Psychology of Aesthetics, Creativity, and the Arts
2013, Vol. 7, No. 1, 1–12

1931-3896/13/$12.00 DOI: 10.1037/a0031842

Introduction to the Special Issue: Toward an Interdisciplinary Neuroaesthetics

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Had we been there, we might have noticed that the people entering the cave, on the cliff overlooking the ocean, were carrying several objects. We might have given in to our curiosity, and quietly followed them in. Once inside, we would have seen them laboriously rubbing reddish rocks against shiny gray slabs of stone, producing a thin red powder. We would also have noticed them using sharp stone tools to break off small pieces from the red rocks, which they then crushed with stone hammers. A large mammal bone that had previously been heated with fire was also mashed. They subsequently mixed the powder, the crushed rock and bone with charcoal and a liquid in two large abalone shells. The mixture was stirred gently and extracted from the two containers with a long thin broken bone. After applying the deep red compound, they left their tools in two neat packages on a sandy mound in the cave, ready to be used the next time. Neither toolkit, however, was used ever again. They were covered by the sand blowing in from the outside, and remained buried for about 100,000 years. They were not seen again until 4 years ago, when the team of archeologists working at what is known today as Blombos Cave, on the shore of the Indian Ocean, 300 km east of Cape Town, unearthed both sets of tools, still tightly piled and set 16 cm apart from each other (Henshilwood et al., 2011) (see Figure 1).

The toolkits were preserved in excellent condition, allowing researchers to retrieve ochre from the hammer, the grinding slab and the flakes, and samples of the mixture itself from the shell and a canid ulna that was probably used as a spatula. Chemical analyses have revealed the red pigment's composition, but we will probably never know with certainty what those early *Homo sapiens*, physically very similar to us, used it for. On what did they apply it? The compound contained no resin or wax, so it was probably not used as an adhesive. More likely, it was used to paint a surface or to create a design on it. People had been processing ochre for tens of thousands of years before in several places across Africa, and researchers believe that they used it for coloring in general, and body painting in particular, because highly saturated red minerals were preferred to other colors (Marean et al., 2007). Ochre sought for the specific red hues it produced, and dated to 90,000–100,000 years, has also been found in Qafzeh Cave, Israel. Again, researchers have claimed that its primary purpose was painting bodies (Hovers, Ilani, Bar-Yosef, & Vandermeersch, 2003), and maybe the bodies of the deceased, as inferred from the association of pigment with burials.

Ochre was not only used as a source for pigment. There is evidence for a true tradition of engraving ochre at Blombos Cave itself, less than 25,000 years after the pigment preparation episode described above (Henshilwood, d'Errico, & Watts, 2009). Engraving, however, was not limited to ochre or Blombos Cave. It was practiced in many locations throughout Africa, and also on bone and ostrich shells used as containers (Texier et al., 2010). There is also evidence that between 100,000 and 70,000 years ago our ancestors in northern and southern Africa created personal ornaments using shells collected from the seashore and riverbeds. The shells were perforated and strung together. They were often painted or worn against painted bodies or clothes (Bouzouggar et al., 2007; d'Errico, Henshilwood, Vanhaeren, & van Niekerk, 2005; d'Errico et al., 2009; Henshilwood, d'Errico, Vanhaeren, van Niekerk, & Jacobs, 2004; Vanhaeren et al., 2006).

With the possible exception of Neandertals (Roebroeks et al., 2012; Zilhão et al., 2010), there is little evidence of such an intense and consistent interest in color and ornamentation in earlier hominin species. And there is growing evidence that our species expressed itself through color, ornaments, and other symbolic means wherever it went (Balme, Davidson, McDonald, Stern, & Veth, 2009; Brumm & Moore, 2005). Such behaviors seem to be, thus, inherent constituents of our human nature, a true species property, to borrow the expression Chomsky (1988) used when referring to language. All humans engage aesthetically with different forms of visual representation, or music, dance, literature, theater, landscapes, and so on. Such engagement can take the form of liking, disliking, preferring, or finding beauty or ugliness in the world around us. As Lorblanchet put it, "humans are by nature

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The organization of this special issue was funded by the government of the Balearic Islands (Special Action Grant No. AAEE124/09), the European Regional Development Fund, and the Department of Psychology, University of the Balearic Islands.

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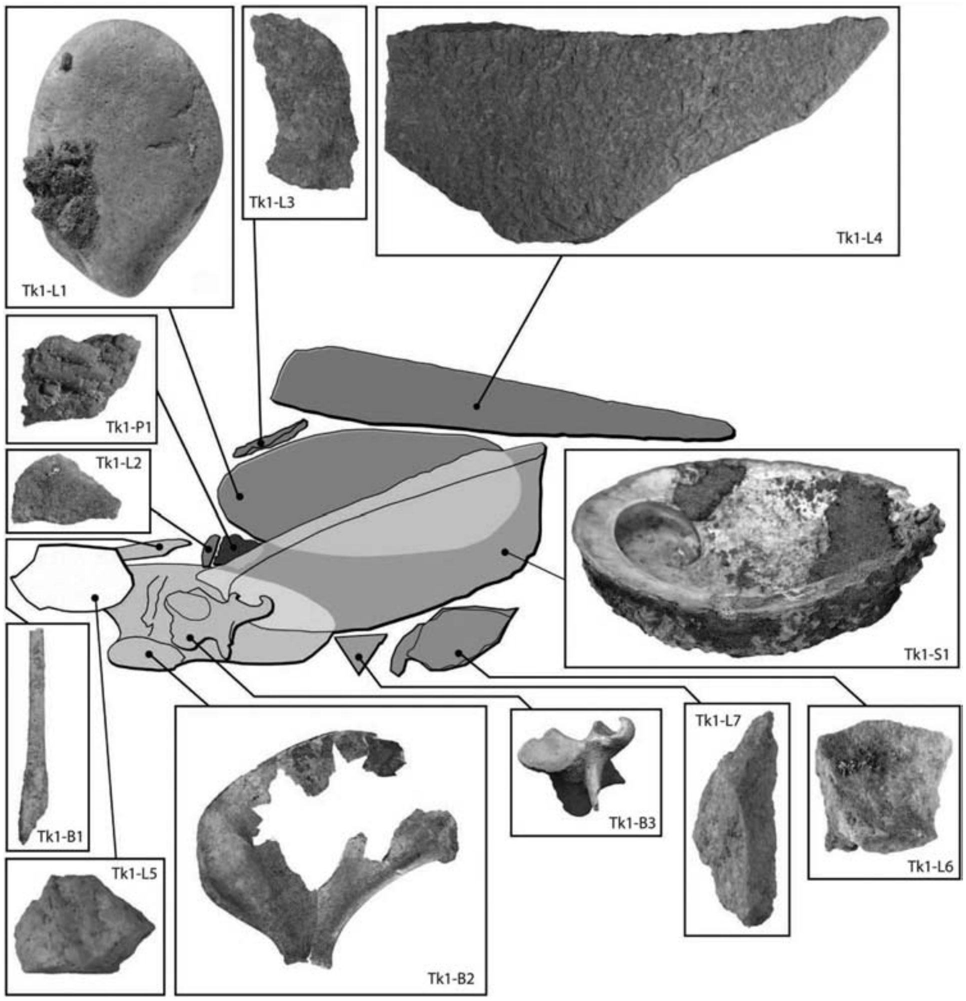

Figure 1. Toolkit 1 (Tk1) recovered at Blombos Cave, South Africa. B1 = canid ulna with ochre residue on the tip; B2 = seal scapula; B3 = broken bovid vertebra; L1 = quartzite cobble used as a hammer; L2, L3 = quartz flakes; L4 = quartzite slab with longitudinal streaks of red ochre used as a grinder; L5, L6, L7 = quartz flakes; P1 = small piece or red ochre rubbed on one face; S1 = abalone shell (*Haliotis midae*). Figure created by C. Henshilwood and F. d'Errico. Copyright 2011 by the American Association for the Advancement of Science and C. Henshilwood and F. d'Errico. Reprinted with permission.

artists and the history of art begins with that of humanity" (Lorblanchet, 2007, p. 109).

Science is challenged to explain the biological foundations of such a unique trait. And this is, in fact, the general goal of neuroaesthetics. Experimental studies of brain mechanisms involved in the appreciation of art and aesthetics have proliferated rapidly in the last decade. The development of new neuroscientific methods and the growing number of researchers interested in the biological foundations of art and aesthetics have contributed to the emergence of neuroaesthetics as a proper research field. However, to avoid tripping over itself even before it can make significant steps forward, neuroaesthetics needs to search for firm footing in closely related disciplines. We expect more from neuroaesthetics than a mere catalog of brain regions whose activity is related with aesthetic and artistic activities. We expect it to contribute to fundamental discussions raised by psychologists, anthropologists, and other scientists, but we also expect it to pose new questions, and offer new answers that will intrigue our colleagues. Neuroaesthetics needs to ask and answer questions that are meaningful beyond its own boundaries. We believe that the only way neuroaesthetics will achieve this is through a fluid dialogue with other disciplines. The aim of this special issue is to initiate this dialogue. Because introducing oneself is always a good and polite way to start a conversation, let us begin by talking about neuroaesthetics, its history, its scope, its methods, and the kind of topics with which it is currently concerned. As we proceed, we will also introduce the contributions to this special issue.

Historical Roots of Neuroaesthetics

Neuroaesthetics received its name late. It was only at the very end of the 20th century that Zeki (1999) coined the term. By being nameable, neuroaesthetics suddenly became visible as a distinct field of research in its own right, and was then able to flourish. But, if we understand neuroaesthetics as the inquiry into the neurobiological substrates of aesthetic experience, it has existed, unnamed, for at least 250 years. Burke (1757) was probably one of the first to write about the physiological bases of aesthetic experience in some depth. His central proposition was that there are no specific biological mechanisms that give rise to such experiences. The physiological explanation of the beautiful and the sublime was the same as for the nonaesthetic emotions. He believed that objects, landscapes, and other people were experienced as beautiful 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, like pain, fear, or terror, were experienced as sublime. Other scholars subsequently extended Burke's notion that aesthetics is rooted in the physiology of common emotions to music (Webb, 1769, as reproduced in Katz & HaCohen, 2003) and to the picturesque (Price, 1810).

Very shortly after Darwin (1859/1991) had offered natural selection as an explanation for the evolution of living organisms, scientists began advancing hypothetical scenarios describing the origin and evolution of art and aesthetics (Allen, 1880; Balfour, 1893; Clay, 1908; Hirn, 1900). Darwin (1871/1998) himself thought that sexual selection had played a major role. Two main drawbacks limit the significance of these approaches. First, they were mostly based on logical deduction, conjecture, and speculation. Little was offered to support the claims. Second, the aim of most of these proposals was to identify a single selective advantage afforded by art or aesthetic appreciation. They limited art or aesthetics to performing one major function in human lives, a highly adaptive one. Some recent perspectives (Miller, 2000; Miller, 2001; Orians, 2001; Orians & Heerwagen, 1992; Tooby & Cosmides, 2001) show similar shortcomings. The aim of Zaidel, Nadal, Flexas, and Munar's (2013) contribution to this issue is to assemble the relevant archeological and neuroscientific evidence that could serve as a basis for any proposal on the evolution of art or aesthetic experience. They also use these facts to propose a general framework, a sketch, of how the capacity to appreciate the aesthetics of objects might have evolved.

The feelings of pain and pleasure became the center of psychological theories of aesthetics toward the end of the 19th century. Marshall (1892, 1893) even considered psychological aesthetics as a branch of hedonics. And, anticipating current interest in the embodiment of aesthetics, Allen (1877) made the bodily processes of pain and pleasure the cornerstone of his *Physiological Aesthetics*.

It was Fechner's (1876) *Vorschule der Aesthetik*, however, that marked the inception of empirical aesthetics. Fechner developed a suite of basic principles to which he believed aesthetic phenomena could be reduced. 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 aesthetics as quickly as the use of the other two declined, to the point that most of what empirical aesthetics has shown about people's aesthetic experience has been based on a single method: choosing.

Different variants of the method of choice have become popular, including ordering, paired comparisons, or selecting a number that represents the degree of preference or liking. Külpe (1895, 1907), who compiled and refined some of Fechner's methods and developed new ones, stated that only the method of choice "has any general claim to rank as a real experimental method" (Külpe, 1895, p. 238). He believed, however, that the method of production should not be abandoned, for it could constitute a valuable complement to the method of choice. The main problem resided in making it amenable to quantification and statistical treatment. In this issue, Westphal-Fitch, Oh, and Fitch (2013) tackle this longstanding challenge by developing an ingenious system that overcomes the inherent limitations of the method of production. Their software allows quantifying specific parameters, which can then be subjected to the usual, as well as innovative, statistical tests. It also avoids the method of production's most problematic drawback: that participants' technical limitations can prevent their productions from reflecting their originally intended output. Almost anyone could learn to use FlexTiles, their interactive pattern generation software.

During the 20th century, the incipient neuroaesthetics turned toward 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; Dupré & Nathan, 1911; Gourevitch, 1967; Souques & Baruk, 1930; Zaimov, Kitov, & Kolev, 1969). Because these 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. Thus, as we will see later, researchers have recently devised proper measurement instruments and procedures.

The neuroimaging techniques that became available toward the end of the 20th century allowed scientists to explore their hypothesis experimentally in controlled situations, with the participation of healthy subjects, and to correlate appreciation and enjoyment of music, painting, architecture, sculpture, and dance, with the activity of several brain structures. As Burke (1757), Marshall (1893), and Allen (1877) foresaw, neuroimaging studies have revealed that neural activity in the reward circuit is a key component of aesthetic experience. But the picture is rather more complex than anyone anticipated. Our positive feelings of liking or enjoying beauty are the product 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) (Blood & Zatorre, 2001; Cupchik, Vartanian, Crawley, & Mikulis, 2009; Harvey, Kirk, Denfield, & Montague, 2010; Ishizu & Zeki, 2011; Kawabata & Zeki, 2004; Kirk, Skov, Hulme, Christensen, & Zeki, 2009; Kranz & Ishai, 2006; Lacey et al., 2011; Mitterschiffthaler, Fu, Dalton, Andrew, & Williams, 2007; Salimpoor, Benovoy, Larcher, Dagher, & Zatorre, 2011; Vartanian & Goel, 2004).

Additionally, aesthetic appreciation involves at least two other kinds of brain activity (Nadal & Pearce, 2011): (a) an enhancement of low- and mid-level cortical visual, auditory, and somatosensory processing (Calvo-Merino, Urgesi, Orgs, Aglioti, & Haggard, 2010; Cela-Conde et al., 2009; Cupchik et al., 2009; Koelsch, Fritz, von Cramon, Müller, & Friederici, 2006; Mitterschiffthaler et al., 2007; Vartanian & Goel, 2004), presumably reflecting the engagement of attention or the biasing effects of affective processes on perception; and (b) high-level top-down processing and activation of cortical areas involved in evaluative judgment, including the anterior medial prefrontal cortex and the ventral and dorsal aspects of the lateral prefrontal cortex (Cela-Conde et al., 2004; Cupchik et al., 2009; Jacobsen, Schubotz, Höfel, & von Cramon, 2006; Lengger, Fischmeister, Leder, & Bauer, 2007).

Can psychological aesthetics profit from these recent findings in neuroaesthetics? Should psychological aesthetics have a more prominent role in the development of neuroaesthetics? The relation between psychological and neuroscientific approaches to aesthetics is the main topic of Leder's (2013) contribution to this issue. He approaches this topic by reexamining Leder, Belke, Oeberst, and Augustin's (2004) influential model in the light of new psychological, psychophysiological, and neuroimaging data, and by suggesting future avenues of research. Leder et al.'s (2004) principal accomplishment was to provide an account of the main factors that play a role in the experience of art in the form of a predictive model formulated at the level of cognitive processes. One of this model's main features is that the whole aesthetic experience is embedded in a context whose significance is given by a specific social discourse and that determines the experienced object's particular meaning. The aesthetic episode is broken down into five main stages, varying in the extent to which processing is automatic and deliberate as well as the susceptibility to the subject's previous experience and knowledge. These stages, ordered in the direction of ascending information processing from perception to evaluation, interact continually with affective processes (see Figure 2).

Leder (2013) highlights how the initial model did not fully account for the intricacy of affective processes involved in aesthetic appreciation, as revealed by neuroimaging studies (e.g., Lacey et al., 2011; Salimpoor et al., 2011), and how one of the outstanding questions for future psychological and neuroscientific research is the understanding of the temporal dynamics of cognitive and affective processing of art and aesthetics.

Neuroaesthetics: Aims, Methods, and Domains

What Is Neuroaesthetics?

The backgrounds and particular interests of researchers within the field of neuroaesthetics differ considerably. Not surprisingly, they have divergent views on the aims and scope of neuroaesthetics. Di Dio and Gallese (2009), for instance, have stated that neuroaesthetics "refers to the study of the neural bases of beauty perception in art" (p. 682). This restrictive view limits its subject to a unique kind of aesthetic experience—beauty—and a single kind of object—art. When defining neuroaesthetics as "a discipline whose express purpose is to use the tools and paradigms [afforded by neurophysiology and neuroscience] to address questions about which features of artistic expression the brain responds to" (Cross & Ticini, 2012, p. 6), or as "the scientific study of the neural bases for the contemplation and creation of a work of art" (Nalbantian, 2008, p. 357), its scope also becomes limited exclusively to art-

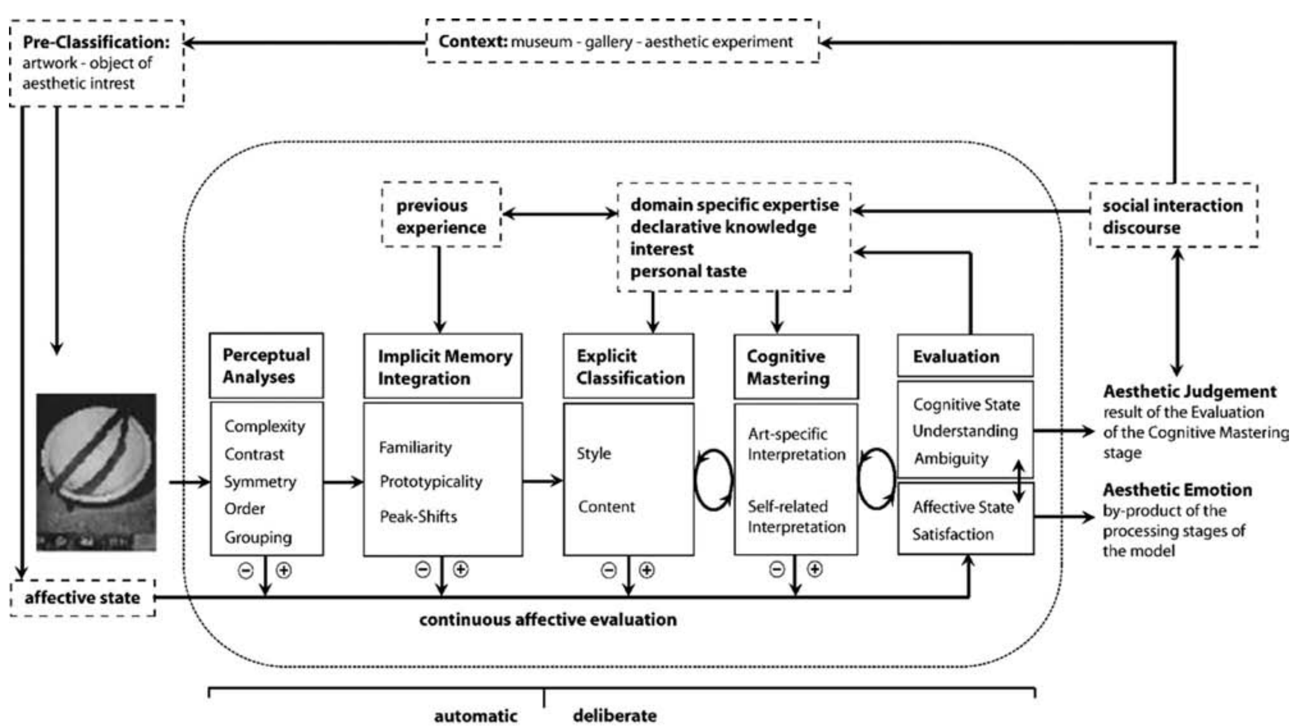

Figure 2. Leder, Belke, Oeberst, and Augustin's (2004) model of aesthetic experience of art. Copyright 2004 by Helmut Leder. Reprinted with permission.

works. Other views are significantly broader, including more kinds of experiences and objects with which they are related. Nadal and Pearce (2011) have argued that neuroaesthetics should aim to study "the neural basis of cognitive and affective processes engaged when an individual takes an aesthetic or artistic approach toward a work of art, a nonartistic object or a natural phenomenon" (p. 172), and Chatterjee (2011) defined neuroaesthetics "as a domain that has something to do with properties of the brain as it engages in aesthetics, [the term is] used broadly to encompass the perception, production, and response to art, as well as interactions with objects and scenes that evoke an intense feeling, often of pleasure" (p. 53).

There is a fundamental reason why we believe that establishing the boundaries of neuroaesthetics along the art–not art division betrays the whole purpose of neuroaesthetics. The notions of art, artist, and artwork are culturally and historically contingent, as are the criteria used to distinguish what is an artwork from what is not, or what is an art form from what is not. Kristeller (1952) emphasized this point when he wrote that "The various arts are certainly as old as human civilization, but the manner in which we are accustomed to group them and to assign them a place in our scheme of life and culture is comparatively recent [. . .] The branches of the arts all have their rise and decline, and even their birth and death, and the distinction between 'major' arts and their subdivisions is arbitrary and subject to change" (p. 45). The fact that most people do no longer regard eloquence or gardening as art forms, along with painting, music, or sculpture, has nothing to do with cognitive or biological considerations. It is the result of a system of arts that emerged during the 18th century to fit new European social and cultural events and views (Shiner, 2001).

Hence, there are good reasons to include within the scope of neuroaesthetics experiences related with human creations that do not fit the modern system of the arts, such as mathematical theorems or computer programming, where aesthetic notions, such as elegance, can also play a role, as well as those related with natural elements or events, such as sunsets, sceneries, plants, or animals, which are often regarded in terms of beauty or ugliness. Neuroaesthetics should not be concerned with—or limited to—a particular class of objects. Rather, we believe neuroaesthetics should focus on a certain kind of way objects can be experienced when people approach them with an "aesthetic attitude" (Cupchik, 1992).

The articles included in this special issue, thus, present a view of neuroaesthetics as:

> the study of the neural processes [underlying] the psychological processes that are evoked in the creator or the viewer of the object in the course of interacting with it. These psychological processes may involve perceptual, sensory, cognitive, emotional, evaluative, and social aspects among others, all of which are presumed to have a biological—neural—basis. We use the term "objects" rather than the "arts" because aesthetic processes typify our interactions with a much wider array of objects than artworks alone. (Skov & Vartanian, 2009, p. 3)

As such, neuroaesthetics can be considered as one of the several branches of cognitive neuroscience, a scientific discipline that aims to "study humans with brain science techniques in concert with cognitive science methodologies" (Gazzaniga, 1984, p. vii), integrating the cognitive and neural explanatory levels of human behavior into a single discipline (Churchland & Sejnowski, 1988; Posner & DiGirolamo, 2000).

The Methods of Neuroaesthetics

In addition to discrepancies concerning the scope and identity of neuroaesthetics, researchers have used a broad variety of methods. One approach, which Chatterjee (2012) refers to as *parallelism*, has aimed to show how throughout the ages and across cultures artists have devised techniques and resources to catch our attention, interest us, and appeal to us by engaging certain neural processes related with rewarding sensations. This is the approach represented by Changeux's (1994), Zeki's (1999), and Ramachandran and Hirstein's (1999) theoretical works on visual neuroaesthetics, which provided the initial thrust for the field's development toward the end of the 20th century.

From the beginning of the 21st century, the field has not ceased to grow, mature, and diversify (Chatterjee, 2011; Nadal & Pearce, 2011), owing mainly to new empirical approaches. One option has been to explore the impact of brain damage and neural degeneration on the production and appreciation of art and on aesthetic experiences. Aiming to overcome the limitations of previous work, mentioned above, a number of researchers have developed quantitative strategies and searched for a unified system to describe changes after the onset of the illness. Chatterjee, Widick, Sternschein, Smith, and Bromberger (2010) introduced the Assessment of Art Attributes (AAA). This scale allows for the measurement of six perceptual features, such as color, balance, depth, or complexity, and six conceptual features, including abstraction, symbolism, or emotional expressiveness. In conjunction with voxel–lesion–symptom mapping, Bromberger, Sternschein, Widick, Smith, and Chatterjee (2011) used the AAA to show how specific brain lesions impair the appreciation of some of these art attributes but not others. Their results indicated that patients with damage to different regions within the right frontal, parietal, and lateral temporal cortices deviated significantly from healthy participants when rating four of the six conceptual scales: Abstractness, Symbolism, Realism, and Animacy. Appreciation of only one formal attribute—Depth—seemed to be affected by brain damage, specifically in the right inferior prefrontal cortex. In this issue, van Buren, Bromberger, Potts, Miller, and Chatterjee (2013) present a complementary use of the AAA: to study how Alzheimer's disease affects artistic production. Their results suggest that neurological illness tends to have a greater effect on conceptual aspects of artists' work than on their perceptual attributes, leading to the production of artworks that are less accurate, less realistic, and more abstract.

Halpern, Ly, Elkin-Frankston, and O'Connor (2008) devised a different strategy to quantify the effects of Alzheimer's and other kinds of neurodegenerative diseases on the appreciation of art and aesthetics, focusing on the stability of their artistic preference. They asked patients suffering from Alzheimer's, as well as a group of age-matched healthy people, to order three sets of cards, reproducing representational, quasirepresentational and abstract art, from most to least liked according to their preference. The same tasks were repeated again 2 weeks later. The comparison of rank orders for each artwork revealed no significant difference between the consistency of patients' and healthy controls' art preferences. Thus, patients with Alzheimer's were just as capable of responding to the aesthetic preference task and of producing a similar order after 2 weeks as their healthy peers, despite not recollecting the artworks from the first session (Halpern et al., 2008). Halpern and O'Connor's (2013) report in this issue extends this strategy to another neurodegenerative disease: frontotemporal dementia. Taken together, both reports illustrate the surprising resilience of preference for art in the face of neurological illnesses that can have devastating consequences for patients' cognitive function.

A second empirical approach, which is becoming increasingly popular, uses neuroimaging methods to study the role of different neural processes in aesthetic experiences in many healthy participants. When applied to neuroaesthetics, such methods have usually involved participants judging the beauty of stimuli presented to them, or stating how much they like them or prefer them, while their brain activity is being monitored. Because facial attractiveness is believed to play a fundamental role in social interaction among humans, a considerable number of studies have focused on the neural underpinnings of evaluations of facial attractiveness. The amygdala, caudate nucleus and nucleus accumbens, medial prefrontal, anterior cingulate, medial orbitofrontal, ventral occipital, anterior insular, dorsal posterior parietal, inferior dorsolateral, and medial prefrontal cortices seem to be the essential components of the neural system involved in processing facial attractiveness (Chatterjee, Thomas, Smith, & Aguirre, 2009; Mende-Siedlecki, Said, & Todorov, 2012; Nakamura et al., 1998). Some of the brain regions involved in evaluating facial attractiveness are sensitive to this feature even when people do not explicitly attend to it (Chatterjee et al., 2009). In this issue, Vartanian, Goel, Lam, Fisher, and Granic (2013) go beyond studies identifying the network of brain regions involved in facial attractiveness assessments common to all people. They focus on the brain regions related to individual differences in facial attractiveness processing and, more specifically, on the extent to which decisions incorporate information beyond the domain of faces, including semantic, social, or emotional aspects.

The Domains of Neuroaesthetics

The breadth of neuroaesthetics has also grown, because researchers have attempted to ascertain the neurobiology of aesthetic engagement in different domains: painting, design, consumer products, architecture, dance, music, bodies, and faces (Calvo-Merino et al., 2010; Cross, Kirsch, Ticini, & Schütz-Bosbach, 2011; Jacobsen et al., 2006; Kirk, Skov, Christensen, & Nygaard, 2009; Müller, Höfel, Brattico, & Jacobsen, 2009; Reimann, Zaichkowsky, Neuhaus, Bender, & Weber, 2010; Salimpoor et al., 2011; Vartanian & Goel, 2004; Winston, O'Doherty, Kilner, Perrett, & Dolan, 2007).

This issue includes two articles that focus on the aesthetic and emotional enjoyment of music (Brattico & Pearce, 2013; Salimpoor & Zatorre, 2013), and one that does so with regard to dance (Christensen & Calvo-Merino, 2013). Music is a central aspect of many people's lives, and it seems to have been so for most of our species' evolution. The oldest known musical instruments are as old as human presence in Europe. It is the sophistication of these instruments that struck Cross and Morley (2008), who pointed out that some of the 36,000-year-old pipes made from bird bones retrieved in Western Europe are more elaborate than many medieval counterparts. Complex musical behavior seems to have been part of modern humans' repertoire when they arrived in Europe, about 40,000 years ago. This raises the possibility that instruments were manufactured many thousands of years earlier, and that music entailing voice and body movement had been practiced even before then (Conard, Malina, & Münzel, 2009; Cross & Morley, 2008).

Brattico and Pearce (2013) review and integrate a large body of research dealing with the neural mechanisms underlying the perception, cognition, and emotion of music, and how these neural processes foster its aesthetic appreciation. Their aim is to put forward a framework that will be useful for developing a neuroaesthetics of music research program. From this perspective, the emphasis is on understanding how we perceive, represent, and are moved by music's artistic expressiveness, and how the brain arrives at aesthetic emotions, judgments, and preferences. The key, Brattico and Pearce (2013) suggest, may reside in the unique combinations of listener, listening situation, and music properties.

Salimpoor and Zatorre (2013) zoom in on the affective component of music appreciation. The main focus of their research is to understand the mechanisms that make certain sound sequences so pleasurable to hear. Their examination takes us deep into the brain, to have a closer look at the reward circuit's role in music enjoyment. A clue to answer this problem might reside in the integration of human brain regions that process natural rewards with neural mechanisms involved in high-level cognition. This close interaction enables top-down processes, allowing previous experience, knowledge, and meaning to mold our perception and interpretation of musical stimuli, and highlighting familiar and surprising musical events.

Christensen and Calvo-Merino (2013) take on the challenge of providing a review of how knowledge of the neural mechanisms underlying body and movement representation have served as foundations for studying how the human brain processes the aesthetics of dance. They also note interesting paradoxes that call for important research. For instance, although a number of studies have shown that people can recognize emotion expressed in body movements, including simplified representations and complex dance sequences, to date neuroimaging studies provide little evidence to suggest that emotional or affective processes play an important role in the aesthetic experience of dance. Christensen and Calvo-Merino (2013) offer some possible explanations for this, and suggest a number of improvements that might allow a better exploration of these and other issues.

Current Themes in Neuroaesthetics

Now that the key neurobiological mechanisms underlying the appreciation of art and aesthetics are becoming clearer, what issues concern neuroaesthetics today? Besides the obvious need to understand how these brain regions act in concert to produce phenomenologically singular aesthetic experiences, two issues stand out, in our minds, for their major implications: (a) Why and how does art move us emotionally? (b) What kinds of factors modulate activity of the neural networks underlying aesthetic appreciation, and how is this modulation achieved?

The first issue immediately raises complex questions. Are there specific aesthetic emotions? Are the emotions we feel during aesthetic experiences somehow attenuated versions of common emotions? Some researchers have argued that there are classes of emotions that constitute fitting responses to art and that are intrinsic to aesthetic experiences. Konecni (2005), for instance, conceived aesthetic awe as a specific aesthetic emotion, as a prototypical response to the sublime. In fact, he argued that "It is the most pronounced, the ultimate, aesthetic response, in all ways similar to the fundamental emotions" (Konecni, 2005, p. 31). Keltner and Haidt (2003), in contrast, viewed awe as an emotion that can, under certain circumstances, accompany different experiences. In the case of the appreciation of art, Keltner and Haidt (2003) suggested that it is art's reliance on depictions of vastness, exceptional actions or moments, or just its sheer size that makes it possible to produce profoundly moving emotions of awe that go beyond aesthetic pleasure per se.

At the opposite extreme, Lazarus (1991) has argued that there is no such thing as an exclusive or prototypical aesthetic emotion. When we talk about aesthetic emotions, we actually mean common emotions that are experienced in response to art: "Aesthetic emotions occur when we react emotionally to movies or drama, a painting, sculpture, music, a natural scene, or a religious experience" (Lazarus, 1991, p. 292). Aesthetic emotions, thus, are elicited by the portrayal of emotional content to which we relate. As a consequence, a crucial aspect of the aesthetic emotions is the extent to which the spectator identifies with what is represented, the personal meaning attributed to the depicted content. The challenge for empirical aesthetics and neuroaesthetics, thus, is to determine the factors—related to the object, the spectator, and the context—under which such kind of emotions are aroused by art.

Silvia (2005, 2006; Silvia & Brown, 2007) has argued that appraisals play a fundamental role in eliciting all kinds of emotions in response to art. Appraisals in terms of novelty, complexity, familiarity, and coping potential can explain why people experience knowledge emotions (i.e., interest, confusion, or surprise) while engaged with art. 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 (i.e., pride, shame, and embarrassment) while experiencing art. They are related to appraising the congruence of artworks with our values, self-image, or goals, the degree to which we have some sort of responsibility, and whether it is consistent with our own standards (Silvia, 2009).

Scherer (2004), however, noted that there is a fundamental difference between these aesthetic emotions, understood as common emotions experienced in response to art, and the utilitarian emotions, the common emotions experienced in response to physical and social events that occur outside of the artistic context. Aesthetic 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 aesthetic emotions are characterized by a stronger phenomenological feeling and clearer appraisals than mere preferences, they exhibit weaker physiological manifestations than utilitarian emotions, and they lack the arousal and action-oriented responses observed in the latter. When physiological responses accompany aesthetic emotions, in the form of chills, shivers, or moist eyes, they are not aimed at preparing the organism for a specific adaptive action.

Finally, other authors have argued that an important aspect of the emotional response involved in the aesthetic experience is its dual nature. Frijda (1986) and Tan (2000) underscored the fact that it is not only the content, and its personal significance, that drives the emotional response in an aesthetic episode. They have noted that the response to what Scherer (2004) referred to as intrinsic qualities constitutes a separate and discrete emotional aspect of the aesthetic experience. Thus, one set of emotions, which Frijda (1986) called "complementing emotions" and Tan (2000) "represented emotions," are triggered by the represented content. These could be any of the common emotions. In addition, Frijda (1986) posited "responding emotions," "artifact emotions" in Tan's (2000) terms, related to the style, the medium, and the process of achieving understanding of the artwork or the object. The enormous expressive potential of art and aesthetics allows for multiple combinations of these classes of emotions. Some artists have exploited the effects of the incongruence of emotions elicited by content and style. Eco (2007) has compiled many instances of emotionally negative content depicted in artistically pleasing ways. In 2012, the Krinzinger Gallery in Vienna exhibited some of Jonathan Meese's most recent artworks. Though filled with imagery of totalitarianism, war, death, and hatred, the canvases were painted using vibrant, playful, and joyful colors.

There are two main ways in which neuroaesthetics can contribute to this psychological discussion. Neuroimaging and psychophysiological techniques can provide psychologists with a whole new analytical level of evidence, and even suggest new interesting questions. For instance, Skov (2010) sought to examine how the brain deals with conflicting emotional responses elicited by images' content and formal aspects. He took a set of 300 pleasant, neutral, and unpleasant photographs from the International Affective Picture System (Lang, Bradley, & Cuthbert, 2008), showed them to the participants in the functional magnetic resonance imaging (fMRI) scanner, and asked them to rate the pictures as beautiful, neutral, or ugly. His comparison of brain activity associated with viewing images rated as beautiful and ugly, regardless of their affective valence, confirmed previous studies that have showed the involvement of perceptual processing (i.e., 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 differed 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 aesthetic qualities of stimuli depicting emotionally negative content.

A different way of examining the impact of content and form on the emotional components of aesthetic experience is to compare art experts and nonexperts. It is well known that experts attend more than nonexperts to compositional and formal elements, while the latter tend to focus preferentially on the depicted content (Nodine, Locher, & Krupinski, 1993; Winston & Cupchik, 1992). Thus, the comparison of brain activity while art experts and nonexperts are aesthetically engaged could provide valuable clues on the emotional responses related with content and formal qualities. Kirk, Skov, Christensen, and Nygaard (2009) asked a group of expert architects and a group of nonexperts to rate their preference for buildings and faces (for which both groups were equally experts). Their results revealed a greater activation of the medial orbitofrontal and anterior cingulate cortices when experts rated their preference for buildings than when nonexperts did. Activity in the nucleus accumbens, in contrast, was greater for both groups of participants when viewing preferred buildings and faces. These results show that expertise, presumably related to knowledge and attention to formal aspects, modulates activity in certain brain regions related with reward, but not others.

Salimpoor et al.'s (2011) study of the neural underpinnings of positive emotional responses to music constitutes an excellent example of how neuroaesthetics 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. They focused on dopamine because it is a crucial neurotransmitter in the reward system. Their results 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.

The second major topic with which neuroaesthetics is currently dealing is trying to understand how certain factors modulate neural activity underlying aesthetic experiences. A number of recent studies have shed some light on this issue, suggesting that personal orientation toward the object of the experience and beliefs about it have strong effects.

Cupchik et al. (2009) showed that people's attitude while viewing paintings modulated brain activity associated with aesthetic preference. They asked their participants either to focus on the artworks with an aesthetic orientation, concentrating on their aesthetic experiences, or to view them merely to obtain information from them, and take note mostly of the depicted content. The aesthetic mode of processing led to a greater involvement of anterior prefrontal brain regions, reflecting a greater degree of cognitive control. In contrast, participants' pragmatic orientation produced an increase in the activity of occipital regions, suggesting that perceptual processes were enhanced. Cupchik et al.'s (2009) work reveals how certain components of the network of brain regions involved in the aesthetic experience are modulated by the intention that guides our engagement with an object.

Kirk, Skov, Hulme, et al. (2009) showed how different semantic contexts, which prompted different expectations on behalf of the participants, also had an important modulatory effect on the activity of the neural network involved in aesthetic appreciation. They showed participants a series of abstract images while their brain activities were recorded with fMRI. In some instances, these images were accompanied by the label *gallery*, which meant that this was a reproduction of an artwork exhibited in a renowned gallery, or the label *computer*, which indicated that it had been created using a photo editing software. In fact, all stimuli had been created by the experimenters. Despite this, participants expressed greater preference for the images they believed were taken from a gallery than those they believed were computer-generated. Also, 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 (see Figure 3). This study clearly shows how beliefs and expectations generated by a simple semantic framing of images can influence neural processes related with the affective aspect of aesthetic experience.

Toward an Interdisciplinary Neuroaesthetics: Aims and Contents of This Special Issue

There is little doubt that neuroaesthetics is blooming, in terms of the increasing attention it is receiving, the depth of the questions it is addressing, or just the sheer quantity of publications. As a field, however, it shows some conspicuous shortcomings (Nadal & Pearce, 2011). As we see it, the main deficiency is its insufficient interdisciplinary integration. Croft (2011) has noted how unsuccessful neuroaesthetics has been in engaging disciplines in the humanities that have traditionally been concerned with aesthetic experiences, such as art theory of philosophy. In addition, Bergeron and Lopes (2012) and Croft (2011) have suggested that neuroaesthetics could also benefit from a greater interaction among the scientific approaches to aesthetics. Psychological, neurological, and evolutionary approaches to aesthetic experience have been surprisingly independent of each other. Psychologists have attempted to identify the factors of the stimuli, context, and person that determine the aesthetic experience, and how they interact. Neuroscientists have attempted to ascertain the brain systems underlying the production and appreciation of art and aesthetics. Evolutionists have tried to identify the adaptive advantages afforded by our capacities to create and appreciate art. These are different questions, and they require searching for different kinds of evidence.

This was one of the issues that motivated a small meeting in Palma (Spain) in 2010. The attendants, many of whom have contributed to this special issue, drafted a road map to facilitate the interaction between scientists of different disciplines interested in the biological underpinnings of aesthetic and artistic behavior. Putting together a special issue of *Psychology of Aesthetics, Creativity and the Arts* on the topic of neuroaesthetics was one of the map's central landmarks. In addition, the time seemed appropriate for a broad review and evaluation of the field of neuroaesthetics. Almost a decade and a half has gone by since it received its name (Zeki, 1999), and it is almost a decade since it first began neuroimaging studies (Cela-Conde et al., 2004; Kawabata & Zeki, 2004; Vartanian & Goel, 2004). In the interim, the field has experienced a true explosion of work. Thus, we hoped that a coherent and updated overview of recent work performed within neuroaesthetics by scientists using different experimental techniques and designs would strengthen the relations between the disciplines concerned with aesthetic experience, and stimulate collaborative work among psychologists, neuroscientists, neurologists, evolutionary biologists, and other scientists. We view the strength of neuroaesthetics not in its potential to replace psychological explanations, but in its potential to successfully interact with them.

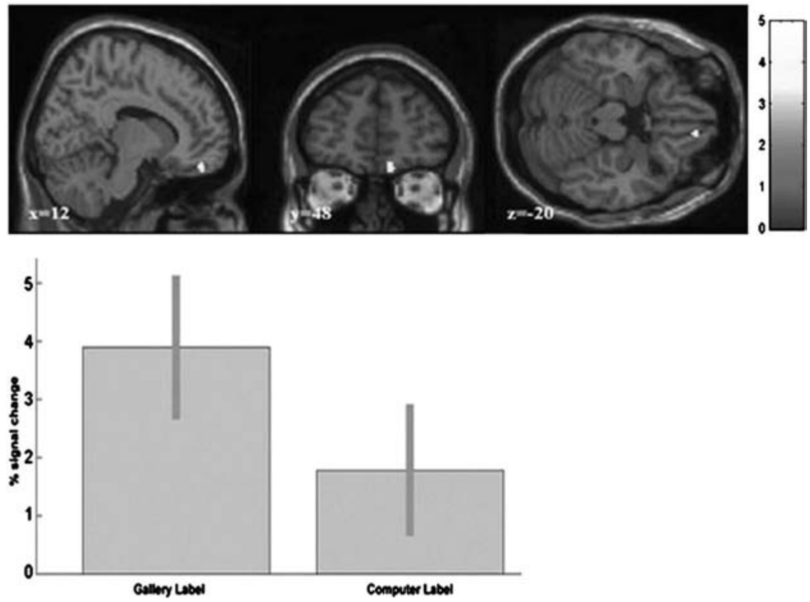

Figure 3. Upper panel: Activation in the right medial orbitofrontal cortex (OFC) where the blood oxygenation level-dependent (BOLD) signal correlates with the first-order linear term for the contrast (gallery–computer). The activation is overlaid on sagittal, coronal, and axial sections of the canonical statistical parametric mapping structural image. Lower panel: Parameter estimates for voxels in medial OFC for the two conditions Gallery and Computer where the *x* axis reflects the two stimulus conditions, and the *y* axis shows BOLD signal changes. Error bars indicate 90% confidence interval. Copyright 2008 by Elsevier. Reprinted with permission.

We invited the contributions to this special issue with the aim of representing a broad sample of available methods and procedures, derived from neurology, neuroimaging, psychology, and evolutionary biology. We also wanted to include contributions that touched on people's aesthetic experience of diverse kinds of objects (e.g., music, dance, paintings, faces), avoiding the common bias within scientific aesthetics to focus on the visual arts. Finally, in preparing this special issue, we contacted researchers who were actively engaged in the field of neuroaesthetics, whose work has shaped the field, and who showed a special interest in closing the gap between psychological and neuroscientific approaches to the aesthetic experience.

The contents of this special issue represent four main approaches to the biological underpinnings of art and aesthetics: psychology, neuroimaging, neurology, and evolution. Westphal-Fitch et al. (2013) and Leder (2013) provide a solid psychological foundation for empirical research in art and aesthetics, dealing with issues past, present, and future that need addressing from an integrated neural and cognitive perspective. The development of neuroimaging techniques as research tools has had a great impact on the growth of neuroaesthetics. The studies by Vartanian et al. (2013), Brattico and Pearce (2013), Salimpoor and Zatorre (2013), and Christensen and Calvo-Merino (2013) provide empirical data and reviews based mainly on neuroimaging technology, revealing the brain mechanisms underlying the appreciation of faces, music, and dance. The effects of neurological illness and lesion on the appreciation and production of art also constitutes a valuable resource for neuroaesthetics. The challenge in this case has been to come up with quantitative and objective methods for measuring such effects. Van Buren et al. (2013) and Halpern and O'Connor (2013) present two ways of meeting this challenge. Finally, Zaidel et al. (2013) argue that greater integration and interdisciplinary effort among psychological, neuroscientific, and evolutionary approaches to art and aesthetics are required to achieve a comprehensive understanding of these human capacities.

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Received December 20, 2012
Revision received January 14, 2013
Accepted January 15, 2013 ■