

Neuroesthetics

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Abstract

Neuroesthetics is a subfield of cognitive neuroscience that studies the biological mechanisms and psychological processes evoked in the creator or the spectator when adopting an esthetic orientation toward an artistic or nonartistic object in the course of interacting with it. These psychological processes are related to perception, cognition, emotion, evaluation, social, and contextual aspects. Here, we outline the scope of neuroesthetics and summarize its historical background. We thereafter sketch three current approaches to neuroesthetics, and examine recent developments in three areas: emotions, context, and expertise. We finish with an exploration of the potential for future inquiry in neuroesthetics.

Introduction: Aims and Scope of Neuroesthetics

Stated briefly, neuroesthetics is a scientific field that aims to understand the neural mechanisms that underlie esthetic behavior. Despite possessing the virtue of conciseness, such a characterization is unsatisfactory because it ignores important conceptual subtleties. First, neuroesthetics can properly be viewed as a subfield of cognitive neuroscience. As such, it combines neuroscience techniques and cognitive science methods (Gazzaniga, 1984), bringing the cognitive and neural levels of explanation of behavior together into a single approach (Churchland and Sejnowski, 1988). Second, rather than regarding esthetics as an abstract concept, neuroesthetics conceives it as a form of human cognition, and thus, it focuses on particular esthetic experiences, esthetic creation, esthetic preference, esthetic choice, and so on. Third, neuroesthetics assumes that such forms of esthetic cognition arise from the interaction of perceptual, emotional, and evaluative processes with social and contextual factors. In fact, understanding such interaction is one of the field's main goals. Fourth, the creation and appreciation of artworks are within the scope of neuroesthetics. However, just as the field of esthetics is concerned with other objects in addition to artworks, so is neuroesthetics. To understand the biological

underpinnings of the human capacity for art production and appreciation is the goal of the cognitive neuroscience of art (Seeley, 2011). Both fields overlap, but they are not identical (Figure 1). Neuroesthetics deals with a broader set of objects of esthetic interest, such as utensils, commodities, or graphic and industrial designs. The cognitive neuroscience of art, in turn, sets out to understand a broader set of issues related to art, beyond the purely esthetic ones, such as grasping the meaning of an artwork, or understanding its significance in its art-historical or art-critical contexts. Both fields overlap when attempting to understand how esthetic qualities are used to produce and appreciate the content and form of an artwork.

Neuroesthetics, thus, is not concerned with a particular class of objects. Rather, it focuses on a certain kind of way objects can be experienced when people approach them with an esthetic orientation (Cupchik, 1992). From this perspective, neuroesthetics can be conceived as the study of the biological mechanisms and psychological processes evoked in the creator or the spectator when adopting an esthetic orientation toward an artistic or nonartistic object in the course of interacting with it. These psychological processes and their biological underpinnings are related to perception, cognition, emotion, evaluation, as well as to social and contextual aspects (Skov and Vartanian, 2009).

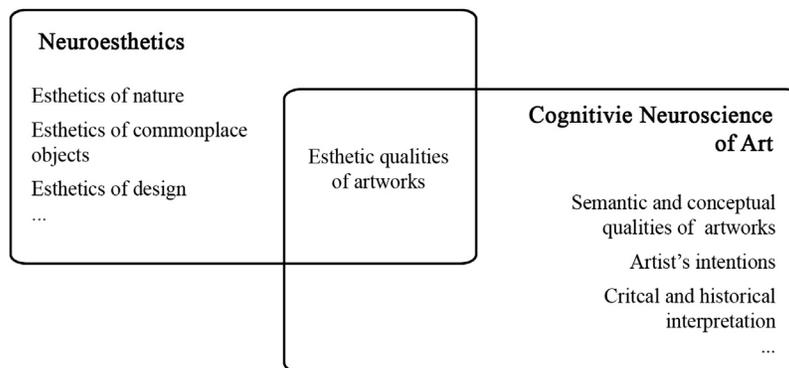


Figure 1 Representation of the relation between neuroesthetics and the cognitive neuroscience of art and their research topics.

Historical Background of Neuroesthetics

The term neuroesthetics was coined at the end of the twentieth century (Zeki, 1999). Scientists and humanists, however, have been interested in the neurobiological substrates of esthetic experience for at least 250 years. Burke (1757) argued that such experiences did not rely on specialized biological mechanisms, that the beautiful and the sublime were mediated by the same physiological mechanisms as common emotions like love and fear. Objects, landscapes, and other people were regarded as beautiful – he believed – because they caused the same relaxation of the nerves as the emotions of love or tenderness. Objects and events that agitated and tensed the nerves, in a similar way to pain, fear, or terror, were experienced as sublime. Two main issues became the focus of scientists' attention during the second half of the nineteenth century. First, the relation between pleasure, pain, and esthetics was extensively discussed. Whereas Marshall (1893) went as far as considering psychological esthetics as a branch of hedonics, and Allen (1877) made the bodily processes of pain and pleasure the cornerstone of his *Physiological Aesthetics*, James (1890) believed that what defined esthetic feelings was precisely the absence of the physiological component of common emotions. Second, the issue of the adaptive value of art and esthetics spurred hypothetical scenarios – based on natural selection or sexual selection – that hoped to explain the origin and evolution of art and esthetics (Darwin, 1871/1998).

It was Fechner's (1876) *Vorschule der Aesthetik*, however, that marked the inception of an empirical science of esthetics. Fechner developed a suite of basic principles that aimed to explain esthetic appreciation. His methodological innovations were, nevertheless, his most lasting and influential contributions. It was he who introduced the now familiar practice of measuring the responses of samples of participants, representative of certain populations, to large numbers of objects. He devised three main methods to elicit his participants' responses: the method of choice, the method of production, and the method of use. The first of these became dominant in the experimental psychology of esthetics, while the use of the other two declined, to the point that most of what empirical esthetics has shown about people's esthetic experience is based on participants' choices or ratings (Westphal-Fitch et al., 2013).

During the twentieth century, the incipient neuroesthetics explored the effects of brain lesions and neurological illnesses on artistic creation. The focus of much of this work was the relation between aphasia and music, painting, and literature (Alajouanine, 1948). Because such reports often described artistic change in single cases after the onset of lesions or illnesses in ambiguous or imprecise terms, it was not easy to arrive at meaningful conclusions or to identify general trends (Chatterjee, 2004). The neuroimaging techniques that became available toward the end of the twentieth century allowed scientists to explore their hypothesis experimentally in controlled situations, with the participation of healthy subjects, and to correlate the appreciation and enjoyment of music, painting, architecture, sculpture, and dance, with neural activity.

Approaches to Neuroesthetics

The biological underpinnings of esthetic behavior have been explored using a broad variety of methods. One approach, which Chatterjee (2011) refers to as parallelism, aims to illustrate how artists throughout the centuries have devised techniques and used resources that catch the attention of spectators, interest them, and appeal to them by engaging certain neural processes related with reward and arousal (Zeki, 1999; Ramachandran and Hirstein, 1999).

Relying on clinical cases, other researchers have described the impact of brain damage and neural degeneration on the production and appreciation of art and on esthetic experiences. This second approach has shown that artists are vulnerable to the same visual, motor, auditory, and cognitive neuropsychological deficits that affect other people, despite their proficient perceptual and motor skills, though they manifest these deficits in strikingly eloquent ways (Chatterjee, 2004). Most artists suffering from neurological disorders continue to be artistically motivated, productive, and expressive after the onset of their condition (Zaidel, 2005). There usually is, however, a noticeable change in the work of most artists who have suffered a stroke. Those sufferings from neurodegenerative disorders, such as Alzheimer's disease, seem to gradually lose the ability to represent the world with precision, but are able to make use of color and form in esthetically appealing ways (Miller and Hou, 2004). Neurological disorders can also affect esthetic appreciation. Depending on the nature of the disorder, people might have difficulties perceiving objects' particular sensory features, recognizing or recollecting them, or engaging emotionally with them. In most cases, however, patients are capable of recognizing and experiencing the esthetic qualities of art and other objects in a meaningful and consistent way (Halpern and O'Connor, 2013). Neurological studies suggest that esthetic preference is surprisingly resilient in the face of neurological conditions, and argue against the existence of specialized brain mechanisms underlying the experience of art (Zaidel, 2005).

The third approach to neuroesthetics noted by Chatterjee (2011) is experimental neuroesthetics. This approach has mostly – though not exclusively – used neuroimaging methods to study the role of different brain regions in esthetic experiences. When applied to neuroesthetics, such methods have usually required participants to judge the beauty, the attractiveness or the appeal of stimuli presented to them, or to state how much they like or prefer them, while their brain activity is being registered. Neuroimaging studies have revealed that neural activity in the reward circuit is a key component of esthetic experience, but the picture is a complex one. Positive or negative esthetic experiences are the result of a complex interplay of neural processes related to reward representation, prediction and anticipation, affective self-monitoring, emotions, and the generation of pleasure, that take place in cortical (i.e., anterior cingulate, orbitofrontal, and ventromedial prefrontal) and subcortical (i.e., caudate nucleus, substantia nigra, and nucleus accumbens) regions, as well as some of the regulators of this circuit (i.e., amygdala, thalamus, and hippocampus) (Cupchik et al., 2009; Harvey et al., 2010; Ishizu

and Zeki, 2013; Kirk et al., 2009b; Lacey et al., 2011; Salimpoor et al., 2011; Salimpoor et al., 2013; Vartanian and Goel, 2004).

However, neuroimaging studies have shown that there is more to esthetic appreciation than pleasure and reward (Nadal and Pearce, 2011). Such studies have also shown that esthetic experiences involve an enhancement of activity in cortical regions related to sensory processing. These regions include the bilateral fusiform gyri, angular gyrus, and the superior parietal cortex in visual esthetic experiences (Cela-Conde et al., 2009; Cupchik et al., 2009; Lengger et al., 2007; Vartanian and Goel, 2004), primary and secondary auditory cortices during musical esthetic experiences (Brown et al., 2004; Salimpoor et al., 2013), and the extrastriate body area of the occipital cortex and the ventral premotor cortex during esthetic appreciation of dance (Calvo-Merino et al., 2010). The analysis of functional connectivity suggests that this enhancement of perceptual processes owes primarily to the effects of attention (Lacey et al., 2011). Finally, viewing artworks or designs that are liked, found appealing, or beautiful, is also accompanied by an increase in the activity throughout a network of cortical regions related to evaluative judgment, the allocation of attentional resources, and the retrieval of information from memory to contextualize the stimuli and judgment, including the dorsolateral and ventrolateral prefrontal cortex, anterior medial prefrontal cortex, temporal pole, posterior cingulate cortex, and precuneus (Cela-Conde et al., 2004; Cupchik et al., 2009; Jacobsen et al., 2006; Lengger et al., 2007).

Main Current Research Topics

Emotion

What are the biological mechanisms that underlie the affective and emotional aspects of esthetic experience? What does it mean, in biological terms, to be moved by such esthetic qualities as beauty, grace, or sublimity? These questions can be answered only in part when there still is much debate surrounding such fundamental issues as whether there are specific esthetic emotions, whether esthetic experiences can involve common emotions – such as joy, anger, or sadness – or whether emotion is even a necessary ingredient of esthetic experience.

Is there such a thing as esthetic emotions? Some researchers have argued that there are indeed certain classes of emotions that are intrinsic to esthetic experiences. Konecni (2005), for instance, conceived esthetic awe as a specific esthetic emotion, a prototypical response to the sublime. In his view “It is the most pronounced, the ultimate, esthetic response, in all ways similar to the fundamental emotions” (Konecni, 2005: p. 31). Keltner and Haidt (2003), in contrast, suggested that awe might accompany a variety of experiences, including the appreciation of art, though only under certain circumstances. It is art’s reliance on depictions of vastness, exceptional actions or moments, or just its sheer size – Keltner and Haidt (2003) argue – that makes it possible to produce profoundly moving emotions of awe that go beyond mere esthetic pleasure.

Lazarus (1991) has espoused the opposite view, namely, that there are no exclusive or prototypical esthetic emotions.

In his view, an ‘esthetic emotion’ is a common emotion experienced in response to art or any other object of esthetic contemplation. Thus, esthetic emotions are elicited by portrayals of emotional content to which people can relate. The strength of such esthetic emotion depends fundamentally on the extent to which spectators identify with the representation and the personal significance of the depicted content. Emphasizing the role of appraisals, Silvia (2006) has also argued that a broad range of common emotions can be a part of an esthetic experience. Appraisals constitute the key mechanism underlying the elicitation of all kinds of emotions in response to objects of esthetic contemplation, and specifically to artworks. Interest, confusion, and surprise, that is to say, the knowledge emotions, are elicited by appraisals in terms of novelty, complexity, familiarity, and coping potential. Appraisals of goal-incongruence, intentionality, harmfulness, or contamination can lead to such hostile emotions as anger, disgust, or contempt. People can also feel self-conscious emotions, such as pride, shame, and embarrassment, while engaging with art. They are related to appraising the congruence of artworks with one’s own values, self-image, or goals, the degree personal responsibility, and the consistency with one’s standards (Silvia, 2009).

Scherer (2004), however, argued that esthetic emotions – understood as common emotions experienced in response to art – differ from utilitarian emotions, that is to say, common emotions experienced in response to physical and social events occurring outside any artistic context. Esthetic emotions lack the appraisals of goal relevance and coping potential, common to utilitarian emotions: “an aesthetic experience is one that is not triggered by concerns with the relevance of a perception to my bodily needs, my social values, or my current goals or plans, nor with how well I can cope with the situation, but one where the appreciation of the intrinsic qualities of a piece of visual art or a piece of music is of paramount importance” (Scherer, 2004: p. 244). Although esthetic emotions can come with strong phenomenological feelings, they exhibit weaker physiological manifestations than utilitarian emotions, and they lack the arousal and action-oriented responses observed in the latter: when physiological responses – in the form of chills, shivers, or moist eyes – accompany esthetic emotions, they are not aimed at preparing the organism for any specific adaptive action.

Finally, others have maintained that the emotional facet of esthetic experiences is dual. It is not only the content and its personal significance, that drives the emotional response in an esthetic episode (Frijda, 1986; Tan, 2000). The response to Scherer’s (2004) intrinsic qualities constitutes a separate and discrete emotional aspect of the esthetic experience. Thus, the represented content arouses one kind of emotions, called ‘complementing emotions’ (Frijda, 1986) or ‘represented emotions’ (Tan, 2000). These could be any of the common emotions. In addition, the style, the medium, or the process itself of achieving understanding of the artwork or the object, can elicit a different sort of emotions, called ‘responding emotions’ (Frijda, 1986) or ‘artifact emotions’ (Tan, 2000). The enormous expressive potential of art and esthetics allows multiple combinations of these classes of emotions. Artists throughout the centuries have, in fact, exploited the effects of

the incongruence of emotions elicited by content and style (Eco, 2007). Some Hellenistic artists, for instance, abandoned idealist representations in favor of the accurate depiction of profane and everyday topics, which sometimes involved portraying the visible manifestations of old age, violence, or suffering (Stokstad and Cothren, 2011) (Figure 2).

Neuroesthetics has contributed to this discussion, mainly through the use of neuroimaging and psychophysiological techniques, in two different ways. First, it has provided psychologists with a new level of analysis. Second, it has allowed asking fascinating new questions. For instance, Skov (2010) sought to characterize the neural mechanisms that enable us to deal with the aforementioned conflicting emotional responses elicited by images' content and formal qualities. He showed participants a series of 300 pleasant, neutral, and unpleasant photographs from the International Affective Picture System, while in the functional magnetic resonance imaging (fMRI) scanner, and asked them to rate them as beautiful, neutral, or ugly. His comparison of brain activity while viewing images rated as beautiful and ugly, regardless of their affective valence, confirmed previous studies that had revealed the involvement of perceptual processing (i.e.,

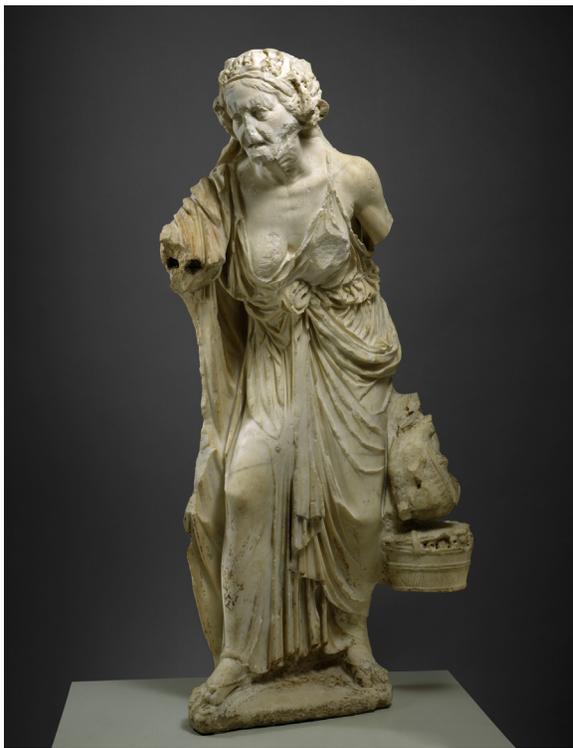


Figure 2 Statue of an old market woman (first century AD). She constitutes the opposite of the composed and ideally represented beauty of the Greek Classical period. Her dropped lower jaw, unsteady gait, foggy gaze, and indifference toward her exposed breast, suggest she might be a debauched Dionysian follower on her way to an offering. Technically, however, the statue constitutes a masterful rendering of complex textures and forms that create the striking contrasts of light and shadow that characterize much of Hellenistic sculpture (Stokstad and Cothren, 2011). Original height: 49 5/8 in. (125.98 cm). The Metropolitan Museum of Art, Rogers Fund, 1909 (09.39). Image © The Metropolitan Museum of Art. Reprinted with permission.

superior occipital gyrus, fusiform gyrus, among other regions), reward processing (i.e., orbitofrontal cortex, cingulate cortex), and executive processing (i.e., several prefrontal regions). By examining the interaction between the affective valence of the images' content and participants' ratings, he identified brain regions whose activity was different when participants rated unpleasant images as beautiful and when they rated pleasant images as beautiful. This comparison revealed activity in additional regions of the brain, especially in high-level perceptual processing areas, such as the inferior and superior temporal sulci, and certain regions related with reward, such as the caudate nucleus. These results suggest that specific perceptual and affective mechanisms come into play when we appreciate the esthetic qualities of stimuli depicting emotionally negative content.

Salimpoor et al.'s (2011, 2013) studies on the neural underpinnings of positive emotional responses to music constitute excellent examples of how neuroesthetics can open new avenues of inquiry. Salimpoor et al. (2011) examined the release of dopamine in different brain regions while people listened to musical pieces that they either did or did not deeply enjoy with a special interest in participants' arousal peaks. Their study revealed an unforeseen functional dissociation. Whereas the caudate was more active during the anticipation of peak emotional experiences, the actual experiences were associated with dopaminergic activity in the nucleus accumbens, showing how the emotional experience of music is mediated by two distinct anatomical pathways that play two different, but complementary, roles in anticipating and generating pleasurable feelings. But how is this positive emotional response tied into the overall esthetic experience? Salimpoor et al. (2013) subsequently used a bidding paradigm, in which participants were asked to listen to unfamiliar fragments of music and allocate amounts of money to listen to them again if they wished. The degree of activity in the nucleus accumbens and an increase in functional connectivity between this region and the auditory cortex, the amygdala, and the ventromedial prefrontal cortex, predicted the amount of money participants were willing to pay to listen to their preferred fragments again (Figure 3). These results attest to the importance of the interactions among brain regions involved in reward, sensory processing, and valuation in the generation of the esthetic experience.

Context

With *Fountain* (1917), Marcel Duchamp revolutionized the debate about what constitutes an artwork, and attempted to demonstrate that esthetic qualities could not be part of necessary criteria (Figure 4). However, even when his readymade aimed to divorce esthetics from art, some critics were unable to detach themselves from their esthetic orientation toward artworks, believing that "Duchamp was drawing attention to the white gleaming beauty of the urinal" (Danto, 1997), and even stating that "A lovely form has been revealed, freed from its functional purpose, there a man has clearly made an esthetic contribution" (Danto, 1997). A fundamental question arises, thus: what are the contextual conditions that foster such esthetic admiration for everyday objects whose esthetic qualities go otherwise unnoticed?

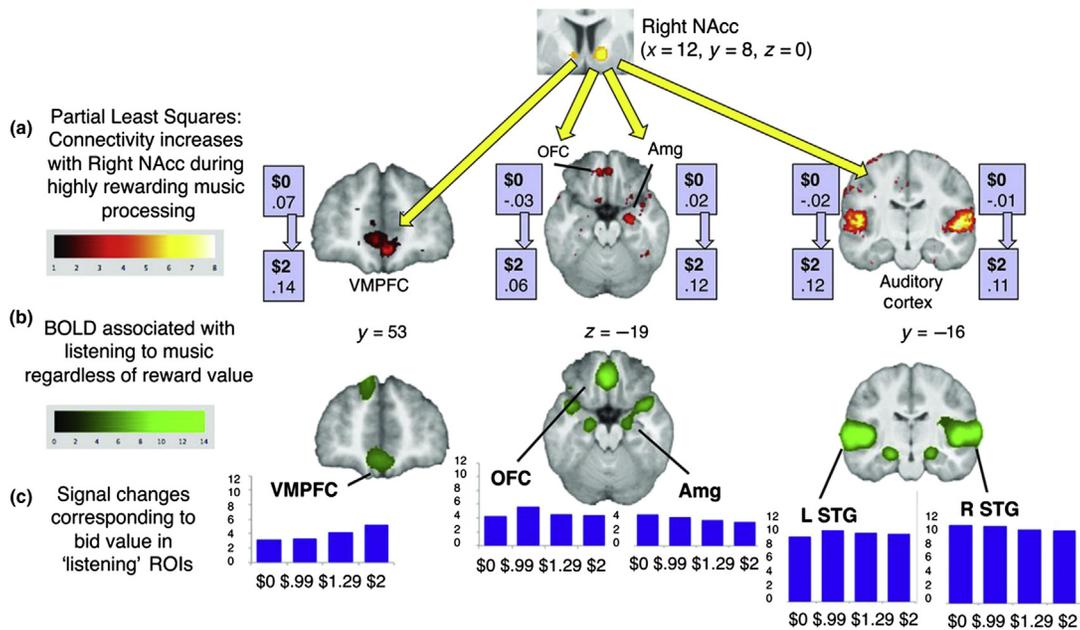


Figure 3 Changes in NAcc functional connectivity associated with increasing desirability of music. (a) Partial least-squares analysis revealed robust increases in connectivity between the nucleus accumbens (NAcc) and other subcortical and cortical regions when individuals hear music they consider highly desirable, compared with music they do not want to hear again. The boxes show changes in correlation as a function of amount bid between the NAcc and each region. A subset of these regions (shown in panel a) overlap with areas that are recruited during music listening compared with rest (panel b). These areas show equally high activity during all music valuation conditions compared with rest (panel c), but their interactions with the NAcc increase as items become more desirable. Amg, amygdala; ROI, region of interest. Copyright 2013 by the American Association for the Advancement of Science. Reprinted with permission.



Figure 4 Marcel Duchamp 'Fountain, 1917'/© Succession Marcel Duchamp/VBK, Vienna 2013. Photo: Alfred Stieglitz 'Fountain, photograph of sculpture by Marcel Duchamp (1917)'/© VBK, Vienna 2013. Reprinted with permission.

The conditions under which certain contextual features modulate neural activity underlying esthetic preference are, in fact, a major topic for neuroesthetics. Several studies have shown that personal attitude toward the object presented and beliefs about it have strong effects. Cupchik et al. (2009) demonstrated that people's orientation toward paintings modulated brain activity associated with esthetic preference. They asked participants to focus on the artworks with an esthetic orientation, attending to their esthetic experiences and the works' esthetic qualities, or to view them merely to obtain information from them and take note mostly of the depicted content. The esthetic orientation led to a greater activity in prefrontal brain regions, suggesting a greater degree of cognitive control. The pragmatic orientation, in contrast, was related to an increase in the activity of occipital regions, suggesting an enhancement of perceptual processes. These results show how certain parts of the network of brain regions involved in computing esthetic preference are modulated by the attitude with which we approach an object.

Kirk et al. (2009a) showed how different semantic contexts, which prompted different expectations on behalf of the participants, had a modulating effect on the activity of certain brain regions involved in esthetic appreciation. Participants viewed a series of abstract images while in the fMRI scanner. They were led to believe that some of these images, which were accompanied by the label 'gallery,' were reproductions of artworks exhibited in a renowned gallery. They were told that the other images, presented with the label 'computer,'

had been created by the experimenters using an image editing software. In reality, all stimuli had been created by the experimenters for the experiment. Despite this, participants preferred the images they believed were taken from a gallery more than those they believed were computer generated. Moreover, the authors found that the activity of the medial orbitofrontal cortex, a brain region known to play a key role in the processing of reward value, increased significantly when participants were viewing the images under the gallery-label condition. A similar study was performed by Huang et al. (2011). They asked their participants to view a set of Rembrandt portraits, and led them to believe that some were authentic and others were copies. Their results showed that believing that the images were copies increased the activity in the frontopolar cortex, which in turn modulated activity in the visual cortex, which is consistent with participants' reports that in this condition they had attempted to identify the cues indicating that those portraits were copies. When the portraits were accompanied by the label 'authentic,' activity in the orbitofrontal cortex increased, similarly to Kirk et al. (2009b) finding. This sort of framing-effects appears to influence neural activity as soon as 200 ms after the presentation of the stimuli (Noguchi and Murota, 2013). These studies clearly show how beliefs and expectations generated using semantic framing with simple words, such as 'authentic,' 'fake,' or 'copy,' can influence neural processes related with the affective processes involved in esthetic preference. These contextual effects, however, can be overridden by participants' expertise (Kirk et al., 2011).

Expertise

Understanding how humans acquire, store, and use knowledge is one of the central aims of cognitive science. Because experts excel at these tasks within their own domains, they have attracted the attention of cognitive scientists. Within their particular domain, experts arrive at the best solution faster and more accurately, they are able to select adequate strategies more successfully, they detect features that novices cannot, they represent problems at a deeper level, they have more accurate self-monitoring strategies, and they execute skills with greater automaticity and less effort (Chi, 2006). There are three fundamental reasons why researchers within the field of neuroesthetics have turned to the study of art or esthetic expertise. In the first place, it provides an optimal strategy to understand how art and esthetic knowledge is acquired, organized, and used. Second, it allows understanding how prior knowledge and experience interact with cognitive and affective processes to produce the esthetic experience or to modulate esthetic preference (Leder et al., 2004). Finally, given that expertise and long-term training are related to modifications in brain processes underlying domain-relevant tasks, expertise can be regarded as a 'natural model' of neural plasticity (Münte et al., 2002).

Studies on the neural foundations of expertise in the domains of art and esthetics have yielded four main findings. First, when making judgments about their objects of expertise, experts tend to show greater activity than nonexperts in brain regions related to conceptual association, memory retrieval, and the activation of referential contexts (Kirk et al., 2009a; Wiesmann and Ishai, 2010), illustrating how experts rely to

a greater extent on stored knowledge than nonexperts, who rely more on subjective impressions and momentary feelings.

Second, experts in the domains of art and architecture seem to process their objects of expertise with greater 'neural efficiency,' as suggested by a reduced neural activity in certain regions when compared with nonexperts (Berkowitz and Ansari, 2010; Pang et al., 2013). This finding mirrors the decreases in the extent and intensity of brain activation observed when experts in many other domains perform tasks they are specialized in, suggesting that training and practice reduces the extent or intensity of brain activation by increasing neural efficiency, defined as a sharpening of neural responses in task-relevant processing networks (Kelly and Garavan, 2005).

Third, studies have shown that experts are able to filter out the less relevant information for the task at hand. Expert dancers, for instance, rely less than nonexperts on visual information, and emphasize proprioceptive information (Jola et al., 2011). When evaluating their own objects of expertise, musicians, architects, and art experts integrate reward-related processes in a different way to nonexperts, and are able to ignore irrelevant contextual information biasing such processes (Kirk et al., 2009a, 2011; Müller et al., 2010). For instance, Müller et al. (2010) found that, when asked to rate musical stimuli esthetically, laypeople relied on their affective reactions to the stimuli more than experts, who were able to set aside such reactions and focus on the esthetic qualities of the stimuli to a greater degree. Kirk et al. (2011) demonstrated similar emotional regulation in art experts. Whereas monetary sponsorship enhanced laypeople's appreciation of artworks, and increased activity in the ventromedial prefrontal cortex, art experts were not affected by sponsorship. Results showed that, in the case of experts, the dorsolateral prefrontal cortex downregulated activity in the ventromedial prefrontal cortex, suppressing the effects of the monetary favor on the appreciation of art.

Finally, although expertise is by definition domain-specific, experts outperform nonexperts in tasks that are not directly related to their domain of expertise, and several studies have begun exploring the neural underpinnings of these effects. Musicians, for instance, are able to detect small local deviations in foreign language pitch better and earlier, and such ability is related with underlying neural processes related to the categorization of pitch contours (Marques et al., 2007). Electrophysiological data have shown that musicians are also better than nonmusicians at learning linguistic structures, presumably because of their training in segmentation and memory of auditory streams (Francois and Schön, 2011). The application of abilities learned in one domain to a related one has also been observed in the area of visual arts (Pang et al., 2013). This sort of studies suggests that art and music experts transfer their strategies and abilities to nonartistic and nonmusical stimuli.

Future Avenues for Research in Neuroesthetics

Probably, the greatest challenge neuroesthetics facing today is to expand beyond its reliance on neuroimaging and its focus on brain regions involved in esthetic experience. The tools and

methods afforded by cognitive neurogenetics, for instance, could foster a deeper understanding of the biology of esthetic experience below the level of networks of regions, clarifying the role of hormones, neurotransmitters, or genes. Alterations in neurotransmitter function in disorders such as Parkinson's, depression, or anxiety, can have clear effects on value-based decision making in other domains (Ramsøy and Skov, 2010). Increased dopamine levels can interfere with the integration of emotional and cognitive processes, a crucial mechanism underlying decision making in normal conditions. High concentrations of serotonin, on the other hand, can shift choice strategy, from searching for gains to avoiding loss, risk, or ambiguity.

As Green et al. (2008) argued, however, studying genetic variation as a determinant factor of brain function is not only relevant to understanding the origin and development of pathologies. It also holds great potential to clarify healthy cognitive function. In fact, the aforementioned effects linked to certain disorders only reflect the extremes of a continuum of individual variability in naturally occurring neurotransmitter levels. Such variation is, in turn, the result of the interaction between genetic differences among individuals and particular life experiences (Green et al., 2008; Ramsøy and Skov, 2010). Individual differences in specific genes lead to quantifiable differences in the synthesis of proteins. Because genetic variation can occur in genes related to neurotransmitter function, they can produce differences in neurotransmitter synthesis, transport, postsynaptic uptake, presynaptic reuptake, or breakdown. In turn, this sort of variation in molecular function can affect the degree or location of neural activity underlying certain cognitive operations, which might even translate into differences in overt behavior or performance (Green et al., 2008; Ramsøy and Skov, 2010).

Although these facts have been shown for domains unrelated to art or esthetics, they constitute firm grounds for testing hypotheses regarding esthetic appreciation. It is conceivable that genetic imaging could be used in future studies to point to certain genomic variations that are linked to emotional or cognitive processes involved in esthetic appreciation, and even characterize neural connectivity patterns associated with such processes in participants that differ as a function of the underlying genetic variation. Is this a viable direction for research within neuroaesthetics? Will this sort of strategies lead to an integral understanding of the biology of esthetic experience? "Well, we must wait for the future to show" (Woolf, 1930).

See also: Cognitive Neuroscience; Emotion, Neural Basis of; Human Cognition, Evolution of; Neuroeconomics; Neuromarketing; Prefrontal Cortex; Visual Perception, Neural Basis of.

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Relevant Websites

- <http://www.association-of-neuroesthetics.org> – Association of Neuroesthetics.
- <http://neuroesthetics.org> – Institute of Neuroesthetics.
- <http://www.brams.org/en/> – International Laboratory for Brain, Music and Sound Research.
- <http://neuroaesthetics.net> – International Network for Neuroaesthetics.