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The neural time course of art perception: An ERP study on the processing of style versus content in art

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ABSTRACT

A central prerequisite to understand the phenomenon of art in psychological terms is to investigate the nature of the underlying perceptual and cognitive processes. Building on a study by Augustin, Leder, Hutzler, and Carbon (2008) the current ERP study examined the neural time course of two central aspects of representational art, one of which is closely related to object- and scene perception, the other of which is art-specific: content and style. We adapted a paradigm that has repeatedly been employed in psycholinguistics and that allows one to examine the neural time course of two processes in terms of when sufficient information is available to allow successful classification. Twenty-two participants viewed pictures that systematically varied in style and content and conducted a combined go/nogo dual choice task. The dependent variables of interest were the Lateralised Readiness Potential (LRP) and the N200 effect. Analyses of both measures support the notion that in the processing of art style follows content, with style-related information being available at around 224 ms or between 40 and 94 ms later than content-related information. The paradigm used here offers a promising approach to further explore the time course of art perception, thus helping to unravel the perceptual and cognitive processes that underlie the phenomenon of art and the fascination it exerts.

1. Introduction

1.1. Theoretical background

Many people report that art constitutes an important part of their lives. It inspires and fascinates them. Consequently, the phenomenon of art is not only puzzling to art historians but also to cognitive researchers and neuroscientists, whose interest in the possible sources as well as neural correlates of such fascination has been reflected in a significant number of relatively recent publications that are related to questions of art perception and aesthetics (e.g., Cela-Conde et al., 2004; Chatterjee, 2003; Di Dio, Macaluso, & Rizzolatti, 2007; Jacobsen & Hofel, 2003; Jacobsen, Schubotz, Hofel, & von Cramon, 2006; Leder, Belke, Oeberst, & Augustin, 2004; Muller, Hofel, Brattico, & Jacobsen, 2010; Nadal, Munar, Capo, Rossello, & Cela-Conde, 2008; Ramachandran & Hirstein, 1999; Redies, 2007). A review of many of these contributions was recently provided by Chatterjee (2011).

From a vision scientist's point of view, the central question regarding art is yet even more basic than questions about fascination – but equally unsolved: what is specific about art perception, i.e., what differentiates it from normal object and scene perception? One aspect that has been proposed in this respect is the way by which ambiguities are resolved (Mamassian, 2008) – either with a view to prior constraints ("normal" vision) or by conventions (art). Another important aspect differentiating art perception from normal object and scene perception is the presence and relevance of (artistic) style (Augustin, Leder, Hutzler, & Carbon, 2008). In representational art, content (motif) is closely related to objects and scenes in our surroundings. In contrast, style, the way how something is depicted, is generally of very little relevance in object and scene perception. It might be that we, for instance, have to find our way or recognise an object through fog or a snowstorm, but in such cases most of us would probably regard the fog or snow as random noise in perceptual terms – which hardly anyone would claim with respect to style in art. Rather, style is an essential aspect of an artwork, not only from an art historical point of view but also with

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respect to visual perception and cognition. For example, it has been shown that even people without special expertise in the arts are able to successfully judge the style-related similarity of artworks (Cupchik, Winston, & Herz, 1992), are sensitive to style across different media (Hasenfus, Martindale, & Birnbaum, 1983) and refer to both content and style when asked to judge the similarity of representational artworks (Augustin et al., 2008). By comparing the processing of these two essential perceptual aspects of representational artworks scientists have the opportunity to contrast general processes of vision with art-specific processes, which may yield important knowledge about the vision-related underpinnings of the phenomenon of art.

One central and very basic question with respect to style- and content-related processing is their temporal relation, following the idea that percepts do not exist ex nihilo, but undergo a temporal evolution, a *microgenesis* (Bachmann, 2000). In the literature on object-, face- and scene perception the question of the time course and interrelations of different processes has received noticeable attention in the past few years (e.g., Bacon-Mace, Mace, Fabre-Thorpe, & Thorpe, 2005; Bar, Neta, & Linz, 2006; Carbon & Leder, 2005; Grill-Spector & Kanwisher, 2005; Hegde, 2008; Joubert, Rousselet, Fize, & Fabre-Thorpe, 2007; Joubert, Rousselet, Fabre-Thorpe, & Fize, 2009; Kent & Lamberts, 2006; Rahman, Sommer, & Schweinberger, 2002; Thorpe, Fize, & Marlot, 1996; VanRullen & Thorpe, 2001b). With respect to the time course of the processing of style and content in art, empirical data is much more scarce so far, even though first theoretical approaches have been published (Chatterjee, 2003; Leder et al., 2004) and few empirical studies have generally taken on the question of temporal aspects of art perception (Bachmann & Vipper, 1983; Locher, Krupinski, Mello-Thoms, & Nodine, 2007). Given that we know so little empirically, what assumptions could we derive from current theories? The model of aesthetic appreciation and aesthetic judgments by Leder et al. (2004) proposes that explicit classifications of style and content take place during the same processing stage, with the general probability of classifying in terms of content or style being related to a person's art-related expertise (see also Belke, Leder, Harsanyi, & Carbon, 2010). This view reflects a definition of style in terms of an abstract category that has to be learned in order to be successfully applied and recognised (see also Hartley & Homa, 1981). Given such a view, one could also argue for a sequence of processing with style following content, as the classification of content is presumably far more overlearned in real life than the classification of style, given that classification of objects and scenes is an essential ability for biological and social survival. From a completely different perspective, style can be regarded as a combination of different low level features (Augustin et al., 2008), and recent attempts to characterise particular styles on the basis of low level cues by means of image processing tools seem to be in accord with such a view (e.g., Johnson et al., 2008). Regarding this definition of style, important information on the time course of style- versus content-related processing comes from the literature on the relation of low level information versus object-related information in object and scene perception (e.g., Grill-Spector & Kanwisher, 2005; Marr, 1982; Sanocki, 1993). Yet, this information is not entirely clear either: On the one hand, classical theories of object recognition assume, for instance, that the perception of single features such as colour precedes the perception of the object as such (Marr, 1982). According to *Feature Integration Theory* (FIT) the binding of features to more complex units also requires attention (Treisman & Gelade, 1980). On the other hand there is evidence that processing of some low-level features comes into play relatively late (Yao & Einhauser, 2008), as is for example indicated by evidence showing that visual attention may be guided by complete objects rather than by the early saliency of single features (Einhauser, Spain, & Perona, 2008).

To our knowledge, there is only one experimental study that focused especially on the temporal relation between style- and content-related processing (Augustin et al., 2008). This study assessed similarity judgments for pairs of pictures that were systematically crossed in style (artist) and content (motif), with presentation times systematically varied between 10 ms and 3000 ms. Effects of content could be found from PTs as short as 10 ms on and stayed relatively stable over time. In contrast, effects of style slightly emerged from 50 ms on, with effect sizes increasing steadily over time. These results suggest that the processing of style starts later and develops more slowly than the processing of content. More precisely, they indicate that the information extracted within a presentation time window of 10 ms is enough for content to become a relevant criterion of similarity, while from 50 ms of presentation time on similarity judgments also significantly rely on style. Two characteristics of similarity judgments have to be borne in mind: On the one hand, similarity judgments reflect the relevance of a certain variable rather than the ability to distinguish that variable. Thus, it would theoretically be possible that participants are able to refer to style as early as to content, if they are explicitly asked to focus on both. On the other hand, if people refer to style or content in similarity judgments this does not necessarily mean that they are also able to explicitly classify style and content (see Augustin et al., 2008). Therefore, the time course suggested by the study by Augustin et al. (2008) cannot necessarily be generalised to tasks requiring explicit classification. The current study aimed to fill this gap. It investigated the relative duration of the processing of style and content in terms of when information has processed far enough to allow successful classification of style and content, respectively. To this end, we employed a paradigm that has repeatedly been used in psycholinguistics (Rodriguez-Fornells, Schmitt, Kutas, & Munte, 2002; Schmitt, Munte, & Kutas, 2000; Schmitt, Schiltz, Zaake, Kutas, & Munte, 2001; Zhang & Damian, 2009) to track the timeline of different processes: a combination of a go/nogo- and a dual choice-task with assessment of event related potentials (ERPs). The dependent measures of interest are the *Lateralised Readiness Potential* (LRP) and the *N200 effect*, which are both illustrated in the following sections.

1.2. Methodological background

1.2.1. The Lateralised Readiness Potential (LRP)

The Lateralised Readiness Potential is derived from the *Bereitschaftspotential* (engl. *Readiness Potential*, RP), a negative shift in brain activation preceding voluntary hand- (and also foot-) movements (Kornhuber & Deecke, 1965), with the largest amplitude over the central region contra-lateral to the response limb (Kornhuber & Deecke, 1965; Kutas & Donchin, 1974). While the RP strongly corresponds with the readiness for hand-related motor actions, its lateralised aspect, the LRP, correlates with the preparation of voluntary motor actions of a specific hand, thus allowing to assess not only general but task-related aspects of preparation in a dual choice task (Osman, Coles, Donchin, Bashore, & Meyer, 1992). According to van Turennout, Hagoort, and Brown (1998: 573), the LRP "...has been shown to develop as soon as task-relevant perceptual and cognitive information is available for the motor system..." Importantly, it can not only be observed prior to executed movements, but also occurs when a movement is planned but finally not executed (Osman et al., 1992; van Turennout et al., 1998). These two characteristics make the LRP an excellent tool for studies on the temporal relation of different processes. A paradigm for this purpose was proposed by Osman et al. (1992) and further explicated by van Turennout et al. (1998): the employment of the LRP in a combined dual choice go/nogo task. In such a task, participants have to refer to two different dimensions of the same stimulus at the same time. Dimension A determines whether or not to react at all (*go/nogo*), and Dimension B determines which hand to react with if Dimension A signals a "go" (*hand*). The crucial case regarding the temporal relation of processes are the nogo trials: If Dimension A is processed before Dimension B, no nogo LRP (i.e., no significant divergence of the LRP curve from baseline in nogo trials), should develop, because the decision not to react should precede any decision about response hand. In contrast, if Dimension B is processed before Dimension A, a nogo LRP should be traceable, because response preparation presumably starts before the nogo information from Dimension A comes into play.

This paradigm has been successfully employed to examine the time course of processing for different questions in psycholinguistics (Schmitt et al., 2000, 2001; van Turennout et al., 1998) as well as in face perception (Rahman et al., 2002).

1.2.2. The N200 and the N200 effect

The term N200 or N2 denotes the second negative peak in an averaged ERP waveform (Folstein & van Petten, 2008). One condition under which the N200 has been shown to be especially pronounced is under conditions of response inhibition, such as in so-called go/nogo tasks (Folstein & van Petten, 2008; Schmitt et al., 2000, 2001; Zhang & Damian, 2009). In such tasks, where participants are instructed to react to one kind of stimulus (*go*) and withhold responses to another (*nogo*), nogo trials were shown to be associated with larger negativity than go trials (Pfefferbaum, Ford, Weller, & Kopell, 1985), especially at frontal sites (Folstein & van Petten, 2008).

Subtraction of the *go*- from the *nogo* waveform yields a difference curve known as the *N200 effect* (Schmitt et al., 2000). The N200 effect at frontal sites comprises nogo-specific activation. Thus a common interpretation of this effect is in terms of activation related to the inhibition of inappropriate responses (Falkenstein, Hoormann, & Hohnsbein, 1999; Thorpe et al., 1996), even though alternative interpretations have also been proposed (e.g., Donkers & van Boxtel, 2004). Importantly, this effect can be utilised to estimate processing times: If a person is able to correctly withhold a response in a go/nogo task, this means that she must have analysed the relevant information to a sufficient amount. Of special importance in this respect is the onset of the N200 effect, the point from which on nogo- and go-curve diverge. According to Schmitt et al. (2000: 474), the onset of the N200 effect ". . . can be taken as the time by which there must have been enough information available to help the person decide whether or not to respond". Very prominently this was illustrated by Thorpe et al. (1996), who used a go/nogo-paradigm to examine the speed of processing in scene perception. Participants saw scenes flashed at 20 ms and were required to release a button (*go*) when they saw an animal in the scene, and to keep this button pressed (*nogo*) when there was no animal. There was a significant difference between go- and nogo ERPs at frontal electrodes starting from 152 ms after stimulus onset, which according to Thorpe et al. (1996) indicates that a great deal of processing of relevant information must have been completed before this time.

Unlike the LRP, the N200 effect is not related to motor activity and can be traced earlier than motor-related activity (Thorpe et al., 1996). Its onset has successfully been employed to estimate processing times in psycholinguistics, regarding questions such as processing times for semantic versus phonological encoding in picture naming (Schmitt et al., 2000) or segment versus tone encoding in Chinese spoken word production (Zhang & Damian, 2009). In the present study we utilised the characteristics of the N200 effect to find out more about the time course of style- and content-related processing in art perception by gaining first numerical estimates regarding the respective processing times.

1.3. Rationale of the present study

Following up on the findings by Augustin et al. (2008) the current study examined the time course of the processes underlying successful classification of style and content in artworks. We employed a combination of a go/nogo- and a dual choice task that has been reported in studies of psycholinguistics (Schmitt et al., 2000, 2001; van Turennout et al., 1998) as well as face perception (Rahman et al., 2002), but – to our knowledge – has not been applied to art perception up to now. The paradigm allows to investigate the relative time course of two cognitive processes. The general logic is that participants have to consider two different dimensions of the same stimulus at the same time. For each trial, one stimulus dimension determines whether to react or not to react (*go/nogo*), the other dimension determines which hand to react with (*hand*) – if the go/nogo-dimension signals a "go". In the present study, the two relevant stimulus dimensions were style and content. The two levels of style used consisted of pictures from two artists with very distinct individual styles, Paul Cézanne (*Cézanne*) and Ernst Ludwig Kirchner (*Kirchner*). The two levels of content were operationalized by using pictures of those artists that depicted the motifs *landscape* and *person(s)*, respectively. To make sure that style- and content-related information were comparably salient in the materials used, the stimuli were chosen on the basis of a pre-study. To furthermore ensure that participants in the present study were definitely able to master both the content- and the style-related part of the task, they received a training prior to participating in the main experiment (see Section 2.4).

In the dual choice go/nogo-task the roles of style and content, the roles of the sublevels and the response hands were completely balanced, resulting in 2 (dimension determining the go/nogo-decision) × 2 (level signalling "go") × 2 (meaning of left and right hand) conditions. Fig. 1 illustrates the experimental paradigm by depicting the go/nogo- and hand-logic for one of the experimental conditions.

Inferring from the results by Augustin et al. (2008), we supposed that participants would be able to classify content earlier than style. The two dependent variables we wanted to test this with were the LRP and the N200 effect.

As described above, the crucial conditions regarding the LRP are the nogo conditions, because in the case of go trials the presence of an LRP is self-evident (if there is motor activity there should be motor preparation). A nogo LRP should be visible for those cases in which the information determining the hand decision is processed before the information regarding the go/nogo decision. Thus, we expected a nogo LRP for those conditions in which the hand-decision was about content and the go/nogo decision was about style (*hand = content*). In those cases, the LRP was expected to rise but to flatten out as soon as the style-related information was available. In contrast, no nogo LRP at all was expected for cases in which the hand decision was about style and the go/nogo decision was about content (*hand = style*), because in those cases the information about response inhibition was assumed to be available earlier than information about the response hand.

Table 1 summarises the hypotheses regarding the LRP results. In addition to an analysis of the relative time course of the pro-

Table 1
Summary of hypotheses regarding the LRP (in terms of a significant divergence from baseline) for the two hand conditions, *Hand = Style* and *Hand = Content*.

Trial type	*hand = style*	*hand = content*
go	LRP	LRP
nogo	no LRP	LRP (that flattens out as soon as stylistic information becomes available)

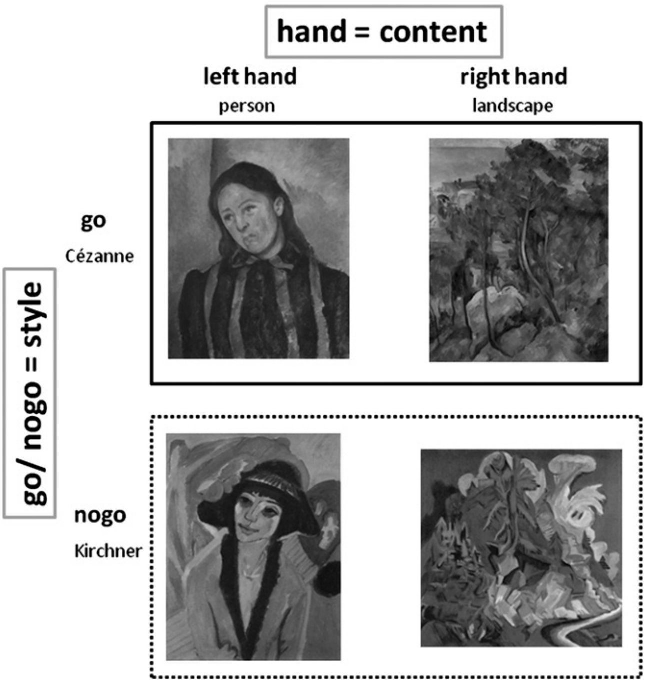

Fig. 1. An example of the *hand* = *content* condition to illustrate the logic of the experimental design. The pictures' style determines the go/nogo decision, their content the hand decision. In the *hand* = *style* condition this relation would be switched. The pictures shown are black and white versions of four examples of stimuli used in the study. In the experiment all pictures were shown as colour versions. From top left to bottom right: Paul Cézanne, *Madame Cézanne aux Cheveux Dénoués*, 1890–1892 (Philadelphia Museum of Art, The Henry P. McIlhenny Collection, http://philamuseum.org); Paul Cézanne, *La Mer à l'Estaque*, 1895–1898 (Staatliche Kunsthalle Karlsruhe); Ernst Ludwig Kirchner, *Bildnis Gerda*, 1914 (Von der Heydt-Museum, Wuppertal); Ernst Ludwig Kirchner, *Der Berg. Der Weg zur Stafel*, 1920 (Ernst Ludwig Kirchner Archiv, Galerie Henze & Ketterer, Wichtrach/Bern).

cessing of style versus content we also aimed to use the LRP data to derive some information about absolute time course, following the analysis by van Turennout et al. (1998). The idea was to statistically compare the go- and the nogo LRP in those cases where style decided over go and nogo to estimate the length of the time interval in which content-related, but no style-related information was available. The relevant time points to estimate the length of this interval were the point from which the go- and nogo LRPs started to diverge from zero and the point from which go- and nogo LRP differed in amplitude, with the go LRP rising further and the nogo LRP returning to baseline.

With regard to the N200 effect (*nogo* minus *go*), we were also interested in numerical estimates regarding the time course of processing, but the logic was slightly different. As explained above, the onset of the N200 effect might be taken as the time point at which enough information is available in order to correctly withhold a response. We aimed to use the onset latencies of the N200 effects to come to first estimates of the processing times required for content- and style-related classifications, respectively. Following the behavioural study by Augustin et al. (2008), the decision to conduct an EEG-study with the paradigm just described was motivated by the fact that this method provides the opportunity to examine the relative time course of different processes with a focus on processing times themselves rather than required stimulus duration (variation of presentation times, as in Augustin et al., 2008). A central advantage of the current method over a behavioural classification–response time paradigm was that confounds by times required for response execution are reduced.

2. Methods

2.1. Participants

Twenty-nine people participated, seven of which had to be excluded due to low recording quality or excessive artefacts (less than 75% of data remaining after artefact correction, see below). The remaining sample of 22 persons (12 men, 10 women) had an age range between 18 and 33 years (mean age 23.2 years). All participants were either students of non-art subjects or graduates who worked in fields that were not art-related. All were right-handed, as tested by the *Edinburgh Handedness Inventory* and had normal or corrected-to-normal vision, as assured by the standard *Snellen Test*. All participants gave informed consent.

2.2. Stimuli

The stimuli were reproductions of 50 paintings by the French Post-Impressionist Paul Cézanne (1839–1906) and 50 paintings by the German Expressionist Ernst Ludwig Kirchner (1880–1938), who represented the two levels of the style dimension in the materials. The content dimension was defined by the two motifs landscape and person/persons. The dimensions *style* and *content* were completely crossed, resulting in 25 pictures per cell (25 Cézanne landscapes, 25 Cézanne persons, 25 Kirchner landscapes, 25 Kirchner persons). We chose works by Cézanne and Kirchner, because additional analyses of data from a previous study (Augustin et al., 2008) had shown their styles to be clearly differentiable, and because both have a very broad oeuvre that includes a relatively large number of paintings with similar motifs. The motifs *landscape* and *person/persons* were chosen because they constitute two classical motifs in painting, and because this also entails a comparatively broad choice of suitable material.

All pictures were high quality reproductions that had been scanned from art books or downloaded from the Internet. Artists' signatures were removed to exclude any external aid regarding style classification. The same was true for small human figures in some of the landscape paintings in order to make the distinction between the two contents as clear-cut as possible. In cases where local retouching was not possible, we used sections of the original artworks. To ensure comparable sizes without changing the original size ratio, all pictures were brought to a size of 140,000 square pixels at a resolution of 72 dpi.

The final set of 100 stimuli was selected from a range of 168 pictures by means of a pre-study that served to select stimuli with a comparable accuracy of classification of both style and content and with low familiarity. This was to ensure that the distinctiveness of style and of content in the materials was comparable and that it was not confounded by familiarity (in terms of very famous examples of the style of one of the artists). In this pre-study, 16 participants classified the 168 pictures in terms of their style and their content (order of blocks balanced between persons), gave ratings of how certain they were about each classification and rated their familiarity with the pictures. In order to ensure that the participants were sufficiently familiar with the styles of Cézanne and Kirchner, they had received a style-training beforehand (for details see Section 2.4). Criteria for inclusion of pictures in the final set were an average familiarity below 20% and an average percentage correct classification of both style and content of at least 90%. Among pictures meeting these criteria we selected the final set on the basis of a combined *z*-score of the two certainty ratings for the style- and the content classification. For each cell of the *style* × *content* matrix, three pictures that met the criteria but whose *z*-values of classification certainty lay just below those of the final set were selected for the practice trials in the main experiment (see below). For the pictures in the final set, the mean percentage correct style classification was 98.19% (*SD* = 2.85), the mean percentage correct content classification 99.69% (*SD* = 1.37). The titles and dates of origin of all works used in the study can be found in the Appendix.

2.3. Apparatus

The training phase was controlled by the experimental software *PsyScope* (Cohen, MacWhinney, Flatt, & Provost, 1993) and run on an Apple iMac Power PC G3 with a 15" monitor with a resolution of 1024 × 768 and a refresh rate of 75 Hz. Stimulus presentation in the EEG experiment was controlled by the experimental software *Presentation* (Neurobehavioral Systems), version 10.3, running on a IBM-compatible PC. Recording of electrophysiological data was done on a separate PC by the software *Portilab2* (TMS International). As response device in the EEG experiment we used a Logitech Precision USB Gamepad. Participants were seated at a distance of about 70 cm from a 19" CRT display Ilyama Vision Master Pro 454 with a resolution of 1280 × 1024 and a refresh rate of 60 Hz.

EEG was recorded from electrode positions *Fz*, *Cz*, *Pz*, *C*3 and *C*4 (see Schmitt et al., 2000, 2001), with a modular elastic cap (Easy Cap, Falk-Minow Systems, Germany) on standard positions according to the 10–20 systems. Signals were digitized by a 32-channel EEG amplifier (Refa 8) by TMS International with an online 0.01–40 Hz Bandpass filter. Scalp electrodes were recorded referentially against linked earlobes (as common reference) with a sampling rate of 512 Hz. To monitor horizontal and vertical eye movements, EOG was recorded bipolarly from the outer canthus of each eye as well as from above and below the right eye, respectively. Impedances for scalp electrodes were kept below 5 kΩ.

Push-button reaction times were measured from picture onset. Based on the mean reaction time for correct responses (809.05 ms, $SD = 158.31$ ms), continuous EEG data was segmented from 100 ms pre-stimulus to 1000 ms post-stimulus. The pre-stimulus interval of 100 ms was chosen for baseline correction (see below). All data were low-pass filtered offline at 30 Hz. Incorrect responses were removed from further analyses. The remaining data were visually inspected and trials with eye- or muscle artefacts eliminated on that basis. The amount of data left after elimination of incorrect and artefact-contaminated trials was 86.08% ($SD = 13.92$).

2.4. Procedure

The procedure comprised four phases: pre-testing, training, EEG experiment and post-tests, which are described in detail in the following.

2.4.1. Pre-testing

After arrival, participants first read and signed the consent form, which informed them about the general procedure of EEG data acquisition and about their rights as a subject. Then they were tested for handedness via the *Edinburgh Handedness Test* and for their vision abilities via the standard *Snellen Test*.

2.4.2. Training

The training phase consisted of two parts: in the first part, the participants were familiarised with works by Cézanne and Kirchner that showed different motifs than those used in the study and allowed direct comparisons between the two styles. This part, that had already been used in the pre-study (see above), served to help the participants form general concepts of the two styles that were independent of particular paintings. For each of the two artists we used nine paintings that depicted three motifs: house, still life and nude. First, each individual painting was shown with the name of the artist above. Which style was learned first was balanced across participants. Then the participants saw paintings of the two artists with the same motif side by side, with the first-learned style always being shown on the left side. The trials were randomised. In this part, presentation times were unlimited.

In the second part of the training phase, the participants saw all 112 pictures to be used in EEG experiment (the 100 pictures for the main trials plus the 12 stimuli for the practice trials) in random order. Each picture appeared for 4 s, a duration which has been shown to be well above presentation times needed for the processing of both style- and content-related information (Augustin et al., 2008; Leder, Carbon, & Ripsas, 2006). Above each picture the information about style and content was displayed. Whether style or content was mentioned first, was balanced between participants. This second part of the training served to ensure that the participants would be able to apply their acquired knowledge about the styles of Cézanne and Kirchner as well as their general knowledge from object and scene perception to the actual stimuli used in the study.

2.4.3. EEG experiment

As further described in Section 1.3, there were 2 (dimension determining the go/nogo decision) × 2 (level signalling "Go") × 2 (meaning of left and right hand) different blocks in the EEG experiment. For each participant, the order of these blocks was pseudo-randomised beforehand, resulting in a different order of blocks for each participant. The blocks were separated by self-paced breaks.

Each block started with a written instruction. A visual illustration of the task followed: a picture of the gamepad, with signs representing the go- and the nogo-conditions of that block and the meaning of the two buttons of the gamepad illustrated. Then all 12 (practice) + 100 (test) pictures were presented in random order, with the pictures for the practice trials shown first. The practice trials were not explicitly named as such and were immediately followed by the main trials, but were excluded from analysis later on.

Each trial started with a fixation cross shown for 150 ms, followed by a randomised interval of 250–350 ms length. Then the stimulus appeared for 2000 ms, followed by a screen indicating allowance for eye blinks. Fig. 2 illustrates the trial structure. Basis for the choice of a presentation time of 2000 ms was the mean reaction time for classifications of style and content in the pre-study (2079.40 ms). In addition, for the sake of data quality we aimed to avoid excessive eye-artefacts, the probability of which increases with presentation time.

2.4.4. Post tests

After completing the EEG experiment the participants saw the 100 test pictures again in random order and indicated whether they would have known any of the paintings before participating in the experiment (dichotomous criterion: known/unknown). Finally they filled in a questionnaire regarding their interest and education in art and art history.

The EEG experiment itself took about 1.5 h. Together with pre-testing, mounting of electrodes and calibration as well as post tests every participant spent between 2.5 and 3 h in the lab.

3. Results

3.1. Behavioural results

On average, the participants indicated that they would have known only 4.18% ($SD = 5.72\%$) of the pictures before participating in the study. This cross-validates our stimulus selection for low familiarity (see above), indicating that influences of prior knowledge of the materials themselves were relatively unlikely for the given material. All following analyses exclusively concentrated on the behavioural and EEG results of the dual choice go/nogo task.

The mean RT for correct go responses was 809.05 ms ($SD = 158.31$ ms), with 818.35 ms ($SD = 174.54$ ms) in the *hand = content* conditions and 800.87 ms ($SD = 148.18$ ms) in the *hand = style* conditions. The two response conditions did not differ significantly in response time, $t(21) = 1.30$, *n.s.* The same was true with respect to percent correct rates: mean percentage correct was 97.98% ($SD = 2.49\%$), 97.31% ($SD = 4.22\%$) in the *hand = content* conditions, and 98.65% ($SD = 1.34\%$) in the *hand = style* conditions, $t(21) = 1.66$, *n.s.*

3.2. LRP analyses

LRPs were calculated from the mean amplitude relative to pre stimulus baseline at positions $C3$ and $C4$, following the formula: $(C3 - C4)_{right\ hand} - (C3 - C4)_{left\ hand}$ (van Turennout, Hagoort, & Brown, 1997). As a first step, we individually checked for every participant whether a go LRP was generally observable, irrespectively of response condition, as the existence of a traceable go LRP can be seen as a prerequisite for the analysis of nogo LRPs (e.g., Schmitt et al., 2001). Four participants did not show a general go LRP and were thus excluded from all further LRP-related analyses. For each of the remaining 18 participants, we calculated four LRPs: (1) *hand = style, go = content*, (2) *hand = style, nogo = content*, (3) *hand = content, go = style* and (4) *hand = content, nogo = style*. Fig. 3a shows the go- and nogo LRPs for the two response conditions *hand = style* and *hand = content*, averaged over 18 participants.

As can be seen, we obtained no *nogo* LRP in the condition *hand = style*, while a small, but visible nogo LRP could be found in the condition *hand = content*. The statistical analyses support these

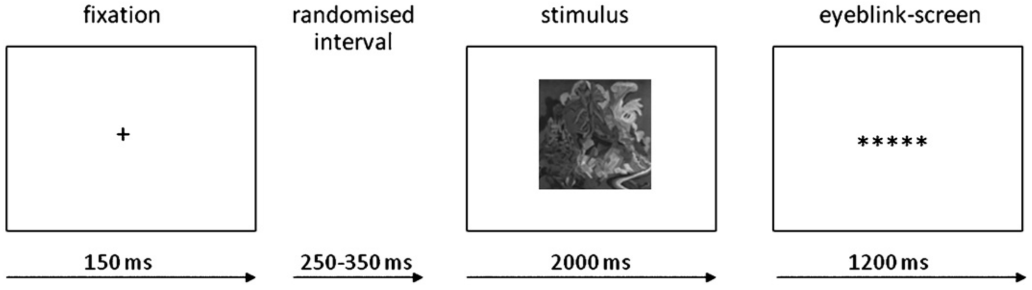

Fig. 2. An illustration of the trial structure.

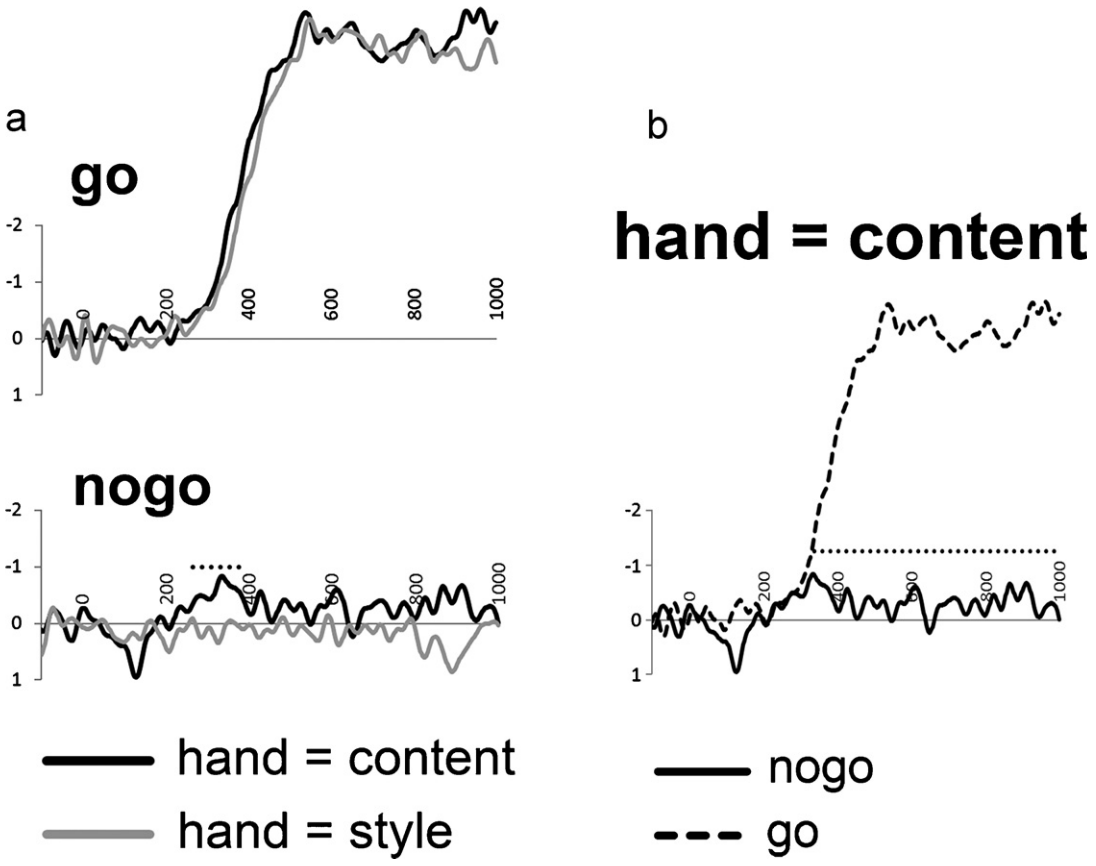

Fig. 3. (a) Grand average LRPs ($n = 18$) on go- and nogo trials in the two dual choice conditions, *hand = content* and *hand = style*. LRPs were calculated from the mean amplitude relative to pre stimulus baseline at positions *C*3 and *C*4. The *x*-axes represent the time relative to picture onset, the *y*-axes plot activation in μV, with negative voltage plotted up. The dashed line over the nogo LRPs in the bottom graph indicates the period for which the nogo LRP in the condition *hand = content* diverges from baseline. (b) Grand averages ($n = 18$) of go- versus nogo LRPs for the condition *hand = content*, calculated from the mean amplitude relative to pre stimulus baseline at positions *C*3 and *C*4. The *x*-axes represent the time relative to picture onset, the *y*-axes plot activation in μV, with negative voltage plotted up. The dashed horizontal line in the graph indicates the period during which the two LRPs differ significantly from each other.

observations: We conducted one-tailed serial *t*-tests against zero in the time window 200–800 ms after stimulus onset, with a step size of 1.95 ms and a moving average window size of 39.08 ms (approx. ±20 ms around each time point). Onset latency was defined as the point from which eight consecutive *t*-tests' *p*-values were all below the significance level of 0.05, adapting the criterion used by Schmitt et al. (2001) to a smaller step size. There was a significant nogo LRP in the condition *hand = content* between 265.36 and 384.55 ms after stimulus onset. In contrast, the mean amplitude for nogo trials in the condition *hand = style* ranged between 0.005 and 0.371 μV and never even reached a negative value. For a direct comparison between the two nogo conditions we also conducted a paired *t*-test with the mean amplitude between 200 and 800 ms post-stimulus as dependent variable. The difference in mean amplitude between the two nogo-conditions was significant, $t(17) = 1.91$, $p < .05$. For the go LRPs the onset latencies were 245.83 ms for the condition *hand = content* and 279.04 ms for the condition *hand = style*, respectively. A statistical comparison of the two go LRPs by a serial paired sample *t*-test yielded no significant differences.

Following the logic presented by van Turennout et al. (1998), we statistically compared the go- and the nogo LRP for the condition in which style determined the go/nogo decision (*hand = content*) in order to derive an estimate of the length of the time interval in which content-related, but no style-related information was available. The idea behind this was that the go- and nogo LRP should develop in a comparable way – until the style-related information comes in for nogo trials. We compared the two LRPs via repeated measures one-tailed serial *t*-tests in the time window between 200 and 800 ms after stimulus onset. For each data point (step size 1.95 ms) we averaged 39.08 ms (approx. ±20 ms) of data. The go- and nogo LRP diverged significantly from 339.61 ms on. Given that both LRPs developed from ∼246 or ∼265 ms on, respectively, this analysis suggests that the length of the time interval in which content-related but no style-related information is available lies between ∼74 and ∼94 ms. Fig. 3b plots the go- and nogo LRP for the condition *hand = content* against each other. A dashed horizontal line indicates where the two LRPs differ significantly.

3.3. Analysis of the N200 effect

With respect to the N200 effect we conducted analyses for *Fz*, *Cz* and *Pz*. Our main interest was focused on *Fz*, as an N200 in relation to phenomena of cognitive control has mostly been localised at frontal sites (Folstein & van Petten, 2008). For both response conditions we calculated the grand average ERPs relative to pre-stimulus baseline for go- and nogo trials separately as well as the difference curve nogo minus go, the N200 effect. This difference is supposed to reflect the nogo-specific activation and can thus render information about the timing of inhibition processes. Fig. 4 shows the grand average ERPs for go- and nogo trials for both response conditions on all three electrodes and the respective difference curves.

Following the logic of the analyses presented by Thorpe et al. (1996), we traced the onset of the N200 effects for the conditions *hand = style* and *hand = content* by conducting serial *t*-tests against zero starting from 100 ms after stimulus onset. As in the LRP analyses (see above), step size was 1.95 ms with data referring to time

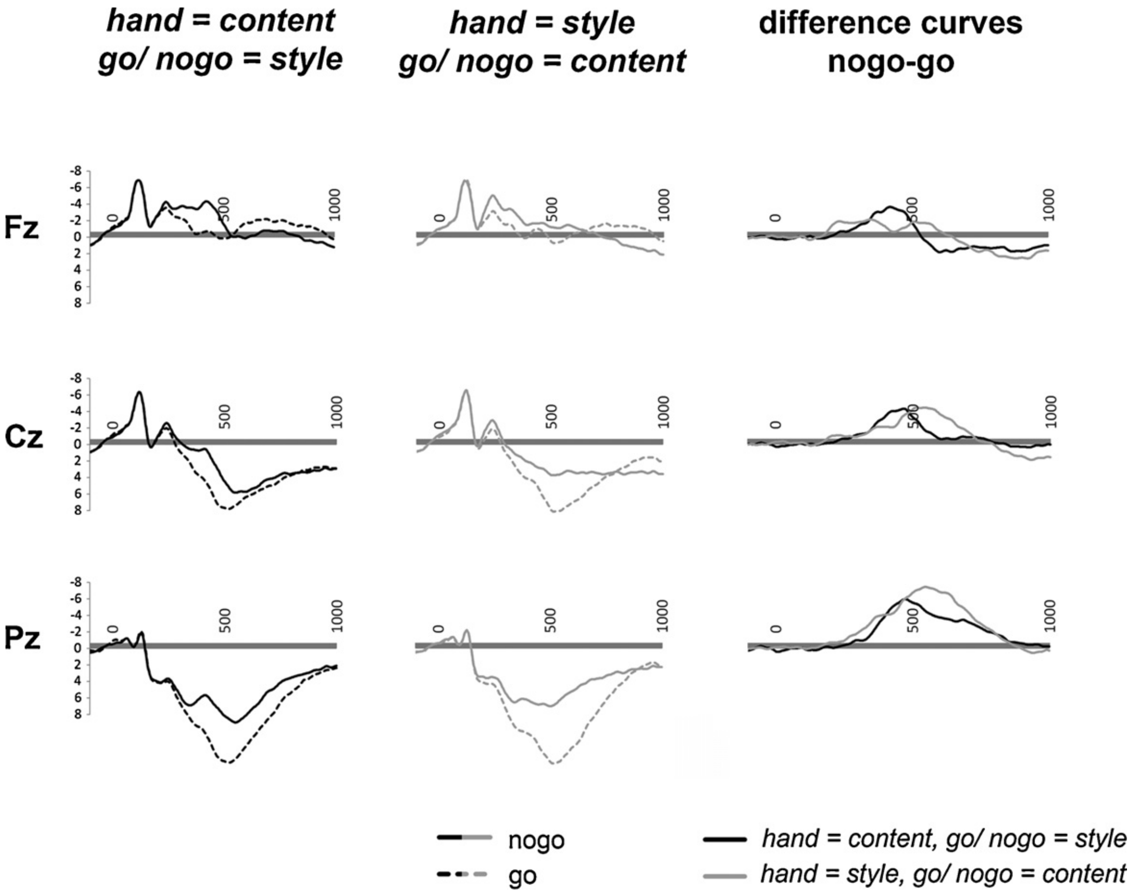

Fig. 4. Grand average ERPs ($n = 22$) for go and nogo trials for the two dual choice conditions *hand = content*, *go/nogo = style* and *hand = style*, *go/nogo = content* at the three electrode sites *Fz*, *Cz* and *Pz*. The right column illustrates the results regarding the N200 effect: Each graph plots the difference waves nogo–go for the two dual choice conditions. The *x*-axes represent the time relative to picture onset, the *y*-axes plot activation in μV, with negative voltage plotted up.

windows of 39.08 ms. The criterion for defining onset was that *p*-values of 15 consecutive *t*-tests were below the significance level of 0.05 (see Thorpe et al., 1996). On the basis of this criterion, the onset of the N200 effect in the condition *hand = style* (i.e. when a reaction to content was to be held back) could be traced at *Fz* from 183.30 ms onwards. The respective value for both *Cz* also detected at 183.30 ms, for *Pz* at 179.40 ms. In the condition *hand = content* (i.e. when a reaction to style had to be held back) the onset at *Fz* lay later, at 224.33 ms (236.06 ms for *Cz*, 263.41 ms for *Pz*).

4. Discussion

The current study aimed to investigate the neural time course of the processing of style and content in representational art, using materials that systematically varied in style (artist) and content (motif). Following up on the behavioural study by Augustin et al. (2008), we were interested in finding out about the relative duration of style- and content-related processing in terms of when processing would have proceeded far enough to allow successful classification. Could we find evidence that this occurs later in the case of style? And would that be the case although – in contrast to the similarity task used by Augustin et al. – participants in our task were explicitly instructed to focus on both content and style? To investigate these questions we employed a paradigm that has repeatedly been used to analyse the time course of processes in psycholinguistics (Schmitt et al., 2001; van Turennout et al., 1998; Zhang & Damian, 2009): a combination of a dual choice with a go/nogo paradigm with assessment of LRP and N200 effect. For our purpose, the advantage of this paradigm over a simple reaction time study was that it allows to study the time course of the two processes irrespective of motor execution times and furthermore, with a view to the results presented by Thorpe et al. (1996), allows the numerical estimation of the processing times themselves.

The behavioural parameters, i.e., both percent correct rates and response times for the go-trials, did not reveal any differences between the two response conditions (*hand = style* and *hand = content*). This is in line with results from other studies which used the same paradigm (Schmitt et al., 2000, 2001) and can probably at least partially be attributed to the nature of the dual choice go/nogo task. On the other hand, it illustrates that behavioural measures alone might not always be sufficient to unravel the details of the time course of processing, as becomes clear when inspecting the LRP results.

The results of the LRP analyses support the assumption suggested by Augustin et al. (2008), namely that in art perception the processing of content precedes the processing of style. More precisely, Augustin et al. (2008) proposed that the processing of content starts earlier and develops more quickly than the processing of style, based on the fact that less visual information (in terms of presentation time) was required for similarity judgments to rely on content than to rely on style. Continuing on this issue, the current study now provides evidence on the question of when the processing of style and content have proceeded far enough to allow successful classification. According to our data, processing reaches this point earlier in the case of content than in the case of style. We infer this from the fact that we found neural correlates of response preparation for content-based responses even when the stylistic information present in a picture signalled the participants to withhold their responses. In contrast, no such preparation-related activation was visible for style-based decisions, when it was the content-related information that determined to hold back responses. This suggests that people are ready to classify content before they are ready to classify style. In comparison to the results of Augustin et al. (2008) the results provide evidence that the relation of style following content can not only be found for implicit measures like similarity, where participants are not obliged to refer to style, but also when explicit judgments about both style and content are required. Therefore, the differences in time course cannot be explained by mere differences in relevance of content versus style but seem to be due to differences in availability of the respective information.

How can the results be explained and what do they imply? One possible explanation for the finding of style following content relates to the aspect of evolutionary significance and the resulting amount of training and task familiarity, respectively: the processing and classification of content is extremely overlearned due to the outstanding relevance of object classification in different aspects of humans' everyday lives – be it orientation in space or face recognition, to name but two of many possible examples. The speed of object classification and classification-related processing observed in a number of different studies (Li, VanRullen, Koch, & Perona, 2002; Thorpe et al., 1996; VanRullen & Thorpe, 2001a) has even brought scientists to assume that it may possibly rely on feed-forward, automatic processes (VanRullen & Thorpe, 2001a). In contrast to content, style is a visual aspect that many people are hardly ever confronted with in their everyday lives, unless they deliberately get engaged with art or design. Thus, the evolutionary relevance is much less obvious than in the case of content, and the advantage of content over style with respect to onset and relative duration of processing may therefore at least partly be due to an optimisation of the visual system for object- and scene perception (e.g., Parraga, Troscianko, & Tolhurst, 2000).

As to our understanding of style as a psychological phenomenon, the results, in our view, are in favour of the hypothesis that style is acquired and processed as an abstract category (see e.g., Hartley & Homa, 1981) rather than as a combination of different low level features. This interpretation is based on the assumption that what is generally referred to as low-, mid- and high-level vision (for a relation to art see e.g., Chatterjee, 2003) corresponds to relatively hierarchical temporal relations. If style, in this view, could be distinguished on the basis of single features alone or following mid-level feature binding, it should be classified earlier than content. We found the opposite, namely that classifying style is even slower than classifying content. This speaks for the assumption that the classification of style involves some kind of higher level processing – the exact nature of which certainly remains to be disclosed. There have been successful attempts in the past few years to analyse particular artists' styles with respect to image statistics (e.g., Graham, Friedenberg, Rockmore, & Field, 2010) and create models that may even be able to differentiate forgeries from originals (Hughes, Graham, & Rockmore, 2010; Johnson et al., 2008), but it is in question to what extent the higher level processing that humans express in their categorisations can be modelled on the basis of low level features. For example, Wallraven et al. (2009) presented results according to which single low level features like luminance or amplitude spectrum correlated surprisingly low with human classification behaviour. The assumption that classification of style is based on top-down knowledge is also shared by the model of aesthetic appreciation and aesthetic judgments by Leder et al. (2004). Yet, the model assumes that classification of style and content take place during the same processing stage, labelled *explicit classification*. Adding to the results by Augustin et al. (2008) the findings of the current study suggest that this assumption of the model might have to be reformulated, e.g., by subdividing *explicit classification* into smaller sub-stages, one related to content and one to style.

Regarding numerical estimates of processing times and temporal relations, we conducted two different kinds of analyses: analyses of the N200 effect and further comparisons of the LRP data. The N200 effect comprises nogo-specific activation in tasks where people have to respond to one stimulus and withhold responses to another. This effect is especially pronounced at frontal sides (Folstein & van Petten, 2008; Thorpe et al., 1996). One interpretation of the effect is in terms of a correlate of inhibition of inappropriate responses (Thorpe et al., 1996). As successful inhibition requires the relevant information to have been analysed to a sufficient amount, the onset of the effect may be taken as an estimate of the time point at which enough information was available to respond correctly (Schmitt et al., 2000). In our case, the onset of the N200 effect could be traced at approx. 183 ms for go/nogo-decisions about content, while it was traceable at approx. 224 ms for go/nogo-decisions about style. The logic of the use of the LRP for numerical estimations was slightly different, given that the LRP does not refer to the question when information is analysed generally but when it is used to prepare motor reactions. A statistical comparison of the go- and the nogo LRPs in those cases where the go/nogo decision was about style (i.e., in which a nogo LRP is traceable) was supposed to yield an estimate of how long it takes before style-related information comes into play after content-related information is already available for the motor system. As go- and nogo LRP start to rise at about 245 and 265 ms, respectively, and diverged from 340 ms on, the results suggest a delay between 74 and 94 ms.

How can such numerical estimates of processing times be interpreted and how do they relate to existing literature? The seminal study by Thorpe et al. (1996) stated that about 150 ms may be sufficient to process the visual information required to decide whether a scene contains an animal or not. If we compare our results from the N200 effect-analysis to this finding, we find an effect of content only slightly later in time: the nogo-specific activation for content significantly differed from zero from 183 ms on. Given the slightly more complex nature of the task as compared to the study by Thorpe et al., i.e., differentiation between two different contents (landscape or person) rather than a simple decision "animal – yes or no?", the numerical estimate for the duration of content-related processing seems to fit in with the result reported by Thorpe et al. (1996). As to processing of style, the onset of the N200 effect in our study could be traced slightly later, namely from 224 ms on. This suggests that about 224 ms of processing time may be sufficient for people in order to successfully be able to classify style. If one uses these absolute values determined separately for style and content as an estimate of the relative time course, they suggest that processing of style may take only about 40 ms longer than the processing of content. The results of the LRP analysis inspired by van Turennout et al. (1998) render a slightly different estimate, namely that the processing of style comes in between 74 and 94 ms after the processing of content has already been accomplished. One important reason for the differences in estimations within our study is probably the fact that they were derived from different methodological approaches and measures – one assessing activations related to motor preparations (LRP) and allowing direct comparisons between the conditions, the other being unrelated to any motor activity (N200 effect) and involving an indirect comparison of values. On the other hand, they illustrate that all values reported can certainly only be seen as rough preliminary estimates – especially as the number of electrode used for measuring the N200 was very limited. Additional studies are needed that, for example, investigate the N200 effect at different frontal sites and that assess speed of processing of style versus content in a mere go/nogo paradigm without additional dual choice demands.

Apart from these technical aspects, there are some more general things that have to be borne in mind when interpreting the current study, and in our view two are of special importance.

First of all, the results must certainly be interpreted with a view to the stimulus materials used. Although the results of the pre-study suggest that we succeeded in making the saliency of style and content relatively comparable (see above), it may certainly be possible to find materials for which the style dimension is even more salient than the content dimension, such as male and female portraits by cubist and impressionist painters. To examine relative processing times for such cases will be a crucial test to find out how far-reaching and generalisable the results are.

The second important issue concerns the participants' background knowledge. Many articles on art perception and aesthetics (e.g., Augustin & Leder, 2006; Belke et al., 2010; Cupchik & Gebotys, 1988; Hekkert & vanWieringen, 1996; Leder et al., 2004; Wiesmann & Ishai, 2010) assume a high relevance of art-related expertise for the classification and evaluation of artworks, especially in the context of the processing of style. In order to find out whether the time course of art perception proposed here is a relatively general phenomenon or to what extent it depends on expertise, future studies with carefully selected samples of art-experts and non-experts are needed.

As Chatterjee puts it, these are still the "early days in neuroaesthetics" (2011: 60), and this is also true for our understanding of the time course of processing of style and content in art. The current study provides one further step in this direction, but to unveil the different facets of this time course, a number of systematic additional studies with a variety of paradigms are required. As stated in Section 1, the relevance of style-specific information is probably one of the aspects that differentiates art perception from normal object and scene perception. In this light our results also lend further empirical support to the common idea that art perception is special – and it seems to be special not only in terms of the pleasures it might give us, but also in terms of its processing demands.

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Appendix A.

Table A1

Table A1
List of paintings used in the experiment.

Artist	Motif	Title	Year
Cézanne, Paul (1839–1906)	Landscape	Auvers, Vue Panoramique	1874
		Bassin et Lavoir du Jas de Bouffan	1880–1890
		Château de Médan	1879–1881
		Clairière	1895
		La Route en Provence	1890–1892
		La Chaîne de l'Etoile avec le Pilon du Roi	1878
		La Maison abandonnée	1878–1879
		La Maison Lézardée	1892–1894
		La Mer à L'Estaque	1895–1898
		La Mer à L'Estaque	1876
		La Montagne Sainte-Victoire, vue de Bellevue	1882–1885
		L'Aqueduc du Canal de Verdon au Nord d'Aix-en-Provence	1883
		Le Golfe de Marseille, vu de L'Estaque	1886–1890
		Le Pigeonnier de Bellevue	1889–1890
		L'Estaque aux Toits Rouges	1883–1885
		Les Peupliers	1879–1882
		Le Viaduc à L'Estaque	1883
		Maison au Toit Rouge. Le Jas de Bouffan	1887
		Maison devant la Saint-Victoire près de Gardanne	1886–1890
		Maison en Provence – La Vallée de Riaux près de L'Estaque	1879–1882
		Moulin sur la Couleuvre, a Pontoise	1881
		Paysage à Auvers sur Oise	1881
		Paysage aux Peupliers	About 1888
		Route Tournante en Provence	1867–1868
		Les Rives de la Marne	1888
	Person	Cézanne au Chapeau Melon (Esquisse)	1885–1886
		Esquisse d'un Portrait du Fils de l'Artiste	1883–1885
		Hortense Fiquet en Robe Rayée	1883–1885
		Jeune Homme à la Tête de Mort (section)	1896–1898
		Jeune Italienne Accoudé – Arlésienne	1900
		L'enfant au Chapeau de Paille	1896
		Le Paysan	1891
		L'Homme au Bonnet de Coton (L'Oncle Dominique)	1865
		Louis-Auguste Cézanne, Père de l'Artiste, Lisant L'Evénement	1866
		Madame Cézanne Assise	1893–1894
		Madame Cézanne au Fauteuil Jaune	1888–1890
		Madame Cézanne Cousant	1877
		Madame Cézanne aux Cheveux Dénoués	1890–1892
		Paul Alexis Lisant à Émile Zola	1869–1870
		Portrait d'Ambroise Vollard	1899

Table A1 (*Continued*)

Artist	Motif	Title	Year
		Portrait d'Antony Valabrègue	About 1866
		Portrait de Fillette	1868 (1896)
		Portrait de l'Artiste au Fond Turquoise-vert	1885
		Portrait de Louis-Auguste Cézanne. Père de l'Artiste	1865
		Portrait de l'Artiste au Béret	1898–1900
		Portrait de Paul Cézanne, Fils de l'Artiste, au Chapeau	1888–1890
		Portrait de Paysan Assis	1898–1900
		Portrait de Victor Choquet (retouched)	1876–1877
		Portrait Gustave Boyer (section)	1870–1871
		Portrait Madame Cézanne	1883–1885
	Practice trials	Arbres au Jas de Bouffan	1875–1876
		La Route Tournante	1881
		L'Estaque Effet du Soir	1870–1871
		Le Jardinier	1885
		Paysan Assis	1902–1904
		Portrait de Peintre Alfred Hauge	1899
Kirchner, Ernst Ludwig (1880–1938)	Landscape	Alphütte (retouched)	1919
		Bahnhof Davos (section)	1925
		Baumgrenze	1918
		Bergwald (retouched)	1918–1920
		Die Brücke bei Wiesen	1926
		Bündner Landschaft mit Sonnenstrahlen (retouched)	1937
		Burg auf Fehmarn	1912
		Davos im Winter. Davos im Schnee (retouched)	1923
		Davos mit Kirche. Davos im Sommer (retouched)	1925
		Der Berg. Der Weg zur Stafel	1920
		Der blaue Baum. Bergwald	1920–1922
		Der Junkerboden von der Stafel aus (section)	1919–1920
		Die Berge Weissfluh und Schafgrind (retouched)	1921
		Dorf Monstein bei Davos (retouched)	1927
		Dünen auf Fehmarn (retouched)	1912
		Frauenkirch im Winter (section)	1918–1919
		Gut Staberhof, Fehmarn I (retouched)	1913
		Kummeralp	1920
		Mondaufgang auf der Stafelalp (section)	1917
		Rotes Elisabethufer, Berlin (section)	1912
		Stafelalp im Schnee (section)	1917
		Tinzenhorn. Zügenschlucht bei Monstein	1919–1920
		Unser Haus. Unser Haus in den Wiesen (retouched)	1920–1922
		Wildboden im Schnee (retouched)	1924
		Wintermondlandschaft (retouched)	1919
	Person	Artistin – Marcella	1910
		Bauernmittag	1920
		Bildnis-Gerda	1914
		Der Maler, Selbstportrait	1919–1920
		Der Maler Stirner mit Katze	1919
		Der Trinker	1914–1915
		Erna am Meer (retouched/section)	1913
		Erna mit Japanschirm	1913
		Fränzi Fehrmann	1910–1920
		Frauenbildnis (retouched)	1911
		Frauenkopf Gerda	1914
		Graef und Freund (retouched)	1914
		Grüne Dame im Gartencafe, Erna Schilling (retouched)	1912
		Holländer Maler im Atelier – Jan Wiegers	1924–1926
		Mädchen im Föhn (section)	1919
		Max Liebermann in seinem Atelier (section)	1926
		Pantomime Reimann (Die Rache der Tänzerin) (retouched)	1912
		Portrait des Dichters Guttmann (retouched)	1911
		Portrait Dr. Alfred Döblin (retouched)	1912
		Porträt Nele van de Velde (section)	1918–1919
		Russisches Tanzpaar	1926
		Selbstbildnis mit Mädchen	1914
		Sitzende Dame (Erna Kirchner)	1926
		Sitzende Frau mit Holzplastik (retouched)	1912
		Toilette; Frau vor Spiegel (retouched)	1913–1920
	Practice trials	Seewald (section)	1913
		Sertigtal im Herbst (section)	1925–1926
		Stafelalp bei Mondschein	1919
		Der Trinker	1914–1915
		Mandolinistin	1921
		Zwei Mädchen. Midinetten	1911–before 1924

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