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Research Report

Functional neuroanatomy of the perception of modern art: A DC–EEG study on the influence of stylistic information on aesthetic experience

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ABSTRACT

The present study was conducted to determine the functional neuroanatomical correlates of aesthetic experience using slow cortical potentials (SCPs). Thirty participants without any particular background in the fine arts were presented with various representational (semi-abstract) and abstract paintings dating from the 20th and 21st century in two experimental conditions, i.e. with or without stylistic information. The paintings had to be rated by the participants in terms of understanding and aesthetic qualities. In order to identify the cortical structures involved, the SCPs were subjected to current density analysis using low-resolution electromagnetic tomography (LORETA). The comparison of representational and abstract paintings revealed significantly higher activation for representational artworks in several regions of the brain, predominantly in the left frontal lobe and bilaterally in the temporal lobes. According to the participants' reports, the representational artwork stimuli evoked more associations, accompanied by stronger activation of multimodal association areas in the temporal lobe. Furthermore, without stylistic information, the stimuli evoked stronger activation mainly in the left frontal and parietal lobes. Results also showed that stylistic information led to a better understanding of the paintings, but resulted in reduced cortical activation in the left hemisphere. This might have been due to less verbally oriented processing. These observations help explain the difficulties many beholders often have in appreciating abstract artworks.

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1. Introduction

The aim of this study is to establish the functional neuroanatomical correlates of aesthetic processing of abstract and representational paintings. In addition, it attempts to assess the role of stylistic information on art appreciation. The localization of brain regions that are involved in aesthetic processing poses a challenge, given the many factors that are involved. For

example, individuals differ in respect to background experience and taste, which are acquired through repeated exposure to artworks (Leder et al., 2004). They also differ in their aesthetic understandings, which are based on gradual acquisition of insights attained through education (Parsons, 1987). Kawabata and Zeki (2004) have indicated that the association of specific cognitive functions with distinct brain regions is not readily apparent in the field of aesthetics. The relationship between

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neuroanatomical correlates and aesthetic processing is thus a complex issue deserving of empirical investigation, especially as it relates to the experience of artworks.

Presenting participants with artworks does not necessarily guarantee aesthetic involvement. In order to encourage aesthetic rather than perceptual processing, participants in the present study saw additional stylistic information in some conditions. This kind of information consisted of a description of stylistic devices used by the artist and was designed to facilitate the viewer's understanding of the painting. Models of aesthetic experience (Leder et al., 2004; Parsons, 1987) emphasise the importance of style related processing as essential for aesthetic processing of art. These models further indicate that increasing experience and expertise are modifying the referential frame and the aesthetic judgement and that it is important to somehow gain a state of understanding for an artwork.

Until now, only few studies have been conducted to determine the functional neuroanatomical correlates of aesthetic experience in visual arts, though various behavioral studies have been concerned with the perception of artworks and style-related aspects of processing (e.g., Belke et al., 2006; Cupchik et al., 1994; Locher, 2003; Vartanian et al., 2005). At the same time, aesthetics have had a long tradition as an empirical discipline, with the heyday in the beginning of the 19th century. Fechner (1876), the founder of psychophysics and a forerunner of experimental aesthetics, established aesthetic principles in which he tried to define explanations for pleasure and displeasure. His investigations were based on very simple stimuli, i.e. geometric forms. Later, Berlyne (1971, 1974) carried out experiments in his program of "the new experimental aesthetics". He was particularly interested in collative properties of stimulus pattern and motivational questions. Berlyne stated that these collative properties (especially novelty and complexity), probably among other properties, give a positive hedonic value.

Neuroimaging studies to determine functional neuroanatomical correlates of aesthetic preference for paintings were carried out by Hansen et al. (2000), Vartanian and Goel (2004) as well as by Kawabata and Zeki (2004) using functional magnet resonance imaging (fMRI). Hansen et al. (2000) demonstrated that activation of primary and association visual cortices varied with preference judgement. The findings suggested quantitative changes in activation as well as qualitatively distinct networks of brain areas in frontal and limbic areas associated with positive, negative, and neutral judgements to images of artworks. In the study by Vartanian and Goel (2004), representational and abstract paintings were used in different formats (original, altered, and filtered). The results have shown that activation in the right caudate nucleus decreased in response to decreasing preference, whereas activation in bilateral occipital gyri, left cingulate sulcus, and bilateral fusiform gyri increased in response to increasing preference for the paintings. Kawabata and Zeki (2004) investigated the neural correlates of the perception of paintings considered to be beautiful. The perception of beautiful and ugly paintings led to a different involvement of the orbito-frontal and the motor cortex. They also found that the perception of different categories of paintings was associated with a distinct pattern of activation. Albeit the results of these studies correspond only in parts, they indicate that neuroimaging techniques can be used to examine aesthetic experiences.

Table 1 – Talairach coordinates of significantly higher activated structures within representational artworks in comparison to abstract artworks

x	y	z		Brodmann area	Pseudo t-value
<i>Time frame: 1000–1250 ms (P=0.014) after stimulus onset</i>					
53	38	-6	BA 47	Inferior frontal gyrus	4.3479
-52	-60	-6	BA 19	Middle occipital gyrus	4.4893
-59	-60	-6	BA 37	Inferior temporal gyrus	4.4893
<i>Time frame: 1500–1750 ms (P=0.002) after stimulus onset</i>					
4	-60	43	BA 7	Precuneus	3.9931
18	-88	43	BA 19	Precuneus	3.9931
53	-32	22	BA 13	Insula	4.1205
18	-74	50	BA 7	Precuneus	4.2055
39	-32	15	BA 29	Superior temporal gyrus	4.2905
<i>Time frame: 2000–2250 ms (P=0.000) after stimulus onset</i>					
11	10	36	BA 32	Cingulate gyrus	4.1924
-10	17	43	BA 32	Cingulate gyrus	4.2888
4	-74	-6	BA 18	Lingual gyrus	4.3370
11	-74	-6	BA 18	Lingual gyrus	4.3370
4	-81	-6	BA 18	Lingual gyrus	4.3370
<i>Time frame: 2500–2750 ms (P=0.007) after stimulus onset</i>					
-24	24	-20	BA 47	Inferior frontal gyrus	4.2846
46	-60	-6	BA 19	Inferior temporal gyrus	4.6909
53	-67	-13	BA 37	Middle occipital gyrus	4.6909
<i>Time frame: 3000–3250 ms (P=0.003) after stimulus onset</i>					
-45	-74	15	BA 39	Middle temporal gyrus	4.0863
-24	52	8	BA 10	Middle frontal gyrus	4.7535
-45	-4	8	BA 13	Insula	4.9203
25	66	8	BA 10	Superior frontal gyrus	5.2539
-38	-11	-6	BA 21	Sub-gyral	5.2956
<i>Time frame: 3500–3750 ms (P=0.008) after stimulus onset</i>					
53	31	15	BA 46	Inferior frontal gyrus	4.0658
-45	31	-13	BA 47	Inferior frontal gyrus	4.0658
-45	17	-13	BA 38	Superior temporal gyrus	4.1767
-38	3	-6	BA 13	Extra-nuclear	4.3985
-17	59	22	BA 10	Superior frontal gyrus	4.6942
<i>Time frame: 4000–4250 ms (P=0.009) after stimulus onset</i>					
18	17	-20	BA 47	Inferior frontal gyrus	3.8637
-31	-11	-27	BA 20	Uncus	4.1165
11	38	8	BA 32	Anterior cingulate	4.5498
4	52	15	BA 10	Medial frontal gyrus	4.5860
<i>Time frame: 4500–4750 ms (P=0.010) after stimulus onset</i>					
-3	-67	15	BA 31	Posterior cingulate	3.9178
67	-39	15	BA 22	Superior temporal gyrus	4.5905
-59	-53	8	BA 22	Superior temporal gyrus	4.7398
<i>Time frame: 5000–5250 ms (P=0.005) after stimulus onset</i>					
25	10	-20	BA 47	Inferior frontal gyrus	3.8901
-24	52	1	BA 10	Superior frontal gyrus	3.9286
18	-11	-20	BA 34	Parahippocampal gyrus	3.9672
-52	-46	8	BA 21	Middle temporal gyrus	4.0442
-52	10	-27	BA 21	Middle temporal gyrus	4.7375
<i>Time frame 5500–5750 ms (P=0.001) after stimulus onset</i>					
11	45	-6	BA 32	Anterior cingulate	4.0640
-10	45	-6	BA 32	Anterior cingulate	4.1514
-3	38	1	BA 32	Anterior cingulate	4.1514
-45	38	29	BA 46	Middle frontal gyrus	4.8943
-38	38	-13	BA 11	Middle frontal gyrus	5.5498

Table 1 (continued)

x	y	z	Brodmann area		Pseudo t-value
<i>Time frame: 6000–6250 ms (P=0.000) after stimulus onset</i>					
60	-32	-20	BA 20	Inferior temporal gyrus	3.9052
60	-25	-13	BA 21	Middle temporal gyrus	3.9052
4	10	29	BA 33	Anterior cingulate	4.0934
-3	10	29	BA 33	Anterior cingulate	4.0934
-24	-11	50	BA 6	Middle frontal gyrus	4.1875
<i>Time frame: 6500–6750 ms (P=0.000) after stimulus onset</i>					
-17	17	64	BA 6	Superior frontal gyrus	3.9060
39	-4	15	BA 13	Insula	3.9060
-17	-53	71	BA 7	Postcentral gyrus	4.0321
-24	38	-20	BA 11	Inferior frontal gyrus	4.0951
46	10	22	BA 44	Inferior frontal gyrus	4.2841
<i>Time frame: 7000–7250 ms (P=0.000) after stimulus onset</i>					
67	-11	-6	BA 21	Middle temporal gyrus	3.8560
25	-88	29	BA 19	Cuneus	3.8560
-59	-18	-20	BA 21	Inferior temporal gyrus	3.8560
25	-81	43	BA 19	Precuneus	3.9074
-24	-53	-6	BA 19	Fusiform gyrus	4.0102
<i>Time frame: 7500–7750 ms (P=0.000) after stimulus onset</i>					
60	-18	29	BA 2	Postcentral gyrus	3.9399
-45	-67	-13	BA 37	Fusiform gyrus	4.0348
-38	-67	-13	BA 19	Fusiform gyrus	4.0348
46	-25	43	BA 3	Postcentral gyrus	4.1772
67	-39	29	BA 40	Inferior parietal lobule	4.3197
<i>Time frame: 8000–8250 ms (P=0.000) after stimulus onset</i>					
-17	38	50	BA 8	Superior frontal gyrus	4.0381
60	-39	36	BA 40	Inferior parietal lobule	4.0381
-17	66	15	BA 10	Superior frontal gyrus	4.1444
60	-25	43	BA 3	Postcentral gyrus	4.1444
-17	-11	-27	BA 28	Parahippocampal gyrus	4.4632
<i>Time frame: 8500–8750 ms (P=0.020) after stimulus onset</i>					
-52	-4	50	BA 6	Precentral gyrus	3.9495
-3	-53	43	BA 7	Precuneus	4.0165
67	-11	-13	BA 21	Middle temporal gyrus	4.0499
18	10	64	BA 6	Middle frontal gyrus	4.0499
-10	59	29	BA 10	Superior frontal gyrus	4.2173

Note. The structures were selected using the LORETA-KEY full software package (version 03; R. D. Pascual-Marqui). Only the first five highest significant areas are reported (Talairach coordinates: x: left/right; y: posterior/anterior; z: inferior/superior).

In the present study textual information about the paintings' style was provided in combination with modern abstract and representational artworks. Bartlett (1932, p. 20) called the "process of connecting a given pattern with some setting or scheme: effort after meaning". In this context, the effort after meaning should be facilitated by the information given to the artworks, so that understanding, and consequently pleasingness, should increase. Millis (2001) found that aesthetic experiences were greater for artworks paired with elaborative titles, providing additional information, which he called the elaboration effect. Millis stated that metaphorical titles could lead to a more elaborated representation because of different schemata and concepts triggered by this kind of title. Cupchik et al. (1994) investigated the effects of stylistic, affective, and contextual information on responses on artworks. The results

indicated the benefit of an interpretive task on the experience of the artworks, pointing out the importance of a constructive approach to art appreciation. Russell (2003) demonstrated that the meaningfulness of semi-abstract and abstract paintings increased with provided information, while pleasingness increased only in the case of using a within-subjects design. Leder et al. (2006) revealed that titles had an impact on the understanding of abstract paintings. They also found that descriptive titles increased understanding when paintings had been presented for very short time only, while elaborate titles, which presumably affect the later interpretation, affected understanding of abstract art only after some seconds. These findings are in accordance with the predictions of the above mentioned model proposed by Leder et al. (2004), which

Table 2 – Talairach coordinates of significantly higher activated structures within artworks presented without information in comparison to artworks presented with information

x	y	z	Brodmann area		Pseudo t-value
<i>Time frame: 2000–2250 ms (P=0.004) after stimulus onset</i>					
-59	3	8	BA 6	Precentral gyrus	4.9761
-45	31	-6	BA 47	Inferior frontal gyrus	4.0749
<i>Time frame: 4000–4250 ms (P=0.048) after stimulus onset</i>					
67	-4	22	BA 6	Precentral gyrus	3.9111
<i>Time frame: 5000–5250 ms (P=0.002) after stimulus onset</i>					
-52	-4	29	BA 6	Precentral gyrus	5.3157
-59	-4	36	BA 6	Precentral gyrus	5.3157
-52	-60	36	BA 40	Inferior parietal lobule	4.1437
<i>Time frame: 5500–5750 ms (P=0.033) after stimulus onset</i>					
-24	24	57	BA 8	Superior frontal gyrus	4.1521
-24	38	50	BA 8	Middle frontal gyrus	4.0867
-10	24	64	BA 6	Superior frontal gyrus	3.9886
<i>Time frame: 6000–6250 ms (P=0.025) after stimulus onset</i>					
25	17	64	BA 6	Superior frontal gyrus	4.2100
-31	-53	-6	BA 37	Fusiform gyrus	4.2100
<i>Time frame: 7000–7250 ms (P=0.008) after stimulus onset</i>					
60	17	22	BA 45	Inferior frontal gyrus	4.0156
<i>Time frame: 7500–7750 ms (P=0.047) after stimulus onset</i>					
-52	-25	22	BA 40	Postcentral gyrus	4.0038
-66	-32	22	BA 40	Inferior parietal lobule	3.9722
<i>Time frame: 8500–8750 ms (P=0.024) after stimulus onset</i>					
-38	-18	1	BA 13	Insula	4.1983
-52	-4	50	BA 6	Precentral gyrus	4.0330
-24	10	57	BA 6	Superior frontal gyrus	3.9999
-3	-39	22	BA 29	Posterior cingulate	3.9999
<i>Time frame: 9000–9250 ms (P=0.031) after stimulus onset</i>					
-3	31	57	BA 8	Superior frontal gyrus	4.2004
-10	45	50	BA 8	Superior frontal gyrus	4.2004
-10	17	64	BA 6	Superior frontal gyrus	4.1342

Note. The structures were selected using the LORETA-KEY full software package (version 03; R. D. Pascual-Marqui). Only the first five highest significant areas are reported (Talairach coordinates: x: left/right; y: posterior/anterior; z: inferior/superior).

proposed levels of information-processing in order to explain aesthetic appreciation and aesthetic judgements. This model of aesthetic experience emphasised the importance of style-related processing especially within modern art.

The present study examines the influence of stylistic information on the processing and aesthetic judgement of abstract and representational (semi-abstract) artworks of the 20th and 21st century within participants with no specific background in the fine arts. Information that facilitates the interpretation of an artwork was expected to increase its understanding and pleasuringness, based on Bartlett's (1932) effort after meaning theory. Since the comparison of experts and novices revealed that a more efficient procedure is associated with a reduced cortical activation (e.g., Solso, 2001), it was assumed that stylistic information should influence, and maybe even facilitate, the neural processing of the artworks. The information may also cause stronger effects on the processing of abstract paintings, since it seems that the lack of discernable elements poses a particular challenge to the beholder.

2. Results

2.1. Behavioral data

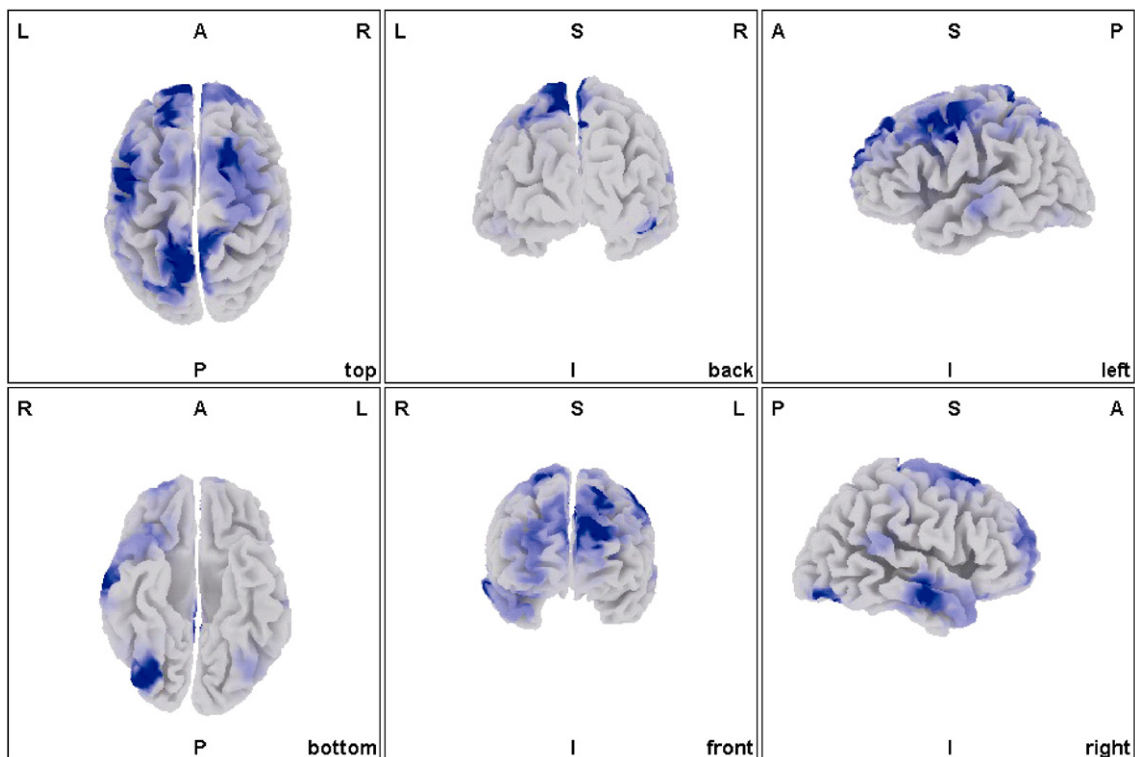
Participants rated the paintings in terms of understanding and aesthetic qualities. The resulting behavioral data indicated that the participants of the present study preferred abstract and

representational paintings in an equal manner, albeit the abstract stimuli evoked more positive emotions. Representational artworks were classified as more interesting and were understood better; furthermore, they evoked more associations. Results showed that information increased the understanding of the paintings, but did not influence the judgements on the dimensions of pleasuringness, interest, emotions and associations.

Significant interactions were observed for rating×style [$F(3.223, 90.246)=25.916$; $P=0.000$] and rating×information [$F(3.362, 94.129)=5.268$; $P=0.001$]. Post hoc tests revealed that the interaction rating×style was not significant on the dimension of pleasuringness, indicating that the participants liked the abstract paintings as well as the representational paintings. However, subjects declared the representational stimuli more interesting [$F(1, 28)=4.431$; $P=0.044$] and understood them better [$F(1, 28)=21.512$; $P=0.000$]. Abstract paintings evoked more positive emotions [$F(1, 28)=44.613$; $P=0.000$], whereas the representational paintings elicited more associations [$F(1, 28)=18.091$; $P=0.000$]. Regarding the factor 'Stylistic information', differences were observed only on the dimension of understanding. Stylistic information enhanced the understanding of the paintings [$F(1, 28)=6.195$; $P=0.019$], regardless of the style.

2.2. EEG data

EEG data were of good quality, except for the recordings of two subjects, which had to be expelled after artefact inspection. In



LORETA-KEY

L:left, R:right, A:anterior, P:posterior, S:superior, I:inferior

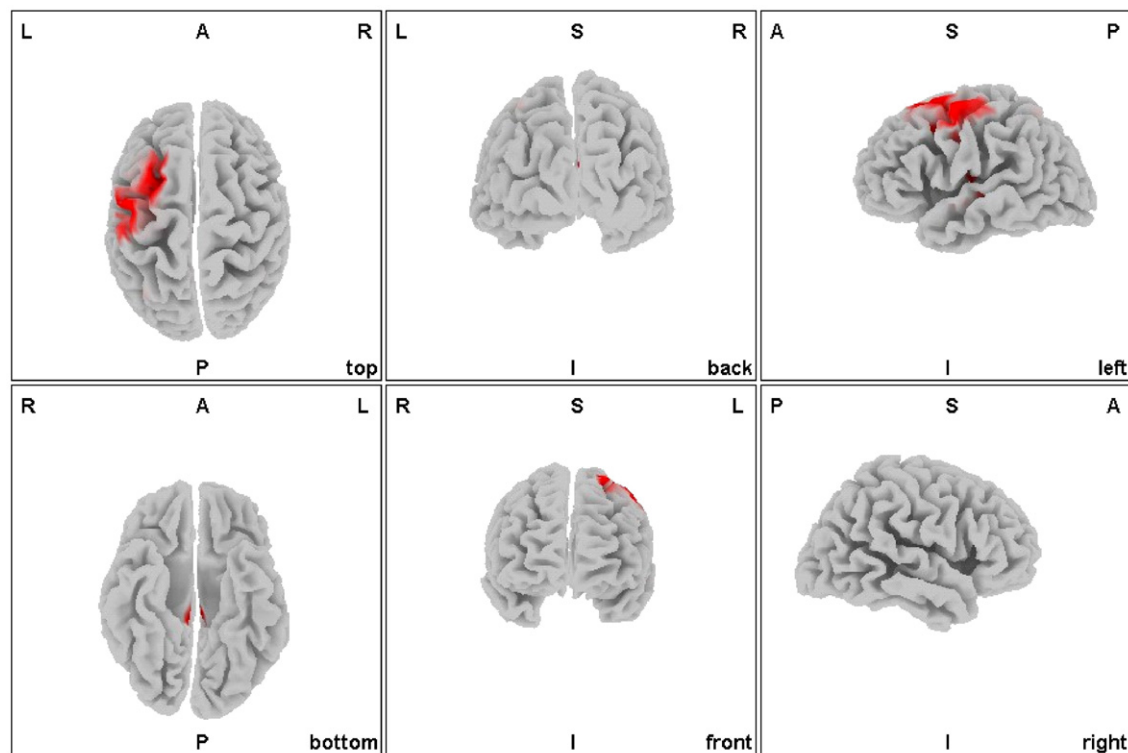
Fig. 1 – Significantly higher activated structures within representational artworks in comparison to abstract artworks, 8500–8750 ms after stimulus presentation. Activated areas are within the left precentral gyrus and precuneus, in the right middle temporal and lingual gyrus, in the left superior frontal gyrus and paracentral lobule. Blue shaded areas correspond to a t -value of >3.8099 .

the grand mean (i.e., average across all subjects and the condition of abstract and representational stimuli) the maximum current density value for the N1 was located at the cuneus (BA 18: $x=4, y=-74, z=15$).

Regarding abstract versus representational paintings, the statistical comparison of the source localization obtained with LORETA revealed significantly higher activation for representational paintings in many regions of the brain. Highly significant differences were observed in every period within a timeframe of 1000–8750 ms after stimulus presentation, with the only exception of the last period of 9000–9250 ms (see Table 1). The highest number of differences between representational and abstract paintings was observed within the period 6000–6250 ms after stimulus onset. Significantly higher activation for representational stimuli was located mainly bilaterally in the temporal lobes, and, with predominance of the left hemisphere, in the frontal lobes. Additionally, differences were found bilaterally in the parietal and in the limbic lobes, and furthermore in the insula, mainly in the left hemisphere.

The detailed differences in activation between representational and abstract paintings are listed, whereas all significantly higher activations were found in the case of representational artworks. Within the time window of 1000–1250 ms ($P=0.014$) differences were observed in the right inferior frontal lobe (BA 47), in the left occipital (BA 19), and the temporal lobes (BA 37). Furthermore, significantly higher activated structures were found within 1500–1750 ms ($P=0.001$) mainly in the left insula

(BA 13), and within the right parietal lobe in the precuneus (BA 7/19/31), as well as in the right (BA 29/40) and the left (BA 22) temporal and the frontal (BA 47) lobes. Regarding 2000–2250 ms ($P=0.000$) after stimulus presentation, activations were detected predominantly bilaterally in the cingulate gyrus (BA 32), the right lingual gyrus (BA 18), the left (BA 25/32) and right (BA 37) limbic lobes, as well as in the left (BA 37) and right (BA 22) temporal lobes. The period 2500–2750 ms ($P=0.007$) showed activations within the left inferior frontal gyrus (BA 47), besides the right temporal (BA 19) and occipital lobes (BA 37). 3000–3250 ms ($P=0.003$) after stimulus onset differences were observed mainly in the left hemisphere, concerning the insula (BA 13), the temporal lobe (BA 39/21), and bilaterally the frontal (BA 10) lobes. The time window 3500–3750 ms ($P=0.008$) was associated with activations both in the left (BA 47/10) and right (BA 46) frontal lobes, in the left temporal lobe (BA 38) and in the insula (BA 13). Within 4000–4250 ms ($P=0.009$) higher activations were identified in the right frontal lobe (BA 47/10), in the anterior cingulate cortex (BA 32) and in the left uncus (BA 20). 4500–4750 ms ($P=0.010$) after stimulus presentation activations were revealed bilaterally in the temporal lobes (BA 22) and within the left posterior cingulate (BA 31). The period 5000–5250 ms ($P=0.005$) exposed differences primarily in the left frontal (BA 10) and temporal (BA 21/20) lobes in addition to the right frontal (BA 47) and limbic (BA 34) lobes. Further differences were detected 5500–5750 ms ($P=0.001$) regarding bilaterally the limbic lobes (BA 32) and the left frontal lobe (BA 46/11). The period 6000–6250 ms ($P=0.000$) after stimulus onset revealed



LORETA-KEY

L:left, R:right, A:anterior, P:posterior, S:superior, I:inferior

Fig. 2 – Significantly higher activated structures within artworks presented without information in comparison to artworks presented with information, 8500–8750 ms after stimulus presentation. Activated areas are within the left insula, in the left precentral and superior frontal gyrus and in the posterior cingulate. Red shaded areas correspond to a t -value of >3.9141 .

significantly higher activation in the right temporal lobe (BA 20/37/19/21/41/13/22/42), as well as bilaterally in the frontal lobes (BA 6/11/10/47/45/25/9), in the limbic lobes (BA 33/34/28/25), and in the insula (BA 13). Within 6500–6750 ms ($P=0.000$) differences were identified again bilaterally in the frontal lobes (BA 6/10/11/44/9/34), and in the insula (BA 13). Significantly higher activation was recorded within the period 7000–7250 ms ($P=0.000$) mainly in the left temporal (BA 20/22/29/42/21) and frontal lobes (BA 6/4/11/10) and in the right parietal lobe (BA 19/40/7/5). At a period of 7500–7750 ms once more differences were found bilaterally in the temporal (BA 21/38/37) and parietal lobes (BA 2/3/40). Significantly higher activation was found 8000–8250 ms ($P=0.000$) after stimulus presentation mainly in the frontal (BA 8/10/6) and limbic lobes (BA 28/24/31/23), predominately within the left hemisphere. Finally, differences were observed at 8500–8750 ms ($P=0.020$) primarily in the left frontal lobe (BA 10/9/6).

The comparison of artworks presented with versus without stylistic information led to significantly higher activation only without information (see Table 2). Regarding the time window 2000–2250 ms ($P=0.004$) after stimulus onset differences were observed in the left frontal lobe (BA 6/47). Again activation was found in the left precentral gyrus (BA 6) after 5000–5250 ms ($P=0.002$), and in the left inferior parietal lobe (BA 40). Additionally, activated structures were detected within the time window 5500–5750 ms ($P=0.033$) in the left frontal lobe (BA 8/6). The period 6000–6250 ms ($P=0.025$) after stimulus presentation revealed higher activation in the right superior frontal gyrus (BA 6) and in the left fusiform gyrus (BA 37). Further activation was found within 7000–7250 ms ($P=0.008$) in the right hemisphere in the inferior frontal gyrus (BA 45). Within the period of 7500–7750 ms ($P=0.047$) after stimulus onset differences were observed in the left postcentral gyrus (BA 40) and inferior parietal lobule (BA 40). Within 8500–8750 ms ($P=.024$) significantly higher activation was recorded in the left hemisphere concerning the Insula (BA 13), the precentral gyrus (BA 6), the superior frontal gyrus (BA 6) as well as the posterior cingulate (BA 29). At last 9000–9250 ms ($P=0.031$) after stimulus presentation differences were observed again within the left hemisphere in the superior frontal gyrus (BA 8/6).

Comparing abstract versus representational paintings pooled across the factor information, revealed significantly higher activations only without information in both, abstract and representational stimuli. This was in the condition of abstract stimuli in relation to the timeframe 8500–8750 ms ($P=0.025$) after stimulus onset, namely the left middle frontal gyrus (BA 8) and the left precentral gyrus (BA 6). Within the condition of representational stimuli significant differences were detected at 4000–4250 ms ($P=0.007$) both in the right (BA 6/11) and left (BA 6) frontal lobes. Finally, significantly higher activations were observed within the time window 4500–4750 ms ($P=0.012$) in the left inferior temporal gyrus (BA 20) and in the right parietal lobe (BA 7/5) (Figs. 1 and 2).

3. Discussion

The present study investigated the neural correlates of aesthetic experience and the influence of stylistic information

on the processing of abstract and representational modern artworks, using SCPs. Behavioral data were obtained by having the participants rate the artworks on understanding and aesthetics qualities.

3.1. Behavioral data

Studies conducted upon preferences for paintings indicated that participants often prefer abstract artworks over representational artworks, especially if not experts in the fine arts (e.g., Cupchik et al., 1994; O'Hare, 1976; Vartanian and Goel, 2004). These findings were not supported by the present investigation. The preference ratings for abstract and representational artworks did not differ significantly. This may have been due to the kind of artworks chosen or to the specific sample of participants. Participants rated the representational artworks more interesting; further, they were understood better, although there were no differences within the preference ratings. These results may indicate the independence of meaningfulness and pleasingness.

On a behavioural level, based on Bartlett's (1932) effort after meaning theory, it was supposed that the provided stylistic information alongside the artworks would enhance their understanding and pleasingness. A positive effect of the stylistic information was observed only on the understanding of the artworks. The effect of information on pleasingness failed to reach significance. As mentioned above, it seems that having understood an artwork does not necessarily mean liking it. Russell (2003) yielded similar results using a between-subjects design, whereas in the case of a within-subjects design an increase in pleasingness was observed. Yet significantly, the effect of information on pleasingness observed by Russell was only weak. Although a within-subject design was conducted in the present study, the data did not support these findings. The understanding of a painting seems to be only one of other cognitive and affective aspects in aesthetic appreciation.

3.2. EEG data

The neural data revealed that the comparison of representational and abstract paintings led to significantly higher activation for representational artworks in several regions of the brain, predominantly bilaterally in the temporal lobes. This may not be surprising since object recognition is a function of the ventral pathway of the visual system (Ungerleider and Mishkin, 1982). The very different activations evoked by abstract and representational paintings have not been demonstrated so clearly often. However, Vartanian and Goel (2004) yielded similar findings using fMRI, indicating that representational artworks led to higher activation bilaterally in the ventral occipital pole and in the right middle temporal gyrus and precuneus. The most salient increase of significant activations was observed between 6000 and 8250 ms after stimulus onset. This may indicate an almost parallel processing of abstract and representational stimuli to a certain point, in the sense of a merely physical analysis of the stimuli.

Due to their inherent content of meaning representational artworks elicited many more associations than the abstract

stimuli, as reported by the participants. This was reflected by the current density data through stronger activation of multimodal association areas in the temporal lobe for representational stimuli. Furthermore, the representational stimuli led to significantly higher activation in several other regions of the brain, mainly in the left frontal lobe (BA 6/47) and bilaterally in the parietal and limbic lobes. The frontal lobe has high integrative functions, which allow a new combination of information and therefore contribute to the generation of associations (e.g., [Dietrich, 2004](#)). At the same time, the frontal lobe plays an important role concerning working memory ([Baddeley, 1998](#)), as well as direction and maintenance of attention (e.g., [Posner and Dehaene, 1994](#)). The parietal lobe has similar functions regarding memory and attention. Representational paintings were rated as more interesting; therefore, it is possible that this kind of stimulus was endowed with more attention, which could help explain these findings.

One of the main objectives of the present study was to detect the influence of style-related information on cortical activation. All of the significantly higher activations were observed within the condition without information, which may indicate that the information facilitated the processing of the stimuli. This is consistent with studies reporting reduced cortical activation and therefore facilitated processing in the case of experts (e.g. [Solso, 2001](#)). Without stylistic information, the stimuli evoked higher activation mainly in the left frontal lobe; further activation was found within the parietal lobe and the insula. Without the information participants maybe had difficulties to categorise the stimuli and therefore tried to find related concepts within memory structures. On the other hand, the style of paintings presented with information became more familiar to the participants, so that succeeding paintings of the same style may have caused less activation than paintings of a style not presented before. Usually activation in response to novel stimuli is higher than with familiar stimuli (e.g., [Habib et al., 2003](#)). This is also supported by [Vandenberghe et al. \(1995\)](#), observing in a PET study reduced cortical activation in the case of nonverbal familiar stimuli. Another explanation could be a more verbally oriented processing of stimuli without provision of information and therefore a higher activation within the left hemisphere.

It was assumed that the stylistic information may cause stronger effects on the processing of abstract paintings because of the lack of discernable elements in this kind of paintings. This was not supported by the findings since both, abstract and representational artworks evoked higher activations without information. This leads to the conclusion that without information it is equally difficult to process abstract and representational paintings.

In sum, the findings reported here indicate that processing of abstract and representational paintings differs substantially. This was reflected by the participants' ratings, which differed notably for the two kinds of artworks. It seems that the lack of discernable elements within abstract artworks – reflected also by cortical activations – poses a particular challenge to the beholder. Information can help to increase understanding, but has no significant influence on preference. Artworks presented with information were accompa-

nied by reduced cortical activation. Generally it can be stated that information on artworks influences and it seems even facilitates the neural processing of the stimuli.

4. Experimental procedures

4.1. Participants

Thirty-two right-handed subjects (16 females) with no history of neurological or psychiatric disorders participated in this study. Handedness was ascertained with the German version of the Marian Annett Handedness Inventory ([Annett, 1970](#)). Written informed consent was obtained from each participant before the experiment. Most participants were students or had a university degree and had no specific background in the fine arts. The level of expertise in the fine arts was ascertained at the end of the experiment using an art expertise questionnaire (see [Belke et al., 2006](#), for details). The participants were between ages 20 and 35 years (mean age=27.5).

4.2. Material

The material was selected from art books and catalogues. From 20 artists of the 20th and 21st century 4 similar paintings were chosen. Ten of these artists were working in an abstract manner (see Supplementary Fig. 3) and 10 in a representational, almost semi-abstract manner (see Supplementary Fig. 4). The semi-abstract works contained recognizable elements which were not painted realistically. For 1 of each 4 paintings per artist, style related information was compiled from information found in art books and on the internet. This information, aimed at increasing the understanding of the beholder, contained stylistic devices used by the artist. As an example, the stylistic information for the abstract artwork 'Vick' of the artist Bernard Frize will be given:

This artist is characterised by his fondness of experimenting. He leaves painting to the material, in the form of a controlled hazard. In detailed commentaries he delineates adopted procedures. In this way the model of artistic authorship is challenged. Through mixing mother of pearl and ink with acrylic the painter succeeded in fabricating an emulsion of two distinct colours. For separating the colours the canvas is tilt, which causes the typical flows.

Overall, the material consisted of 80 paintings, whereas for 20 of them stylistic information was compiled. The reproductions of the paintings were scanned with 150 dpi and presented via an 18-in. TFT monitor with a resolution of 1024×768 pixel.

4.3. EEG recordings

During task performance, DC-EEG was recorded from 40 – relevant for further analysis – Ag/AgCl electrodes, corresponding approximately to the 10–20 international system

(Jasper, 1958). Electrode locations were at Fpz, AF3, AFz, AF4, F7/5/3, FZ, F4/6/8, FC5/3, FCz, FC4/6, T7, C5/3, Cz, C4/6, T8, CP5/3, Cpz, CP4/6, P7/5/3, PZ, P4/6/8, PO3, POz, PO4, O1/2. Electrodes were filled previously with degassed electrolyte. The skin was scratched at each position. After this the electrode was attached using electrode adapters filled with electrolyte and collodion glue (see Bauer et al., 1989). This procedure ensures electrode impedance less than 1 k Ω . Using a photogrammetric 3D scanner (3D-PHD; Bauer et al., 2000), individual three-dimensional coordinates of all electrode locations were measured.

The EEG recordings were referenced to a non-cephalic sterno-vertebral site, above the seventh vertebra and the right manilum sternum (Stephenson and Gibbs, 1951). The vertical EOG (electrodes below and above the right eye) and the horizontal EOG (electrodes at the outer canthi) were recorded bipolarly, so as to compensate for eye movement artefacts after the recordings. All signals were recorded within a frequency range from DC to 95 Hz and sampled at 250 samples/s for digital storage. During the experiment, participants were seated in a comfortable chair in front of an 18-in. TFT monitor in a sound-attenuated and dimmed room, which was equipped with an intercom to the experimenter.

4.4. Procedure

The experiment consisted of a 2 \times 2 factorial design. The factors 'Style' (representational/abstract) and 'Stylistic information' (yes/no) were manipulated within subjects. Due to this within-subjects design all participants were exposed to the experimental conditions which arise from crossing these two independent variables (abstract or representational paintings and with or without information).

The abstract material, for which stylistic information was compiled, was divided randomly into two groups (A1 and A2; see Appendix); the same procedure was applied to the representational material with stylistic information (R1 and R2; see Appendix). Participants were assigned alternately to two groups. One group was shown the paintings of A1 and R1 (i.e., 5 abstract and 5 representational paintings), whereas the other group was shown the paintings of A2 and R2. While the paintings were presented via monitor, the stylistic information appeared on the screen below the artworks for 60 s each. Instructions were given via monitor. Participants were asked to read the given stylistic information carefully and to try to relate the information with the elements of the presented artwork. After this the actual task started. All the participants were shown the remaining 60 paintings (see Appendix), not seen before, in addition to two 'warm-up' items. Each artwork was shown at the beginning in a scrambled version for a variable timeframe from 3 to 7 s. Subsequently each painting was presented for 10 s. After that presentation participants were instructed to rate the artwork on a 7-point scale, by pressing a button of a response box. This way participants rated how much they enjoyed the artwork, how much they were interested in the artwork, how well they understood the artwork, what kind of emotions – negative or positive – the artwork evoked, and to what extent the artwork elicited associations (in correspondence to Millis, 2001). The order in which all the

paintings were presented was randomized for each participant. At the end, participants were given the aforementioned questionnaire to determine their level of expertise in the fine arts.

4.5. Behavioral data

To evaluate the relationship between the independent (style and information) and dependent variables (ratings on the five scales: pleasingness, interest, understanding, emotions, associations) a General Linear Model for repeated measures was applied. For every subject the mean rating was computed within each of the five scales for each interaction (abstract artworks with and without information/representational artworks with and without information). To compensate for violations of the sphericity assumption the degrees of freedom were adjusted using Greenhouse-Geisser epsilon. *P* values <0.05 were considered statistically significant.

4.6. SCP analysis

In a first step, weighted vertical and horizontal EOG signals were subtracted from each EEG channel trial per trial to compensate for eye movement artefacts. Subject- and channel-specific weights separately for the vertical and the horizontal EOG were calculated per EEG channel as the ratio of the covariance of the EEG and the EOG and the variance of the EOG. These weights were determined in two pre-experimental calibration trials in which subjects performed voluntary vertical and horizontal eye movements (Bauer and Lauber, 1979). By visual inspection, trials were excluded if they were judged to contain artefacts. Several SCP studies proved this procedure as appropriate (e.g., Bauer et al., 2003; Lamm et al., 2005).

Artefact-free single trials were selected and averaged separately for each subject using a baseline of 500 ms pre-stimulus, where the relevant stimulus was presented in a scrambled manner, according to the various conditions. That is, data from the artworks presented in the second task relevant phase, from abstract and representational artworks and from artworks presented with or without information. It is well established that higher cognitive processes do occur in a later moment than do mere physiological responses to a stimulus, thus only a timeframe from 1000 to 9250 ms after stimulus presentation was considered for the analysis of the SCP data. Within this timeframe, SCP-amplitude values separately at 40 electrode locations were averaged across 250-ms epochs.

4.7. Low-resolution electromagnetic tomography (LORETA)

Due to the volume conduction properties of the human head, SCP topographies supply only a vague view of the generating activity within the cortex. To determine the neural generators, low-resolution electromagnetic tomography analysis (LORETA; Pascual-Marqui et al., 1994) was applied to the extracted single subject SCP averages, using the LORETA-KEY software package (version 03; R. D. Pascual-Marqui, KEY Institute for Brain-Mind Research, University

Hospital of Psychiatry, Zürich). For the inverse solution, individual electrode coordinates, cross-registered to the Standard Talairach Atlas (Talairach and Tournoux, 1988) were used. The inverse solutions given by LORETA are the smoothest of all possible current density distributions, corresponding to a given scalp potential topography. This solution is constrained on the assumption that neighbouring voxel are similarly activated. Within LORETA, the solution space is restricted to the cortical grey matter and hippocampus, consisting of a totality of 2394 voxel at 7-mm spatial resolution. LORETA makes use of the three-shell spherical head model registered to the Talairach human brain atlas (Talairach and Tournoux, 1988), which is available as a digitised MRI from the Brain Imaging Centre, Montreal Neurologic Institute.

Statistical inferences were based on Statistical non-Parametric Mapping analysis (SnPM; Holmes et al., 1996; Nichols and Holmes, 2002). A pseudo t-statistic for dependent measures was calculated voxel by voxel against 5000 permutations. *P* values <.05 were considered statistically significant. No subject-wise normalization was adopted.

In order to validate individual SCP topographies and LORETA results, the N1 was analysed by visual inspection. N1, one of the first endogenous ERP components, is expected to reflect neural activity in primary and higher order sensory projection areas. Since a visual task was performed by the participants, N1 was defined to as the highest negative SCP amplitude at electrode POz occurring in a timeframe from 100 to 200 ms after stimulus presentation.

Appendix A

Abstract paintings presented with information	Representational paintings presented with information
A1	R1
Mark Rothko: Number 7, 1951	Oswald Oberhuber: Esel, 1982
Bernard Frize: Vick	Jean Dubuffet: Die verlorenen Schritte, 1979
Gerhard Richter: Abstraktes Bild (858–6), 1999	Clemens Kaletsch: Vier Beweise, 1985/86
Antoni Tàpies: Dents, 1988	Maria Lassnig: Illusion von der versäumten
Fiona Rae: Untitled (Phaser), 1996	Mutterschaft, 1998
	Peter Pongratz: Home Town Blues, 1996
A2	R2
Yves Klein: Peinture feu-couleur sans titre (FC 16), 1962	Jean Michel Basquiat: Untitled (Fallen Angel), 1981
Franz Kline: Spagna, 1961	Louis Soutter: Lucifer dans son repos, 1937/42
Jackson Pollock: Number 34, 1949	Franz Ringel: Aufbruch, 1998
Willem de Kooning: Untitled XVII, 1984	A. R. Penck: System-Painting-End, 1969
Emil Schumacher: Paso, 1983	Gary Hume: Jealousy and Passion, 1993

Appendix A (continued)

Abstract paintings presented without information	Representational paintings presented without information
Bernard Frize: Romi	Jean Michel Basquiat: Self-Portrait, 1982
Vony	Untitled (Skull), 1981
Mona	The Death of Michael Stewart, 1983
Yves Klein: Peinture feu-couleur sans titre (FC 3), 1962	Jean Dubuffet: Ferien, 1979
Peinture feu-couleur sans titre (FC 9), 1962	Zeit und Ort, 1979
Peinture feu-couleur sans titre (FC 2), 1962	Guter Spaziergang, 1978
Franz Kline: Palladio, 1961	Gary Hume: Vicious, 1994
Meryon, 1960–1961	Begging for it, 1994
Merce C, 1961	Two Three Leaf Clovers, 1994
Willem de Kooning: Untitled V, 1983	Clemens Kaletsch: Querren, 1985/86
Untitled VII, 1985	Dahinter, 1985/86
Untitled VIII, 1986	Klare Position, 1985/86
Jackson Pollock: Reflection of the Big Dipper, 1947	Maria Lassnig: Profitanskis, 2001
Watery Paths, 1947	Fußballerin, 1998
Enchanted Forest, 1947	Die müde Turnerin, 2000
Fiona Rae: Untitled (Parliament), 1996	Oswald Oberhuber: Ochsen, 1982
Untitled (Yellow with Circles 1), 1996	Knochen, 1982
Untitled (Blue and Purple Triptych), 1994	Tiere, 1982
Gerhard Richter: Abstraktes Bild (858-1), 1999	A. R. Penck: What is Gravitation? III., 1984
Abstraktes Bild (858-4), 1999	The Man, The Woman, The Lion, and the Animals at the Water Hole, 1989
Abstraktes Bild (858-5), 1999	Standart-West III., 1983
Mark Rothko: Number 12, 1951	Peter Pongratz: Kleines weinendes Mädchen, 1994
Untitled, 1954	Kinderspielplatz, 1994
Orange and Yellow, 1956	Versteckspiel, 1995
Emil Schumacher: Fluss, 1983	Franz Ringel: Der Mythos, 1998
Edina V, 1984	Philosophisches, 1998
Scala I, 1987	Traum, 1998
Antoni Tàpies: Cama, 1988	Louis Soutter: L'obus printanier, 1938
Taca De Vernís, 1988	Employées du sang, 1937/1942
Paper Amb Vernís Núm. I, 1988	Soupless, 1939
Warm-up Items: Max Weiler: Naturbild Danae, 1986	
Ernst Trawöger: Untitled, 1986	

Appendix B. Supplementary data

Supplementary data associated with this article can be found, in the online version, at [doi:10.1016/j.brainres.2007.05.001](https://doi.org/10.1016/j.brainres.2007.05.001).

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