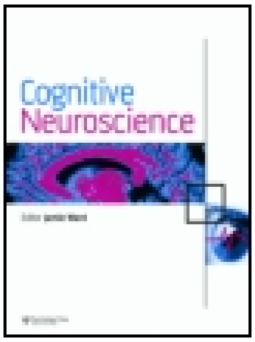

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A TMS study on the contribution of visual area V5 to the perception of implied motion in art and its appreciation

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Abstract

Over the last decade, researchers have sought to understand the brain mechanisms involved in the appreciation of art. Previous studies reported an increased activity in sensory processing regions for artworks that participants find more appealing. Here we investigated the intriguing possibility that activity in cortical area V5—a region in the occipital cortex mediating physical and implied motion detection—is related not only to the generation of a sense of motion from visual cues used in artworks, but also to the appreciation of those artworks. Art-naïve participants viewed a series of paintings and quickly judged whether or not the paintings conveyed a sense of motion, and whether or not they liked them. Triple-pulse TMS applied over V5 while viewing the paintings significantly decreased the perceived sense of motion, and also significantly reduced liking of abstract (but not representational) paintings. Our data demonstrate that V5 is involved in extracting motion information even when the objects whose motion is implied are pictorial representations (as opposed to photographs or film frames), and even in the absence of any figurative content. Moreover, our study suggests that, in the case of untrained people, V5 activity plays a causal role in the appreciation of abstract but not of representational art.

Keywords: neuroaesthetics; painting; motion; implied motion; V5; TMS

Introduction

Static images can contain cues conveying information about objects' direction and speed, such as dynamic balance, stroboscopic effects, forward lean, blurring, or action lines (Cutting, 2002). In such cases, motion is implied in form. These form cues contribute to enhance, or even create, the perception of motion (e.g., Krekelberg, Vatakis, & Kourtzi, 2005; Pavan, Cuturi, Maniglia, Casco, & Campana, 2013; Ross, Badcock, & Hayes, 2000). Deriving a sense of motion from form cues is the basis for understanding action photography, graphics, flow charts, and narrative illustrations (Cohn & Maher, 2015). It is in the visual arts, however, that form cues are used most often, systematically, and successfully to create a sense of motion. Artists have exploited visual form resources to convey a sense of motion from static depictions in painting and sculpture for centuries (Gombrich, 1964). The use of form to convey a sense of motion in art reached its peak in the early twentieth century, when some groups of artists developed novel means to reflect the remarkable dynamism and speed that characterized their time. The Futurist Manifesto explicitly declared that "... the splendor of the world has been enriched by a new beauty: the beauty of speed." (Martinetti, 1908, p. 286). The representational content of the images was still present, but only as an embodiment of motion, seeking to capture "the dynamic sensation itself" (Boccioni, Carrà, Russolo, Balla, & Severini, 1910, p. 289). Figure 1A illustrates the use of stroboscopic effects to convey the sensation of movement of a dog walking. Similarly, abstract action painting represents another paradigmatic example of the use of formal features in art to create a sense of motion in the viewer, even in the absence of recognizable objects (Figure 1B). Indeed, in abstract action painting, developed towards the mid twentieth century by some of the American Abstract Expressionists, the canvas became "an arena in which to act" (Rosenberg, 1952), rather than a place to produce (or reproduce) an object.

[Please insert Figure 1 about here]

Over the last decade, researchers have sought to understand the brain mechanisms involved in the appreciation of art (Chatterjee, 2011, 2014; Chatterjee & Vartanian, 2014; Freedberg & Gallese, 2007; Ishizu & Zeki, 2011, 2013; Nadal, 2013; Nadal & Pearce, 2011). The picture emerging from this line of research is that of a complex interaction between neural systems involved in sensory, affective, and semantic processing (Chatterjee & Vartanian, 2014; Freedberg & Gallese, 2007; Nadal, 2013; Ticini et al., 2014). Consistent neuroimaging results show an increased activity in sensory processing regions for artworks and other visual stimuli that people find more appealing. For instance, Vartanian and Goel (2004) asked participants to evaluate their preference for representational and abstract paintings on a 0-4 scale. Their fMRI results showed that activity in bilateral occipital gyri, left cingulate sulcus, and bilateral fusiform gyri increased together with preference (see also Cupchik, Vartanian, Crawley, & Mikulis, 2009; Lacey et al., 2011). In another fMRI study, Zeki and Stutters (2012) asked participants to rate their preference for kinetic dot patterns. They observed that preferred configurations produced stronger activity in visual areas V5, V3A/B and in the parietal cortex. The functional significance of this enhanced activity in sensory brain regions during aesthetic appreciation is probably related to an increased orientation towards the perceptual features people find appealing (Cupchik et al., 2009; Nadal, 2013). Similar findings have also been reported in studies on the appreciation of dance (Calvo-Merino, Jola, Glaser, & Haggard, 2008; Cross, Kirsch, Ticini, & Schütz-Bosbach, 2011) and music (Koelsch, Fritz, von Cramon, Müller, & Friederici, 2006). In line with these neuroimaging results, brain stimulation studies have shown that transcranial magnetic stimulation (TMS) reduces the appreciation of dance when applied over the extrastriate body area (Calvo-Merino, Urgesi, Orgs, Aglioti, & Haggard, 2010), and reduces the appreciation of representational paintings—though not abstract ones—when applied over the lateral occipital area (Cattaneo et al., 2015).

Converging evidence from neuroimaging and brain stimulation studies shows that area V5 in the occipito-temporal cortex plays a key role in the computation and cognitive representation of the direction and speed of moving objects (e.g. Beckers & Zeki, 1995; Zeki et al., 1991; for reviews, see Born & Bradley, 2005; Zeki, 2015). The representation of *implied* motion also relies on neural activity in V5 (e.g., Fawcett, Hillerbrand, & Singh, 2007; Kourtzi & Kanwisher, 2000; Krekelberg et al., 2005; Lorteije et al., 2006; Proverbio, Riva, & Zani, 2009; Senior, Ward, & David, 2002). In particular, in implied motion processing V5 is thought to be involved in the integration of top-down object categorization and knowledge with low-level form cues to provide a unified perception of the motion of objects (e.g., Kourtzi & Kanwisher, 2000; Lorteije et al., 2006).

In this study we were interested in investigating the intriguing possibility that V5 activity is related not only to the generation of a sense of motion from visual cues used in artworks (Kim & Blake, 2007; Thakral, Moo, & Slotnick, 2012), but also to the appreciation of those artworks. To this aim, we presented art-naïve participants with a series of (unfamiliar) paintings and asked them to express whether or not the paintings conveyed a sense of motion, and whether or not they liked them, while TMS was simultaneously applied either over Vertex (control condition) or over V5. We expected TMS over V5 to cause a reduction in participants' perception of motion in the paintings. As noted above, aesthetic appreciation is accompanied by enhanced activity in sensory brain regions (Cupchik et al., 2009; Lacey et al., 2011; Vartanian & Goel, 2004; Zeki and Stutters, 2012). In line with such evidence, it is conceivable that, by encoding the sense of motion, V5 also contributes to the appreciation of art. Therefore, if the strength with which motion is perceived is related to art appreciation, then interfering with motion detection should also result into a reduction in the liking of artworks. However, in a prior fMRI study Thakral et al. (2012) found that activity in V5 tracked motion but not pleasantness when participants viewed representational paintings. Hence, the extent to which sensory regions are involved in the aesthetic process seems to depend on the kind of stimuli. Indeed, previous studies suggest that different cognitive and neural mechanisms mediate laypeople's aesthetic appreciation of representational and abstract artworks (e.g., Cattaneo et al., 2015; Pihko et al., 2011). In particular, when viewing abstract art, more attention is allocated to the low-level features (i.e., motion, colors, or orientation; Cupchik et al., 2009, Nadal, 2013). Thus, the aesthetic appreciation of abstract art seems to be closely related to activity in sensory brain regions. If this is the case, TMS over V5 can be expected to reduce the experience of motion for both abstract and representational paintings, but reduce liking only—or mainly—for abstract paintings. Hence, although implied motion can be elicited by both figurative and abstract artworks, interfering with motion detection may affect appreciation of representational and abstract art to a different extent. To examine this possibility, in our experiment we used both representational and abstract paintings.

Method

Participants

Thirty-six neurologically healthy Italian students (10 males, mean age: 23.3 yrs, SD: 2.8 yrs) with no previous training or special interest in art, assessed with a brief screening questionnaire (Brieber, Nadal, Leder, & Rosenberg, 2014; Brieber, Leder, & Nadal, 2015), participated in the study. All participants were right-handed (Oldfield, 1971), and were naive to the purpose of the study. They all had normal or corrected-to-normal vision, and normal color vision. Prior to the experiment, each participant filled out a questionnaire (translated from Rossi et al., 2011) to evaluate any contraindications related to the use of TMS. Written informed consent was obtained from all participants before the experiment was conducted. The protocol was approved by the local ethical committee, and participants were treated in accordance with the Declaration of Helsinki.

Material

Stimuli consisted of 80 representational paintings and 80 abstract paintings taken from a large set of reproductions of paintings from the 18th to the 21st century, covering a wide range in the extent to which they conveyed a sense of motion (i.e., from quite stationary to very dynamic; see Figure 2 for examples). Representational paintings contained examples of varied representational content, such as still lives, landscapes, and genre painting, and from varied styles, including—but not limited to—classic and contemporary realism, impressionism, and futurism. Abstract artworks exemplified different manifestations of abstract painting, including geometrical abstraction, neoplasticism, lyrical abstraction, abstract expressionism, and action painting. Although they were the work of renowned artists, this set included only relatively unknown pieces, in line with previous research (Cattaneo et al., 2014a,b; Cela-Conde et al., 2004, 2009). In a pilot study, 18 right-handed participants (9 males, mean age=24.0 yrs, SD=2.16), with no previous training or practice in art and not taking part in the TMS experiment, rated on a 1-7 Likert scale the sense of motion conveyed by each painting (1= "very stationary"; 7= "very dynamic") and their liking for each painting (1= "I do not like it at all"; 7= "I like it very much"). The order of Motion and Liking task was counterbalanced across participants; abstract and representational paintings were presented blockwise, in random order and viewed at a self-paced rate. Pearson correlation (two-tailed) analysis indicated that the more a painting was perceived as dynamic the more it was liked, this being the case for both representational paintings, $r(78)=.433$, $p<.001$, and abstract paintings, $r(78)=.829$, $p<.001$.

Procedure

The experiment was conducted in a normally lit and silent room. Participants were seated in front of a 17'' PC screen (1280*800 pixels) at an approximate distance of 57 cm, and asked to perform a computerized rating task. The experiment consisted of two task conditions: a motion rating task and a liking rating task. Each task was consecutively performed twice, once for each TMS site (see below). Figure 2 shows the timeline of an experimental trial. Each trial started with a fixation cross presented for 2500 ms on a white background. This was followed by a 250 ms white screen after which a painting (subtending approximately 10 x 10 degrees of visual angle) was presented in the central field of view. In the sense of motion task, participants were instructed to indicate, as fast as possible, whether they got a sense of motion from the painting or not. In the liking task, they were asked to indicate whether they liked the painting or not. In both cases participants used left/right key pressing with their right index and middle finger. Response key assignment for yes/no responses was counterbalanced across participants. After the response, a new trial started. In each TMS block, 80 paintings were presented (all representational or abstract, depending on the art condition group, see below). Within each TMS block, stimuli were presented in random order. There was a short break (2–3 min) between blocks. Order of tasks (Motion and Liking) and order of TMS site stimulation (V5 and Vertex) was counterbalanced across participants. The order of TMS site stimulation was kept the same for each participant for the two experimental tasks. Participants were randomly assigned to two different groups: one group only viewed representational paintings, and one group only viewed abstract paintings .

[Please insert Figure 2 about here]

Transcranial Magnetic Stimulation

TMS was delivered using a Magstim Rapid2 stimulator (Magstim Co Ltd, Whitland, UK) connected to a 70mm butterfly coil at a fixed intensity of 60% of the maximum stimulator output. A fixed intensity was used in accordance with previous studies reporting disrupting effects of V5 TMS on motion perception at this stimulation intensity (e.g., Muggleton, Juan, Cowey, & Walsh, 2003; Silvanto, Lavie, & Walsh, 2005; Campana et al., 2006; Cattaneo & Silvanto, 2008). V5 was localized as the point situated 3 cm dorsal and 5 cm lateral to the inion, as in previous studies (e.g., Beckers & Zeki, 1995; Ellison et al., 2003; Grossman et al., 2005; Senior et al., 2002; Silvanto et al., 2005). The coil was held tangential to the skull with the handle oriented parallel to the horizontal plane and pointing towards the occiput, and hence adjusted for each participant in order to minimize discomfort. We stimulated the left hemisphere, as done by many other studies (Antal, Kincses, Nitsche, & Paulus, 2003; Beckers & Homberg, 1992; Koivisto et al., 2010; Silvanto & Cattaneo, 2010; Silvanto et al., 2005; Stewart, Battelli, Walsh, & Cowey, 1999). Vertex was used as a control site for nonspecific effects of TMS caused by noise and tactile sensations. The Vertex was localized as a midpoint between the inion and the nasion and equidistant from the left and right intertrachial notches. For the Vertex the coil was oriented tangentially to the scalp parallel to the nasion-inion line. Three TMS pulses were delivered at 10 Hz (pulse gap of 100 ms) 100 ms after the onset of each painting. This timing of stimulation was chosen on the basis of previous electrophysiological evidence showing that implied motion (i.e., motion in pictures) detection activates V5 100 ms later than real motion (see Loterije et al., 2006). Short 10 Hz pulse trains are standard protocols for interfering with activity in the targeted brain regions, inducing virtual lesions (e.g., Bona, Cattaneo, & Silvanto, 2015; Cattaneo, Mattavelli, Papagno, Herbert, & Silvanto, 2011; Pitcher, Walsh, Yovel, & Duchaine, 2007). Moreover, triple-pulse 10 Hz TMS allows to cover an early time window in which a first aesthetic impression is likely to be formed, as evidenced by prior converging evidence (e.g., Cattaneo et al., 2014a,b; Cela-Conde et al., 2009; De Tommaso et al., 2008; Jacobsen & Hofel, 2003; Sbriscia-Fioretti, Berchio, Freedber, Gallese, & Umiltà, 2013; Wang, Huang, Ma, & Li, 2012).

Prior to the experiment, short practice blocks (with stimuli different to those used in the experiment) were performed in order to familiarize participants with the task and sensations generated by TMS pulses. The software E-prime 2.0 (Psychology Software Tools, Pittsburgh, PA) was used for stimuli presentation, data collection and TMS triggering. The whole experiment lasted approximately 75 minutes. None of the participants reported phosphene detection during the experiment.

Results

Percentage of yes/no responses and mean response times were recorded for both the Motion and Liking task. Figure 3 shows the mean percentage of paintings judged as dynamic in the Motion task and the mean percentage of paintings liked in the Liking task, for participants judging representational paintings and for those judging abstract artworks.

[Please insert Figure 3 and Table 1 about here]

A mixed repeated-measures ANOVA with TMS site (V5 vs. Vertex), Task (Motion vs. Liking) as within-subjects variables and Art-Group (Representational vs. Abstract) as between subjects variable was performed on the percentage of “yes” responses . The analysis revealed a significant TMS site × Task ×Art- Group three way-interaction, $F(1,34)=4.38$, $p=.044$, $\eta^2_p=.11$ (see Table 1 for complete statistical output). The significant three-way interaction was further investigated in each group by a repeated-measures ANOVA with Task and TMS site as within-subjects variable.

For the Representational art group, the ANOVA showed no significant main effects of either Task, $F(1,17)=1.2$, $p=.33$ $\eta^2_p=.06$, or TMS site, $F(1,17)<1$, $p=.87$, $\eta^2_p=.002$. The TMS × Task interaction was significant, *F*(1,17)=6.19, *p*=.024, η^2_p =.27. Post-hoc comparisons showed that TMS over V5 reduced the number of paintings perceived as dynamic compared to the Vertex condition, *t*(17)=2.70, *p*=.030 (Bonferroni-Holm correction applied). In turn, TMS did not affect the Liking task, *t*(17)=1.46, *p*=.32.

For the Abstract art group, a similar analysis revealed a significant main effect of Task, *F*(1,17)=6.61, *p*=.02, η^2_p =.28, indicating that the number of paintings perceived as dynamic was higher than the number of paintings liked. The main effect of TMS was significant, *F*(1,17)=17.86, *p*=.001, η^2_p =.51, whereas the interaction Task × TMS was not, *F*(1,17)=3.13, *p*=.71, η^2_p =.01. Overall, for the Abstract art group, TMS over V5 reduced the number of "yes" responses irrespective of the task, that is to say, it reduced both the number of abstract paintings perceived as dynamic and the number of abstract paintings liked.

Mean response times are shown in Figure 4. A mixed repeated-measures ANOVA with TMS site (V5 vs. Vertex), Task (Motion vs. Liking) as within-subjects variables and Group (Representational vs. Abstract) as between-subjects variable performed on the mean response times revealed a significant main effect of Task, *F*(1,34)=10.34, *p*=.002, η^2_p =.24, indicating that it took overall longer to participants to decide whether they liked a painting (mean response time=824 ms) rather than deciding whether the painting was dynamic or not (mean=764 ms). The main effect of TMS was not significant, *F*(1,34)=1.16, *p*=.29, η^2_p =.03, nor was the main effect of Art-Group, *F*(1,34)<1, *p*=.485, η^2_p =.01. None of the interactions reached significance: Task × Art-Group (*p*=.97), TMS × Art-Group (*p*=.49), Task × TMS (*p*=.57), Task × TMS by Art-Group (*p*=.52).

[Please insert Figure 4 about here]

Discussion

We presented participants with a series of abstract and representational paintings varying in the range of the dynamism they express and we asked them to indicate whether they found the image dynamic or not and whether they liked it or not, while interfering with activity in motion-sensitive region V5 via triple-pulse TMS. V5 TMS caused a significant reduction in the sense of motion participants perceived in artworks, both representational and abstract. Moreover, V5 TMS significantly reduced liking of abstract paintings, but it did not affect liking of representational paintings, even though a pilot experiment showed that liking of both representational and abstract paintings positively correlated with the extent to which paintings were perceived as dynamic, in line with prior evidence (Massaro et al., 2012; Valentine, 1962). Overall, participants took longer to decide whether they liked a painting or not than do decide about whether they found the painting dynamic. TMS did not affect response latencies.

The selective effect of V5 stimulation on liking for abstract paintings discourage an interpretation of our results in terms of TMS affecting response bias (i.e., TMS did not make participants less willing to respond “yes” regardless of task requirements). In turn, our results fit well with previous TMS evidence showing that the same cortical regions mediating perception of physical motion also mediate processing of implied motion (e.g., Urgesi et al., 2006; Senior et al., 2002; but see Alford, van Donkelaar, Dassonville, & Marrocco, 2007). In particular, our data add to prior (correlational) neuroimaging evidence (e.g., Kim & Blake, 2007; Thakral et al., 2012) demonstrating that V5 is *causally* involved in the representation of movement based on form features depicted in paintings. Moreover, given that the abstract paintings we used lack any representation of discernable objects and are constituted solely of formal features, such as color, line, stroke, composition and texture, our results suggest that V5 activity is causally related to the perception of motion even in the absence of real objects, that is to say, based solely on formal cues.

The TMS effects we observed on liking of abstract art are in accordance with Zeki and Stutters’ (2012) finding that patterns of moving dots that were preferred by participants elicited greater activity in V5 than those patterns that were least preferred (but see Thakral et al., 2012). Indeed, as abstract art is devoid of any physical form, it is likely closely related to sensory neural processes (i.e., motion perception). Prior studies showed increased activity in sensory brain regions also when viewing representational paintings liked by the viewer (e.g., Lacey et al., 2011; Vartanian & Goel, 2004) as well as other figurative stimuli, such as dance movements (e.g., Calvo-Merino et al., 2008). However, representational art is defined by the physical form/content and therefore the aesthetic experience (i.e., pleasantness) is likely tied to a relatively more conceptual as opposed to sensory neural process (cf., Thakral et al., 2012). Accordingly, modulating activity in prefrontal cortices, tied to more conceptual processing, affected aesthetic appreciation of representational artworks in prior studies (Cattaneo et al., 2014a,b), whereas it would be unlikely to affect sensory judgments, such as motion detection.

The increase in sensory activity in aesthetic appreciation is believed to reflect an orientation towards the perceptual features people find appealing in the stimuli (Cupchik et al., 2009; Nadal, 2013), as also suggested by brain stimulation studies demonstrating that interfering with activity in these regions modulates aesthetic appreciation (Calvo-Merino et al., 2010; Cazzato, Mele, & Urgesi, 2014). Indeed, naive viewers tend to look at art searching for recognizable objects they can associate with stored knowledge, under the (naive) belief that understanding the artwork equates to understanding the depicted scene (Cupchik & Gebotys, 1988). Content-related features, such as familiarity or affective valence, therefore, take precedence over the artwork's formal features, and the way the medium heightens its expressiveness, and other aspects that are central to art experts' approach of art (Cupchik & Gebotys, 1988; Nodine, Locher, & Krupinski, 1993; Winston & Cupchik, 1992). Abstract art, by definition, represents no recognizable objects, so liking can only be based on formal features, some of which constitute cues for motion. Because in abstract art the contribution of form to liking is not overshadowed by the contribution of content, it stands to reason that the effects of interfering with formal features should be larger than for representational art. This notwithstanding the importance that the dynamism perceived in a representational painting has in driving its aesthetic appreciation, as demonstrated by our pilot study and by prior evidence (Massaro et al., 2012; Valentine, 1962).

Finally, in considering our results, it is important to acknowledge that V5 was localized in our participants relying on craniometric coordinates, without further adjusting the coil position on the basis of phosphenes appearance (Campana et al., 2011, 2013) and without relying on neuronavigation. However, the finding that TMS over V5 reduced motion perception indicates that V5 was successfully targeted.

To conclude, our study demonstrates that V5 is causally involved in the use of form cues to represent motion information even when the objects whose motion is implied are not real, but pictorial representations (as opposed to photographs or film frames), and even in the absence of any representation, as in the case of abstract art, where only formal features are present. Moreover, our study shows that TMS over V5 causes a reduction in liking for abstract painting in laypeople, suggesting that aesthetic experience of art (at least, for the abstract art we considered) is directly related with activity in sensory regions.

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Figure 1. A) *Dynamism of a Dog on a Leash*. Giacomo Balla, 1912. Free from copyright at *http://www.wikiart.org/* . B) *Untitled (Abstraction No. 3).* Earle M. Pilgrim, 1964. Free from copyright at *https://commons.wikimedia.org/*

A

B

Figure 2. A) Upper panel, from left to right: example of a representational painting mostly perceived as dynamic (*The Cyclist*. Natalia Goncharova, 1913) and of a representational painting conveying little sense of motion (*Salisbury Cathedral from Lower Marsh Close*. John Constable, 1820). Lower panel, from left to right: example of an abstract painting mostly perceived as dynamic (*Red Rayonism*. Mikhail Larionov, 1913) and of an abstract painting mostly perceived as static (*Suprematism, 18th Construction.* Kazimir Malevich, 1915). B) Example of an experimental trial. In each trial a painting was presented in the middle of the screen and participants had to indicate as fast as possible whether they perceived the image as dynamic or not (sense of motion task) or whether they liked it or not (liking task). The painting shown in this figure is *Le Comte Alphonse de Toulouse Lautrec Conduisant un Attelage à Quatre Chevaux*, by Henri de Toulouse-Lautrec, 1881. All paintings shown in this Figure are free from copyright at <u>*http://commons.wikimedia.org/*</u> and/or <u>*http://www.wikiart.org/*).</u>

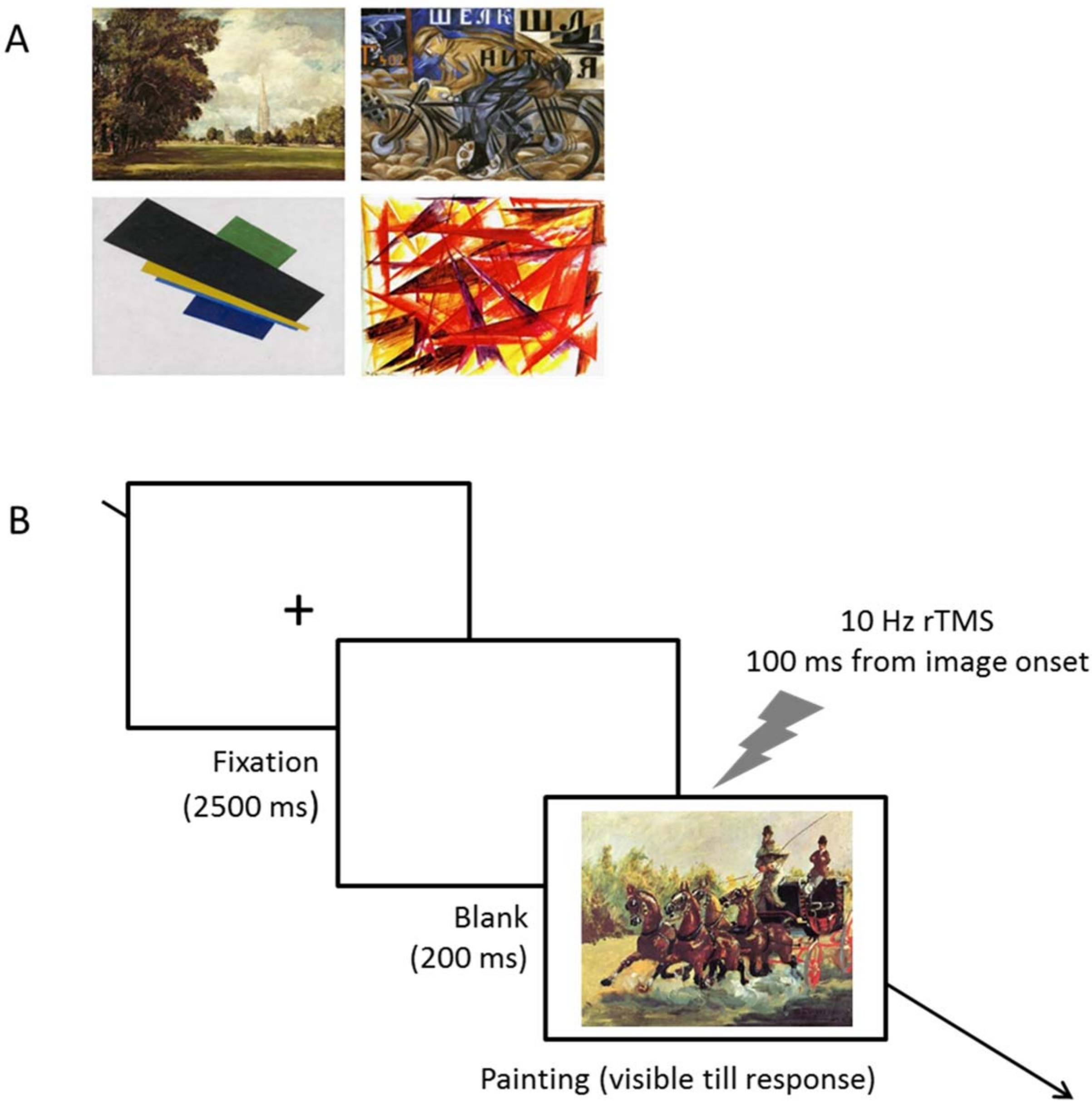

Figure 3. Frequency histograms for “I find this dynamic” (Motion task) and “I like it” (Liking task) responses as a function of Art-style (half participants viewed abstract paintings and half representational paintings). TMS over V5 reduced the number of paintings perceived as dynamic irrespective of art style. In turn, TMS over V5 selectively reduced appreciation for abstract artworks. Error bars depict ± 1 SEM.

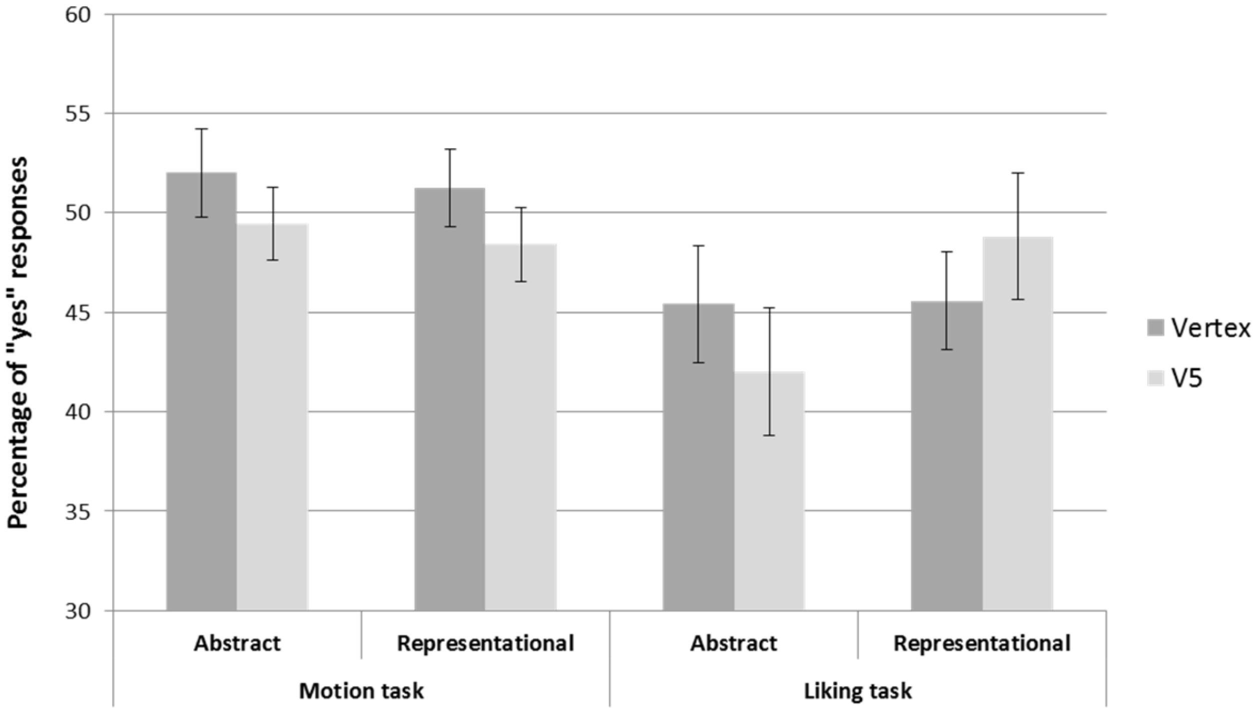

Figure 4. Participants' mean response latencies (msec) in deciding whether they found a painting dynamic (Motion task) and whether they liked a painting or not (Liking task) as a function of art style (representational vs. abstract). Participants were overall slower in deciding whether they liked a painting rather than deciding whether the painting was dynamic or not. TMS did not affect response latencies. Error bars depict ± 1 SEM.

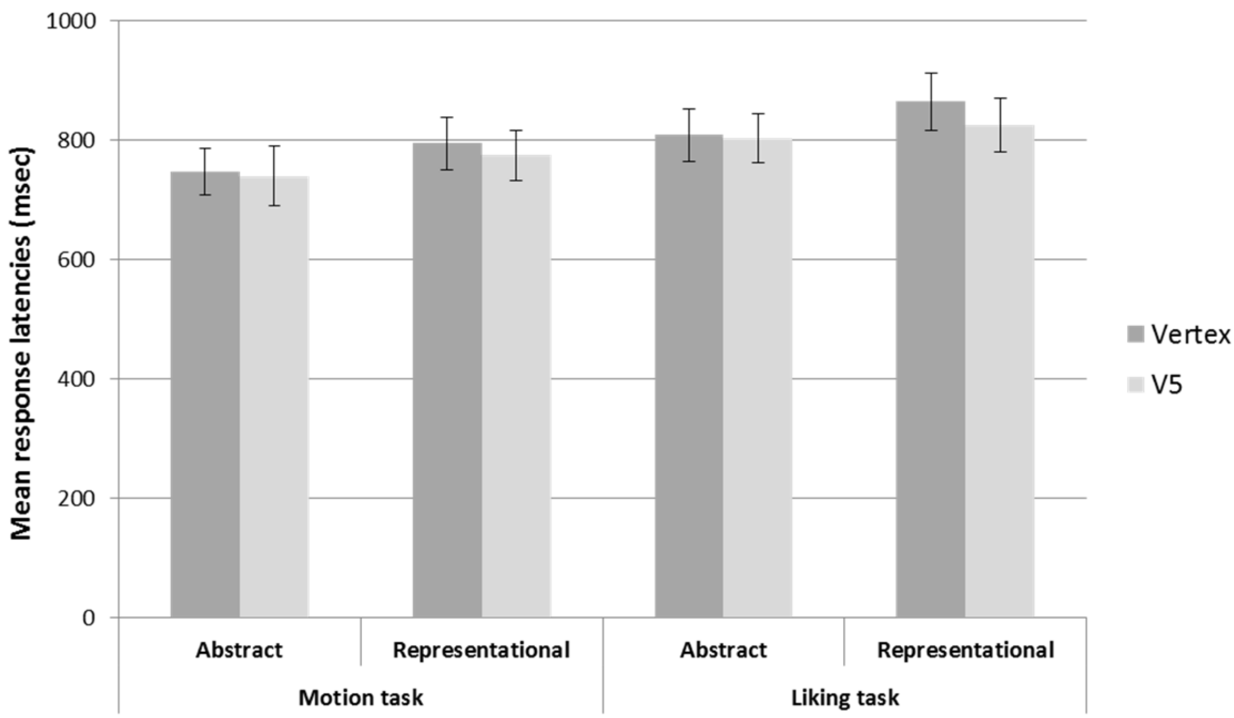

Table 1.

Output of the ANOVA on the percentage of “yes” responses with TMS site (V5 vs. Vertex), Task (Motion vs. Liking) as within-subjects variables and Art-Group (Representational vs. Abstract) as between subjects variables.

Effect	*df*	*F*	*p*
TMS	(1, 34)	3.79	.06
Art group	(1, 34)	.21	.65
Task	(1, 34)	6.54	.015
TMS by Art group	(1, 34)	5.01	.032
Task by Art group	(1, 34)	1.34	.25
TMS by Task	(1, 34)	2.53	.12
TMS by Task by Art group	(1, 34)	4.38	.044