A neural mechanism for aesthetic experience

Preston P. Thakral[a], Lauren R. Moo[b] and Scott D. Slotnick[a]

Aesthetic experience associated with viewing art has been hypothesized to depend on both low-level sensory processing and high-level conceptual processing. To test these hypotheses, we used functional MRI to evaluate the magnitude of activity in sensory motion processing region MT+ and in the prefrontal cortex while participants viewed van Gogh paintings that evoked a range of motion experience. In support of the sensory hypothesis of aesthetic experience and the conceptual hypothesis of aesthetic experience, MT+ activity was correlated to the degree of motion experience (but not the experience of pleasantness) and activity in the right anterior prefrontal cortex was associated with the experience of pleasantness (but not motion experience). These findings provide a neural mechanism for aesthetic experience that depends on sensory processing and conceptual processing. The techniques employed in the current study will serve as a framework for future studies to investigate the neural basis of aesthetic experience associated with other visual and nonvisual art forms such as sculpture, architecture, or music. *NeuroReport* 23:310–313 © 2012 Wolters Kluwer Health | Lippincott Williams & Wilkins.

NeuroReport 2012, **23**:310–313

Keywords: art, functional magnetic resonance imaging, motion, MT+, prefrontal cortex

[a]Department of Psychology, Boston College, Chestnut Hill, Massachusetts, USA and [b]Department of Neurology, Massachusetts General Hospital, Boston, Massachusetts, USA

Correspondence to Preston P. Thakral, BA, Department of Psychology, Boston College, McGuinn Hall, Chestnut Hill, Massachusetts 02467, USA
Tel: +1 617 552 9248; fax: +1 617 552 0523; e-mail: thakralp@bc.edu

Received 23 December 2011 **accepted** 12 January 2012

Introduction

When viewing a piece of art, such as a painting or a sculpture, one can have the experience that it is beautiful. This aesthetic experience has been hypothesized to intimately depend on visual sensory details in the art [1], such as the wavy lines and colors that constitute the modern painting *Stairway at Auvers* by van Gogh (Fig. 1a, bottom; [2]). It has also been hypothesized that aesthetic experience depends on concepts or thoughts associated with viewing art to a greater degree than visual sensory details [3], such as a contemporary sculpture *Brillo Soap Pads Box* by Andy Warhol [4] that is nearly identical – perceptually – to those that were once found on supermarket shelves.

Brain-based evidence has provided some support for both the sensory hypothesis of aesthetic experience [5] and the conceptual hypothesis of aesthetic experience [6]. That is, increasing preference for paintings has been correlated with systematically greater activity in occipital brain regions [7] that mediate visual sensory processing, and pictures of art or true-life photographs (e.g., landscapes or objects) that were classified as beautifully produced activity in prefrontal brain regions [8] that mediate conceptual processing. However, previous studies that have investigated the neural basis of aesthetic experience have not disentangled low-level visual sensory processing and high-level conceptual processing.

In the present study, to provide a more complete neural mechanism of aesthetic experience, participants viewed modern paintings and we separately evaluated sensory effects and conceptual effects in the brain. The sensory analysis capitalized on the fact that each visual feature, such as color or motion, is preferentially processed in a particular cortical region [9]. Specifically, we used functional MRI (fMRI) to measure the magnitude of activity in visual sensory motion processing region MT+ and in the prefrontal cortex while participants viewed van Gogh paintings that evoked a range of motion experience (Fig. 1a; [10]).

Methods

The experimental protocol was approved by the Massachusetts General Hospital Institutional Review Board. Sixteen participants with normal or corrected-to-normal vision took part in the study. During fMRI, participants viewed 20 van Gogh paintings and classified each painting as either pleasant or unpleasant, a measure of the aesthetic (Supplemental digital content 1, *http://links.lww.com/WNR/A184*, Fig. 1, shows all the paintings). Paintings ranged in size from 5.7 to 13.8° by 2.1° of visual angle. All of the paintings were presented at fixation for 4–8 s and then were repeated (there was a 4-s fixation period at the end of the run). Participants were instructed to maintain central fixation and make a pleasant or an unpleasant judgment using their left index and middle finger, respectively, such that there was an approximately equal number of each response type. All images were acquired with a Siemens Trio 3 T scanner (Erlangen, Germany). Functional images were acquired using an echo-planar imaging sequence (TR = 2 s, TE = 30 ms, 64 × 64 acquisition matrix, 33 slices, no gap, 4 mm isotropic resolution). Anatomic

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Website (*www.neuroreport.com*).

0959-4965 © 2012 Wolters Kluwer Health | Lippincott Williams & Wilkins DOI: 10.1097/WNR.0b013e328351759f

images were acquired using a magnetization-prepared rapid gradient echo sequence ($1.33 \times 1 \times 1$ mm resolution). Analysis was conducted using BrainVoyager QX (Brain Innovation, Maastricht, the Netherlands). Participants also completed a functional run to localize sensory motion processing region MT+ [11] in which dots alternated every 14 s between moving from the outer edge of the screen toward the fixation point and remaining stationary.

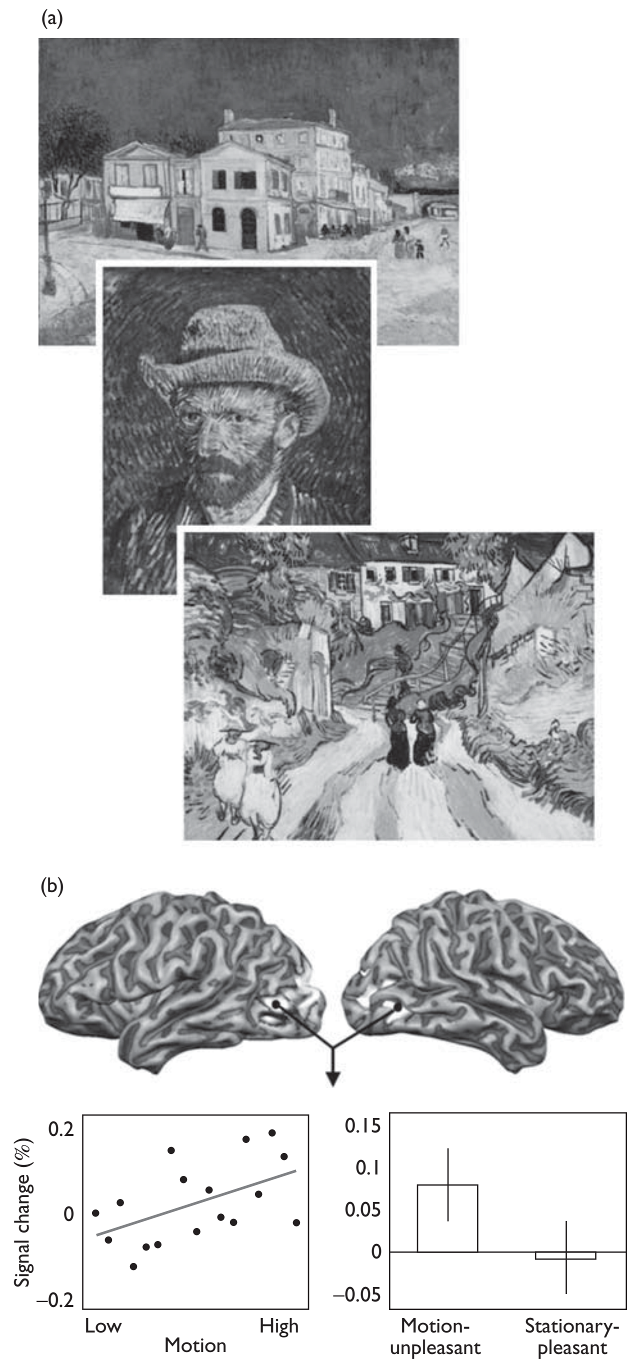
fMRI data preprocessing included slice-time correction, motion correction, and temporal high-pass filtering by removal of low-frequency components below 2 cycles per run length using a Fourier basis set. A random-effect general linear model analysis was conducted. For each participant, MT+ was identified by contrasting moving dots versus stationary dots. To restrict motion-related activity to the ascending limb of the inferior temporal sulcus, the known anatomic location of MT+ [11], an individual voxel threshold of $P < 5 \times 10^{-38}$ was enforced (Bonferroni corrected for multiple corrections to $P < 0.001$). Event-related activation timecourses associated with each painting were extracted from a 7 mm cube centered at MT+ (identified by the localizer results of each participant), and were then collapsed across both hemispheres. Activation timecourses were extracted from 0 to 10 s following event onset (baseline corrected from 0 to 2 s). The timecourse analysis was restricted to 6 s following event onset (to ensure statistical independence), the expected maximum of the fMRI response. The motion-unpleasant versus stationary-pleasant analysis was restricted to the 10 participants who had at least four trials of each event type.

Following fMRI, each participant rank ordered the previously presented paintings from the lowest degree of motion experience to the highest degree of motion experience (Fig. 1a), and then identified a boundary that separated paintings that were relatively stationary from paintings that were relatively in motion. Analysis was restricted to the 17 paintings (Supplemental digital content 1, *http://links.lww.com/WNR/A184*, Fig. 1) in which implied object motion could not be inferred [12–14]. Activity in MT+ (Fig. 1b, top) was evaluated as a function of motion experience and pleasantness experience.

Results

A parametric analysis revealed a significant positive correlation between the degree of motion experience associated with viewing each painting (based on each participant's motion experience ranking) and the magnitude of activity in MT+ [$t(15) = 2.07$, $P < 0.05$, $r = 0.25$; Fig. 1b, bottom left]. Furthermore, paintings classified as pleasant were associated with a greater magnitude of activity in MT+ as compared with paintings classified as unpleasant [$t(15) = 1.83$, $P < 0.05$, $r = 0.20$]. These findings suggest that activity in MT+ is associated with the experience of both motion and pleasantness. To assess which of these factors was driving the activation of MT+, we compared activity associated with motion-unpleasant paintings with stationary-pleasant paintings (based on each participant's stationary-motion boundary). MT+ activity was significantly greater for motion-unpleasant paintings than stationary-

Fig. 1



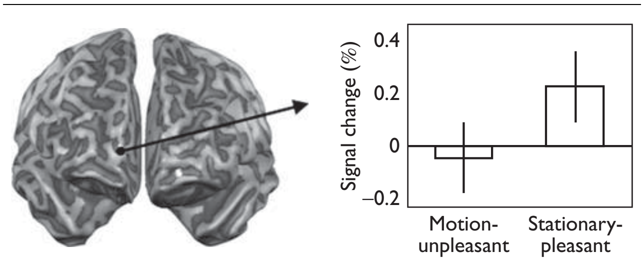
(a) Representative van Gogh paintings associated with increasing levels of motion experience (from top to bottom). (b) Top, cortical surfaces with motion processing activity in MT+ (demarcated by black circles); bottom left, MT+ activity (percent signal change) as a function of motion experience associated with each painting, with the best-fit line shown in red; bottom right, MT+ activity (percent signal change) associated with motion-unpleasant paintings and stationary-pleasant paintings (mean ± 1 SE).

pleasant paintings [$t(9) = 1.98$, $P < 0.05$; Fig. 1b, bottom right]. In addition, consistent with previous results [15], the magnitude of activity associated with viewing stationary-pleasant paintings did not differ from 0 [$t(9) < 1$]. The fact that viewing certain paintings activated MT+, which presumably produced the experience of motion, provides support for the sensory hypothesis of the aesthetic. However, although MT+ activity did track motion experience, this region did not reflect the experience of pleasantness. Thus, these results constrain the role of MT+ during aesthetic processing by indicating that the computation mediating the experience of pleasantness must be conducted in a different neural region.

We next evaluated activity in the dorsolateral and anterior prefrontal cortex given that these regions have been associated with aesthetic processing [6,8,16]. Paintings classified as pleasant were contrasted with paintings classified as unpleasant, and activations within the anterior or dorsolateral prefrontal cortex were identified ($P < 0.001$, uncorrected). This contrast produced two activations in the anterior prefrontal cortex (Fig. 2, left; both in Brodmann area 10, Talairach coordinates $x = -13$, $y = 54$, $z = 4$, and $x = 9$, $y = 55$, $z = 6$). Within the left anterior prefrontal cortex, the magnitude of activity associated with stationary-pleasant paintings was not significantly greater than that associated with motion-unpleasant paintings [$t(9) < 1$]. Critically, within the right anterior prefrontal cortex, the magnitude of activity associated with stationary-pleasant paintings was significantly greater than motion-unpleasant paintings [$t(9) = 2.00$, $P < 0.05$], and the magnitude of activity associated with motion-unpleasant paintings did not differ from 0 [$t(9) < 1$; Fig. 2, right]. Considered together, the preceding results suggest that when viewing certain van Gogh paintings, MT+ is involved in processing motion experience and the anterior prefrontal cortex is involved in processing pleasantness experience.

We next used MT+ activity to quantify the degree of motion experience associated with viewing paintings as compared with viewing real motion. The painting with the highest degree of motion experience produced MT+ activity that was 56.6% of the magnitude of activity produced by viewing coherently moving dots. As it can be assumed that the MT+ response is linearly correlated with motion experience [17], this result suggests that viewing paintings can produce a very realistic sensory experience in which approximately half of the elements in the paintings appear to be in motion.

Fig. 2



Left, cortical surface with anterior prefrontal cortex activity associated with pleasantness (the right hemisphere activation is demarcated by a black circle). Right, right anterior prefrontal cortex activity (percent signal change) associated with motion-unpleasant paintings and stationary-pleasant paintings (mean ± 1 SE).

Discussion

The current findings provide a neural mechanism for the aesthetic. Specifically, aesthetic experience associated with viewing van Gogh paintings was driven by sensory activity in MT+ and also involved processing in the anterior prefrontal cortex. It should be highlighted that this is only one mechanism for aesthetic processing. Aesthetic experience associated with viewing other kinds of art, particularly contemporary art, may depend largely or even completely on conceptual processing [3]. Future research will be needed to empirically address this issue.

Of further relevance, event-related potential research has shown that implied motion effects in MT+ occur 260–400 ms after stimulus onset [18], and aesthetic processing effects in the prefrontal cortex occur 300–400 ms after stimulus onset [19]. The overlapping windows of activation suggest that these processes may interact to give rise to aesthetic experience. Additional studies that employ techniques with high temporal resolution, such as event-related potentials, will be needed to evaluate whether these regions are synchronously active or whether they interact in a top-down or bottom-up manner during aesthetic processing [6, cf., 20].

The techniques employed in the current study will serve as a framework for future studies to investigate the neural basis of aesthetic experience associated with other visual and nonvisual art forms such as sculpture, architecture, or music.

Conclusion

In the present study, while participants viewed van Gogh paintings, motion experience (but not pleasantness experience) was associated with activity in motion processing region MT+ and the experience of pleasantness (but not motion experience) was associated with activity in the anterior prefrontal cortex. To date, this evidence constitutes the most complete neural mechanism of aesthetic experience.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

References

1 Bell C. *Art*. London: Chatto & Windus; 1924.
2 van Gogh V. *Stairway at Auvers*. Saint Louis: Saint Louis Art Museum; 1890.
3 Danto AC. *After the end of art*. New Jersey: Princeton University Press; 1998.
4 Warhol A. *Brillo Soap Pads Box*. Pittsburgh: The Andy Warhol Museum; 1964.

5 Zeki SM. *Inner vision: an exploration of art and the brain*. New York: Oxford University Press; 1999.
6 Cela-Conde CJ, Agnati L, Hutson JP, Mora F, Nadal M. The neural foundations of aesthetic appreciation. *Prog Neurobiol* 2011; **94**:39–48.
7 Vartanian O, Goel V. Neuroanatomical correlates of aesthetic preference for paintings. *Neuroreport* 2004; **15**:893–897.
8 Cela-Conde CJ, Marty G, Maestú F, Ortiz T, Munar E, Fernández A, *et al*. Activation of the prefrontal cortex in the human visual aesthetic perception. *Proc Natl Acad Sci USA* 2004; **101**:6321–6325.
9 Slotnick SD. Visual memory and visual perception recruit common neural substrates. *Behav Cogn Neurosci Rev* 2004; **3**:207–221.
10 Aragón JL, Naumis GG, Bai M, Torres M, Maini PK. Turbulent luminance in impassioned van Gogh paintings. *J Math Imaging Vis* 2008; **30**: 275–283.
11 Thakral PP, Slotnick SD. The role of parietal cortex during sustained visual spatial attention. *Brain Res* 2009; **1302**:157–166.
12 Kourtzi Z, Kanwisher N. Activation in human MT/MST by static images with implied motion. *J Cogn Neurosci* 2000; **12**:48–55.
13 Kim CY, Blake R. Brain activity accompanying perception of implied motion in abstract paintings. *Spat Vis* 2007; **20**:545–560.
14 Osaka N, Matsuyoshi D, Ikeda T, Osaka M. Implied motion because of instability in Hokusai Manga activates the motion-sensitive extrastriate visual cortex: an fMRI study of the impact of visual art. *Neuroreport* 2010; **21**:264–267.
15 Kawabata H, Zeki S. Neural correlates of beauty. *J Neurophysiol* 2004; **91**:1699–1705.
16 Jacobsen T, Schubotz RI, Höfel L, Cramon DY. Brain correlates of aesthetic judgment of beauty. *Neuroimage* 2006; **29**:276–285.
17 Rees G, Friston K, Koch C. A direct quantitative relationship between the functional properties of human and macaque V5. *Nat Neurosci* 2000; **3**:716–723.
18 Lorteije JAM, Kenemans JL, Jellema T, van der Lubbe RH, de Heer F, van Wezel RJA. Delayed response to animate implied motion in human motion processing areas. *J Cogn Neurosci* 2006; **18**:158–168.
19 Jacobsen T, Höfel L. Descriptive and evaluative judgment processes: behavioral and electrophysiological indices of processing symmetry and aesthetics. *Cogn Affect Behav Neurosci* 2003; **3**:289–299.
20 Slotnick SD. Synchronous retinotopic frontal-temporal activity during long-term memory for spatial location. *Brain Res* 2010; **1330**:89–100.