaching/setting methods and to help the learning/appreciating process of students/visitors in relation to vision, perception and enjoyment of artistic works.

Art was proposed as an effective way to investigate people's perception and to improve bodily and mental performance in case of abnormal physical/psychical conditions (art therapy). NEVArt research may contribute to the future design of art-therapy applications based on neuroaesthetic knowledge.

ACKNOWLEDGEMENTS

We acknowledge: the Authorities of the Ferrara Municipality and all the staff of Estense Castle, in particular dr. Ethel Guidi, to host NEVArt at the exhibition "Painting affections: sacred painting in Ferrara between the '500 and the '700" and to support the research organization.

The students of the Liceo Classico "L. Ariosto" high school (Ferrara, Italy), who participated in the study as part of a specific internship: Anna Camattari, Elisa Greco, Virginia Piva, Carlo Salzano, Giulia Antonucci, Angelica Biagini, Mirka Ongaro, Cecilia Costanza Morbini, Giulia Zagatti, Sebastiano Bellagamba, Stefania Cersamba, Sara Govoni, Margherita Caselli, Giuseppe Guidoboni and their teachers Caterina Pieri, Annamaria Masi, Stefania Borini and Francesca Papaleo.

Pierluigi Montanari, Rita Tagliati, Giovanni Ganino (University of Ferrara), Valeria Tugnoli (Neurology Department, S. Anna University Hospital of Ferrara) and Davide Orlando, for the help given in the preparation of the research.

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