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Neural correlates of viewing paintings: Evidence from a quantitative meta-analysis of functional magnetic resonance imaging data

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ABSTRACT

Many studies involving functional magnetic resonance imaging (fMRI) have exposed participants to paintings under varying task demands. To isolate neural systems that are activated reliably across fMRI studies in response to viewing paintings regardless of variation in task demands, a quantitative meta-analysis of fifteen experiments using the activation likelihood estimation (ALE) method was conducted. As predicted, viewing paintings was correlated with activation in a distributed system including the occipital lobes, temporal lobe structures in the ventral stream involved in object (fusiform gyrus) and scene (parahippocampal gyrus) perception, and the anterior insula—a key structure in experience of emotion. In addition, we also observed activation in the posterior cingulate cortex bilaterally—part of the brain's default network. These results suggest that viewing paintings engages not only systems involved in visual representation and object recognition, but also structures underlying emotions and internalized cognitions.

1. Introduction

Two theoretical models have proposed that aesthetic experience associated with exposure to works of art arises as a function of the engagement of a distributed set of perceptual, cognitive, and emotional processes (Chatterjee, 2003; Leder, Belke, Oeberst, & Augustin, 2004). Uncovering the neural systems that underlie this distributed functional architecture is one of the major goals of the field of neuroaesthetics (Skov & Vartanian, 2009). Descriptive reviews of studies to date have indicated that aesthetic experience in response to viewing artworks is indeed a function of a distributed set of brain areas, each of which is hypothesized to underlie a different component process modulated by task demands (see, e.g., Cela-Conde et al., 2011; Nadal, Munar, Capó, Rosselló, & Cela-Conde, 2008). For example, whereas explicit instruction to focus on subjective emotions while viewing artworks is more likely to activate structures underlying the experience of visceral emotion (e.g., anterior insula), explicit instruction to examine the objects that make up scenes in paintings is more likely to activate structures underlying visuospatial processing such as the parietal lobes (Cupchik, Vartanian, Crawley, & Mikulis, 2009).

Recently, Brown, Gao, Tisdelle, Eickhoff, and Liotti (2011) conducted a large-scale meta-analysis of neuroimaging studies of positive-valence aesthetic appraisal across sensory modalities. Their aim was to highlight regions reliably activated during *appraisal* of the valence of perceived objects in the visual, auditory, gustatory or olfactory domains. They were motivated by their search for the core processes underlying aesthetic evaluation. As a result, although some studies that had used paintings as stimuli were also included, the selected studies had necessarily used tasks involving aesthetic evaluation, thereby excluding studies in which paintings had been used to study sensory processing, decision making alone, or passive viewing. In contrast, here we subject data from functional magnetic resonance imaging (fMRI) studies in which participants viewed paintings to a quantitative meta-analysis. Our aim was different from Brown et al.'s in that we were motivated to reveal brain regions activated reliably as a function of exposure to paintings regardless of variation in task demands (e.g., passive viewing, active ratings, etc.). Given that paintings constitute a key stimulus set across studies of neuroaesthetics, isolating the neural structures that are activated in response to viewing them will be a useful tool in teasing apart task-related and stimulus-related effects in future studies.

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Table 1
List of studies included in the meta-analysis.

Study	*N*	Peaks	Analysis	Task
Kawabata and Zeki (2004)	10	3	Contrast	Aesthetic judgment
Vartanian and Goel (2004)	12	9	Parametric	Aesthetic judgment
Fairhall and Ishai (2008)	12	12	Contrast	Recognition
Kirk, Skov, Hulme, Christensen, and Zeki (2009)	14	7	Contrast	Aesthetic judgment
Cupchik et al. (2009)	16	4	Contrast	Active viewing
Wiesmann and Ishai (2010)	24	11	Contrast	Recognition
Lebreton, Jorge, Michel, Thirion, and Pessiglione (2009)	20	26	Contrast	Mixed judgment
Harvey et al. (2010)	87	6	Parametric	Passive viewing
Lacey et al. (2011)	8	15	Contrast	Active viewing
Kirk, Harvey, and Montague (2011)	40	5	Parametric	Passive viewing
Huang, Bridge, Kemp, and Parker (2011)	14	6	Contrast	Unrestricted
Ishizu and Zeki (2012a)	21	2	Parametric	Aesthetic judgment
Vessel et al. (2012)	16	19	Contrast	Active viewing
Ishizu and Zeki (2012b)	21	13	Contrast	Aesthetic judgment
Silveira et al. (2012)	15	16	Contrast	Affective judgment

Note. *N* = number of participants. Peaks = Foci of activation for selected contrast or parametric analysis. Aesthetic judgment = making a preference or beauty judgment, passive viewing = viewing not coupled with instruction to form an attitude, active viewing = viewing coupled with instruction to form an attitude, mixed judgment = making aesthetic and other judgments, recognition = memory task, unrestricted = subjects instructed to view each image as they pleased, affective judgment = judging the extent to which one is affected by the painting.

We focused on the visual modality and paintings specifically for two reasons. First, we were able to locate a sufficient number of fMRI studies in this area to enable a meta-analysis. Second, both models discussed above (Chatterjee, 2003; Leder et al., 2004) are based primarily on vision. For this latter reason, we were able to make predictions regarding the involvement of specific neural structures across studies. First, we hypothesized that viewing paintings would activate regions of the visual cortex involved in processing of early, intermediate, and late visual features that underlie painting perception, including color and form (Chatterjee, 2003; Greenlee & Tse, 2008; Wandell, Dumoulin, & Brewer, 2009). Second, we hypothesized that structures involved in the perception of objects and spaces would also be activated, specifically structures in the ventral stream tuned towards object recognition (Grill-Spector & Sayres, 2008; Kanwisher & Yovel, 2009; Mishkin, Ungerleider, & Macko, 1983; Ungerleider & Mishkin, 1982). Third, it is almost universally assumed that a primary objective of art is to evoke affective responses in the viewer, although whether the brain's emotion and reward systems would be activated across studies with varying instructions remains an open question. Conveniently, the structures known to play a role in emotion and reward are well established (Montague & Berns, 2002), including the nucleus accumbens (Aharon et al., 2001), the ventral striatum (Kampe, Frith, Dolan, & Frith, 2001), the orbitofrontal cortex (O'Doherty et al., 2003; Winston, O'Doherty, Kilner, Perrett & Dolan, 2006), and the insula (see Di Dio & Gallese, 2009). Therefore, our third and exploratory hypothesis was whether viewing paintings would activate the brains' reward and/or emotion systems.

2. Material and methods

Studies were selected by conducting Boolean searches in PubMed using the terms "painting", "art", "aesthetic", "beauty", "MRI", "brain", and "neuroimaging" in February 2014. This set of papers was augmented by others in which participants viewed paintings under non-aesthetic conditions. Extracted fMRI studies were subsequently checked to ensure that (a) they involved viewing paintings,[1] (b) they were comprised of neurologically healthy and adult participants, (c) the analyses were whole brain rather than exclusively region-of-interest (ROI), and (d) the complete list of activation peaks (i.e., foci) was published in the paper or made available to us. This resulted in fifteen experiments, involving a total of 330 participants and 166 peaks of activation (Table 1).

2.1. Activation likelihood estimation

Our meta-analysis was conducted using the activation likelihood estimation method (ALE) (Turkeltaub, Eden, Jones, & Zeffiro, 2002). ALE is a quantitative meta-analysis technique that highlights brain regions that are activated reliably across studies. Much like traditional meta-analytic approaches, ALE's advantages include "seeing the "landscape" of a research domain, keeping statistical significance in perspective, minimizing wasted data, becoming intimate with the data summarized, (and) asking focused research questions" (Rosenthal & DiMatteo, 2001, p. 59). In addition, the method has been shown to provide a reliable means for conducting coordinate-based meta-analyses of functional imaging data (Eickhoff, Bzdok, Laird, Kurth, & Fox, 2012). We believe that meta-analyses and qualitative reviews are complementary, jointly providing windows into common and nuanced aspects of a domain, respectively.

ALE's approach involves comparing activation likelihoods calculated from observed activation foci with a null distribution of randomly generated activation likelihoods. It pools peak activation coordinates across studies that have investigated an effect of interest (Laird et al., 2005). For this meta-analysis all coordinates were renormalized to Talairach space using the icbm2tal transformation (Lancaster et al., 2007) implemented in the GingerALE 2.0 toolbox (http://brainmap.org; Research Imaging Center of the University of Texas Health Science Center, San Antonio, TX). The resulting coordinates were used to generate "activation likelihoods" for each voxel in the brain. For each focus, ALE computes each voxel as a function of its distance from that focus using a three-dimensional Gaussian probability density function centered at its coordinates. This generates vectors of values for each voxel representing probabilities of belonging to specific foci. These values are assumed to be independent such that the existence of one focus does not give information about whether another focus will occur. The vector values are combined with the addition rule for log-probabilities, yielding ALE statistics. Thus, the ALE statistic represents the probability of a certain voxel to belong to any of the included foci. Significance tests are conducted by comparing the ALE statistic in each voxel with a null distribution, generated via repeatedly

[1] For this meta-analysis we only selected studies that used paintings, resulting in the exclusion of fMRI studies which had used sculptures or geometric patterns as stimuli (e.g., Di Dio, Macaluso, & Rizzolatti, 2007; Jacobsen, Schubotz, Höfel, & von Cramon, 2005).