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Content

Abstract

The left dorsolateral prefrontal cortex (left DLPFC) seems to play a crucial role in aesthetic appreciation, as found in the study by Cattaneo et al. (2014a), which used anodal transcranial direct current stimulation over the left DLPFC, which resulted in an enhancement of beauty appreciation of representational (but not abstract) artworks. The left DLPFC is believed to be involved in cognitive and perceptual processes in aesthetic experience. This experimental study attempted to partially replicate the study of Cattaneo et al. (2014a), however our results were not conclusive. The left DLPFC was stimulated with the anodal tDCS and the pre- and post- stimulation evaluations of the art stimuli for either beauty (experimental group) or colour (control group) were collected. Participants were non-expert in art. The analysis revealed no significant effects from the transcranial direct current stimulation on either the evaluation ratings or the reaction times. Further research with greater control over the variables is suggested.

Keywords: neuroaesthetics; tDCS; dorsolateral prefrontal cortex; brain stimulation; art

Enhancing aesthetic experience through brain stimulation

Art and aesthetics have been the subject of discussion since ancient times. Most thinkers of repute like Plato, Kant or Hume were interested in the appreciation of beauty (Hume, 1777; Kawabata and Zeki, 2004; Rolls, 2014). Since then art and aesthetics have branched out from a subject almost exclusive to humanities - mostly philosophy, history and artists themselves, to become a subject of broad interest to the field of empirical psychology and neuropsychology. “Art is used to convey fundamental spiritual, ethical, and philosophical meaning and it serves diverse economic, social, political, and symbolic functions all around the world” (Anderson, 1989, 2004). Neuroaesthetics has emerged as a branch of neuropsychology focused on understanding the biological and neural correlates of aesthetic appreciation (Cela-Conde, Agnati, Huston, Mora & Nadal, 2011; Chatterjee & Vartanian, 2014; Shimamura & Palmer, 2012). Aesthetic appraisals are common in everyday life, it is a subjective judgement we make when looking at a painting, a landscape, or indeed – at another person (Cattaneo, Lega, Flexas, Nadal, Munar & Cela-Conde, 2014a). According to Belke, Leder and Augustin (2006), art is ubiquitous because it encompasses characteristics generating rewarding and gratifying experiences.

Mapping out and collecting information about the neural foundations of aesthetic appreciation can contribute to a better understanding of human behaviour. This raises the questions as to what is happening in the brain, the most complex organ in the human body, during aesthetic encounters, which brain areas are involved, is it possible to alter the aesthetic experience etc.

The Goals and Background of this Work

The aim of this piece of work is to examine whether a transcranial direct current stimulation (tDCS) of the left dorsolateral prefrontal cortex (left DLPFC) enhances the aesthetic experience when looking at pictures of art, while evaluating how much the participants liked the artwork. The idea for this particular thesis was inspired by the research of Cattaneo et al. (2014a), in which the scientists stimulated the left DLPFC with tDCS while observing representational and abstract paintings, patterns and photographs. Their results suggested that for the experimental group, which rated how much they liked the artwork, anodal excitatory tDCS on the left DLPFC increased the aesthetic appreciation of representational photographs and paintings, which was not the case for abstract pieces of art. The control group rated the colourfulness of the artwork and this evaluation is an objective judgement and was unaltered after the stimulation.

The Adaptation of the Original Experimental Design

This research adapted the original study from the Cattaneo et al. (2014a) experiment by no division of the stimuli into representational and abstract, in comparison the stimuli set was built from pairs of artwork – created by the same artist with the same content (e.g. landscapes). One half of the images were in set A and used in the pre-tDCS evaluation (of either aesthetic value or colourfulness), the other half were used as set B and used in the post-tDCS evaluation (crossed design). The pairing of stimuli used in this study added to the control aspect.

2 Theoretical Framework

2.1. History of Neuroaesthetics

Neuroaesthetics is a relatively young field of research concerned primarily with the neural basis of cognitive and affective processes engaged when an individual takes an aesthetic or artistic approach towards a work of art, a non-artistic object or a natural phenomenon (Nadal & Pearce, 2011). Samir Zeki was the first to introduce the term neuroaesthetics in 1999 (Nadal, Gomila & Pol, 2014, pp.3) in reference to a potential field dealing with the biological underpinnings of aesthetics. It has historical roots in philosophy and aesthetics, which was born as a branch of philosophy in 1735 with Alexander Baumgarten's use of the term "aesthesis" in his *Philosophical Meditations* (Carroll, Moore, Seeley, 2012, pp. 31).

Philosophers have attempted to describe the nature of aesthetic experiences since ancient times, four philosophical approaches can be established: mimetic, expressionist, formalist and conceptual, each of which highlights different aspects of the beholder's mental processes involved in experiencing art. The mimetic approach presented by, among others, Plato defines art as *mimesis* or imitations of reality, where the artwork mimics the sensory experience of looking at the real world as if through a window. The work of Francis Hutcheson, David Hume and Immanuel Kant reflects the expressionist approach, where an artwork is evaluated on how well it expresses feelings and a sense of beauty. The first two British empiricists define the aesthetic experience as a subjective and emotional matter of pleasure independent of the artwork's purpose, whereas Kant, a German idealist, stated that judgements of taste are subjective evaluations of pleasure (or displeasure). Kant's viewpoint is often considered as the beginning of a *cognitive* approach to the mind. The formalist approach represented by the art critic Clement Greenberg, who postulates that the essence of modern art is its flatness, and the art theorist Clive Bell who stated that art should be appreciated solely on the basis of its sensory qualities. Formalism helps to understand abstract art, as the content and objects in the painting are irrelevant. Finally, there is the conceptual approach, which requires and understanding of the ideas being represented in the artwork. This approach is inspired by the prehistoric purpose of art, where it served as a means to communicate (e.g. with gods). In this way, artists nowadays attempt to communicate with their audience; this approach requires knowledge about the symbolism used in their artwork. (Shimamura, 2012, pp.4-14)

The next section will briefly describe the three milestones that shaped the neuroaesthetic science of today: Fechner's (1876) work, the influence of Gestalt and the contribution of Berlyne (1971, 1974).

Gustav Theodor Fechner's (1876) *Vorschule der Aesthetik* (Cupchik, 1986) is regarded as the beginning of empirical aesthetics. Fechner suggested the study of aesthetics from the bottom up, that means focusing on analysis of elemental perceptual features like size, shape, balance, colour, regularity, rhythm, consonance etc. (Nadal et al., 2011). The idea was to create general theories by studying elemental or base data recorded with reference to physical perception, which opposes the attitude of philosophical aesthetics. With this bottom-up approach from basic sensory features to more complex observations, Fechner defined an empirical approach to the study of aesthetics that is still practiced today (Shimamura, 2012, pp.14). Fechner was also the first to introduce control procedures during his experiments. Most importantly, Fechner contributed to empirical aesthetics through his methodological approach, which is still followed to this day.

In the early 20th century, three Gestalt theorists, Max Wertheimer, Kurt Koffka and Wolfgang Köhler approached the perception holistically, where any human experience works dynamically as a whole, which is different from the sum of its parts (Shimamura, 2012, pp.15). However, the most important contribution of Gestalt was its explanation of perception and understanding of objects and scenes as emergent processes that go beyond the mere recording of the elements in the stimulus (Nadal et al., 2014, pp.17). The Gestalt psychologists developed the principle of *Prägnanz*, which proposes that our perception interprets an ambiguous scene based on the simplest or most succinct concepts. The viewer plays an active role in the perceptual procedure, his organization and interpretation of the visual scene creates the image, not the elemental features alone. The Gestalt defines the appreciation of beauty and art as a process that emerges from the interaction of the viewer's psychological processes and the artwork's features (Nadal et al., 2014, pp.20).

The psychologist Rudolf Arnheim applied the principles of Gestalt psychology and believed that aesthetic experiences arise essentially from dynamic perceptual processes, where perception is not only a passive observation of the visual field, but involves an active awareness of dynamic forces inherent to the stimuli (Nadal et al., 2014, pp.21; Shimamura, 2012, pp.15).

Fechner and Arnheim were focused on perception, but some researchers were interested in what happens to the beholder's emotions. Daniel Berlyne reworked Fechner's methodological and theoretical contributions, but developed a theory about the feelings aroused through looking at an artwork. Starting in the 1960s, Berlyne started broad research in psychobiological aesthetics, which is considered as a starting point for contemporary experimental aesthetics. Berlyne specified three neural systems active during aesthetic experience: (i) a primary reward system; (ii) an aversion system; and (iii) a secondary reward system, whose activity inhibits the aversion system. The activity of these systems depends on the level of the beholder's arousal. According to Berlyne, the hedonic tone induced by a stimulus is defined as a capacity to reward an operant response and to generate preference or pleasure expressed through verbal assessments (Berlyne, 1971; in Nadal et al., 2014, pp.22-23).

Since Fechner's contribution to the establishment of aesthetical neuroscience, empirical analysis has grown, however, even today psychologists and philosophers cannot agree on the compatible theoretical concepts in either empirical aesthetics or aesthetics respectively.

2.2 Aesthetic Processing

In this section a brief overview of the definition, traits and different opinion of an aesthetic experience will be followed by the description of the five-staged model of aesthetic appreciation and aesthetic judgement by Leder et al. (2004).

2.2.1. Nature of Aesthetic Experience

The psychology of aesthetic appreciation explores why people are attracted by art. Firstly, what defines an aesthetic experience? Shusterman (1997) and later Bergeron with Lopes (2012) discussed in their papers factors of what makes an experience aesthetic alongside the discrepancies between sciences and humanities, even within aesthetic sciences themselves. Debates about what *beauty* is have been held since ancient times, it is only logical that we discuss the conditions of aesthetic experience and definition of terms that arise in such a debate – aesthetic value, aesthetic pleasure, aesthetic response etc. Researchers understand aesthetic pleasure differently. Also, features of aesthetic pleasures are often questioned and debated – possibilities include pleasure of reward, evaluation, classification, affective appraisal, emotion and combinations of these (Bergeron & Lopes, 2012). It is unclear whether some of these features are essential (not to be left out) to achieve the aesthetic response, whether all of them have to appear (under what conditions they occur?).

It is generally assumed that a piece of art gives rise to aesthetic responses. On the one hand, an artwork might have an aesthetic value (e.g. the painting required lot of skill), on the other hand it does not have to induce pleasure (e.g. the beholder has no emotional response). Can this particular piece of art still be labelled as artwork or not? If pleasure is part of aesthetic response, the above incongruence proposes that aesthetic response should be distinguished from aesthetic evaluation. Another possibility is to assume that pleasure is a key component of the aesthetic response but aesthetic response is different from artistic response. In that way, an artwork may have great artistic value and little aesthetic value, as it does not evoke pleasure. Therefore, we can make a distinction between beauty and aesthetic pleasure on one side and aesthetic value on the other side, where these two need to be treated independently. The valuable and enjoyable character of the aesthetic experience, the so-called evaluative dimension, represents the first of the three major aspects of aesthetic experience.

Another key to distinguishing the aesthetic response is in defining its phenomenal or affective character, means that art draws our attention. Bergeron and Lopes (2012) acknowledged three different directions. First is the study of mechanisms of aesthetic responses to which we have no conscious access, e.g. the study about the mere exposure effect by Zajonc (1968), where non-conscious, repeated exposure to various kinds of stimuli leads to a preference of those stimuli.

Second is to determine the mechanisms on the edge of consciousness, where these mechanisms have an influence on consciousness, but we do not have a conscious access to them, e.g. Reber, Schwarz and Winkielman (2004) give an explanation of aesthetic response with reference to processing fluency. They declare that aesthetic pleasure is a positive function of the experience of the ease with which the perceiver processes a stimulus (Bergeron & Lopes, 2012). However, perceptual priming, mere exposure and other mechanisms, to which we have no conscious access, are responsible for the perceptual fluency.

Third is differentiation with respect to the phenomenal character of aesthetic response, which is about the explanation of the more explicit side of aesthetic response. The model by Leder et al. (2004) explains aesthetic experiences in connection with cognitive mechanisms such as explicit classification, cognitive mastering and evaluation, of which we are conscious to a certain degree. This model will be explained thoroughly in the next chapter *2.2.2. Model of aesthetic appreciation and aesthetic judgement.*

Thirdly semantic aspect of aesthetic response is accompanied by its meaningful experience, not mere sensation. Many studies found the crucial role of top-down processing and an activation of semantic networks in the aesthetic appreciation. The semantic elements are whatever the work of art appears to say to its viewers. Schusterman (1997) shows the change of aesthetic experience from Dewey's evaluative, phenomenological and transformational notion towards analytic aesthetics with its purely descriptive, semantic notion. The main goal of this semantic direction is to explain and support the established demarcation of art from other human domains.

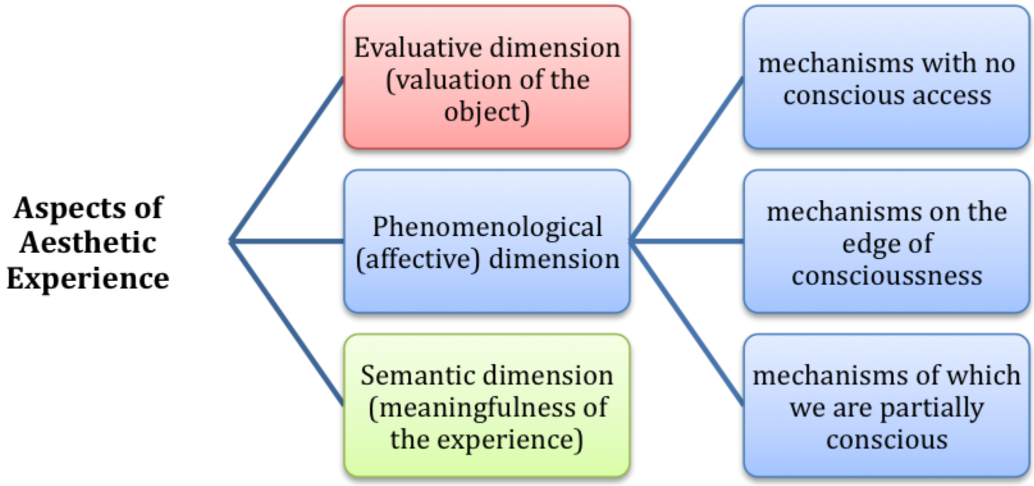

Figure 1: Division of the Aspects of Aesthetic Experience.

To sum up, we described three major aspects of aesthetic experience: an evaluation dimension (valuation of object), phenomenological (affective) dimension and semantic (meaningful) dimension.

2.2.2. Model of Aesthetic Appreciation and Aesthetic Judgements

Leder, Bekle, Oeberst and Augustin (2004) proposed a model of aesthetic appreciation and aesthetic judgements to explore why people get attracted by art. Ten years later, Leder and Nadal (2014) published an updated version with some changes to the model. Thanks to technological advancement, measurement and follow up analysis of behavioural, physiological and eye-movement data, became easy accessible. Progress in neurosciences and neuroimaging techniques enabled the scanning of the neural underpinnings of aesthetic experience. The technological improvement gives us the possibility to measure and influence more precisely brain activity and therefore leads to better understanding (or gives us the opportunity of interpretation) of what is happening in the brain during the aesthetic encounter. This section will expound this model, which is crucial to understand the stages of aesthetic experience. What happens in the human brain while looking at a piece of art, and where in the brain it happens?

According to the authors Leder et al. (2004), an aesthetic experience is an entire process accompanied by continuously upgrading affective states that are reappraised, resulting in an (aesthetic) emotion. They support the idea, that aesthetic experience demands cognitive and affective processing which results in two distinct outputs: aesthetic judgement and aesthetic emotion, respectively. The authors take into account the changing face of art. Art changes, the old concepts of beauty are not sufficient and the whole weight of what is beautiful is shifted from art with a sole criterion of being beautiful towards a more general concept of pleasure and cognitive concept of interest and stimulation (Leder et al., 2014). Therefore, explicit information processing is needed.

The model proposes five stages that are involved in aesthetic processing: perception, implicit memory integration, explicit classification, cognitive mastering and evaluation, as well as continuously ongoing emotional evaluation (Leder & Nadal, 2014). Each stage targets a different cognitive analysis. The first two steps contain important variables affecting aesthetic processing; the third step includes explicit representations, both of content and style. The process of the first three stages is temporarily overlapping; the last two stages form a loop aimed at reducing ambiguity and increasing both the understanding and the affective mastering of the artwork (Leder et al., 2004). In all five stages, the cognitive states influence the emotional affective state and vice versa. The graphic shows the process of aesthetic experience:

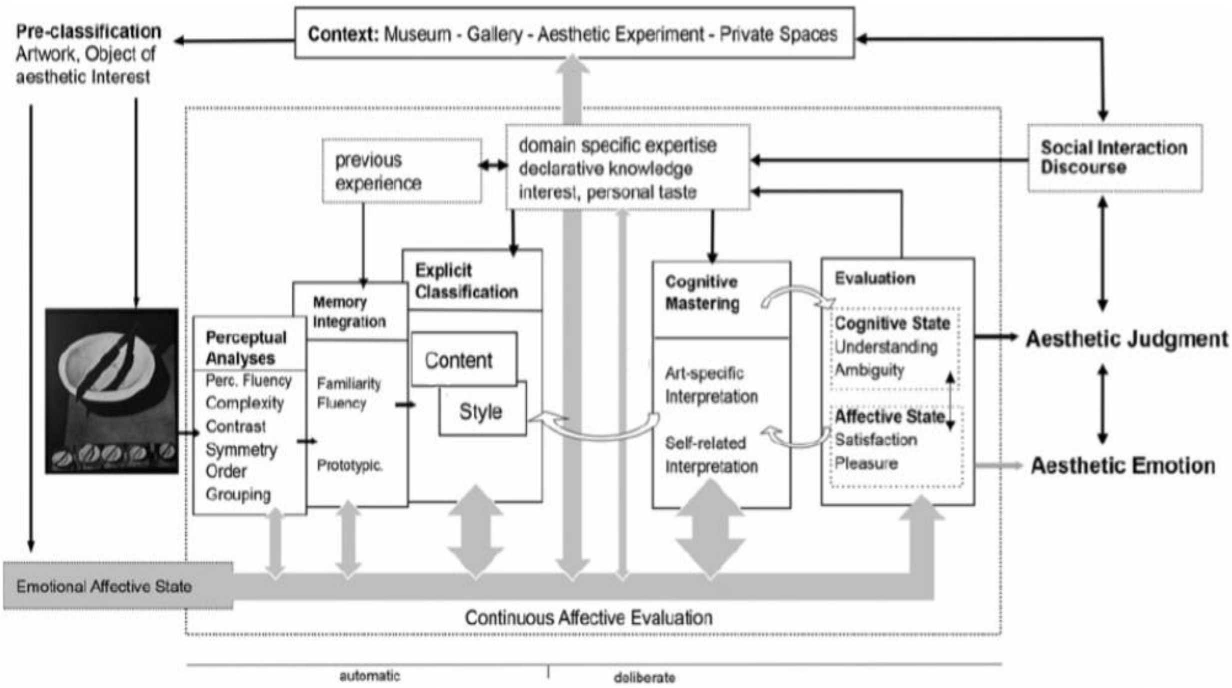

Figure 2: Model of Aesthetic Experience (adapted from Leder, Belke, Oeberst & Augustin, 2004). In Leder & Nadal, 2014.

The input for the model is a piece of art. A pre-classification for an object that is going to be treated as an artwork is generally required; various context features can guarantee this prerequisite (e.g. being in an art exhibition, museum, art gallery). Cupchik and Laszlo (1992) proposed the existence of a state they called “aesthetic attitude”, a state in which the viewer is ready to have aesthetic experiences. Under the above conditions, the viewer is “ready” to face experiencing art. Therefore, the question on participating in laboratory art experiments is in place. Foremost, the participant should be explicitly aware that he is taking part in an art experiment (to prepare him for the art experience).

The model by Leder et al. (2004) assumes an initial positive mood on behalf of the participant, as it has influence on the outcome of the art processing. This assumption is well founded because the experience of art is often pleasurable and self-rewarding. Forgas (1995) researched the connection between affective states and processing of the artwork. The study concluded that a positive mood results in a more holistic approach as opposed to negative mood, which results in a more analytical approach.

The first stage of the model is the perceptual analysis. Most psychological research examines the perceptual variables: e.g. perceptual fluency, complexity, contrast, colour, symmetry, order or grouping; it is easy to control one of these variables in an experiment and see the consequences of such a change on aesthetic processing.

The second stage is the implicit memory integration. Part of aesthetic processing depends on implicit memory effects, because the outcome of this processing does not have to be conscious in order to affect aesthetic processing (Leder et al., 2004). The features for aesthetic judgements at this stage are: familiarity, fluency, prototypicality etc. The study by Zajonc (1968) revealed the mere-exposure paradigm, which means that familiarity through repetition leads to a preference for the stimulus. Prototypicality is the level to which an object is representative of a class of objects (Leder et al., 2004). Preference for prototypicality was studied for example for facial attractiveness (Etcoff, 2000) or prototypical colours (Martindale et al. 1990).

The third stage is explicit classification, where among other things, content and style play an important role. This level of aesthetic processing is affected by the expertise and knowledge of the perceiver. If the expertise and knowledge are insufficient, the perceiver resorts to simple outputs, labelling the artwork as “a landscape” or “a colourful patch of forms" (Leder et al. 2004). Higher expertise results in more awareness of the features of the artworks' content. Also, expertise in the field of art means knowledge to support cognitive processing.

Leder et al. (2004) as well as Gordon and Holyoak (1983) assumed, that a successful classification of style provide self-rewarding cognitive experiences, which can play an important role in answering the question as to why people are attracted by art.

The fourth and the fifth stages involve cognitive mastering and evaluation, respectively. These two closely related stages form a feedback-loop, where the result of cognitive mastering is judged in the evaluation stage. The judgement (in the evaluation stage) depends on the success of the cognitive mastering. If successful, it leads to satisfying understanding, if not successful, then to feelings of ambiguity. The evaluation stage measures the success of the cognitive mastering stage (Leder et al., 2004). If the evaluation is not successful, the backwards-loop begins to trigger information reprocessing. If the evaluation is still unsuccessful, the information processing can return to the previous stages. There is qualitative difference in processing between art experts and naïve perceivers, one relies more on style and visual features, the other, respectively, more on content or external referents (Leder et al., 2004; Parsons, 1987; Winston & Cupchik, 1992).

Personal taste also affects the aesthetic experiences. It can lead to stereotypical answers, where the perceiver does not proceed through the whole aesthetic processing (as depicted in the model of Leder et al., 2004). An art-naïve person viewing an abstract artwork might decide that "it is an abstract piece of art", because he does not understand abstract art and does not even try to process what he sees. On the other hand, an art expert might immediately evaluate an artwork positively or negatively in accordance with his personal preferences for a specific style.

The evaluation stage also contains ambiguity, it is considered to be the cognitive result that provokes further processing of the stimulus until ambiguity itself is reduced (Cupchik, 1992).

These five stages result in an aesthetic evaluation or judgement. In the next section the affective and emotional processing will be discussed. The affective state of the perceiver changes continuously in parallel with the cognitive processing stages. Aesthetic emotions are one of the three main changes, or updates, reviewed in the paper by Leder & Nadal (2014), a paper dedicated to the 10th anniversary of the original model, discussing changes and discoveries in the field of aesthetic neuroscience that have influenced the model. In the last ten years, lot of research has been done; therefore the model needed some fine-tuning and the implementation of new findings.

The model proposes a dynamic interaction between the cognitive and the affective pathways. The affective pathway consists of the feeling of uncertainty, surprise, pleasure and many other emotions that can occur in an aesthetic experience (Leder & Nadal, 2014). The aesthetic judgement, as a result of the cognitive pathway, and the aesthetic emotion, as a result of the affective pathway, are independent – they do not have to be positively correlated. These two independent results represent another difficulty for researchers. Leder et al. (2004) propose that measurement of beauty or interestingness corresponds to the result of the cognitive pathway, whereas pleasantness represents the affective pathway. Anyway, most research is oriented towards cognitive evaluation as the measurement of aesthetic emotions would be difficult, although not impossible with neuropsychological means. The model proposes continuous interaction between cognitive and affective pathways through all the five stages. However, a thorough examination of the relationship between cognition and emotions during aesthetic encounter is needed. The self-rewarding character of aesthetic experience is believed to be one of the main reasons why people get attracted by art.

The model by Leder et al. (2004) gives an explanation on how a person processes an artwork. Five different cognitive stages with a continuously developing affective state result in two distinct outputs – an aesthetic evaluation and an aesthetic emotion. To some degree, we understand what is happening in the brain during an aesthetic encounter. The next section will explain where in the brain these actions take place, or rather what brain areas are activated during aesthetic experience.

2.3 Neural Underpinnings of Aesthetic Experience

Neuroaesthetics as a science is trying to understand the biological basis of aesthetic experiences. According to Nadal (2013, p. 135), these functional components include: (i) prefrontal, parietal, and temporal cortical regions supporting evaluative judgement, attentional processing, and memory retrieval; (ii) the reward circuit, including cortical, subcortical regions, and some of its regulators, generating pleasurable feelings and emotions, and the valuation and anticipation of reward; (iii) attentional modulation of activity in low-, mid-, and high-level cortical sensory regions enhancing the perceptual processing of certain features, relations, locations, or objects.

Nadal (2013, 138-151) describes two main methods used for understanding the brain activity during aesthetic encounter: the analysis of the effects of brain lesions and neurodegenerative diseases on art evaluation; and the use of noninvasive neuroimaging techniques to measure the activity of the brain regions during art experience. This section will focus on the latter method because the experiment described in the second part of this paper uses such a method – tDCS. However, according to Zaidel (2005; as cited in Nadal, 2013, p.140), results from studies on the impact of the neurological diseases on experiencing art presume that a specialized brain mechanism responsible for experiencing art does not exist.

Noninvasive neuroimaging techniques used in studies of the appreciation of art, study healthy participants in controlled situations. These techniques either scan or partially influence the brain activity for a short period of time. This has provided the researchers with the opportunity to outline some general deductions about experiencing art. The brain systems underlying the art experience can be divided in three groups, as depicted in Figure 3. Each of the three systems will be described separately, illustrated with relevant papers on different brain areas.

2.3.1. Cortical regions connected to evaluative judgement, attention and memory

To begin with, the activity of cortical areas involved in evaluative judgement, attention and memory are examined e.g. in following studies: Cela-Conde et al. (2004), Cupchik et al. (2009), Jacobsen and Höfel (2003), Jacobsen et al. (2006). This section will describe brain areas thought to be responsible for executive functions during aesthetic encounter. Aesthetic judgements engage the left temporal pole and the temporoparietal junction (Jacobsen et al., 2006).

2.3.1.1. Dorsolateral prefrontal cortex

Cela-Conde et al. (2004) found a greater activity in left prefrontal activity when participants rated the viewed photographs and paintings as beautiful. Therefore, it is thought to be responsible for grading the beauty of the artwork. Cupchik et al. (2009) also discovered greater activity in the left lateral prefrontal cortex when participants approached the stimuli with either engaged or objective aesthetic attitude, as instructed beforehand by the person conducting the experiment. The authors interpreted this as reflecting top-down control of perception. The left dorsolateral prefrontal cortex is the stimulated area for our experiment; therefore we will focus on this specific area later in *2.5 Left dorsolateral prefrontal cortex.*

2.3.1.2. Anterior medial prefrontal cortex

The anterior medial prefrontal cortex is more active while evaluating the beauty of geometric patterns than their symmetry (Jacobsen & Höfel, 2003; Jacobsen et al., 2006). Kirk (2008) revealed, that the activity in this area correlates with aesthetic attractiveness ratings of unusual pictures or atypical figure-ground combinations. The authors assume that this activity reflects the participation of evaluative judgement processes.

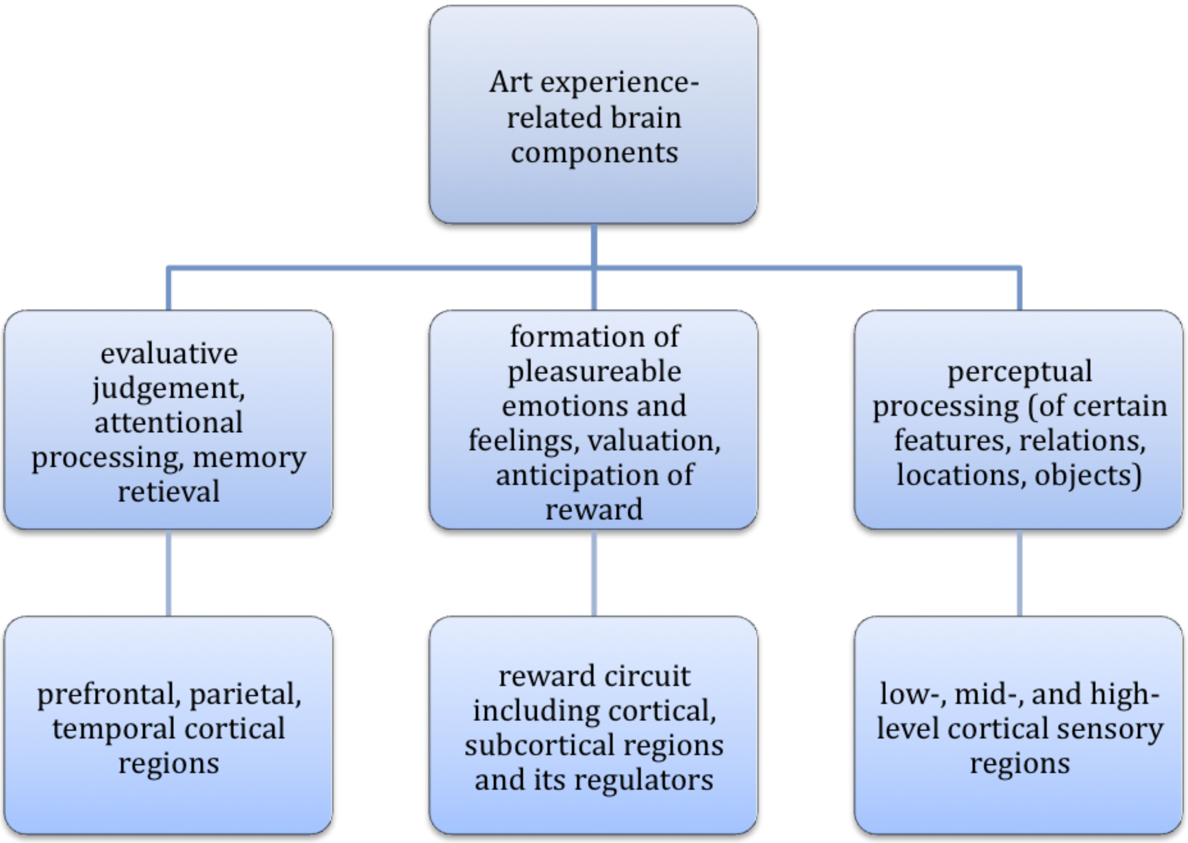

Figure 3: Art experience- related brain systems. (According to Nadal, 2013)

Nadal (2013, p. 142) remarks, that all following studies (Cela-Conde et al., 2004; Cupchik et al., 2009; Jacobsen & Höfel, 2006; Kirk, 2008) found the relationship between the activity in the prefrontal area and evaluative judgements of paintings, photographs and designs. However, some located this activity in the dorsolateral prefrontal cortex, while others in the anterior medial prefrontal cortex. The suggestion is (according to Christoff & Gabrieli, 2000, as cited in Nadal, 2013, p.142), that the dorsolateral prefrontal cortex activity appears to be particularly involved with externally generated information, whereas the frontomedian prefrontal cortex activity seems to express the outcome of internally generated and manipulated information.

2.3.1.3. Ventrolateral prefrontal cortex

Jacobsen et al. (2006) found greater activity bilaterally in the inferior frontal gyrus when participants rated the beauty of geometric designs compared to symmetry judgements (Nadal, 2013), and Kirk (2008) found that the activity of this region correlates with aesthetic fascination with unusual images, or unexpected figure-ground combinations. Both works suggest that this activity is related to greater attentional demands in experimental environment requiring transforming a non-dichtomous judgement into a binary response (Jacobsen et al., 2006) or decoding and processing complex visual stimuli (Kirk, 2008).

2.3.1.4. Temporal pole

Jacobsen et al. (2006) found activity in the left temporal pole increased significantly when participants rated beauty in geometric designs compared to when they where asked to rate their symmetry. They infer that this activity mirrors the retrieval of information from memory, which results in a semantically and emotionally rich context as a reference for valuing the visual stimuli (Nadal, 2013).

2.3.1.5. Posterior cingulate cortex and precuneus

Kirk (2008) found activity in the posterior cingulate cortex (PCC) correlated with aesthetic ratings of scenes portraying congruent figure-ground pairings (Nadal, 2013). The author assumes this result to be a reflection of the semantic memory and familiarity in the participant’s responses to the stimuli. Also, Jacobsen et al. (2006) found greater activity in the PCC and the precuneus when participants rated the beauty of geometric forms than when they rated their symmetry. These studies suggest that this activity represents memory retrieval processes, either because of repeated exposure to the same stimuli during the experiment or information stored in memory from participants’ everyday life.

These five cortical regions (dorsolateral prefrontal cortex, anterior medial prefrontal cortex, ventrolateral prefrontal cortex, temporal pole, PCC and precuneus) have so far been determined to be important and involved in evaluative judgement, attention and memory processes during aesthetic encounter.

2.3.2. Reward circuit brain areas involved in art experiencing

We then move to the reward circuit in the experience of art (see Figure 3). Various regions create the reward circuit: cortical (anterior cingulate, orbitofrontal, and ventromedial prefrontal), and subcortical (caudate nucleus, nucleus accumbens) elements, as well as some of the regulators of this circuit (amygdala, thalamus, hippocampus). Areas that have been investigated most and that will be described in detail, are the orbitofrontal cortex (OFC), the ventromedial prefrontal cortex (VMPFC), the anterior cingulate cortex, insula and nucleus accumbens. (Nadal, 2013)

2.3.2.1. Orbitofrontal cortex

Rating the beauty of distinct visual artworks (Ishizu & Zeki, 2011; Kawabata & Zeki, 2004), or photographs (Kirk, 2008; Kirk et al., 2009), leads to activation of the OFC. It is suggested that this activity reflects the reward value of the presented artwork or aesthetic stimuli. The OFC is sensitive when it comes to changes in environment, such as semantic context, personal factor or prior knowledge (Nadal, 2013).

2.3.2.2. Ventromedial prefrontal cortex

The VMPFC is functionally and anatomically related to the OFC. Kirk et al. (2009) discovered greater activity in the frontopolar aspect of the VMPFC as well as aesthetic appeal scores when the viewed pictures were labelled as gallery artworks.

2.3.2.3. Anterior cingulate cortex

The activity of anterior cingulate cortex increases when people look at artworks they personally like compared to with those they like less (Cupchik et al., 2009; Kirk et al., 2009).

The role of the anterior cingulate cortex, when experiencing art, seems to be related to participants' awareness of their own affective state.

2.3.2.4. Insular cortex

A greater activity was found in the insula (insular cortex), when participants engaged subjectively with the paintings, allowing themselves to go through emotions and moods evoked by the artwork focusing on colours and composition. However, when they took a detached stance, they focused on the content of the picture (Cupchik et al., 2009). It seems that the insula also plays an important role in the emotional response to music (as cited in Nadal, 2013, p.146).

2.3.2.5. Nucleus accumbens

Nucleus accumbens is one of the subcortical areas involved in the reward circuit when engaging with art. This brain region is active when people enter an aesthetic encounter, it is crucial for a variety of complex operations related to learning, reward prediction and anticipation, emotions and pleasure (Nadal, 2013). The ventral striatum is one of the key neurobiological elements, when it comes to the experience of art. Kirk et al. (2009) found that the activity in the nucleus accumbens is greater when the photographs of faces and buildings viewed by the participants are appealing to them, than when they are not. According to Kringelbach and Berridge (2009, as cited in Nadal, 2013, p.147), it seems the nucleus accumbens is involved in generating pleasurable experiences and the ventral striatum is responsible for the pleasurable aspect of our experience of art.

The above-mentioned brain regions contribute to the affective and emotional qualities of the experience of art, while communicating with other brain systems. In our case, it is important to note, that they communicate with the evaluative judgement, memory and attention, as well as those brain regions responsible for the perceptual analysis, which will be described subsequently.

2.3.3. Cortical areas involved in perceptual processing

Cortical regions involved in perceptual analyses demonstrate greater activity during the experience of art, the activation of respective systems depends on the type of art, whether it is a painting, piece of music or dance. Due to the nature of our experiment, this section will focus on brain systems involved in visual perceptual processing.

2.3.3.1. Occipital cortex

Vartanian and Goel (2004, as cited in Nadal, 2013, p.147) found in their study, that when they asked the participants to rate the abstract and representational stimuli, the activity in occipital cortex, including bilateral fusiform gyri, correlated with those ratings. Higher ratings for an artwork resulted in more activity in the visual cortex. Kirk's (2008) study discovered that, independently of aesthetic judgement, bilateral activity in the lateral occipital cortex was greater, when participants rated the aesthetic appeal of images depicting congruent figure-ground pairings, than when rating images depicting unusual or unexpected pairings. Cupchik et al. (2009) tried to distinguish between the bottom-up processes (hard-edge vs. soft-edge style) and top-down processes (objective and detached vs. subjective and engaged orientation) in aesthetic appreciation of art and found a higher activation in bilateral occipital gyri, while participants viewed the pictures in relation to the baseline condition (Nadal, 2013). The authors assume that it mirrors the activation of attentional resources for perceptual analysis of the artworks' visual details.

2.3.3.2. Parietal cortex

Cela-Conde et al. (2009) found greater activity in the bilateral angular gyrus when participants viewed artworks they evaluated as beautiful compared to those they did not regard as beautiful. This study indicates that this activity might be caused by the enhancement of spatial processing strategies while viewing the artworks, considered by each participant as beautiful. The study by Cupchik et al. (2009) referred to in the previous paragraph also found greater activity in the superior parietal cortex, when participants were aesthetically engaged with the soft-edge artworks. As the parietal cortex is involved in spatial cognition and visual imagery, the researchers suggest, that this activity might be due to participants' endeavours to elaborate coherent representations of the indeterminate forms (Nadal, 2013).

To sum up, according to Churchland et al. (1994), appreciating art engages processes related to perception (attentional enhancement of the analyses of certain features), cognition (evaluative judgement, attention, and retrieval of information from memory), and affect (generation of pleasant feelings, emotions, representation and anticipation of reward, and awareness of one's own affective state). These processes are performed in parallel, they are highly interrelated, and they rely heavily on information feedback, making it impossible to describe any meaningful sequence of events. One cannot even say that an art experience begins with perception, given the strong biasing influences, which context, expectations and prior knowledge have even on very early perceptual processes. (Nadal, 2013, p.152)

2.4 Interaction between art-experience related neural systems

Neuroaesthetics combines empirical aesthetics with cognitive and affective neuroscience (Chatterjee & Vartanian, 2014). Researchers are looking for clues and answers on how the aesthetic experience is born, and what processes take place on the neural level. Chatterjee and Vartanian (2014) propose an aesthetic triad, which is a combination of neural systems whose properties and interactions are examined through neuroaesthetic research. These systems are: sensory-motor (perception), emotion-valuation (emotion), and meaning-knowledge (cognition) circuitry. Aesthetic states are defined as a result of interactions between these three neural systems, this division is similar to that defined by Nadal (2013), which is discussed in *2.3 Neural Underpinnings of Aesthetic Experience*. Chatterjee and Vartanian (2014) suggested, that the experience of aesthetic pleasure might arise from the interplay between brain structures that underlie perceptions of specific stimuli and the distribution of relevant neurotransmitters in the cortex. They explain the whole process from the beginning of the art experience to the interplay of connected brain systems as follows:

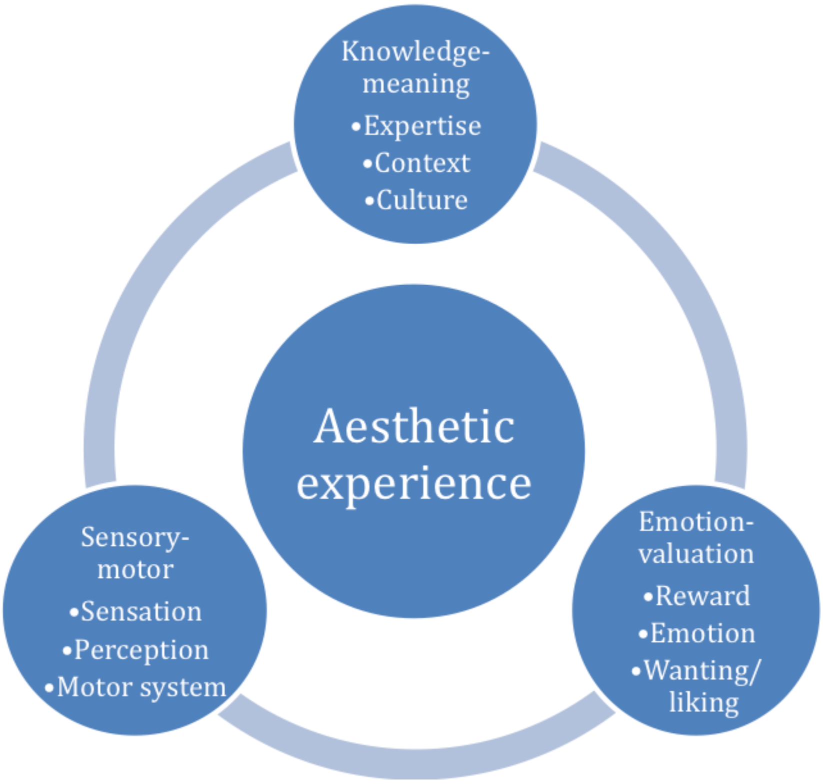

Figure 4: The aesthetic triad (according to Chatterjee and Vartanian, 2014)

The visual brain (perception) selects sensory systems engaged by aesthetic encounters (e.g. luminance, colour, motion, higher-order objects such as faces, bodies or landscapes). Depending on what is depicted in the artwork, the relevant systems are activated. In addition to classifying visual elements, the system responsible for perceptual processing also seems to be involved in the evaluative processes. Looking at artworks that portray actions, engages parts of the motor system. Mirror neurons responding to both the execution and perception of actions are involved in this process. The general reward circuitry is initialized when looking at beautiful objects.

Chatterjee and Vartanian (2014) propose, that the way these three mechanisms influence one another during the aesthetic encounter is similar to their interactions during a non-aesthetic experience. The authors highlight, that in the case of aesthetic appraisals the focus is on objects rather then outcomes, which differentiates aesthetic experiences from other evaluative processes. It is important to note, that during an art-related experience, not all three systems have to be involved equally.

In the next section, the left dorsolateral prefrontal cortex (left DLPFC) will be discussed, as it is the very brain area stimulated during the aesthetic experiment, which will be described in the experimental section of this paper.

2.5 Left dorsolateral prefrontal cortex

Over the last few years, an increasing number of neuroimaging studies have been carried out to provide insights into the neural foundation of aesthetic experiences (Nadal & Pearce, 2011). The left DLPFC is a neocortical brain region, which is involved in processing aesthetic experiences, along with various other executive functions. Neuroaesthetic research documentation suggests the critical role of the left DLPFC in aesthetic judgements (Cattaneo et al., 2014a). Cela-Conde et al. (2004) found in a magnetoencephalography (MEG) study remarkably higher activation in the left DLPFC, when participants evaluated photographs and artworks as beautiful, compared to those they decided to be not beautiful. Cela-Conde et al. (2004) therefore assumed, that the role of the left DLPFC might be responsible for making decisions about the beauty of the stimuli. Furthermore, Lengger et al. (2007) revealed a greater neural activity in the left DLPFC, when the participants evaluated the aesthetic qualities of visual art. In addition, Vessel et al. (2012) also found greater activity in this brain region, when participants rated artworks, which had moved them aesthetically. Importantly, Cattaneo et al. (2014a, 2014b) carried out two studies using anodal transcranial direct current stimulation (tDCS) and a transcranial magnetic stimulation (TMS) respectively, and found greater activity in the left DLPFC, when participants appreciated representational paintings and photographs compared to abstract artworks. These non-invasive brain stimulations modify the neural activity in the left DLPFC by either an induction of weak amounts of direct current (tDCS) or induction of magnetic stimulation (TMS), which allows the examination of causal relationship between the left DLPFC and aesthetic appreciation. This first study (Cattaneo et al., 2014a) is the one used as a model for our experiment. They discovered, that the left DLPFC controls top-down processes in the domain of aesthetic perception (Cattaneo et al., 2014a), but these processes can be disrupted by TMS (Cattaneo et al., 2014b).

Based on the findings from the studies mentioned above, the left DLPFC is believed to be one of the crucial neural correlates of aesthetic appreciation. Cupchick et al. (2009) revealed in an fMRI study, when asking participants to look at the art stimuli with an aesthetic or a detached approach, that even the instructed aesthetic orientation towards an artwork, resulted in a greater activity in the left DLPFC. Similarly, Ridderinkhof et al. (2004) and Cupchik et al. (2009) associated the left DLPFC with cognitive top-down processes, which also suggests that aesthetic appreciation is not entirely driven by bottom-up processes. It seems that the aesthetic experience is a complex interaction between the above-mentioned cognitive bottom-up and top-down processes (Cupchik et al., 2009).

2.6 Transcranial direct current stimulation

Transcranial direct current stimulation (tDCS) is a non-invasive type of brain stimulation, where a weak electrical current is directly applied to the scalp through a pair of electrodes. The weak direct currents polarise the stimulated brain regions and the final effects depend on various parameters, e.g. intensity, geometric configuration of the electrodes, current direction, application during (online) or before (offline) the task. Some factors depend on the anatomy (e.g. properties of the brain tissue and its location, Radman et al., 2007), as well as physiological (e.g. gender, age, Landi and Rossini, 2010; Lang et al., 2011; Ridding and Ziemann, 2010) and cognitive states of the stimulated area or subject (e.g. Miniussi et al., 2010; Silvanto et al., 2008). Depending on the polarity of the stimulation, the cortical excitability in the stimulated brain area is either increased or decreased, which results in facilitation or inhibition of behaviour, and therefore enables the study of causal relationships between brain activity and behaviour by means of neural modulation (Minisussi et al., 2013). tDCS does not effect action potentials, but modifies the neuronal response threshold, which can be defined as subthreshold stimulation. These changes in the neuronal threshold develop from an alteration in membrane permeability (Liebetanz et al., 2002), which influence the response task-related network. This thesis used offline anodal tDCS stimulation, which induces membrane depolarisation compared to the cathodal stimulation, which would lead to hyperpolarisation. The anodal stimulation facilitates the task execution, whereas the cathodal stimulation inhibits the task performance (Miniussi et al., 2013). The offline stimulation leads to neural activity changes, which last for certain period of time after the stimulation depending on stimulation parameters, mostly stimulation polarity (anodal / cathodal), duration of the stimulation and the intensity (Miniussi et al., 2013).

3 Experimental section

3.1 Objectives

The main goal of this paper was to examine the role of the left DLPFC in an aesthetic encounter. Cattaneo et al. (2014a) discovered, that when the art-naïve participants rated the beauty of the stimuli, the actual tDCS over the left DLPFC resulted in higher ratings of representational artworks and photographs compared to the sham condition or the control group. This study has been performed to support this suggestion, that the anodal tDCS over the left DLPFC influences the outcome of the aesthetic judgement (beauty ratings) along with the response time. A shorter response time was expected after actual tDCS in the evaluation of both beauty and colourfulness.

In accordance with Cattaneo et al. (2014a), it was hypothesised, that actual anodal tDCS over the left DLPFC would cause an enhanced neural excitability in the stimulated cortical area and therefore would result in higher rating numbers when evaluating beauty (but not when evaluating colourfulness), in comparison to the sham tDCS condition. As a control measurement, the evaluation of the colourfulness was also tested. It was expected, that actual anodal tDCS over the left DLPFC would not result in changes in evaluation of colourfulness, but would occur in the case of beauty ratings. Cattaneo et al. (2014a) distinguished the ratings for representational artworks (depicting real sceneries or photographs) from abstract artworks. Higher ratings were found only for representational stimuli. These findings are in accordance with Cela-Conde et al.'s (2011) suggestion, which explained the discrepancy of neural activity found in aesthetic appreciation studies, as being caused by the use of different stimuli.

3.2 Method

3.2.1. Participants

Altogether twenty-nine participants (14 females, 15 males; M = 27; SD = 3,10; age range = 23 - 31) were examined, with one being excluded from the analysis, due to technical difficulties during the eye-tracking experiment performed alongside our tDCS study. Twenty participants were native German speakers and eight participants were native Slovak speakers. All participants were naïve to art, none of them had any formal on informal training or education in an art-related field. All of them were right-handed, which was decided according to the Edinburgh inventory (Oldfield, 1971), had normal to corrected-to-normal vision and normal colour vision. Written informed consent was obtained from all participants. All participants were informed about the transcranial direct current stimulation effects, therefore for safety reasons none of them had epilepsy, head injuries, neurological diseases, metallic implants or devices in the head, skin diseases in the head area and the female participants were not pregnant. Also, all participants had had enough sleep the night before the experiments, had not taken any psychoactive substances and had not had excess of alcohol or cigarettes. Participants were randomly assigned to either the experimental group, which consisted of 16 participants, or the control group, which contained 12 participants.

3.2.2. Stimuli

The stimuli consisted of 160 pictures (80 matched pairs), where each pair came from the same author and the content, as well as size, period in which it was made and atmosphere of the artwork was similar (e.g. a pair of landscapes or two abstract artworks). The width-to-height ratio varied, but was always matched for the pair. The stimuli were not divided into representational and abstract as in the study of Cattaneo et al. (2014a). However, different artistic styles were used to give the participants the possibility of experiencing different types of aesthetic appreciation. To avoid the activation of facial-recognition brain mechanisms, pictures of human close-up were not used in the stimuli sets. The artworks were divided into Set A and Set B, where one picture of the pair was in Set A and the other in Set B. Three additional pictures were used in the trial prior to the main rating task without further analysis. The stimuli were presented in a random order on a grey coloured background (R: 150; G: 150; B: 150) positioned in the centre of the screen. The abstract pictures were in minority in comparison to representational artworks.

3.2.3. Transcranial direct current stimulation

The tDCS was applied with two rubber electrodes (5 x 7 cm: 35 cm2) connected to a direct current stimulator (DC-STIMULATOR, neuroConn GmbH, Ilmenau, Germany). The sponges covering the rubber electrodes were soaked with a physiological salt solution and a conductive electrode gel (Electro-Cap International, Eaton, OH, USA), the skin under the electrodes was cleaned with alcohol to minimise the electrical impedance. Two plastic rubber head straps fixed the electrodes in place. The anodal electrode was positioned over the left DLPFC, the exact position on the scalp was determined as the midpoint between the F3 and the F5 in accordance with the international 10/20 electrode system (Jasper, 1958), a properly fitting EEG cap was used on each participant to ascertain the exact position of the left DLPFC. The cathodal electrode was placed over the supraorbital area of the right hemisphere. In accordance with Cattaneo et al. (2014a), the anodal tDCS over the left DLPFC results in an increase in cortical excitability.

Each participant was measured twice; one measurement session consisted of real tDCS and the other of sham tDCS, a three to seven day period was allowed between the measurements to avoid the mere exposure effect (Zajonc, 1968). The order of the tDCS sessions (real vs. sham) was counterbalanced across participants. Thus, one half of the participants (for both experimental and control groups) started with the real tDCS in the first measurement, followed by a sham tDCS in the second session, and correspondingly, the other half began with a sham tDCS measurement followed by the real stimulation in the second session. Each session consisted of two rating runs, one before and one after the tDCS.

The same counterbalance principle applies for the stimuli, one half of the (experimental and control) participants started with Set A in the pre-tDCS ratings and proceeded with Set B in the post-tDCS judgements. The other half of the participants started with Set B in the pre-tDCS and proceeded with Set A in the post-tDCS ratings. The order remained the same for one participant in both real and sham tDCS sessions.

As in Cattaneo et al. (2014a), each tDCS, both real and sham, took 20 minutes. For the real tDCS, a constant current of 1,5 mA intensity with 20 second fade-in and 20 second fade-out was applied. In the sham stimulation, the setting and positioning of the electrodes was exactly the same as in the real stimulation condition, but the tDCS device induced a direct current for 30 seconds with a 20 second fade-in and 20 second fade-out, to give the participant the experience of being stimulated, as the participants felt strong initial itching and burning. Subsequently, during the real condition, they felt a weaker sensation during the whole 20 minutes. The participants did not know whether they were actually stimulated or not. We as the examiners, worked out which code setting on the tDCS device corresponded to the real and the sham stimulation according to the sensation feedback from the participants. An offline tDCS procedure was used, which means the participant was not stimulated during the rating task, as the anodal stimulation and its impact as the enhancement of the cortical excitability persists beyond the active tDCS (Miniussi et al., 2013).

3.2.4. Procedure

At the beginning, the participants were welcomed and familiarized with the process of measurement, written consent was given and visual capacity was measured. The participants were seated in a dimly lit and silent room with no windows, to ensure the same light conditions for every participant, in front of a 24″ LED monitor (1920 x 1080 pixels). As the previously mentioned eye-tracking study was performed alongside our measurement, the participants placed their head in the chin and forehead rest to ensure they did not move during the rating process, which would impair the eye-tracking data. A calibration for the eye tracking was made, instructions were given either in German onscreen or Slovak verbally.

A trial version was carried out and the first pre-tDCS ratings were taken. Before presenting each stimulus, a fixation cross was presented in the centre of the screen and the participant had to fixate on the cross for at least 500 ms to ensure a correct calibration of the eye-tracker. If, during a 3 second period, the participant did not fixate on the cross for at least 500 ms, a re-calibration was automatically required. If the calibration went correctly, the trial started and the stimulus was onscreen for 7 seconds. After 7 seconds, the instruction with a 9-point Likert rating scale (from 1 – very ugly/colourless to 9 – very beautiful/colourful) appeared under the picture, which was still onscreen. The participants were instructed to rate the artwork as quickly as possible, and not to think too much about the decision. The artwork, the instructions and the rating scale remained visible until the participant made his evaluation, followed by a fixation cross before the next stimulus. After the pre-tDCS trial, the tDCS device was placed on the participant's head. During the tDCS, participants viewed a cartoon film, without any sound so as not to stimulate ocular mechanims. The participants were supposed to concentrate on the film and not be distracted by other things. After the tDCS, the device and equipment were taken off the participant's head, and the participant was moved back to the chin and forehead rest to undergo the post-tDCS measurement. The pre-tDCS and the post-tDCS measurements were exactly the same, with the only change in the picture Set (A or B). The participants were divided as follows in Table 1. The participants were randomly assigned to both beauty / colourfulness and the picture Set (A or B) order groups. After the post-tDCS ratings, the participant filled in the onscreen questionnaire KIF (Kunst-Interesse-Fragebogen) about their art education and interests, as well as a tDCS sensation feedback enquiry. One session lasted approximately 90 minutes.

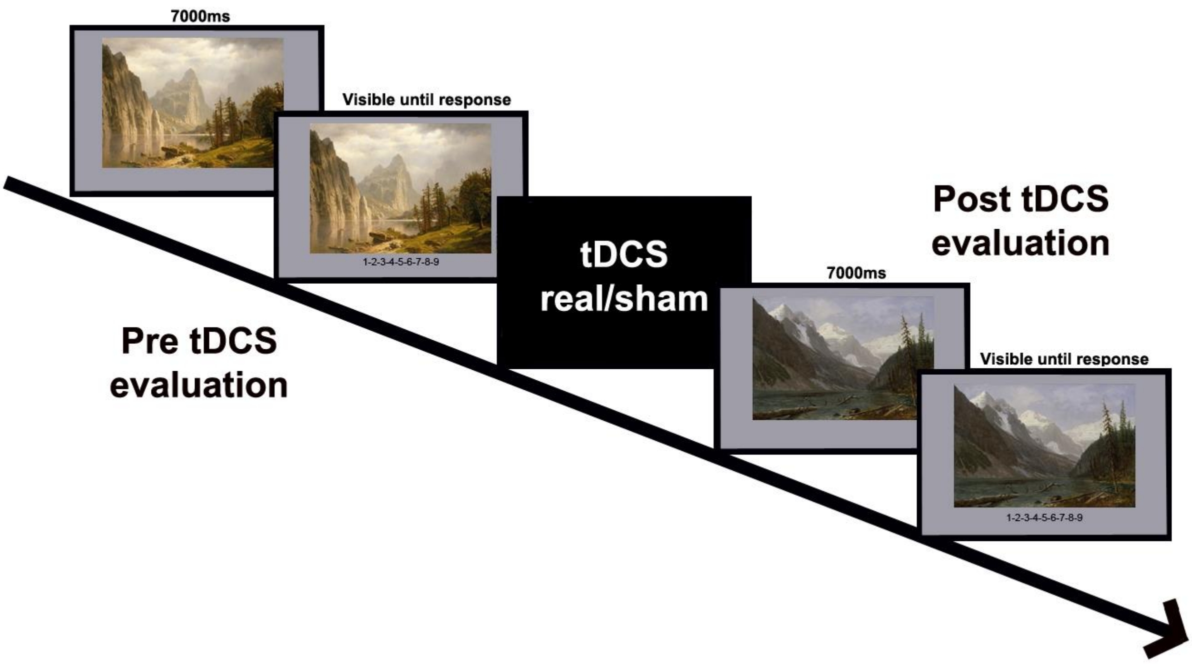

Figure 5: Example of an experimental trial.

3.2.5. Results

Behavioural analyses were performed using IBM SPSS Statistics software (version 22, IBM Corporation, Armonk, NY, USA) to examine the effects of the tDCS on the mean rating scores and mean reaction times.

	Σ	Pre/Post tDCS Picture Set	Sham tDCS in the 1st session	Real tDCS in the 1st session
Experimental group	16	Set A / Set B	5	3
		Set B / Set A	3	5
Control group	12	Set A / Set B	4	2
		Set B / Set A	2	4

Table 1: Distribution of participants across groups in the experiment

Participants were divided into 8 groups from which the analysis was made (4 groups in the experimental group and 4 in the control group). The distribution of the variables (gender, age, the beginning picture set: A or B, beginning stimulation condition: real vs. sham) was roughly balanced across the groups to stop them from influencing the results. Table 1 depicts the distribution of participants in groups, Table 2 shows the mean values of ratings, and the mean values of reaction times are reported in Table 3.

Aesthetic and colour evaluation

A repeated measures analysis of variance (ANOVA) with the factors *task* (aesthetic vs. colour) *x stimulation* (real vs. sham) *x session* (pre- vs. post- tDCS) was carried out on the mean rating scores. The analysis did not reveal a significant overall effect of the tDCS over the left DLPFC, F = 1,591; P = 0,228 for the beauty parameter. As for the colour paramater, the results were also not significant, which was expected, F = 0,943; P = 0,352. These results indicate no significant effect of the transcranial direct current stimulation over the left DLPFC for the aesthetic evaluation. The graphics show that the only case of post-tDCS evaluation ratings being above the pre-tDCS evaluation ratings is the post-real-tDCS evaluation for the beauty condition. This effect is, however, not significant. Possible explanations are further considered in the discussion.

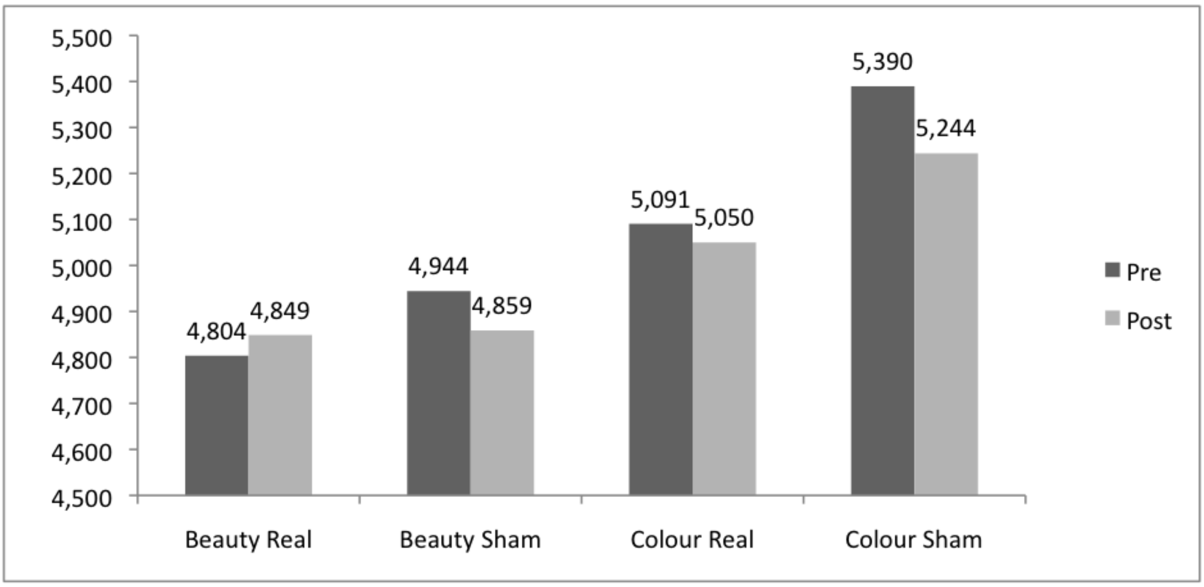

Table 2: Mean rating scores of participants in each condition (beauty vs. colour), stimulation (real vs. sham), and session (pre- vs. post. tDCS), rating scale on the y-axis.

Response latencies

A repeated measures analysis of variance (ANOVA) with the same factors as for the rating scores *task x stimulation x session,* was made for the response times. Table 3. shows the mean reaction times for both the aesthetic and colour evaluation. The ANOVA did not reveal any significant effect, for the beauty condition F=1,591; P=0,228 and for the colour condition F=0,943; P=0,352. However, the graphics show that the post-tDCS evaluation is faster, which could be caused by the task familiarization.

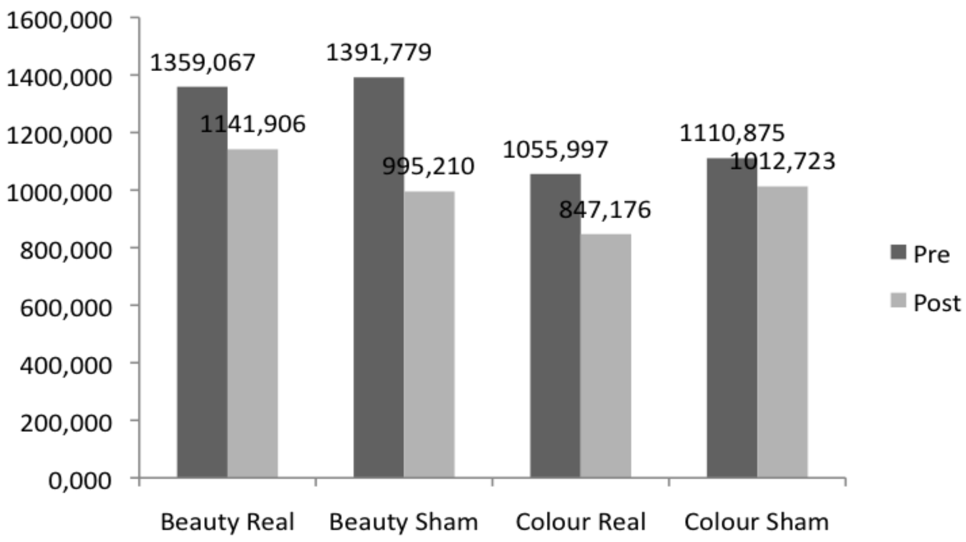

Table 3: Mean response latencies of participants in *ms* for each condition (beauty vs. colour), tDCS (real vs. sham), and session (pre- vs. post- tDCS), time in *ms* on the y-axis.

4 Discussion

The aim of this experiment was to further investigate the function of the left dorso-lateral prefrontal cortex in an aesthetic experience, following the results of the study by Cattaneo et al. (2014a), which was partially replicated. Cattaneo et al. (2014a) found a significant effect of the real tDCS on beauty ratings in comparison to the sham tDCS. The area of interest (lDLPFC) was stimulated with the anodal tDCS and the effect of the stimulation was monitored. In this study, the effects that Cattaneo et al. (2014a) found were not replicated.

One of the possible explanations for this is the different scaling model. Whereas, in the Cattaneo et al. (2014a) study, participants clicked on a 0% - 100% bar, in this study a 9-point Likert scale was used, which might have led to more precise results.

Another possible explanation for the results obtained in this study, is that the data were not divided into *representational* and *abstract* pictures as in Cattaneo et al. (2014a) study. They found, that the tDCS over the lDLPFC gave a 3% increase in aesthetic appreciation for representational images, but not for abstract pictures. In our study, the data set contained much fewer abstract artworks, which could have influenced the overall results, as the participants were naïve to art, which suggests, that they would rate abstract pictures with a lower score than representational images. However, the analysis did not differentiate between the representational and abstract stimuli for evaluation nor for the response latencies. Further analysis would be needed. Also, it might be interesting to compare the results from this study with Cattaneo et al. (2014a) results, if their results from representational and abstract stimuli were combined together. If these hypothetical combined results from Cattaneo et al. (2014a) study did not give a significant result in terms of demonstrating the effect of the tDCS over the left DLPFC in aesthetic appreciation, purely hypothetically, it might mean, that the presence of abstract artworks in the stimuli set leads to non-significant results, and therefore the results from this study would confirm Cattaneo et al. (2014a) findings, that the anodal tDCS over the left DLPFC results in a higher liking of representational artworks.

Another reason for the results of our study is the difference in the instructions. Cattaneo et al. (2014a) asked the participants as follows: “How much do you like this image?” and this study instructed the participants: “Please rate how beautiful you find the picture.” Cattaneo et al. (2014a) called upon the personal taste or personal preferences of the participant, whereas the our study asked explicitly about the beauty, which as an ambiguous term could have led to a different, more objective, approach.

A noticeable difference between this study and the Cattaneo et al. (2014a) study is the number of participants. Cattaneo et al. (2014a) measured 12 people, whereas this study had 16 participants in the experimental group, which equates to one third more. Neither of the studies measured a sufficiently high population to give statistically reliable results, however 33% is a significant increase even for study such as this.

Furthermore, an eye-tracking measurement was taken alongside this study, which could have led to discomforting feelings in the participants, as they had to undergo the pre-experiment eye-tracking calibration, had their head stabilized in the chin and forehead rest for the evaluating parts of the experiment (around 45 minutes together), had to repeatedly undergo the calibration during the experiment if they moved, and also had to sit with minimum movement so as not to interrupt the eye-tracker. Such constrains of the participant's comfort might have influenced the overall capacity to act or feel aesthetically towards the artworks, as is usually considered the case when it comes to lab experiments, whether lab conditions allow the participant to behave as though he were in a "natural" environment, in our aesthetic case, in a museum or at an exhibition (DOPLNIT NEJAKE STUDIES). This study was done in standard university laboratory conditions set for aesthetic experiments in a small room, which was not sufficiently ventilated, also the low level of light in the room sometimes made the participant sleepy. It is difficult to find optimal conditions for experiments while preserving reliability during testing.

Even though the study should have been double blind, which in this case means, that neither those conducting the experiment nor the participants should have known, whether the tDCS they received was real or sham. To begin with, those conducting the experiment did not know, which code represented the real or the sham stimulation. However, due to the fact that the participants gave us feedback about the sensations during the stimulation, it was clear which code represented each stimulation type. Also many participants were familiar or even had previous experience with the tDCS and knew if they were receiving real stimulation or not. These factors could have influenced the behaviour of the participants but also the behaviour of those conducting the experiment, e.g. in terms of attention paid to placing the tDCS device correctly.

To conclude even though this study did not reveal any significant results, additional research and analysis is recommended to further investigate the role of the left DLPFC in aesthetic experiencing, as the left DLPFC seems to be dependant on the type of image (representation or abstract) when testing naïve art viewers.

5 Conclusion

In summary, this study attempted to uncover more detail about the role of the left DLPFC in the aesthetic process. Starting with historical and theoretical information about the aesthetic experience itself, an explanation was given of how the field of neuroaesthetics was built up over time and what findings shaped its current form. We tried to focus on the role of the left dorsolateral prefrontal cortex whilst evaluating artworks. The main goal of this experimental study was to partially replicate the study of Cattaneo et al. (2014a), which suggested that the left DLPFC plays a crucial role when evaluating representational (but not abstract) artwork. They found higher liking ratings for representational artworks after the anodal tDCS over the left DLPFC only when the participant rated the beauty, not colour, of the artworks. These findings were, however, not replicated. The possible reasons for this include minor but not negligible difference in the design of the experiment. For further research, a better control of the variables influencing the experimental process would be required, however, it is not possible to control all of these. It is apparent that the left DLPFC plays an important role in the process of aesthetic experience, which would require further investigation.

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