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Neuroaesthetics: a review

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Neuroaesthetics is a relatively young field within cognitive neuroscience, concerned with the neural underpinnings of aesthetic experience of beauty, particularly in visual art. Neuroscientific investigations have approached this area using imaging and neurophysiological techniques, such as functional magnetic resonance (fMRI), magnetoencephalography (MEG) and electroencephalography (EEG). The results produced so far are very heterogeneous. Nonetheless, an overall view of the findings suggests that the aesthetic experience of visual artworks is characterized by the activation of: sensorimotor areas; core emotional centres; and reward-related centres. In the present review, we discuss the functional relevance of these activations and propose that aesthetic experience is a multilevel process exceeding a purely visual analysis of artworks and relying upon visceromotor and somatomotor resonance in the beholder.

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Introduction

Neuroaesthetics is a term coined by Zeki [1] and refers to the study of the neural bases of beauty perception in art. Zeki's approach to art is modelled on his understanding of how the visual brain works, in particular on its ability to detect constants (i.e. unchanging properties of objects or situations) with the aim of obtaining true knowledge about the world [1]. In this process, the brain (as the artist) needs to discard inessential information from the visual world in order to represent the proper character of objects.

Notwithstanding the conceptual strength of Zeki's parallelism, studying basic neural mechanisms underpinning the brain response to art and the ensuing aesthetic experience is a complex issue. For one thing, there is great heterogeneity across results from the investigations that have attempted to clarify the neural correlates associated with aesthetic experiences. Such discrepancy may also be because of the lack of a fixed consensus on the definition of 'aesthetic experience'. Thus, it is important, before going over the empirical findings, to specify what notion of aesthetics we refer to. In our definition, an aesthetic experience is one that allows the beholder to 'to perceive-feel-sense' an artwork (from the Greek *aisthese-aisthanomai*), which in turn implies the activation of sensorimotor, emotional and cognitive mechanisms.

The present review is confined to the neuroaesthetics of visual arts and describes the relative findings discussing their relevance within the framework of the above definition.

The neural correlates of aesthetic experiences

The aesthetic experience of a visual artwork begins with a visual analysis of the stimulus, which then undergoes further levels of processing. This progression of processes may lead to an aesthetic experience on the basis of, most likely, some biological and embodied mechanisms that, in turn, can be modulated by factors such as the context, individuals' interest in the artwork, prior knowledge and familiarity (e.g. [2]). Thus, one possibility for the heterogeneity observed across the results of the studies dealing with neuroaesthetics is that they may reflect the output of different aesthetic processing levels [3,4]. Even more fundamental is the distinction between emotions directly associated with aesthetics and the cognitive processes that may produce rewarding experiences in the beholder. This distinction highlights concepts of aesthetic pleasure and aesthetic appraisal, which can be related to the emotional and cognitive aspects of aesthetic experiences, respectively.

Aesthetics and reward

The study of neuroaesthetics has mostly dealt with aesthetic appraisal, in that participants are usually asked to explicitly judge a visual stimulus either as beautiful or ugly. Kawabata and Zeki [5] used fMRI to investigate the neural correlates of beauty perception during the observation of different categories of paintings (landscapes, portraits, etc.) that were judged by participants beautiful, neutral or ugly. The core imaging results revealed different brain activations for judged-beautiful stimuli versus both neutral and ugly images in medial orbitofrontal cortex (OFC). The differential activation observed in OFC consisted in decreased activity with respect to baseline, with judged-ugly stimuli evoking the lowest level of activation.

Using a similar methodological approach, Vartanian and Goel [6] carried out an event-related fMRI study, in which explicit aesthetic preference for representational versus abstract paintings was investigated in three stimulus-versions: originals, altered and filtered. Participants indicated their preference with a button press at each stimulus presentation. Representational paintings evoked higher preference than abstract paintings. In both categories, original paintings elicited the highest preference. Brain imaging results showed decreased activation in caudate nucleus with decreasing preference for the observed paintings, suggesting that aesthetic experience also relies on areas involved in the processing of stimuli holding reward properties [7]. Additionally, increasing preference for the presented paintings elicited increased activation in several areas, including the left anterior cingulate sulcus, an area known to be involved in reward-related processing of stimuli that vary in emotional valence (see [8] for a review).

Aesthetics and visuomotor processing

A recent study by Cela-Conde *et al.* [9•] investigated gender-related similarities and differences in the neural correlates of beauty using a set of images of either artistic paintings or natural objects, divided into five groups: abstract art; classic art; impressionist art; postimpressionist art; photographs of landscapes, artifacts, urban scenes and true-life depictions. Through magnetoencephalography (MEG), it was shown enhanced activation for 'judged-beautiful versus judged-ugly' stimuli in several parietal foci, bilaterally for women and mainly in the right hemisphere for men, with a latency of 300 ms after stimulus offset (Figure 1a).

Activation of parietal areas during aesthetic experience was also shown in a recent fMRI study of Cupchik *et al.* [10••], in which participants viewed various categories of representational paintings (portraits, nudes, still-life and landscapes) that were classified as 'hard-edge' (containing well-defined forms) and as 'soft-edge' (containing ill-defined forms). The underling rationale for this classification was based on the hypothesis that 'soft-edge' paintings, by virtue of their structure, should facilitate aesthetic experience by stimulating active image construction. Both 'hard'-edge and 'soft'-edge paintings were presented in two conditions: one that required the participants to observe the images in an objective and detached manner to gather information about the content of the stimulus (pragmatic condition), and one that required the participants to observe the paintings in a subjective and engaged manner, appreciating the feelings evoked by the stimuli (aesthetic condition). Enhanced activation of the left superior parietal lobe was observed for the 'soft-edge' paintings, particularly during the 'aesthetic' condition (Figure 1b).

Activation of parietal regions for aesthetic stimuli [5,9•,10••] brings support to the idea that aesthetic experience is characterized by visuo-spatial coding as well as, importantly, by motor mapping. In fact, there is now consistent evidence that the posterior parietal cortex, including the intraparietal regions, is part of the motor system, playing a fundamental role in visuomotor transformations (for a review, see [11]).

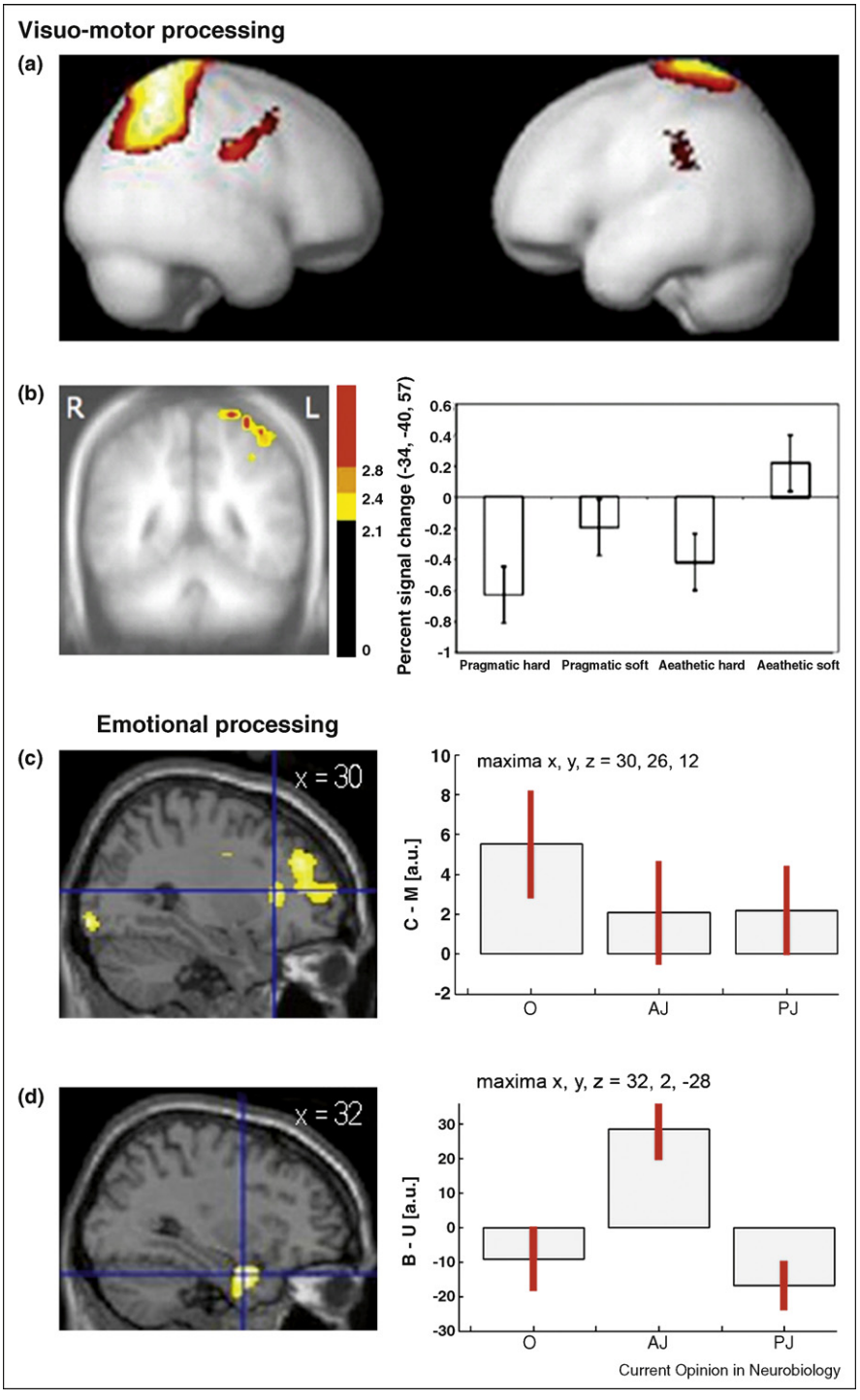
Involvement of parietal and premotor areas in aesthetic experience was observed in the fMRI study of Jacobsen *et al.* [12]. Here, participants were required to make an aesthetic appraisal of abstract geometrical shapes, whose symmetry and level of complexity had been manipulated. Behaviourally, symmetry was shown to strongly affect aesthetic judgment, followed by stimulus complexity. The imaging results indicated that, in the comparison of symmetry judgment and aesthetic judgment tasks versus the control condition (observation of an arrow), activations were enhanced in areas subserving visuomotor processes, including the intraparietal sulcus and the ventral premotor cortex, in both conditions (see also [13••] below).

Aesthetics and embodiment

It has been recently proposed that a crucial element of aesthetic experience of artworks consists of the activation of the embodied simulation of actions, emotions, and corporeal sensations, and that these mechanisms are universal [14••]. This proposal challenges more standard accounts of aesthetic experience privileging the primacy of cognition in our responses to art. This hypothesis [14••], echoing historical views put forward, among others, by the phenomenological tradition in philosophy, stresses the empathic nature of the relationship automatically established between artworks and beholders [15–17], and capitalizes upon the discovery of the mirror mechanism [18]. According to this hypothesis, the embodied view of aesthetic experience consists of two components: firstly, the relationship between embodied simulation-driven empathic feelings in the observer and the representational content (the actions, intentions, objects, emotions and sensations portrayed in a given painting or sculpture); secondly, the relationship between embodied simulation-driven empathic feelings in the observer and the visible traces of the artist's creative gestures (i.e. vigorous modelling in clay or paint, brushwork and signs of the movement of the artist's hand).

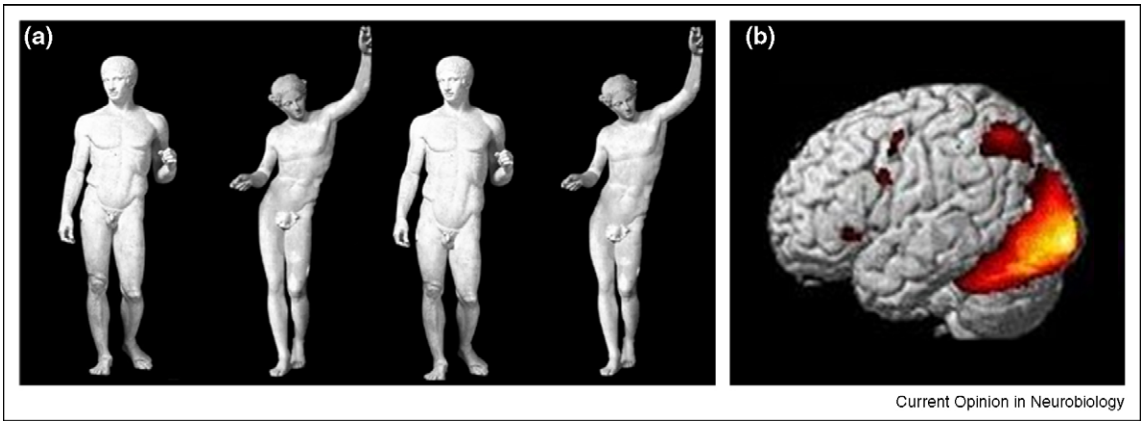
The recent work by Di Dio *et al.* ([13••], see below) provides suggestive evidence compatible with this hypothesis. In this investigation, the observation of Classical and Renaissance sculptures (see Figure 2a for an example of the stimuli) elicited activation of the ventral premotor cortex and of the posterior parietal cortex (Figure 2b), suggesting motor resonance congruent with the implied movements portrayed in the sculptures.

Figure 1



Brain imaging results of the main studies reviewed, grouped by levels of processing. Visuomotor processing: **(a)** Magnetoencephalography (MEG) was employed in Cela-Conde *et al.* [9•] to observe the time course of stimulus processing during aesthetic experience. Results show activations for 'judged-beautiful versus judged-ugly' visual stimuli (artistic and non-artistic) in various parietal foci. This image excerpt depicts bilateral superior parietal lobe and intraparietal region activation, averaged across participants, at the time window of 400–500 ms after stimulus offset. **(b)** Brain activations in the fMRI study of Cupchik *et al.* [10••]. Here participants viewed representational paintings containing either well-defined forms (hard-edge) or ill-defined forms (soft-edge) under two conditions: 'pragmatic' and 'aesthetic'. Enhanced activation was observed in the left superior parietal lobule (Talairach coordinates: −34, −40, 57) for the contrast 'soft-edge' versus 'hard-edge' paintings under the 'aesthetic' condition. The parametric maps are superimposed on to coronal MRI. The colour bar indicates *T*-values. The graph depicts the amplitude of this activation in the four conditions (pragmatic hard, pragmatic soft, aesthetic hard and aesthetic soft) and shows that activation was greater for the 'soft-edge' paintings under the

Figure 2



Imaging results from the study of Di Dio *et al.* [13••]. **(a)** Example of canonical sculptures (first two sculptures on left side of the figure) and proportion-modified stimuli (the two sculptures on the right side) used in the study. The modifications were made by altering the relation torso:legs. **(b)** Imaging results from the contrast 'canonical and proportion-modified sculptures versus rest', averaging activity across the three experimental conditions (observation, aesthetic judgment and proportion judgment). The lateral view of the brain shows activations of visual, parietal and premotor areas in the left hemisphere. The statistical parametric maps were rendered onto the MNI brain template.

Aesthetics and emotions

A common problem of most investigations is the experimental setting. It is difficult, in fact, to induce in the participants the proper mind-state, particularly in fMRI, MEG and EEG studies. For investigations dealing with very subtle human abilities, participants' 'attitude' [19] and intention [20] play a crucial role in the classification of a visual experience into an aesthetic one. Explicit judgments, therefore, are usually required to induce specific mind-states that, however, may mask basic neural processes.

An attempt to address this problem was made by Di Dio *et al.* [13••]. In this fMRI study, Classical and Renaissance sculptures were presented in two versions: originals and proportion-modified (Figure 2a). The distinctive feature of this study was to allow participants to observe the images without expressing any explicit judgment. In the attempt to induce the required implicit 'aesthetic attitude', participants were instructed to examine the images as if they were in a museum (as much as they could in a scanner). Explicit aesthetic and proportion evaluations were required only in subsequent conditions. Imaging results showed that the observation of original sculptures, relative to the modified ones, produced activation of some lateral and medial cortical areas (lateral occipital gyrus, precuneus and prefrontal areas) and, importantly, of the right anterior insula (see Figure 1c). Activation of the insula was particularly strong during simple observation condition, in which the brain could be said to respond most spontaneously to the presented images. Support for this finding comes from the study of Cupchik *et al.* [10••], above discussed, in which the observation of representational paintings under the 'aesthetic' condition versus baseline condition (viewing of non-representational paintings accompanied by no explicit task-related instructions) elicited bilateral activation of the insula. It is interesting to note that, in this study, no explicit behavioural responses were required in the scanner and that implicit 'aesthetic attitude' was induced in the participants by specific instructions provided prior scanning.

The contrast of canonical versus proportion-modified images in Di Dio *et al.* [13••] highlighted the brain areas that preferentially code for aesthetic stimuli, so defined by their intrinsic physical properties (also supported by brain activations observed in the contrast 'aesthetic and symmetry judgments versus control condition' in Jacobsen *et al.* [12]). We can define the aesthetic experience evoked by parameters intrinsic to the stimuli an 'objective' one. It

'aesthetic' task. Emotional processing: **(c)** Brain activations in the fMRI study of Di Dio *et al.* [13••]. Classical and Renaissance sculptures were employed in two versions, with canonical proportion and with modified proportions, and presented in three conditions: observation (O), aesthetic judgment (AJ) and proportion judgment (PJ). The parasagittal view of the brain, rendered onto the MNI brain template, shows activations for the contrast 'canonical versus proportion-modified' sculptures across conditions in the right insular region (MNI coordinates: 30, 26, 12). The graph shows that insular activation was particularly enhanced during observation condition (O). For each condition, the signal plots show the difference between canonical (C) minus proportion-modified (M) sculptures in arbitrary units (a.u.), ±10% confidence intervals (P-corrected < 0.05). **(d)** Brain activations in Di Dio *et al.* [13••] for the interaction stimulus (judged-beautiful versus judged-ugly) × condition (O, AJ, PJ). The parasagittal section of the brain shows activation of the right amygdala (MNI coordinates: 32, 2, −28) rendered onto the MNI brain template. The graph shows that amygdala activation was specific to aesthetic judgment (AJ) condition. For each condition (O, AJ, PJ) the signal plots show the difference between beautiful (B) minus ugly (U)-as judged sculptures in arbitrary units (a.u.), ±10% confidence intervals (P-corrected < 0.05).

emerges from the processing of sensorimotor input and, crucially, from the feeling of pleasure [21], which is mediated by the activation of the insula (see also [22,23]).

Aesthetic experiences, however, are only partially built on objective measures. In order to separate the objective aesthetic value from subjective aesthetic appraisal, a further analysis was carried out [13••], contrasting brain responses to liked versus disliked images as judged by each participant during the explicit aesthetic judgment condition. Here, preferred stimuli selectively activated the right amygdala, relative to those disliked (Figure 1d), supporting the idea that the more 'subjective' aspect of aesthetic experience is mediated by association processes with the observer's own emotional experiences [24].

Overall, these results suggest an overt neural link between aesthetics and emotion, showing that, at least at basic levels of processing, aesthetic preference is mediated by core emotion centres, namely the insula and the amygdala.

Conclusions

Neuroaesthetics has been, so far, mainly concerned with visual perception, with a particular focus on how the properties of artworks are visually processed. However, the evidence here reviewed consistently suggests that aesthetic experience — not differently from the perception of any visual object — only *begins* with a visual description of art works. In fact, sensorimotor and emotional processes are also in place, which colour aesthetic experiences with embodied motor and affective responses. The field of neuroaesthetics, here addressed only for what pertains visual arts, is a new but rapidly expanding area of investigation that also covers other artforms, like music [25–28] and performing arts [29]. One of the future challenges for neuroaesthetics, then, will be that of clarifying whether aesthetic experience shares common neural bases across different artistic domains.

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This is a pioneer work in the neural exploration of gender-related differences in the appreciation of artworks. The use of magnetoencephalography (MEG) allows to study the various temporal stages at which stimuli are processed. Through this technique, it was possible to pinpoint fine gender-differences in parietal regions, which are then discussed by the authors from an evolutionary perspective.

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