universität wien

DIPLOMARBEIT

Titel der Diplomarbeit

"Enhancing beauty appreciation in art works: A neurological eye tracking experiment"

verfasst von

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angestrebter akademischer Grad

Magistra der Naturwissenschaften (Mag. rer. nat.)

Wien, 2015

Studienkennzahl lt. Studienblatt:	A 298
Studienrichtung lt. Studienblatt:	Psychologie
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Wien , am 09.09.2015 Unterschrift: _____

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Danksagung

An dieser Stelle möchte ich mich bei all jenen bedanken die zum Gelingen dieser Diplomarbeit beigetragen haben.

Allen voran möchte ich mich bei Dr. Marcos Nadal für die hervorragende Betreuung und die Bereitstellung des spannenden Themas bedanken, sowie für die freundliche und rasche Unterstützung bei allen anfallenden fachlichen Fragen und Problemen.

Weiterhin möchte ich mich für die überaus wertvollen Tipps und Hilfestellungen von Mag. Michael Forster bedanken.

Frau Sona Algayerova möchte ich außerdem für die hervorragende Zusammenarbeit in der Durchführung des gemeinsamen Experiments danken.

Besonderer Dank gilt außerdem meiner Familie, insbesondere meiner Mutter die mir mein Studium ermöglicht hat und mich stets unterstützt hat, sowie meiner Oma, die stets ein offenes Ohr für mich hatte.

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1. Abstract

In 2014 Cattaneo, Lega, Flexas, Nadal, Munar and Cela-Conde discovered an enhancement of beauty appreciation after transcranial direct current stimulation (tDCS) on the IDLPFC of their participant's brains. This specific area is known to be crucial for an orientation of the cognitive and perceptual systems towards aesthetic perception. In the present experiment a replication of Cattaneo´s results was aspired with the expansion of eye tracking. A shift towards more focal processing (fewer fixations, longer Saccade amplitudes) after a real tDCS was expected. Also a possible influence of tDCS to a transition from more ambient to more focal processing after 3 seconds of viewing time was examined. Therefore participants were requested to view artworks before and after a tDCS (in one session real stimulation, in another a sham stimulation) and rate their beauty (in a control condition participants rated colorfulness) while eye movements were recorded. While Cattaneo´s results concerning higher ratings after real stimulation could not be replicated in the present experiment, an enhancement of focal processing after real tDCS was visible, but only in lower fixation count. No effect of real tDCS to transition in time from more ambient to more focal processing was found. The results of the present experiment also showed, that more control of confounding variables is necessary with tDCS experiments.

2. Introduction

2.1. Neural mechanisms involved in aesthetic appreciation

Many authors already tried to answer the question where the perception of beauty is laying, if there is a special form of perception for things that are judged as beautiful, and if, where in the human brain those processes take place. To answer that question neuropsychological experiments have been conducted. In 2003, Jacobsen and Höfel investigated evaluative aesthetic judgment processes of the brain with electrophysiological recordings, in this case EEG. Their results show, that the brain does differ between patterns that are judged as beautiful and patterns that are judged as non-beautiful. Those different patterns of activation are visible after only 300-400ms after the stimulus onset. In non-beautiful judgments an early frontocentral phasic negativity was elicited. In their view, this corresponds to activity generated in the anterior frontomedian cortex, which is congruent with fMRI studies that suggest an involvement of the anterior frontomedian cortex in evaluative tasks (e.g., Zysset, Huber, Ferstl, & von Cramon, 2002). Jacobsen and Höfel identified a stronger right-hemisphere involvement in evaluative tasks compared to descriptive processes in this experiment. Also Kawabata and Zeki (2004) tried to find correlates of beauty in brain regions with the method of fMRI, while participants perceived and judged paintings for their beauty or ugliness. Kawabata and Zeki reported a change in relative activity in the orbito-frontal cortex, as well as in the motor cortex. Whereas in the orbito-frontal cortex paintings judged as beautiful produced the highest activity and ugly paintings the lowest (both kinds of judgment lead to a change to the baseline activity), in the motor cortex region the highest activity was produced by ugly judged paintings and the least activity by paintings judged as beautiful. Those described areas seem to have widespread connections with other cortical regions, particularly the anterior cingulate cortex and the

left parietal cortex, which were considerable involved in contrasting beautiful and neutral paintings. The anterior cingulate cortex has often been linked to responses to pleasurable stimuli (Bartels & Zeki, 2000a; Blood & Zatorre, 2001) and therefore a connection between aesthetic sense and emotions is implied. The activation of the motor cortex was interpreted as a general reaction to emotionally charged stimuli. In summary, Kawabata and Zeki argued that the presence of beauty and ugliness is part of the same continuum and is attributed to a stimulus by specific areas of the brain. An experiment conducted by Munar et al. (2012) confirmed Jacobsen and Höfel's results from 2003 that differences in the perception of beautiful and non beautiful pictures already appear after 300-400ms. But they found other brain regions related with a division of beautiful and non beautiful stimuli as Jacobsen and Höfel interpreted. Munar et al.'s results show the right lateral orbitofrontal cortex (OFC) as the source of activity related with non-beautiful stimuli, which supports the findings of Kirk (2008) who also found a negative correlation between aesthetic ratings and activity in the right lateral OFC. Kringelbach and Rolls (2004) tried to synthesize the functions of the human OFC and described among other things two general trends of neural activity in this area. The lateral OFC seems to be involved most in the value of punishment, which can lead to behavioral change. On the other hand, the medial OFC seems to be most involved in monitoring the value of a reward from reinforcers, even from abstract reinforcers. Tremblay and Schultz (1999) showed that in primates, the response of both OFC areas (medial and lateral) to the same perceptual stimulus is dependent on the relative value in context of the reward and not the absolute value. Results from Munar et al. (2012) show, in contrast to findings from Kawabata and Zeki described previously, clearly distinct area activities for stimuli rated beautiful or ugly. In 2004 Cela-Conde et al. also investigated the role of the prefrontal cortex in aesthetic perception. They found increased activity in

the left dorsolateral prefrontal cortex at a latency of 400-1000ms when participants perceived beautiful stimuli.

2.2. The role of the IDLPFC in aesthetics

The specific area of the left dorsolateral prefrontal cortex seems to play a crucial role in perception of aesthetics. (E.g. Cela-Conde et al., 2004) This area is strongly connected to the orbitofrontal cortex (OFC), the role in perceiving and judging stimuli of this area was described previously. The DLPFC also terminates the dorsal pathway ("What-path") of viewing and therefore has to do with the question what to do with the perceived stimulus (O´Reilly, 2010). As the DLPFC is also known for its cognitive control function ((Burgess, Dumontheil, & Gilbert, 2007; Ridderinkhof, Ullsperger, Crone, & Niewenhuis, 2004; Sakai & Passingham, 2003; Simons, Schölvinck, Gilbert, Frith, & Burgess, 2006; van Veen & Carter, 2006), several authors argued that it plays a crucial role in those aspects of aesthetic appreciation that have to do with executive control functions in general (Vessel, Starr & Rubin, 2012; Lengger, Fischmeister, Leder & Bauer, 2007). Cupchik, Vartanian, Crawley and Mikulis (2009) investigated through an fMRI experiment how the process of aesthetic perception is distinguishable from the process of object identification. They found out, that the left lateral prefrontal cortex is activated if an aesthetic orientation task was given to the participants. Visuospatial orientation task on the other hand did not activate this specific area. Cupchik and colleagues concluded from those results, that the top-down functions, to control internal and self-referential goals of the left lateral PFC, are extendable to aesthetic perception. The relatively higher activation of the left lateral PFC in the aesthetically oriented viewing task led Cupchik et al. to the conclusion that the increased cognitive control is necessary to direct attention to the task-related, necessary input. Therefore the IDLPFC

appears to be a crucial area for an orientation of the cognitive and perceptual systems towards aesthetic perception. If Cupchik et al. are right and the IDLPFCs function is to control the direction of attention to task related features there should be task related differences in eye movements visible as well.

2.3. Transcranial direct current stimulation

TDCS is a method of neurostimulation that induces a membrane depolarization through anodal stimulation and membrane hyperpolarization through cathodal stimulation (Liebetanz, Nitsche, Tergau, & Paulus, 2002). In 1962 Bindman, Lippold and Redfearn already discovered the prolonged change in neuron activity after a few minutes of stimulation. They found out, that if the flow of current is constant for 5-10 minutes, an enduring after-effect in the same direction for 1-5 hours is produced. As such, tDCS can be used to enhance the activity in certain brain areas in a non-invasive way, without affecting the setting of the required task to much. In further research the prefrontal area was discovered to be activated while participants perceived objects they described as beautiful; more specifically, an area localized as the left dorsolateral prefrontal cortex (Cela-Conde et al., 2004; Cupchik et al., 2009; Jacobsen, Schubotz, Höfel, & von Cramon, 2006.). More recently Cattaneo et al. (2014) applied anodal tDCS in an experiment to enhance activity over the IDLPFC. In said experiment participants, who were naïve to art, viewed representational and abstract artworks. They were instructed to express an aesthetic judgment, or in a control group, indicated the colorfulness of the pictures via a 0-100% rating scale. Those tasks were given to the participants before and after a tDCS. Each participant went through this procedure twice with one tDCS being a real stimulation and the other sham stimulation. A significant increase around 3% of mean rating scores in the aesthetic judgment, only in the task after the real stimulation,

but not in the sham stimulation was discovered. This effect did not appear in the evaluation of colorfulness. Cattaneo and colleagues concluded from those results, that the IDLPFC is causally involved specifically in visual aesthetic appreciation, but not in general for any kind of visual judgment.

2.4. Eye tracking – Overall viewing

2.4.1. Aesthetic orientation vs. pragmatic orientation

The crucial role of certain eye movements within the process of gathering visual information from the environment was highlighted in earlier literature (Buswell, 1935; Henderson & Hollingworth, 1998). To study potential effects of stimulation over the left dorsolateral prefrontal cortex on eye movements, a general knowledge of the nature of eye movements on specific tasks is necessary. Several previous researches also indicate that the given task has a strong effect on location of fixations, as people tend to look mostly at those elements that are relevant to solve the task (Rothkopf, Ballard, & Hayhoe, 2007). Therefore elements of a stimulus that are valued as beautiful or ugly should be fixated most in a beauty rating task. Cupchick and colleagues discovered in an fMRI study, that different tasks (aesthetic oriented task vs. pragmatic oriented task) lead to different specific patterns of brain activity (Cupchick et al., 2009). Forster (in prep.) further investigated eye movement patterns related to those findings and discovered specific patterns for an approach with aesthetic attitude in comparison to a more pragmatic approach. In Forster's experiment aesthetic evaluation tasks led to significantly more fixations than pragmatic evaluation tasks.

2.4.2. Eye movements and ratings

Previously described findings lead to the question of whether a more positive or negative evaluation of an aesthetic viewing experience results in specific patterns of eye movements. In an experiment about visual decision-making, Mackenzie, Mei-Chun and Eyal (2009) found out, that the fixation duration on certain stimuli was positively correlated to the likelihood of preferring those stimuli. In conclusion, previous findings describe patterns of eye movements that are specific to aesthetic judgment. Also, those patterns seem to be influenced by liking of said stimuli. Due to previous studies, we would expect higher fixation durations in an aesthetic evaluation task after a real tDCS, compared to the same task after sham stimulation. However, Forster (in prep.) discovered a positive correlation between rating and fixation count, independent of the given task. Also a negative correlation between rating and saccade amplitude was found, which is unsurprising, as fixations on more relevant areas also imply shorter distance between those areas (Forster, in prep.). Therefore, because higher ratings are expected in an aesthetic judgment task after real tDCS, higher fixation count could be expected, too. As fixation count and fixation duration tend to be negatively correlated with each other, those predictions are conflicting, so the present experiment could help to clarify those results.

2.5. Ambient processing mode vs. focal processing mode

2.5.1. Model of dual visual processing

The human visual brain consists of a very complex patchwork of areas that interact in context of viewing. Many different areas are known to be associated with visual perception and interact in complex ways with each other (Zeki, 1993). Nevertheless, in 1983 Mishkin, Ungerleider and Macko described two broad cortical visual pathways,

both originating in the primary visual cortex (V1). They identified a ventral stream, projecting to the inferior temporal cortex, and a dorsal stream, projecting to the posterior parietal cortex. Each stream plays a different, but complementary role in visual perception. The ventral stream is crucial for the identification of objects in shapes, patterns and color. As this stream utilizes stored representations to recognize the viewed stimulus, it is tend to be more memory based. In contrast, the dorsal stream, which is crucial for the visual location of objects and perception of movement, utilizes no considerable amount of stored information (Velichkovsky, Joos, Helmert, & Pannasch, 2005). Those findings were considerably supported by work with monkeys, as lesions of inferior temporal areas generate disabilities in discriminating objects, but had no effect on tasks demanding merely spatial vision. Opposite effects were found in lesions of posterior parietal areas (Ungerleider & Mishkin, 1982). Although there is evidence for a separation of both streams there are still of course several connections and successful visual perception depends on effective collaboration of both systems (Milner & Goodale, 1995).

2.5.2. Ambient and focal processing

Many authors relate two different modes of visual processing to those separate streams described previously: An ambient processing mode is modulated by the dorsal stream which is related to the analysis of an overall spatial configuration, whereas the ventral pathway modulates a focal processing mode, more related to composition of an object (Trevarthen, 1968; Pannasch & Velichkovsky, 2009). Leibowitz, Shupert, and Post (1984) described a number of dimensions, which ambient and focal processing differ from each other: Whereas the focal processing mode is almost exclusively visual, other senses, like vestibular and somatosensory inputs, are contributive to ambient processing

as well. Also focal vision is described as more attention related, whereas ambient vision is more reflexively. In reference to previous findings about separate temporal and dorsal pathways, Pannasch and Velichkovsky (2009) described relations between eye movement patterns and those two processing modes. They characterized a pattern with relatively long and fewer fixations in combination with shorter saccades, which is specific to focal viewing, whereas shorter and more fixations often combined with longer saccades are indicative for ambient processing (Pannasch, Helmert, Roth, Herbold, & Walter, 2008; Pannasch & Velichkovsky, 2009; Velichkovsky, Joos, Helmert, & Pannasch, 2005). As the different processing modes have specific uses, it can be expected that diverse stimuli or tasks lead to different patterns of viewing. Forster (in prep.) for example discovered more focal processing for a beauty rating task compared to a complexity rating task. These results lead to the assumption that viewing stimuli with an aesthetic attitude leads people to focus more on certain features they appreciate, which then results in an aesthetic experience. Because previous findings (Cattaneo et al. 2014) suggest that a tDCS on the specific area IDLPFC leads to an enhanced aesthetic experience, there should also be an increase of focal processing, which seems to be more crucial in aesthetic judgment than in other rating tasks, (Forster, in prep.) after the real stimulation compared to sham stimulation in a beauty rating task.

2.6. Two phases of viewing

In 1973 Kahneman already described a paradox phenomenon regarding eye movements: He characterized fixation duration as a measure of intensity of visual information processing. So he concluded that in the beginning of viewing a new stimulus, when there is no information yet to be processed, fixation duration should be lower and

increase over time. But the findings from different authors were contrary: after a few seconds of viewing the average fixation duration decreased (Kahneman, 1973, p.59; Unema, Pannasch, Joos & Velichkovsky, 2005). A pioneer in systematic studies of eye movements was Guy Buswell, who in 1935 already described a continuing increase in fixation duration until around the 100th fixation. In 1974 Antes described, additionally to Buswell's findings, a decrease in saccade amplitudes over time. Further researchers concluded from those findings, that there are two different phases, with a different purpose in the process of viewing. A first period serves mainly orientation and scanning the relevant features of a stimulus, and afterwards a period of fixations on informative or interesting areas (Karpov, Luria, & Yarbus, 1968). Pannasch, Helmert, Roth, Herbold, and Walter (2008) described a transition from more ambient processing, governed mainly by the dorsal stream, after about three seconds of viewing to a predominantly focal processing mode, governed mainly by the ventral pathway.

2.7. Goals of the present experiment

The present experiment was partly designed as a replication of an experiment from Cattaneo et al. (2014). They found out that an enhancement of beauty appreciation is possible through stimulation of a specific area (IDLPFC) of the human brain per tDCS. The present experiment was designed to replicate the found increase in liking of artworks in a post tDCS measurement and expand this experiment through eye tracking. As eye movements seem to be very sensitive to changes, the reason for this method was to find out where exactly the differences happen to enhance beauty appreciation, more precisely, if they are visible in eye movements. Another big topic of the present experiment is a transition of eye movements in time. Previous findings discuss a shift from more ambient processing to more focal processing. A possible influence of a real

tDCS to this transition, in form of bigger magnitude of the transition, should also be analyzed in the present experiment. The present experiment used a double blind design with a beauty rating group and a color rating group, each participant of both groups rating 80 pictures 4 times. Every participant rated the pictures previously and after sham tDCS, as well as previously and after a real tDCS. Both measurements previously to tDCS serve as a baseline and therefore are expected to not differ from one another in eye movements or ratings. Possible effects of tDCS are expected to be visible in differences only in a change from the measurement previously to the one after tDCS, in the real tDCS condition, but not in the sham condition. Furthermore, if those changes in ratings or eye movements only appear in the experimental beauty rating group, but not in the control color rating group, it can be deducted, that those chances happen because of an enhancement of aesthetic appreciation.

3. Method

3.1. Participants

Altogether 28 volunteers took part in the present experiment (14 female, 14 male). All participants were students from different universities and different disciplines of study between 23 and 31 years of age (M= 27, 18; SD= 3, 10). They had normal or corrected-to-normal visual acuity and color vision. None of the participants had received formal education or had special interest in art or design. Of all participants, 20 were German speaking, 8 Slovakian, all participants were right handed. Due to required safety precautions for the tDCS stimulation participants with epilepsy, head injuries, neurological diseases, metallic implants or metallic devices, skin diseases that concern the head and also pregnant women had to be excluded from the experiment. All participants were assigned randomly to an experimental group (16 participants) or a

control group (12 participants). A written informed consent about the tDCS stimulation was given from all participants previous to the experiment.

3.2.Apparatus

3.2.1. Eye tracker

All eye movements were recorded by a SR research Ltd. EyeLink 1000 desktop mounted eye tracker. The participants were viewing binocular, but only information gathered from the leading eye was recorded. Also a combination of chin- and headrest was used to keep the participants head steady. Errors in computation of gaze position were less than 1° after a 9-point calibration and validation. The definition of a saccade was set to a minimum motion of 0.1° having a minimum velocity of 30°/s, and a minimum acceleration of 8,000°/s². The experimental software programming was performed with Experiment Builder 1.6.121 and the export of the data with Eye Data Viewer 1.10.123 (SR research Ltd., Ontario, Canada). The stimuli and rating tasks were presented to the participants on a Windows XP computer and a 19'' monitor with a screen resolution of 1980x1200 pixels, 32-bit color depth and a refresh rate of 120Hz. The viewing distance was kept constant at approximately 57 cm between desktop and headrest, creating a horizontal visual angle of 35.4° and a vertical visual angle of 27.0°. The rating was performed on a standard keyboard which was in a raised position in front of the participant, so that moving the head for the rating was not required. Participants were instructed to use either the number keys at the top or the number keys on the right side of the keyboard.

3.2.2. TDCS device

The transcranial direct current stimulation (tDCS) was carried out by a tDCS device, driven by battery. Therefore two sponge electrodes soaked with a NaCl solution and

coated with an electrode gel on the underside were placed over the head of the participant. The excitability-enhancing anodal electrode was positioned over the left dorsolateral prefrontal cortex (lDLPFC). This point was localized by measuring the CZ in the Electroencephalography (EEG) system of the participant's head. A fitting EEG cap was used to locate the lDLPFC area between F3 and F5 in relation to the CZ in the EEG system. The cathodal electrode was positioned over the right supraorbital region. Each participant went through a real stimulation and sham stimulation with 3 to 7 days between those two sessions (M= 5.43; SD= 1.37). In the real stimulation the current increased gradually until 1,5mA were reached, after 20 minutes of stimulation the tDCS device turned itself off. In the sham stimulation the procedure was exactly the same as in the real stimulation session, but the device turned itself off after 30s and therefore provides no effective modulation of cortical excitability in the lDLPFC. Because of the initial current stimulation for 30 seconds in the sham stimulation an itching sensation was felt by the participants in the beginning of both sessions and thus should prevent the participant recognizing a difference. The experiment was carried out in a double blind setting through different codes for real and sham stimulation that were typed in the tDCS device.

3.3.Stimuli

Two matched sets of stimuli were used, each containing 80 pictures from Spanish artists. Also 3 additional pictures per set were used as practice trials but data gathered from those was not analyzed any further. The two sets were matched by same artists, same periods, same contents and same sizes. The used Images were comparable in artistic styles and contents to the pictures used by Cattaneo et al. (2014) in their experiment, also pictures containing close views of humans were excluded to prevent

mechanisms that are specific to face-recognition. But in contrast to Cattaneo and colleagues' experiment the stimuli chosen for the present experiment were only representational ones. The width-to-height ratio varied from the different pictures but was always the same in matched pairs. The stimuli were presented in a random order to the participants on a grey colored background (R: 150; G: 150; B: 150) and were positioned at the center of the screen.

3.4. Procedure

After a brief initial welcoming and short summary of the whole procedure a written informed consent was given and visual abilities were tested. The participants were asked to sit in a dimly illuminated and silent room on a chair in front of the screen and place the head in the chin and headrest. After a successful 9-point calibration and validation instructions about the following task were given onscreen in German language (For the Slovakian participants instructions were translated verbally). Afterwards, the first task ("Pre tDCS") started. Participants first viewed either picture set 1 or picture set 2, each picture set containing first 3 pictures as practice trials and afterwards 80 pictures ordered randomly as experimental trials. Previous to each trial a fixation cross was presented at the center of the screen and had to be fixated for a minimum duration of 500msec to ensure correct calibration of the eye tracker over the trials. If 3 seconds passed without successfully fixing on the fixation cross for 500ms a recalibration was initialized, otherwise the trial starts with the picture being shown for 7 seconds. After this time instructions appeared additional to the image to rate the pictures in beauty, ("Bitte bewerten Sie wie SCHÖN Sie das Bild finden") in the "Beauty condition", or colorfulness ("Bitte bewerten Sie wie FARBIG Sie das Bild finden") in the "Color condition". Also a 9-point Likert rating scale from 1 ("Sehr hässlich" / "Sehr

farblos") to 9 ("Sehr schön" / "Sehr farbig") appeared under the images after the 7 seconds of viewing time. The participants were instructed to rate the images from their first impression and not to ponder for a long time. The image, scale and instruction remained visible until the participants gave their judgment, afterwards a fixation cross and thereafter the next picture appeared. Eye tracking data was gathered only during the 7 seconds of viewing merely the picture without instructions or rating scale. The whole procedure of the pre tDCS eye tracking took averagely about 20 minutes for each participant. The pre tDCS eye tracking served as a baseline evaluation to compare the effects of real tDCS stimulation. Thereafter the head and chin rest was removed from the table and the anodal and cathodal sponge electrodes for the tDCS were applied over the participants head and fixed with two rubber bands. Each participant underwent to similar sessions, differing only in one including a real stimulation and the other one sham stimulation. The whole experiment was a double blind setting, so neither the participants nor the experimenter were informed which code of stimulation was the real or sham one. During the 20 minutes of stimulation (or non stimulation in the sham stimulation) a cartoon was shown to the participants without any sound, they were instructed not to do anything distracting during the stimulation. Afterwards, the electrodes were removed and the chin and headrest placed on the same location as in the previous task. This was followed by the post tDCS eye tracking task which contained the exact same procedure as the pre tDCS task merely differing in the picture set that was to be rated. Altogether the participants were divided into 8 different groups: 4 experimental groups and 4 control groups. The 4 experimental groups were divided by the picture set which was viewed first and additional each group was divided by the stimulation code that was used first or second. An equal subdivision was done with the control group. The numbers of participants in each group are shown in Table 1

Table 1: *Distribution of Participants over All 8 Groups*

		First session: Sham stimulation	First session Real stimulation	∑
Experimental groups	Picture set 1 Pre tDCS; Picture set 2 Post tDCS	5 participants	3 participants	16
	Picture set 2 Pre tDCS; Picture set 1 Post tDCS	3 participants	5 participants	
Control groups	Picture set 1 Pre tDCS; Picture set 2 Post tDCS	4 participants	2 participants	12
	Picture set 2 Pre tDCS; Picture set 1 Post tDCS	2 participants	4 participants	

The participants were randomly assigned to those groups. At the second Session after the post tDCS eye tracking task each participant received the onscreen questionnaire KIF (Kunst-Interesse-Fragebogen) about art education and interests.

3.5. Measuring variables

3.5.1. Eye tracking variables

The visual exploration of the images was operationalized through the number of fixations (fixation count) and the duration of those fixations. During fixations, the eye maintains mostly on one location, while information is gathered by the viewer. Fixations have a mean duration of 100-400ms. The saccade amplitude is defined as distance between two fixations. Saccades are rapid eye movements from one area of interest to another, during those no information is gathered by the viewer. They have a average duration of 30-80ms and mean amplitudes around 4°-15° with a mean velocity of 600°/sec. In 2011 Pannasch, Schulz and Velichkovsky described those measurements

as the most sensitive of all eye movement information to different modes of visual exploration.

3.5.2. Other variables

Additional to the eye tracking data ratings were given for each of the 80 pictures per set on a 9-point Likert scale. The rating scales labeling was dependent of the task, either 1-“sehr hässlich” to 9-“sehr schön” in the beauty rating task or 1-“sehr farblos” to 9-“sehr farbig” in the color rating scale. Also information was gathered through the KIF to make sure participants were naive to art.

3.6. Preparing data

To clear up the raw eye tracking data and prepare it for further analysis fixations out of boundaries of the stimuli area were deleted. Because of the fixation cross presented previous to each image in the middle of the screen the first fixation on the image tend to be in the center of the screen also and was therefore removed. Also fixations ending after the 7 seconds of viewing time were removed. After this procedure the resulting data was aggregated twice. The first aggregation computed a mean fixation count, median fixation duration and median saccade amplitude for each picture within each participant. The median was used because saccade amplitudes and fixation durations are anticipated to reveal a right skewed distribution. (Pannasch et al., 2008) In the second step of aggregation a mean of fixation count, fixation duration and saccade amplitude was computed over all pictures for each participant. Additionally, only for testing hypothesis regarding a variation of eye movement patterns in time, the whole dataset was divided into two parts by time. The first part contained all fixations that ended within the first 3 seconds, whereas the second part contained all fixations that started

after the 4th second and ended within 7 seconds. Therefore both parts contain only fixations that begin and end within 3 seconds of viewing time.

4. Results

4.1. Descriptive statistics

As described previously participants were divided into 8 different groups (4 experimental, 4 control) with 4 measurements each. An approximately balanced distribution of the variables gender, age, the picture set which is used first and the real tDCS being used in the first or second session was aimed, even though no evidence of those variables confounding the results were found previously. Tables 2-5 display mean values of the experimental and control group over all 4 measurements for relevant variables (*Rating*, *Fixation count*, *Fixation duration*, *Saccade amplitude*)

Table 2: *Mean Ratings of Pictures*

	Pre tDCS Sham	Post tDCS Sham	Pre tDCS Real	Post tDCS Real
Experimental Group	4.77	4.64	4.71	4.67
Control Group	5.39	5.24	5.09	5.05

Table 3: *Mean Fixation Count*

	Pre tDCS Sham	Post tDCS Sham	Pre tDCS Real	Post tDCS Real
Experimental Group	19.12	19.43	19.17	19.08
Control Group	18.88	19.21	18.63	19.38

Table 4: *Mean Fixation Duration in msec.*

	Pre tDCS Sham	Post tDCS Sham	Pre tDCS Real	Post tDCS Real
Experimental Group	264.22	258.80	265.76	259.94
Control Group	259.19	252.77	264.67	254.33

Table 5: *Mean Saccade Amplitude in deg.*

	Pre tDCS Sham	Post tDCS Sham	Pre tDCS Real	Post tDCS Real
Experimental Group	3.93	3.82	3.99	3.84
Control Group	4.19	3.98	4.08	4.02

For the purpose of testing the hypothesis regarding a transition from ambient to more focal processing, the dataset was divided into two parts, each containing only fixations beginning and ending within 3 seconds of viewing time. The tables 6-8 show the mean values of eye tracking variables for both timeslots (from the start of viewing time until second 3: *0-3*; from second 4 until the end of viewing time: *4-7*)

Table 6: *Mean Fixation Count Divided into two Timeslots*

	Timeslot	Pre tDCS Sham	Post tDCS Sham	Pre tDCS Real	Post tDCS Real
Experimental Group	Sec. 0-3	8.37	8.20	7.87	7.82
	Sec. 4-7	7.15	7.27	7.08	7.00
Control Group	Sec. 0-3	8.19	8.19	7.95	8.08
	Sec. 4-7	7.32	7.55	7.09	7.25

Table 7: *Mean Fixation Duration in msec. Divided into two Timeslots*

	Timeslot	Pre tDCS Sham	Post tDCS Sham	Pre tDCS Real	Post tDCS Real
Experimental Group	Sec. 0-3	244.15	245.50	253.43	251.95
	Sec. 4-7	301.26	303.55	305.03	303.47
Control Group	Sec. 0-3	246.21	244.13	251.63	251.02
	Sec. 4-7	285.87	286.23	304.61	296.59

Table 8: *Mean Saccade Amplitude in deg. Divided into two Timeslots*

	Timeslot	Pre tDCS Sham	Post tDCS Sham	Pre tDCS Real	Post tDCS Real
Experimental Group	Sec. 0-3	4.10	4.04	3.91	3.84
	Sec. 4-7	4.08	4.02	3.96	3.96
Control Group	Sec. 0-3	4.06	4.07	4.14	4.05
	Sec. 4-7	4.00	3.98	4.04	3.92

4.2. Interferential statistics

4.2.1 Complete data

As described previously, Cattaneo et al. (2014) discovered an enhancement of liking in the beauty rating task after the real tDCS, but not in the color rating task. To identify such an effect in the present study repeated measurement 2x2x2 ANOVAs with the factors *Task (Beauty-Color), Stimulation (Real-Sham)* and *Session (Pre tDCS-Post tDCS)* were calculated for the variables *Rating, Fixation count, Fixation duration* and *Saccade amplitude*. To identify the influence of a real stimulation, statistically significant interaction effects between *Task*, *Stimulation* and *Session* over the tested

variables would be necessary. Significant main effects on the other hand indicate systematic mistakes in the data. The results are displayed in table 9. For the dependent variables *Rating* and *Saccade amplitude* no significant main effect or interaction effect was found. In *Fixation duration* a significant main effect of the factor *Session* was found, also in *Fixation count* a trend towards a main effect in *Session* was analyzed. No interactions were found for the dependent variable *Fixation duration.* A three-way interaction of *Task x Session x Stimulation* was found for the variable *Fixation count.* For interpretation of this interaction Figures 1 and 2 are helpful, they display the *Task x Session x Stimulation* interaction, while the factor *Task* is separated. In the experimental group (Figure 1) the *Fixation count* is increasing only after the *Sham-stimulation* while in the *Post-Real* measurement it is very slightly decreasing. In the control group both *Post-tDCS* measurements show an increase in *Fixation count* compared to the *Pre-tDCS* measurements.

Table 9: R*esults for ANOVAs Task x Session x Stimulation*

	Rating		*Fixation count*		*Fixation duration*		*Saccade amplitude*	
	F	*p*	*F*	*p*	*F*	*p*	*F*	*p*
Session	1.86	.20	3.70	.08	5.40	.04*	17.00	<0.01
Stimulation	3.53	.09	.03	.86	.67	.43	.00	.99
Task	.59	.46	.05	.83	.05	.83	.28	.61
Session x Stimulation	2.23	.16	1.13	.31	.03	.86	.23	.64
Session x Task	.05	.82	1.02	.34	.07	.80	.00	1.00
Task x Stimulation	1.95	.19	<0.01	.98	.01	.92	.29	.60
Session x Stimulation x Task	.05	.83	9.05	.01*	.61	.45	.73	.41

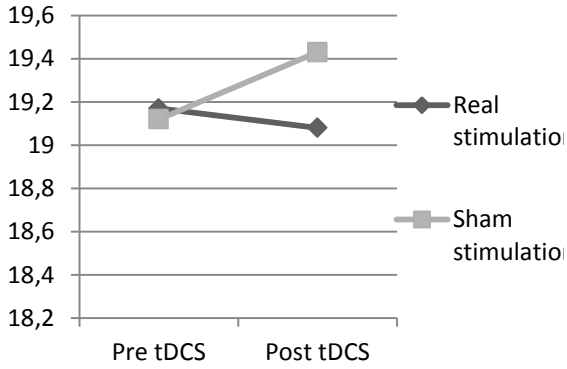

Figure 1: *Interaction Stimulation x Session in Experimental Group for Fixation Count*

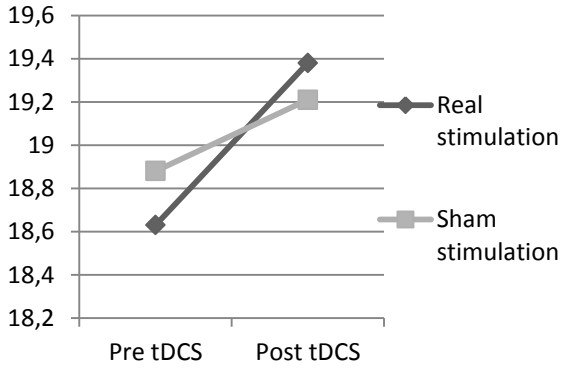

Figure 2: *Interaction Stimulation x Session in Control Group for Fixation Count*

4.2.2. Data divided into two timeslots

To identify influences of tDCS to a transition from ambient to focal processing a previous analysis of a general presence of this transition is necessary. Therefore t-tests for independent groups were operated to analyze a transition from timeslot 1 (sec.0-3) to timeslot 2 (sec. 4-7) over all 4 measurements in the experimental group and the control group for all three eye tracking variables. Those results for all three eye tracking variables are displayed in table 10. Over all Measurements, *Fixation count* and *Fixation duration* show highly significant differences in the experimental group and also in the control group. In all cases, *Fixation count* decreased while *Fixation duration* increased. No statistically significant differences between the two timeslots were found in *Saccade amplitudes.*

Table 10: T-*test Results of all Measurements between Timeslot 0-3 and Timeslot 4-7 for Fixation Count, Fixation Duration and Saccade Amplitude*

		Fixation count		*Fixation duration*		*Saccade amplitude*	
	Measurement	*t*	*p*	*t*	*p*	*t*	*p*
Experimental Group	Pre tDCS / Sham	7.88	<.01*	-7.56	<.01*	.26	.80
	Post tDCS / Sham	5.96	<.01*	-4.43	<.01*	.16	.88
	Pre tDCS / Real	5.81	<.01*	-5.92	<.01*	-.57	.58
	Post tDCS / Real	7.86	<.01*	-3.81	<.01*	-1.15	.27
Control Group	Pre tDCS / Sham	5.30	<.01*	-5.01	<.01*	.47	.65
	Post tDCS / Sham	4.64	<.01*	-5.50	<.01*	.58	.57
	Pre tDCS / Real	4.66	<.01*	-4.74	<.01*	.93	.37
	Post tDCS / Real	4.89	<.01*	-5.03	<.01*	1.10	.30

Furthermore the influence of R*eal-tDCS* to the transition from ambient to focal processing in time was analyzed with 2x2x2 ANOVAs for all eye tracking variables. The three factors used were *Session* (*Pre tDCS-Post tDCS), Stimulation (Real-Sham) and Timeslot (first-second).* Similar to the analysis of the complete data set, main effects of the factors *Session* or S*timulation* indicate systematic mistakes, whereas main effects of the factor *Timeslot* represent the transition in time described previously. Two-way- or three-way-interactions indicate possible effects of the experimental conditions. The ANOVA results for the experimental group are displayed in the table 11, for the control group in table 12. In the experimental group and in the control group significant main effects were found in the variable *Fixation count* for the factor *Stimulation.* Also a trend

towards a significant main effect of *Stimulation* in *Saccade amplitudes* is visible in the experimental group. Whereas in the control group a trend towards a main effect of *Stimulation* in *Fixation duration* resulted. Furthermore main effects for the factor *Timeslot* were found in both groups for the variables *Fixation count* and *Fixation duration.* Which is unsurprising as the expected transition in time was already displayed in the table 10. No Statistically significant interactions appeared in the control group, whereas in the experimental group significant two-way-interactions were found for *Stimulation x Timeslot* in the variables *Fixation count* and *Saccade amplitude.* Also a significant interaction was detected for *Stimulation x Timeslot* in the variable *Saccade amplitude.* No significant three-way-interactions were detected in either group or variable, but a trend towards a *Session x Stimulation x Timeslot* interaction was found in the experimental group and also in the control group.

Table 11: *Experimental Group (N=16) results for ANOVAs Session x Stimulation x Timeslot*

	Fixation count		*Fixation duration*		*Saccade amplitude*	
	F	*p*	*F*	*p*	*F*	*p*
Session	.47	.53	.00	.98	.07	.54
Stimulation	6.41	.02*	.60	.45	2.98	.11
Timeslot	73.12	<.01*	31.02	<.01*	.16	.70
Session x Stimulation	.05	.82	.15	.70	.08	.78
Session x Timeslot	3.23	.09	.00	.95	.48	.50
Stimulation x Timeslot	4.75	.05*	1.00	.33	4.58	.05*
Session x Stimulation x Timeslot	3.12	.10	.01	.92	.27	.61

Table 12: *Control Group (N=12) results for ANOVAs Session x Stimulation x Timeslot*

	Fixation count		*Fixation duration*		*Saccade amplitude*	
	F	*p*	*F*	*p*	*F*	*p*
Session	.76	.40	.26	.62	.41	.54
Stimulation	5.55	.04*	3.39	.09	.03	.87
Timeslot	31.62	<.01*	37.02	<.01*	.75	.41
Session x Stimulation	.04	.84	.26	.62	.27	.61
Session x Timeslot	2.52	.14	.13	.73	.07	.80
Stimulation x Timeslot	.48	.50	2.11	.18	.21	.65
Session x Stimulation x Timeslot	3.40	.09	.93	.36	.00	.99

To interpret those interactions a closer look at the mean values is necessary. Figures 3 and 4 graphically display the interactions concerning *Fixation count* separately for the *Pre tDCS* and *Post tDCS* measurement in the experimental group. Clearly visible is the main effect of *Stimulation* described previously in more fixations in the *Sham stimulation* and the main effect of *Timeslot* in fewer fixations in *Timeslot 4-7* over all measurements. The *Stimulation x Timeslot* interaction seems to be happening predominantly in the *Pre TDCS* measurements in a slightly lower decrease in *Fixation count* in the *Real stimulation* measurement compared to the *Sham stimulation.* The Figures 5 and 6 display the *Stimulation x Timeslot* interaction for the *Saccade amplitudes*. The trend towards a main effect of *Stimulation* is apparent in shorter *Saccade amplitudes* in both measurements of the *Sham stimulation* for both *Timeslots.* The significant interaction is visible in both, the *Pre tDCS* and the *Post tDCS*

measurement in the same direction. Whereas in then measurements *Pre* and *Post* a *Sham stimulation* only a very light decrease of *Saccade amplitudes* is detectable between *Timeslot 0-3* and *Timeslot 4-7*, a much bigger increase of *Saccadic amplitudes* happened Pre and *Post* the *Real stimulation* measurements during the *Timeslots*

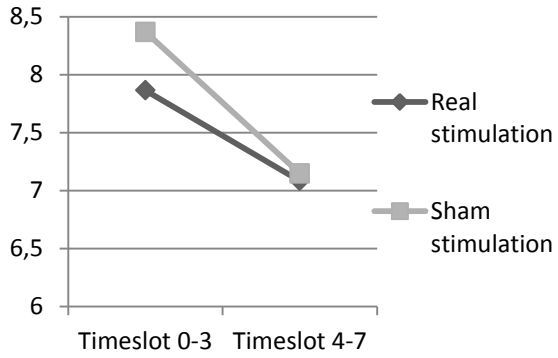

Figure 3: *Interaction Pre tDCS Stimulation x Timeslot in Experimental Group for Fixation Count*

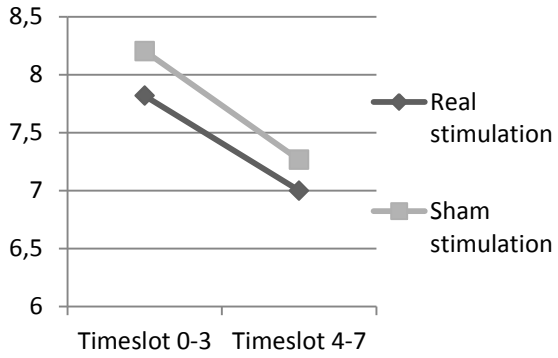

Figure 4: *Interaction Post tDCS Stimulation x Timeslot in Experimental Group for Fixation Count*

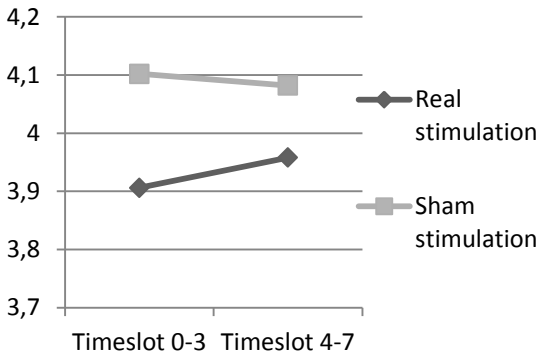

Figure 5: *Interaction Pre tDCS Stimulation x Timeslot in Experimental Group for Saccade amplitude*

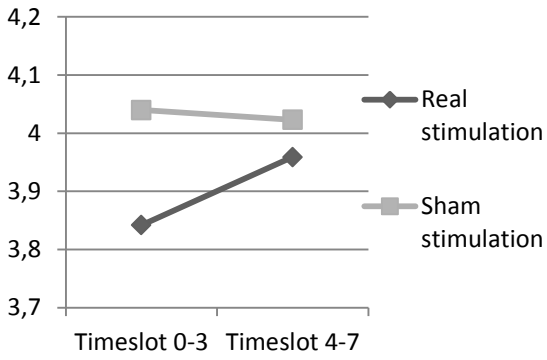

Figure 6: *Interaction Post tDCS Stimulation x Timeslot in Experimental Group for Saccade amplitude*

5. Discussion

5.1. Complete data

The goal of the present experiment was to show whether the left dorsolateral prefrontal cortex's function, of directing attention to task related features could be discovered in a change in eye movements, after stimulating this specific area with a tDCS. Therefore, amongst others, results from Cattaneo et al. (2014) should be replicated. They found a significant enhancement of beauty ratings after a real tDCS compared to a sham tDCS. In the present experiment no such effect was found (see table 9). A possible explanation for those results is the use of different rating scales in both experiments. Cattaneo et al. instructed their participants to express their judgment by mouse click on a bar from 0% to 100%. This scale is much more finely graduated than the 9-point Likert scale used in the present experiment and thus more able to evaluate a small and subtle effect a tDCS could have caused. Furthermore, maybe an even bigger impact had the different instructions given to the participants. In Cattaneo and colleagues' experiment, participants were instructed to rate on the scale "How much do you like this image", in the present experiment on the other hand the instructions given were "Bitte bewerten Sie wie SCHÖN Sie das Bild finden" (Please rate the BEAUTY of the picture). Those instructions could have caused quite different reactions, as Cattaneo and colleagues' requests specifically for personal taste and pleasure caused by the given stimulus. In the present experiment a more objective instruction was used, but rating for beauty does not necessarily represent aesthetical pleasure caused by the image. One could describe a picture as very beautiful, because one expects the general public to prefer the presented type, but still feeling no aesthetic pleasure while watching it oneself, because one prefers a different kind of art. Table 9 also presents the possible effect of tDCS on eye tracking variables. There is a significant three-way-interaction of the factors *Task x*

Stimulation x Session for the dependent variable *Fixation count.* Figures 1 and 2 demonstrate this interaction graphically, the factor *Task* being divided into two different graphs (Figure 1: experimental group; Figure 2: control group). The graphs show an increase in the number of fixations the participants made from the measurement previously to the stimulation and after the stimulation in both *Sessions (Real-tDCS, Sham-tDCS)* in the control group, but in the experimental group only in the *Sham Session* the amount of fixations increased, while after the *Real tDCS* the *Fixation count* very slightly decreased. Therefore it seems the stimulation of the IDLPFC caused participants to look for fewer interesting areas when looking for beauty, but not when looking for colors. This is a hint towards an increase of focal processing through tDCS, but as this effect is only found in *Fixation count*, but not in *Fixation durations* or *Saccade amplitudes* this conclusion is to be made with caution. Besides those results, there are hints in table 9 for problems in the experimental procedure: Main effects of *Session* in the dependent variables *Fixation duration* and *Saccade amplitude* were found; also a trend towards a main effect in *Fixation count* is visible. As effects of a real tDCS tend to be rather small and subtle, other uncontrolled factors could easily overlay those. For example tiredness of participants, times of day in which the testing took place, stress, emotional state and many other factors that could not be controlled in the present experiment. Tables 3, 4 and 5 show higher *Fixation durations* and *Saccade amplitudes* in the *Real tDCS* Sessions compared to the *Sham tDCS* in the experimental and control group as well as two out of four higher *Fixation duration* mean values in the *Sham tDCS* sessions. Additionally to the problems described before, those main effects could have been caused by experimenter effects. The experiment was originally designed as a double blind study, through a code for the different stimulation types. The experimenters did not know which code was assigned to the *Real* or *Sham* stimulation.

But other noticeable clues made it very clear which code initialized the *Real* stimulation, like the different amount of battery that was unloaded with each code. Also participants recognized differences, like a different itching sensation in the beginning of the stimulation. Many participants had previous experience with tDCS and therefore recognized a *Real* stimulation. A conclusion that could be drawn out of those results is that very strict control of experimental conditions is necessary to analyze effects of a tDCS, as well as better control of the double blindness of the setting. Those problems are drawn through the whole experiment concerning the tDCS.

5.2.Data divided into two timeslots

Another main goal of the present study was to discover an influence of a real transcranial current stimulation to a transition from a more ambient processing mode to a more focal processing mode after about 3 seconds in viewing time, which was described by many different authors (Buswell, 1935; Antes, 1974; Unema et al. 2005; Pannasch et al., 2008). To be able to analyze a shift in this transition, caused by a real tDCS, a general analysis of the existence of the described phenomenon was necessary. The expected decrease in *Fixation count* and the expected increase in *Fixation duration* were clearly detected in the present experiment per highly significant T-test comparisons of both *Timeslots* (see table 10). Over all four measurements in the experimental group as well as in the control group a highly significant shift from more ambient (Higher *fixation count*, lower *Fixation duration*) to focal processing (lower *Fixation count,* higher *Fixation duration*) happened. Merely in *Saccade amplitudes* this transition was not visible. Von Wartburg, Wurtz, Pflugshaupt, Nyffeler, Lüthi and Müri (2007) described a connection between picture size and Saccade amplitudes. Smaller pictures led to smaller Saccade amplitudes, in the present experiment the pictures were

presented rather small on the computer desktop. This may have led to rather small *Saccade amplitudes* in the first place, leaving less space for variation and therefore detectable differences between *Timeslots*. Nevertheless, the evidence for transitions from ambient to focal processing is clearly visible in *Fixation duration* and *Fixation count.* Another main goal of the present experiment was the analysis of a possible effect of real tDCS stimulation on a transition from ambient processing to focal processing in form of an enhancement of this transition. The eye tracking variables of the divided data were analyzed by ANOVAs with the factors *Session*, *Stimulation* and *Timeslot.* Several main effects appeared apart from the previously described transition in *Timeslot*: In the experimental and in the control group significant main effects resulted in the factor *Stimulation* in *Fixation count* (see table 11 and table 12). Table 6 offers valuable clues to those results. The main effect of *Stimulation* becomes apparent in higher mean values in the *Pre* and *Post* measurement in both *Timeslots* in the *Sham* stimulation, compared to the *Pre* and *Post* measurement in both *Timeslots* of the *Real* stimulation. As the participants showed significant differences in the number of fixations between the two baseline (*Pre*) measurements a possible effect of a *Real tDCS* in the *Post* measurement could be overlaid through the unknown effect or mistake, which caused this difference. Also a trend towards a main effect in the experimental group in *Saccade amplitudes* (see table 11) appeared. Possible explanations for the cause of these results were given previously. Another trend towards a main effect was analyzed in the control group for the *Fixation duration,* table 7 displays higher mean durations over both *Timeslots* for the *Pre* and *Post Real stimulation* compared to the *Pre* and *Post Sham stimulation.* The Figures 3 and 4 display the *Stimulation*Timeslot* interaction separately for the *Pre tDCS* and *Post tDCS* measurement. As the interaction seems to appear in the *Pre tDCS* measurements in a slightly lower decrease in *Fixation count* from *Timeslot 0-3* to

Timeslot 4-7 this interaction cannot be caused by a real tDCS. The results for the interaction between *Stimulation*Timeslot* in *Saccade amplitudes* is displayed in figure 5 and 6. Almost no change in *Saccade amplitudes* between *Timeslot 0-3* and *Timeslot 4-7* is visible in the *Sham stimulation,* whereas in the *Real stimulation* an increase from *Timeslot 0-3* to *Timeslot 4-7* is detectable. But as this phenomenon appears previously (see figure 5) and after (see figure 6) the stimulation, it again can be no effect of tDCS. Those interactions in *Saccade amplitudes* and *Fixation count* are only allegeable through the same problems discussed earlier regarding the main effects in *Stimulation.* No two- or three-way-interactions were found in the control group.

5.3. Conclusion

Two main parts of results could be distinguished in the present experiment. One part concerns the influence of a current stimulation of the IDLPFC to a change in eye movements. The other part concerns the question, whether stimulation enhances the transition from a more ambient viewing process to a more focal viewing process in time. Regarding the eye movements a significant move towards more focal processing in the beauty rating task, compared to the color rating task was visible, but only for the *Fixation count.* Also the discovery of main effects that should not be there makes an interpretation of those results difficult as there clearly seem to be effects that confounded the whole experiment. Clear evidence for a transition from more ambient processing at the beginning of viewing time to more focal processing after 4 seconds was visible in all measurements in both groups. The results regarding an influence of tDCS show effects, but no effect that is clearly caused by a real current stimulation. Furthermore, there were effects apparent that could only be explained through problems in the experimental procedure. In conclusion, more control of confounding variables is

necessary with tDCS experiments, like tiredness and other factors within the participants, as well as the daytime of measurements. Also there could be differences between the ratings of beauty and a rating of preference, as Cattaneo et al. (2014) used the latter and could identify an enhancement in the beauty rating, which could not be reproduced in the present experiment. Therefore the choice of specific task and rating scales could have had an even bigger impact as expected. Moreover a better control of the double blind setting in the experiment could prohibit effects that overlay a tDCS.

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Zusammenfassung

Cattaneo und Kollegen entdeckten 2014, dass eine Stimulation mittels tDCS im Bereich des IDLPFC zu einer Erhöhung der Gefallens-Beurteilung von Kunstwerken führt. Vorangegangene Studien zeigten eine zentrale Bedeutung des dorsolateral präfrontal Kortex bei der Orientierung auf ästhetische Wahrnehmung. Im vorliegenden Experiment sollten die Ergebnisse von Cattaneo und Kollegen (2014) repliziert werden, sowie durch den Einsatz eines Eyetrackers erweitert. Ziel der Untersuchung war es dabei einen Einfluss der transcranial direct current stimulation (tDCS) auf die Bewegung der Augen während der Betrachtung von Kunstwerken zu untersuchen. Hierzu wurden Versuchspersonen instruiert vor und nach einer Stimulation mittels tDCS Kunstwerke zu betrachten und nach ihrer Schönheit zu beurteilen, außerdem wurde eine Kontrollgruppe instruiert bei äquivalenten Versuchsaufbau die Farbigkeit der Kunstwerke zu beurteilen. Für jede Versuchsperson gab es zwei Messzeitpunkte, zum einen wurde eine echte Stimulation durchgeführt, zum anderen eine Sham-Stimulation. Dabei wurde eine Erhöhung der Fixationsanzahl in allen Messungen nach der Stimulation festgestellt außer in der Versuchsgruppe nach der echten Stimulation, hierbei wurde eine etwas geringere Fixationsanzahl gemessen. Trotz des Hinweises auf einen Einfluss des tDCS in Richtung erhöhtes focal processing (geringere Fixationsanzahl, längere Sakkaden-Amplituden) sind diese Ergebnisse aufgrund von unerwartet aufgetretenen Haupteffekte die nur durch andere, konfundierende Variablen erklärbar sind, nur schwer interpretierbar. Außerdem wurde im vorliegenden Experiment ein Einfluss des tDCS auf einen Übergang von ambient in Richtung focal processing nach etwa 4 Sekunden Betrachtungszeit untersucht, jedoch kein Eindeutig auf die Stimulation zurückzuführender Einfluss gefunden.

Curriculum Vitae

Ausbildung

01/2016	Voraussichtlicher Abschluss als Diplom-Psychologin (Universität Wien)
Seit 10/2012	Studium der Statistik Universität Wien
10/2008 bis 01/2016	Studium der Psychologie Universität Wien Titel der Diplomarbeit: *"Enhancing beauty appreciation in art works: A neurological eye tracking experiment"*
06/2008	Abitur (Note 2,8) Aventinus Gymnasium, Burghausen

Praktika

07/2014 - 10/2014	Rogator AG, Nürnberg Consulting, Marktforschung
03/2014 - 06/2014	Telemark-Marketing GmbH, Wien Telefonische Marktforschung

Sprachen

Englisch	Verhandlungssicher
Spanisch	Grundkenntnisse

EDV

MS Office	Sehr gut
SPSS	Sehr gute Kenntnisse (auch Kenntnisse in Syntax)
R	Grundkenntnisse

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(Ort, Datum) (Unterschrift)