Electrophysiological correlates of looking at paintings and its association with art expertise

C.Y. Pang a, M. Nadal b, J.S. Müller-Paul c, R. Rosenberg d, C. Klein e,f,∗

a Institute for Psychology, University of Leipzig, Germany
b Department of Psychology, University of the Balearic Islands, Spain
c Department of Cognitive Biology, University of Vienna, Austria
d Department of History of Art, University of Vienna, Austria
e School of Psychology, Bangor University, United Kingdom
f Department of Child and Adolescent Psychiatry and Psychotherapy, University of Freiburg, Germany

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This study investigated the electrophysiological correlates of art expertise, as defined by a newly developed, content-valid and internally consistent 23-item art expertise questionnaire in N = 27 participants that varied in their degree of art expertise. Participants viewed each 50 paintings, filtering-distorted versions of these paintings and plain colour stimuli under free-viewing conditions whilst the EEG was recorded from 64 channels. Results revealed P3b-/-LPC-like bilateral posterior event-related potentials (ERP) that were larger over the right hemisphere than over the left hemisphere. Art expertise correlated negatively with the amplitude of the ERP responses to paintings and control stimuli. We conclude that art expertise is associated with reduced ERP responses to visual stimuli in a way that can be considered to reflect increased neural efficiency due to extensive practice in the contemplation of visual art.

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1. Introduction

Visual art is one of the most widespread forms of artistic expression, and is created in one form or another by virtually all human cultures. Ever since Fechner's (1876) seminal work, the omnipresence of art in people's daily lives has stimulated the empirical investigation of this anthropologic universal (Averill et al., 1998; Silvia, 2005). Current psychological models underscore the role of the complex interaction of mnemonic–cognitive and evaluative–affective processes in the appreciation of art (Leder et al., 2004). Researchers have attempted in recent years to characterise some of the attributes of art that contribute to aesthetic appraisals such as “liking” (e.g., Jacobsen and Höfel, 2002, 2003; Landau et al., 2006; Locher et al., 1999; Nodine et al., 1993), as well as the influence of distortions in the composition of paintings on participants' aesthetic valuation (Locher et al., 1999; Vartanian and Goel, 2004). Furthermore, neuro-aesthetic research has begun to unveil the complex patterns of neural activation that accompany aesthetic experience (Ramachandran and Hirstein, 1999; Nadal and Pearce, 2011), including its perceptual (Brown et al., 2006; Calvo-Merino et al., 2010a; Cela-Conde et al., 2009; Cupchik et al., 2009; Koelsch et al., 2006; Lacey et al., 2011; Vartanian and Goel, 2004), cognitive-evaluative (Cela-Conde et al., 2004; Cupchik et al., 2009; Jacobsen et al., 2006) and motivational (Blood and Zatorre, 2001; Brown et al., 2004; Cupchik et al., 2009; Ishai et al., 2007; Kawabata and Zeki, 2004; Kirk et al., 2009a; Koelsch et al., 2006; Salimpoor et al., 2011; Vartanian and Goel, 2004) components.

While many people across many cultures undoubtedly share a liking for visual art, empirical studies have identified a number of systematic inter-individual differences in people's appreciation of art that can be related to theoretical models of aesthetic experience. Leder et al. (2004) comprehensive model of aesthetic appreciation includes a number of component processes that refer to long-term memory, and hence implicit or explicit knowledge, in which individuals obviously differ. One of these sources of systematic inter-individual differences is expertise. It has been shown that art experts and non-experts differ in various aspects of art perception, including the way they explore and perceptually organise paintings (Hekkert and van Wieringen, 1996; Kristjanson and Antes, 1989; Schmidt et al., 1989), the way they process complexity (Reber et al., 2004), and their aesthetic preferences and judgements (Hekkert and van Wieringen, 1996; McWhinnie, 1968; Nodine et al., 1993).

The investigation of expertise is relevant for the study of art, and beyond, because expertise and the accumulated effects of long-term training are accompanied by changes in brain processes involved in domain-relevant tasks (Gauthier et al., 2010) and can
thus serve as a "natural model" of neural plasticity (Bukach et al., 2006; Münte et al., 2002; Rossion et al., 2004, 2007; Scott et al., 2008; Tanaka and Curran, 2001). In addition, systematic experimental task modifications during the contemplation of paintings inspired by explicit theoretical models of aesthetic experience such as Leder et al. (2004) model, could empirically link the effects of training and expertise to the various components of the complex amalgam of cognitive, evaluative and affective processes that characterise aesthetic experience.

It is thus reasonable to expect art experts to differ from non-experts in certain aspects of brain activity while processing art-related stimuli and performing art-related tasks. Such differences have indeed been shown with various neuroscience techniques (Solso, 2001), including the EEG. A study in solving chess problems, for instance, has revealed that experts as compared to non-experts, exhibited higher EEG synchronisation in general, including higher delta band synchrony in more posterior cortical regions, as well as stronger right hemispheric dominance (Volke et al., 2002). Volke and colleagues (1999, as cited in Volke et al., 2002) work showed that increased EEG coherence correlated with simple, well-mastered, and largely automatically performed tasks, whereas decreased coherence correlated with difficult and poorly mastered tasks. Bhattacharya and Petsche (2002) found higher EEG phase synchronisation, particularly in the delta and gamma bands in the right hemisphere and in more posterior brain regions, when artists were asked to imagine a painting after viewing it. These results are in accordance with the aforementioned findings of Volke et al. (2002) study, and suggests the interesting possibility that contemplating paintings may be simpler for art experts, who, owing to their greater efficiency in solving tasks in their particular domain, might rely on more well-mastered and effortless cognitive and perceptual processes.

However, considering the art expertise literature, it is interesting to note that virtually all of the aforementioned studies defined art "experts" according to their formal education background or working experience in fine art or art history, and "non-experts" as people who have equivalent educational level in areas unrelated to art (such as psychology undergraduates) but have no formal art training. Such differentiation between (art) experts and non-experts render art expertise a (quasi-) categorical variable (e.g., artists and non-artists, Bhattacharya and Petsche, 2002, 2005; Kristjanson and Antes, 1989; art-trained and untrained, Nodine et al., 1993; experts and non-experts, Hekkert and van Wieringen, 1996; experts and novices, Schmidt et al., 1989). Such classifications, however, can be considered as the results of an artificial dichotomisation of an otherwise continuous quantitative variable: the degree of study or practice. Smith and Smith’s (2006) Aesthetic Fluency Scale and Chatterjee et al. (2010) Art Experience Questionnaire, which yield a continuous measure for participants’ art expertise, constitute attempts to overcome this drawback. Silvia’s (2007) results suggest that such quantitative measures represent valid means to measure the degree of expertise, and avoid other problems derived from defining expertise based solely on the amount of experience or work (Farrington-Darby and Wilson, 2006; Shanteau et al., 2003).

Based on these considerations, the present study pursued the following aims and hypotheses. First, considering aesthetic experience as the product of a complex amalgam of cognitive, evaluative and motivational processes (possibly) rising during the free and effortless viewing of paintings for pleasure (Kant’s "Wohgefallen"), we realised a free viewing condition without the addition of certain cognitive, evaluative or motivationally relevant tasks and assured participants attention for the presented stimuli by pre-announcing questions about the stimuli at the end of the session. Second, we compared individuals with varying degrees of art training and experience with art with regard to their electro-cortical correlates during the contemplation of art. Here, we predict lower electro-cortical activity in those with greater art expertise as an expression of increased neural efficiency due to practice. Third, in order to tackle the specificity of neural responses to visual art, we employed two types of control stimuli that differ from visual art either by “dissolving” its constituting elements by filtering, or by realising visual stimulation in one of its simplest manners as coloured plain visual fields. While the original paintings contain all visual elements that contribute to their aesthetic value, with the filtering we eliminated recognisable visual elements but preserved the overall form and colour palette. It has been shown that the processing of stimuli in which the compositional structure is changed differs from the processing of paintings with “intact” compositional structure (e.g., Locher et al., 1999; Vartanian and Goel, 2004). Plain colour screens were used as a third experimental stimulus type, as plain colour stimuli lack even the faintest information regarding form and pattern. For this comparison we therefore predict a right-sided predominance of electro-cortical activity and greater amplitudes for paintings than for control stimuli (see also next point). Fourth, referring to the aforementioned expertise-related EEG literature as well as further studies using visual stimuli that are relevant here (Cuthbert et al., 2000; Keil et al., 2002), we focus our analyses on the ERP components at posterior locations as our “region of interest”. These ERP components can be expected to resemble the P300 and the Late Positive Complex (LPC) and are thus relevant for models of aesthetic experience that stress the importance of memory processes (such as recognition and long-term memory) in the appreciation of visual art (Leder et al., 2004). These processes should be most pronounced in response to the original paintings with their recognisable compositional elements and structure. In addition to these theoretical rationales of focusing on posterior LPC-like potentials, this topographical focus minimises the potential confounds of proper EEG activity with residual eye movement artefacts due to volume conduction to negligible.

2. Methods

2.1. Participants

On the basis of a recently developed art expertise questionnaire that focuses of elements of formal art and musical education (see Appendix 1), N=27 participants (mean age: 24.48 ± 5.60, range: 19–40 years; 17 females; 22 right-handed; visual art expertise sum score: 27.13 ± 11.76, range: 9.0–48.75) were selected from a larger screening sample with N=146 undergraduate students. The questionnaire consisted of 44 closed-ended questions, in which the first 23 were related to visual art education and the remaining ones to education in music. Of these, questions 9, 17 and 24 were not included in the computation of the art expertise sum score as these are nominal variables without numerical information. For the other 20 art-related questions, the answer scores were summed up. This questionnaire differs from similar measures (see Section 1) in covering more areas of art expertise (formal art education, art preferences and specific interests) in greater detail (also covering rather elaborated skills such as specific art analysis techniques to differentiate individuals in the upper expertise range). Questions about education in art and the time contributed to visual art contemplation weighted the most. An expert in the history of art (HR) and an expert in the study of art expertise (MN) have considered these items as content valid for the construct of art expertise. The internal consistency of the 22 questions which contributed to the visual art expertise scores was very high (Cronbach’s α = 0.906). Participants in both groups were native or at least proficient English speakers (25 European, 1 Indian, 1 South-American). All of the participants had normal or corrected-to-normal vision. All participants gave informed written consent before they participated in questionnaire screening and EEG recording sessions.

2.2. Apparatus

The experiment took place in sound-attenuated and electrically shielded EEG lab at Bangor University. BrainAmps DC amplifiers (sampling rate: 500 Hz, online band pass: DC-250 Hz; resolution: 0.1 μV, Brain Products, UK) and EasyCaps (Falk Minow Systems, Munich) were used to record the EEG from 64 positions of the international 10-10 system (American Electroencephalographic Society, 1991), including F9 and F10 near the outer canthi for EOG measurement. The reference electrode and ground electrode were placed at Cz and AF4, respectively. Electrode impedances were kept below 5 kΩ. The EEG was recorded on a Pentium 3 PC using Brain Vision.
recorder version 1.04 (brain products, uk). the experimental stimuli were edited by adobe photoshop cs3. they were presented with the “presentation” software (neurobehavioral systems, usa) on a 21”-tft monitor in 1024 × 768 pixels resolution. besa version 5.1.6 by megis software was then used to perform ocular artefact correction, eeg data segmentation, and all further eeg analysis. bpplot version 1.4.0.9 (megis software) was used to generate eeg data visualisations and maps. statistical analysis was conducted using spss 13.0 for windows.

2.3. stimuli

fifty representational western paintings of high professional standards in four different categories (14 portraits, 11 landscapes, 18 genre works, and 7 still lives, see fig. 1) were presented under two stimulus types: in their original appearance and filtered. the original stimuli were created by resizing paintings into maximum dimension which fitted in a 1024 × 768 pixels pure black background without distorting the original dimension (fig. 1). the filtered paintings were created by applying the four filters: median noise, gaussian blur, mosaic, or glass distortion (adobe photoshop cs3). depending on the features of the paintings, different filters were applied until the structure and details of the paintings were dissolved but the overall forms were retained. we did not apply the same filter to every painting in order to avoid specific effect related to the filter. the plain colour stimulus type was created by filling 50 different randomly selected colours on the 1024 × 768 pixels background. each stimulus type included 50 different stimuli, thus a total of 150 stimuli were used in the study. these 150 stimuli were randomly divided into 3 sets. each set consisted of 50 stimuli, and these 3 sets of stimuli were presented to all participants in a single fixed order.

in order to minimise the confounding influence of differential familiarity with the paintings in the two groups only relatively unknown paintings were used. familiarity with the paintings in their original form was assessed at the end of the lab session (see below).

2.4. procedure

at the beginning of the session, the laboratory was shown to the participants and the equipment and the different tasks were explained. if a participant agreed to take part in the experiment, s/he gave her/his written consent and testing could begin. the electrode cap was mounted, electrodes were attached and electrode impedances were brought to below 5 kω. next, participants were prompted with arrows pointing to the left, right, up or down as well as with a schematic picture of an eye to produce horizontal and vertical saccades to visually-marked positions outside the monitor or eye blinks (“ calibration”). the proper (quasi-) experiment consisted of two separate parts, the order of which was counterbalanced, namely presentation of (a) art stimuli (35 min duration) and (b) music stimuli (35 min duration). results of the music study will be reported elsewhere.

during the visual art study, each stimulus was presented only once according to the following procedure. at the beginning of each trial, a white fixation cross appeared in the middle of the screen for 6.0 s, followed by an art stimulus that was presented for 6.0 s. after stimulus offset, the fixation point appeared again and
remained there for another 6.0 s before the next trial. Participants were asked to carefully attend to the stimuli as they would be asked about them at the end of the session. After the experiment, participants were shown the paintings used as stimuli and asked to report if they had ever seen the paintings before the experiment. After this task, participants were asked to fill in the Edinburgh Handedness Inventory (Oldfield, 1971) and to indicate their age.

2.5. Primary and statistical data analysis

EEG data analysis was accomplished with BESA and BPlot (MEGIS software, Munich). In the first data analysis step, the MSEC method (Berg and Scherg, 1994) was applied to the “calibration” data. The MSEC method differs from traditional EOG correction methods in that eye activity is described by components that are empirically determined separately for each individual. The components are treated like dipole sources which model the EEG activity. While both eye and cortical activity are assumed to be recorded by all applied channels, albeit to a different degree, the topography of eye versus cortical activity, as described by source vectors, differs. The eye source vectors were determined empirically by applying a Principal Component Analysis (PCA) on co-variances of all time points of the calibration data. While the resulting source vector defines the topography of the eye activity, the source waveform describes the magnitude of the source over time. In order to correct the EEG for eye movement artefacts, the source wave rather than the EOG signal is subtracted from each EEG channel in proportions which are defined by the respective source component. Three types of eye movement were corrected: vertical and horizontal eye movements, and blinks. In addition, the source waveform identifies the eye activity. By averaging these waveforms along with the EOG, an estimate of the time-locked eye activity is obtained. The efficacy of the eye activity correction was checked by visual inspection, and trials still containing artefacts were rejected.

A trial was defined as the interval starting 1000 ms before and ending 6000 ms after stimulus onset, thus including a 1000 ms pre-stimulus baseline. After segmentation, the raw data were re-referenced to the common average reference and 0.1–150.0 Hz zero phase band-pass filtered (both slopes set to 12 db/Octave). Presentation stimulus triggers were used to differentiate the three experimental stimulus types: original painting, modified painting, and plain colour. Accepted trials of the same stimulus type were averaged for each participant. Finally, grand averages were then created for high-scorers and low-scorers from the individual averages. Individual and average waveforms and topographical maps were visually inspected to identify the ERP components following stimulus onset as well as their latency ranges and topographies. The latency ranges were (a) 245–390 ms and (b) 500–525 ms. For the first component, peaks were found based on the P6 electrode within the latency range 245–390 ms due to great variation among the latencies of the peak for each participant. The mean amplitudes of the ERP during 25 ms around the peak for each stimulus type were used for statistical analysis. Eight electrode channels (P3, P4, P5, P6, PO3, PO4, PO7 and PO8) covered the main activity in these latency ranges and were for this reason used for statistical analysis. The topographical maps are based on the BESA standard montage of 81 channels.

Repeated-measures ANCOVAs were conducted with the SAS “Proc GLM” with Type III sums of squares using the amplitude of the 8 selected channels as dependent measures and “EXPERTISE” (the visual art expertise sum score, see above) as predictor in the regression part of the ANCOVA as well as “LATENCY” (245–390 ms; 500–525 ms), “STIMULUS TYPE” (original painting; filtered painting; plain colour), “HEMISPHERE” (left- versus right-sided electrodes), and “ELECTRODE” (P3/P4; P5/P6; PO3/PO4; PO7/PO8) as the within-subject factors in the ANOVA part of the ANCOVA. Although “EXPERTISE” has been considered as a continuous variable both conceptually and in the ANCOVA, in order to display the relationship between art expertise and ERP activity, the following two types of topographical maps were created. Firstly, as the dichotomisation of an otherwise continuous variable, the entire sample was split up into two groups (henceforth called “high-scorers” and “low-scorers”) for the sake of brevity and to indicate that these participants were quite highly experienced or little experienced, respectively) in order to show the proper ERP topographies in those scoring high versus low in art expertise (see Figs. 2 and 3).

Secondly, for each ERP component and condition separately, we determined the correlation between the amplitude in each of the EEG channels and the art expertise sum score. The topography of these correlations is shown in Fig. 4. After excluding 4 participants with poor data quality, data of 11 “high-scorers” (visual art expertise sum score: 37.84 ± 6.15 (ranging from 29.00 to 48.75); 7 females, 9 right-handed, mean age: 24.8 ± 6.0 years (19–39 years)) and 16 “low-scorers” (visual art expertise sum score: 16.42 ± 3.50 (ranging from 9.00 to 22.25); 10 females, 13 right-handed, mean age: 24.1 ± 5.5 years (19–40 years)) remained for these secondary analyses. The cut-off point for this dichotomisation was based on the expertise score distribution of the larger screening sample, and the group difference in visual art expertise was highly significant (t(15.495) = −10.230, p < .001). The number of paintings known to the participants was very low and did not differ between groups (high-scorers: 1.8 ± 2.4; low-scorers: 2.1 ± 2.9; t(25) = 0.23, p = .82).

In addition to the proper test statistics (F-, r-values), significance levels and Huynh–Feldt’s epsilon values are reported. Unless stated otherwise, the ANCOVA results of the non-normalised data remained significant after data normalisation.

3. Results

Fig. 2 shows the temporal course for those eight electrodes that were used for statistical analyses in art high-scorers and low-scorers for the three experimental stimulus types. As can be seen in Fig. 2 (grand average curves) and Fig. 3 (grand average maps), the experimental stimuli elicited ERP components that resemble in terms of latency and topography the Late Positive Complex (LPC) or P3b that is typically seen after the attentive processing of visual stimuli. Plain colours elicited smaller amplitudes than filtered paintings, which in turn elicited smaller amplitudes than the original paintings. It can be seen in Figs. 2 and 3 that both the

**Fig. 2.** Grand average ERP curves displaying the relationship between art expertise and ERP amplitudes at parietal leads and for the three experimental conditions separately. The sample is artificially dichotomised in low-scorers versus high-scorers.
positive deflections and the differences between the three stimulus types in these deflections exhibited topographical maxima at posterior positions. While Figs. 2 and 3 suggest a negative correlation between art expertise and ERP amplitudes, this negative relationship is directly shown in Fig. 4. This figure reveals that for the first ERP component, greater art expertise is associated with lower ERP amplitudes at right-posterior leads. For the second ERP component and the original and filtered paintings, the negative ERP-expertise correlation is more symmetrical over the two hemispheres.

**Fig. 3.** Grand average ERP maps displaying the relationship between art expertise and ERP topographies as well as differences in ERP topographies for the three experimental conditions and the two analysed components. The sample is artificially dichotomised in low-scorers versus high-scorers.
The statistical analyses of the first ERP component revealed a significant STIMULUS TYPE × HEMISPHERE × ELECTRODE interaction ($F_{1, 176, 94, 179} = 3.858, p = .007, \epsilon = .628, \eta^2_p = .134$) that can be further specified by its subordinate interaction and main effects (STIMULUS TYPE × HEMISPHERE: $F_{1, 894, 47, 355} = 7.113, p = .002, \epsilon = .947, \eta^2_p = .222$; STIMULUS TYPE × ELECTRODE: $F_{4, 283, 107, 069} = 4.140, p = .003, \epsilon = .714, \eta^2_p = .142$; STIMULUS TYPE: $F_{1, 698, 42, 444} = 11.923, p < .001, \epsilon = .849, \eta^2_p = .323$; HEMISPHERE: $F_{1, 000, 25, 000} = 13.100, p = .001, \epsilon = 1.000, \eta^2_p = .344$; ELECTRODE: $F_{2, 525, 63} = 7.081, p = .001, \epsilon = .842, \eta^2_p = .221$). Together, these effects point to a topographical distribution that favoured the right hemisphere as well as lateral parietal and mesial parieto-occipital leads and showed an amplitude reduction from original paintings over filtered paintings to plain colours at all positions (see Table 1). While this interaction remained significant after data normalisation, the underlying interaction of STIMULUS TYPE with HEMISPHERE just failed conventional significance level ($p = .059$).

The ANCOVA revealed furthermore a significant association between EXPERTISE SCORE and the amplitudes of the first ERP component, in particular at bilateral parieto-occipital electrodes (see Fig. 4) (EXPERTISE SCORE × ELECTRODE: $F_{2, 525, 63} = 4.396, p = .010, \eta^2_p = .150$; EXPERTISE SCORE: $F_{1, 25} = 7.723, p = .010, \eta^2_p = .236$; ELECTRODE: $F_{2, 525, 63} = 7.081, p = .001, \eta^2_p = .221$) and over the right hemisphere (EXPERTISE SCORE × HEMISPHERE: $F_{1, 000, 25, 000} = 7.427, p = .012, \eta^2_p = .229$; EXPERTISE SCORE: $F_{1, 25} = 7.723, p = .010, \eta^2_p = .236$; HEMISPHERE: $F_{1, 000, 25, 000} = 13.100, p = .001, \eta^2_p = .344$). Greater art expertise was thus associated with lower electro-cortical amplitude at parietal leads ($P3/P4: r = -.365, p = .061; P5/P6: r = -.416, p = .031$), parieto-occipital leads ($P03/P04: r = -.504, p = .007; P07/P08: r = -.541, p = .004$) and more so over the right hemisphere ($r = -.546, p = .003$) than over the left hemisphere ($r = -.277, p = .162$). The interaction of STIMULUS TYPE and EXPERTISE SCORE was not significant for the first component.

Table 1

<table>
<thead>
<tr>
<th></th>
<th>Mean amplitude ± SD (µV)</th>
<th>Original – filtered</th>
<th>Original – blank colour</th>
<th>Filtered – blank colour</th>
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<tr>
<td></td>
<td>t</td>
<td>p</td>
<td>Cohen’s d</td>
<td>t</td>
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<tr>
<td>Left</td>
<td>4.81 ± 4.6</td>
<td>2.86 ± 4.3</td>
<td>0.53 ± 2.4</td>
<td>5.359* &lt;.001</td>
</tr>
<tr>
<td>Right</td>
<td>4.38 ± 4.3</td>
<td>3.86 ± 4.3</td>
<td>0.36 ± 2.4</td>
<td>4.389* &lt;.001</td>
</tr>
<tr>
<td>P3</td>
<td>4.64 ± 4.3</td>
<td>3.86 ± 4.3</td>
<td>0.36 ± 2.4</td>
<td>4.389* &lt;.001</td>
</tr>
<tr>
<td>P4</td>
<td>5.07 ± 4.3</td>
<td>3.86 ± 4.3</td>
<td>0.36 ± 2.4</td>
<td>4.389* &lt;.001</td>
</tr>
<tr>
<td>P5</td>
<td>5.38 ± 4.3</td>
<td>3.86 ± 4.3</td>
<td>0.36 ± 2.4</td>
<td>4.389* &lt;.001</td>
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<tr>
<td>P6</td>
<td>5.69 ± 4.3</td>
<td>3.86 ± 4.3</td>
<td>0.36 ± 2.4</td>
<td>4.389* &lt;.001</td>
</tr>
<tr>
<td>P7</td>
<td>5.98 ± 4.3</td>
<td>3.86 ± 4.3</td>
<td>0.36 ± 2.4</td>
<td>4.389* &lt;.001</td>
</tr>
<tr>
<td>P8</td>
<td>6.27 ± 4.3</td>
<td>3.86 ± 4.3</td>
<td>0.36 ± 2.4</td>
<td>4.389* &lt;.001</td>
</tr>
</tbody>
</table>

* Significance determined according to Holm (1979); df = 26; latency range 245–390 ms.
Like the first component, the second component was more pronounced over the right hemisphere as compared to the left (HEMISPHERE: \( F_{1,000,25,000} = 18.738, p < .001, \varepsilon = 1.000, \eta^2 = .428 \)) and larger for original paintings as opposed to filtered paintings or plain colours (STIMULUS TYPE: \( F_{1,787,44,678} = 27.627, p < .001, \varepsilon = .894, \eta^2 = .0525 \)). While the effect of stimulus type was somewhat differently pronounced for the different bilateral electrode pairs (STIMULUS TYPE \& ELECTRODE: \( F_{5,087,122,172} = 2.947, p = .014, \varepsilon = .848, \eta^2 = .105 \)), large effects were found for all of them (F-values ranging between 21.7 at P3/P4 and 28.4 at PO7/PO8). Unlike the first component, the hemisphere asymmetry of the second component did not interact with the type of stimulus being presented or with artist expertise. Nevertheless, also for this component, there was a general negative relationship between artist expertise and ERP amplitude (EXPERTISE SCORE: \( F_{1,25} = 8.331, p = .008, \eta^2 = .250 \); see also Fig. 4). The interaction of STIMULUS TYPE and EXPERTISE SCORE was not significant for the second component (\( p = .059, \eta^2 = .111 \)).

4. Discussion

The aim of the present study was to investigate the relationship between art expertise, as measured through a newly developed questionnaire, and the electro-cortical correlates of processing paintings. To that end, the participants of our study freely contemplated unfamiliar paintings of different genres in their original or filtered versions as well as plain colours. This study revealed the following main results. First, under free viewing conditions the stimuli used here elicited a P3b-like posterior positive deflection. Second, processing original paintings elicited greater posterior ERP amplitudes than processing filtered paintings or plain colours. Third, the electro-cortical correlates of art processing were more pronounced over the right than over the left hemisphere. Fourth, greater art expertise was associated with smaller ERP amplitudes at parieto-occipital sites and over the right hemisphere during an “early” processing stage (around 300 ms) and more broadly posterior at a “late” processing stage (around 500 ms). Fifth, this negative-expertise-amplitude relationship generalised to filtered paintings and even plain colour fields.

Ad (1). The P3b and the Late Positive Complex (LPC; Friedman et al., 1978) that often follows it belong to the most intensively and extensively researched ERP components, and it is beyond the scope of this article to review this literature. Suffice to say, that the P3b has been associated with the “context updating” or contextual “closure” in working memory (e.g., Donchin and Coles, 1988; Verleger, 1988) and has been shown to index the retrieval of knowledge from long-term memory (Koester and Prinz, 2007). As outlined in Section 1, current models of art appreciation have emphasised the role of knowledge in long-term memory (Leder et al., 2004). The mere presence of this component, thus suggests that the participants of our study were attentively processing the stimuli they were exposed to during our free-viewing condition.

Ad (2). The P3b/LPC waveform exhibited the largest amplitudes for paintings and the smallest for plain colours. Various previous studies have shown that degradation of visual stimuli cause reductions in the P3b amplitude (reviewed in Kok, 2001). These findings are in line with the positive relationship between information transmission and P3b amplitude as specified in Johnson’s (1986) Triarchic Model of the P3b. Applying filtering techniques intended to degrade the painting stimuli by dissolving their constituent elements, a technique that was put to an extreme by removing these elements altogether in the plain colour stimuli. The posterior positive deflection reported in the present paper sensitively reflected these experimental manipulations. The original painting stimuli, however, were not only the least degraded ones; with their specific content, that is visual art, they conveyed a kind of information the processing in working memory of which can be assumed to elicit emotional reward and arousal to some extent (Chatterjee, 2004; Leder et al., 2004). The present results therefore not only confirm results of a study that used stimuli similar to the ones used here (Vartanian and Goel, 2004), but also results of studies that used different kinds of emotionally relevant stimuli (e.g., Cuthbert et al., 2000; Keil et al., 2002).

Ad (3). The posterior ERP reported here were not only sensitive to the experimental task manipulations, they also exhibited a clear right-hemispheric preponderance that is in line with previous publications on aesthetic judgement (Höf el and Jacobsen, 2007; Jacobsen and Höf el, 2003) or the processing of metaphors and emotional memories (Bhattacharya and Petsche, 2002). One of the important implications of the posterior, right-sided predominance of the ERP components for paintings, their degraded (filtered) versions and even plain colour stimuli is that the underlying electro-cortical generators are not unique to the processing of visual art. While this conclusion may read peculiar at first glance, it must be stated that more than a decade of neuroimaging of visual art and aesthetic appreciation has yielded no evidence that evolution has produced any anatomic “module” or neurophysiological process that is unique to the processing of visual art (Chatterjee, 2004, 2011; Skov, 2010; Zaidel, 2005). Our findings here thus support the notion that the appreciation of visual art relies on cognitive and neural processes involved in processing other kinds of visual stimuli (Aglioti et al., 2012; Calvo-Merino et al., 2005, 2008, 2010a,b; Harvey et al., 2010; Kirk, 2008; Kirk et al., 2009a,b, 2011; Salimpoor et al., 2011; Skov, 2010). This finding is important because it argues against the popular belief that because “art is special” there should be “some special brain process” associated with art or aesthetics.

Ad (4). The greater the art expertise, the smaller was the electro-cortical activation by the experimental stimuli. This fourth major finding is in agreement with decreases in the extent and intensity of brain activation related with practice and experience observed in many other domains (Kelly and Garavan, 2005) and was also reported in an FMRI study of drawing portraits (Solso, 2001) and an EEG study of preparation and execution of the right movements (Percio et al., 2010). In all of these studies, experts showed lower degrees of activation when performing tasks they are specialised in.

This apparently well replicable observation can be subsumed under the broader topic of “neural efficiency” due to intensive practice (see Haier et al., 1988). As Kelly and Garavan (2005) have elaborated in their review, task practice leads to decreases in extent or intensity of brain activation through increases in neural efficiency, defined as a sharpening of neural responses in task-relevant processing networks (see also Percio et al., 2010; Petersen et al., 1988; Poldrack, 2000).

Our results thus add to the research on the effects of expertise on the cognitive processes involved in the appreciation of art (Augustin and Leder, 2006; Kay, 1991, 2000; Koizlert, 2001; Koizlert and Seeley, 2007; Locher et al., 2008; Nodine and Krupinski, 1998; Pikho et al., 2011; Silvia, 2007; Vogt and Magnussen, 2007) and their neural underpinnings (Altenmüller et al., 2000; Berkowitz and Ansari, 2010; Bhattacharya and Petsche, 2005; Brattico et al., 2008; Calvo-Merino et al., 2005, 2010b; Cross et al., 2006; Kirk et al., 2009b, 2011; Orgs et al., 2008; Tervaniemi, 2009). Understanding the effects of expertise on behaviour and its neural foundations is not only important for research on learning, training, and skill development. In the domain of art appreciation, moreover, it constitutes a key argument against the notion of the stability and objectivity of the art appreciation, and a fundamental tool in understanding how the art experience is generated. The studies quoted here have shown that such experience is modulated by contextual cues, by the information provided, and by the development of expertise.
Despite the plausibility of the interpretation given before, a potential caveat of all expertise studies is the quasi-experimental nature of the comparison between high-scorers and low-scorers, which opens the possibility of confounds between expert status and other known or unknown variables (such as differences in recognition of artistic style, age of production of the artwork, etc.; Augustin et al., 2011) associated with it that may be relevant for the processes under scrutiny. (The same applies to correlative studies like the present one, in which art expertise is investigated as a continuous variable.) Therefore, the present results are preliminary in a specific sense: They do show that art expertise is negatively correlated with the amplitude of the electro-cortical potentials that accompany “higher-order” art processing (cognition, evaluation, affect rather than low-level perception), but they do not show why this is the case. Future studies that put less emphasis on the relative ecological validity of “non-instructed” free viewing conditions, may be guided by current models of aesthetic experience such as Leder et al. (2004) model in designing experimental task modifications that have more specific bearings for processing components specified in this model.

Ad (5). That the negative relationship between art expertise and ERP amplitude held not only for paintings, but also for their filtered versions and even plain colour fields, is another finding that reads counter-intuitive only at first glance. Indeed, although expertise is by definition domain-specific, experts in certain domains have in various studies been shown to excel non-experts in tasks that are not related to their domain of expertise. Chi (1978), for instance, found that young chess experts outperformed children non-experienced with chess in memory and learning tasks through better use of grouping and rehearsal strategies. Similar effects have been found repeatedly in relation to musicians’ performance in general attention (Posner et al., 2008), the recognizing of emotions in speech prosody (Lima and Castro, 2011), spatial abilities (Rauscher et al., 1993; Rauscher and Zupan, 2000), or verbal memory (Chan et al., 1998; Franklin et al., 2008; Ho et al., 2003; Jakobson et al., 2003) as well as visual artists’ performance in detecting and resolving figural problems (Kay, 1991, 2000) or in general perception tests (Kozbelt, 2001; Kozbelt and Seeley, 2007). These studies can be jointly summarised by hypothesising that art experts “export” their art viewing strategies to non-artistic stimuli such that relationships between art expertise and the processing of artistic stimuli are mirrored in the processing of control stimuli.

To summarise, the present study contributed to the existing art expertise literature in demonstrating that art expertise is associated with reduced “higher-order” event-related potential amplitudes under free viewing conditions of visual art and non-artistic visual stimuli that can be considered to reflect increased neural efficiency due to extensive practice.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.biopsycho.2012.10.013.

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