

Neuroaesthetics: The Cognitive Neuroscience of Aesthetic Experience

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Abstract

The field of neuroaesthetics has gained in popularity in recent years but also attracted criticism from the perspectives both of the humanities and the sciences. In an effort to consolidate research in the field, we characterize neuroaesthetics as the cognitive neuroscience of aesthetic experience, drawing on long traditions of research in empirical aesthetics on the one hand and cognitive neuroscience on the other. We clarify the aims and scope of the field, identifying relations among neuroscientific investigations of aesthetics, beauty, and art. The approach we advocate takes as its object of study a wide spectrum of aesthetic experiences, resulting from interactions of individuals, sensory stimuli, and context. Drawing on its parent fields, a cognitive neuroscience of aesthetics would investigate the complex cognitive processes and functional networks of brain regions involved in those experiences without placing a value on them. Thus, the cognitive neuroscientific approach may develop in a way that is mutually complementary to approaches in the humanities.

Keywords

aesthetics, empirical aesthetics, cognitive science, cognitive neuroscience, neuroaesthetics

In all products of human industry we notice the keenness with which the eye is attracted to the mere appearance of things: great sacrifices of time and labour are made to it in the most vulgar manufactures. . . . There must therefore be in our nature a very radical and wide-spread tendency to observe beauty, and to value it. No account of the principles of the mind can be at all adequate that passes over so conspicuous a faculty.

—George Santayana, *The Sense of Beauty: Being the Outline of Aesthetic Theory*, pp. 1–2

Humans, as Santayana (1896) observed, are drawn to the aesthetic features of objects and the environment around them. Such features are not mere inconsequential adornments; they influence people's affective responses, decisions, and behavior. In fact, aesthetics plays a central role in consumers' choice of products (e.g., Reimann, Zaichkowsky, Neuhaus, Bender, & Weber, 2010; Van der

Laan, De Ridder, Viergever, & Smeets, 2012), in judgments of built environments (e.g., Kirk, Skov, Christensen, & Nygaard, 2009; Vartanian, Navarrete, et al., 2013) and natural environments (e.g., Balling & Falk, 1982; Kaplan, 1987), and in attitudes, judgments, and behavior toward other people (e.g., Kampe, Frith, Dolan, & Frith, 2001; Leder, Tinio, Fuchs, & Bohrn, 2010; Mende-Siedlecki, Said, & Todorov, 2012). By virtue of what neural processes do aesthetic features influence people's attitudes, decisions, and behavior? More generally, what are the neural underpinnings of aesthetic appreciation? These are some of the questions neuroaesthetics aims to answer.

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Neuroaesthetics is a relatively recent field of research in which investigators' general goal is to understand the neural substrates of human aesthetic appreciation. Neuroaesthetics can properly be viewed as a subfield of cognitive neuroscience, given that it involves the study of human cognition and behavior using a combination of methods from neuroscience and cognitive science, bringing together the cognitive and neural levels of explanation (Churchland & Sejnowski, 1988; Gazzaniga, 1984). Research in empirical aesthetics has a long history, originating with Fechner's (1876) pioneering use of psychophysics to study aesthetic appreciation. In a general sense, psychophysics deals with the relation between stimulation and sensation, specifically with the scaling of sensory magnitude. This, however, is the object of *outer psychophysics*, which Fechner regarded as an indirect approximation to a more fundamental relation. The crucial aim of psychophysics, in Fechner's (1860) view, was to explain the relation between sensation and neural activity, and this was the object of *inner psychophysics* (Boring, 1950; Scheerer, 1987). Fechner (1860) was unable to study this relation experimentally because the appropriate technology and methods had not yet been developed. Nevertheless, he elaborated the conceptual foundations of inner psychophysics, characterizing the neural concomitants of sensation and memory in terms of oscillatory processes throughout broadly distributed neural networks (Fechner, 1882/1987).

A true experimental study of the neural substrates of aesthetics—what Fechner might have conceived as the *experimental inner psychophysics of aesthetics*—has emerged only in the last decade or so. Nevertheless, the field of neuroaesthetics is finding its feet (Chatterjee, 2011) and developing the proper formal and institutional mechanisms that characterize any scientific domain, as demonstrated by the convening, in 2009, of the field's first international conference (Nadal & Pearce, 2011) and the publishing of a Research Topic on brain and art in the journal *Frontiers in Human Neuroscience* (Segev, Martínez, & Zatorre, 2014), a special issue of the journal *Psychology of Aesthetics, Creativity and the Arts* (Nadal & Skov, 2013), and several books on the neural foundations of aesthetic experience (Chatterjee, 2014a; Shimamura & Palmer, 2012; Skov & Vartanian, 2009; Zaidel, 2005).

With articles reporting experimental research on the cognitive neuroscience of aesthetic preference, valuation, and experience now numbering in the hundreds, neuroaesthetics has reached a stage where it is useful to consider what neuroaesthetics has accomplished and where it should go in the future. In several articles, researchers have reviewed the recent literature (Chatterjee, 2011; Chatterjee & Vartanian, 2014; Cross & Ticini, 2011; Leder, 2013; Nadal, 2013; Skov, 2010; Zaidel, 2010) and reported meta-analyses (Brown, Gao, Tisdelle, Eickhoff, & Liotti,

2011; Vartanian & Skov, 2014). Their efforts have integrated and made sense of the results of brain lesion and neuroimaging studies on the appreciation of painting, sculpture, music, and dance. Moreover, they have galvanized and consolidated research, while also increasing awareness of the field, which, perhaps inevitably, has generated controversies among a wider audience.

Thus, rather than adding another review of neuroaesthetics research to the aforementioned list, we aimed in this article to outline a much needed conceptual framework for the field. In doing so, we also attempted to address some controversies regarding the nature of neuroaesthetics, its aims and scope, and what it can contribute to science and the humanities.

There are at least two reasons that addressing such questions is important in a broader sense. First, as neuroaesthetics has begun to draw attention, it has aroused criticism from several quarters, including humanistic researchers who believe it is either irrelevant or misguided as a scientific enterprise. Similar criticisms have previously been leveled at other subdisciplines of cognitive neuroscience that intrude on topics traditionally addressed using nonbiological approaches, including economics, philosophy, and sociology. It is important not only to show why these arguments, when cast in general terms, are misleading or unjustified, but also to clarify how understanding neural mechanisms can tell researchers something important and novel about aesthetic experience. Second, although it probably appears obvious to most neuroscientists that studying the neural correlates of consciousness, economics, or social behavior is important for understanding cognition and the brain, it is perhaps not readily apparent what is gained by studying the neural substrates of aesthetic experience or the production of artworks. Hence, it is also important to highlight the distinctive features of aesthetic experience that make it an object of interest for neuroscientists.

Aims and Scope

Neuroaesthetics has become an interdisciplinary field of study incorporating research at the intersection of different fields by scientists with varied interests, priorities, and paradigmatic backgrounds (Chatterjee, 2011; Nadal & Pearce, 2011). Nevertheless, we believe there is sufficient empirical evidence and conceptual development to begin delineating a consensus on its aims and scope.

A comprehensive understanding of aesthetics requires explanations at several levels of analysis. Based on Aristotle's four causes, Killeen (2001) argued that complex forms of cognition and behavior call for efficient, material, formal, and final explanations. Briefly, in this context, efficient causes of a behavior refer to its external triggers. Material causes include the anatomy

and physiology underlying the behavior. Formal causes refer to the system of relations reflected in formal models of the behavior (e.g., Leder, Belke, Oeberst, & Augustin, 2004). Final causes refer to the aims and goals of the behavior (i.e., what is its function?). We might also refer in this context to Marr's (1982) distinction between the implementational, algorithmic-representational, and computational levels of explanation in neuroscience. Neuroscientific explanations primarily address material causes (at the implementational level) but also in varying degrees the other causes (Nadal & Skov, 2013). It is important to note that although understanding the material cause of behavior is necessary, it is not sufficient for understanding the complete picture of aesthetic or artistic behavior. Consequently, neuroaesthetics must draw on research in philosophical aesthetics, art theory, neurological aesthetics, psychological aesthetics, and evolutionary aesthetics among others (Zaidel, 2005, 2010) to address the other causal explanations and levels of representation.

What is the object of study of neuroaesthetics? Neuroaesthetics is sometimes characterized as a quest for universal rules relating objective properties of artworks to activation in specialized brain regions that underlie the perception of beauty (Conway & Rehding, 2013; Di Dio & Gallese, 2009). We disagree for two reasons. First, this approach limits neuroaesthetics specifically to art (Conway & Rehding, 2013; Cross & Ticini, 2011; Di Dio & Gallese, 2009; Nalbantian, 2008), leaving nonartistic objects out of scope. Second, it unjustifiably reduces the experience of art merely to its aesthetic qualities or, even more specifically, to beauty (Brown & Dissanayake, 2009; Seeley, 2011). We argue that an interdisciplinary conceptualization of neuroaesthetics warrants a broader view, one that is in line with both humanist and scientific approaches. As a philosophical discipline, aesthetics deals with the conceptual and theoretical aspects of both art and aesthetic experience. This dual focus recognizes that art and aesthetics overlap conceptually and historically, but they are not identical: "The connection between art and aesthetics is a matter of historical contingency, and not part of the essence of art" (Danto, 1997, p. 25). In keeping with this philosophical and historical tradition, we can address the perceived conflation of art and aesthetics in neuroaesthetics (Brown & Dissanayake, 2009; Seeley, 2011) by distinguishing between two different, but overlapping, subfields: the cognitive neuroscience of aesthetics, and the cognitive neuroscience of art (see Fig. 1).

In this sense, the cognitive neuroscience of aesthetics is the scientific quest to understand the neurocognitive and evolutionary underpinnings of the aesthetic experience of a broad range of objects, including—though not limited to—appliances and other commonplace objects

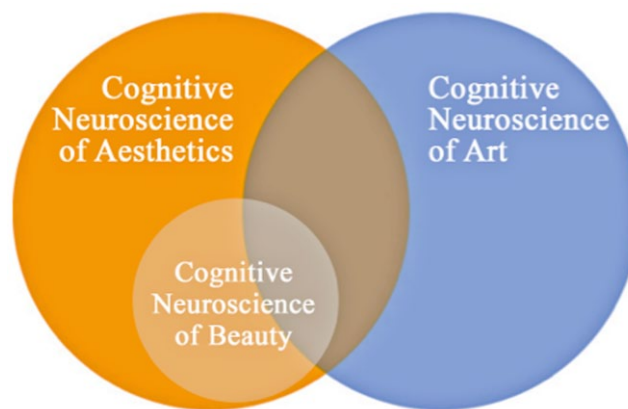


Fig. 1. Relations among the cognitive neurosciences of art, aesthetics, and beauty. In the cognitive neuroscience of aesthetics, researchers investigate the neurocognitive underpinnings of aesthetic experiences in response to many sorts of objects, not just artworks. Aesthetic experiences can relate to beauty but are not limited to beauty alone. In the cognitive neuroscience of art, in turn, researchers investigate the neurocognitive underpinnings of the appreciation and creation of art, which can be approached from many different angles in addition to aesthetics. Both fields intersect when researchers investigate the aesthetic appreciation of artworks.

(Bar & Neta, 2006; Izuma & Adolphs, 2013), graphic and industrial designs (Reimann et al., 2010), mathematical concepts and proofs (Chatterjee, 2014a cf. Hardy, 1940; Zeki, Romaya, Benincasa, & Atiyah, 2014), natural visual scenes (Tinio & Leder, 2009), faces (Aharon et al., 2001; Chatterjee, Thomas, Smith, & Aguirre, 2009; Winston, O'Doherty, Kilner, Perrett, & Dolan, 2007), scents, tastes (Plassmann, O'Doherty, Shiv, & Rangel, 2008; Schifferstein, 2010), and artworks (Cela-Conde et al., 2009; Lacey et al., 2011; Vartanian & Goel, 2004). The emphasis here is on the aesthetic experience of these objects, understood as "emergent states, arising from interactions between sensory-motor, emotion-valuation, and meaning-knowledge neural systems" (Chatterjee & Vartanian, 2014, p. 371; see next section). Thus, for example, we would consider studies of pitch representation in the perception of musical structure (e.g., Shepard, 1982), outside the domain of the cognitive neuroscience of aesthetics because they do not relate directly to issues of valuation and meaning. However, studies of the relations between psychological pitch representations and processing and perceptual pleasure (e.g., Egermann, Pearce, Wiggins, & McAdams, 2013; Huron, 2006) would fall under the umbrella of the cognitive neuroscience of aesthetics.

In the cognitive neuroscience of art,¹ on the other hand, researchers aim to understand the neurocognitive and evolutionary mechanisms by which humans are able to engage with art at many different levels, in addition to the purely aesthetic level (Seeley, 2011; Zaidel, 2005,

2010). These include reflecting about self-referential aspects of art; understanding personal or social meaning of an artwork; recognizing the relation among medium, style, and content; grasping the significance in art-historical or art-critical contexts, and so on. In this sense, as Brown and Dissanayake (2009) wrote

Aesthetic emotions are unquestionably an integral part of the arts, but they are neither necessary nor sufficient to characterize them. Thus, a narrow focus on aesthetic responses is ultimately a distraction from the larger picture of what the arts are about. (p. 54).

As we have defined them, both subfields overlap when studying the neurocognitive foundations of the aesthetic appreciation of artworks. Often, the focus of neuroaesthetics has been biased toward understanding the neural correlates of the appreciation of beauty in art. However, as conceived here and illustrated in Figure 1, this subset should not be equated with the cognitive neuroscience of aesthetics—or of art, for that matter—and it need not be its central focus. In fact, while beauty can play a role in the appreciation of art—which some scholars have suggested is biologically based (Zaidel, 2010)—diverse psychological states (e.g., pleasure and emotions such as wonder, awe, and experience of the sublime but also revulsion, hatred, and experience of the grotesque) can also play a significant role (Leder et al., 2004; Leder & Nadal, 2014; Silvia, 2009; Silvia & Brown, 2007). Therefore, one should be wary of falling foul of the fallacy of composition by assuming that understanding beauty is the only or even the most important goal of the cognitive neuroscience of aesthetics.

Much of the work that falls under the umbrella concept of neuroaesthetics has been carried out at the intersection between aesthetics and art. Consequently, most of what we, Seeley (2011), and Brown and Dissanayake (2009) have conceptualized as the cognitive neuroscience of art remains to be developed, as has been pointed out by others (Gopnik, 2012; Minissale, 2012). Although research on aesthetic responses to art only addresses one part of the larger puzzle, the bias toward using artworks as a resource for research in the cognitive neuroscience of aesthetics has several advantages. First, the arts often come with a long and detailed tradition of analysis (e.g., musicology, art theory, and literary theory and criticism), which can offer valuable insights into aesthetic experience. Second, artworks constitute a primary source of aesthetic experience for many people, to the extent that some scholars have placed aesthetic experience at the core of the definition of art (J. C. Anderson, 2000; Beardsley, 1983).

Conceptual Foundations

If researchers in the cognitive neuroscience of aesthetics investigate the cognitive and neural processes involved in aesthetic experience, they must (a) clarify what is meant by aesthetic experience, (b) develop a conceptual understanding of how it might be related to the brain, and (c) identify the sources that contribute to the experience. We examine these issues in this section.

One of the main conceptual stumbling blocks for the cognitive neuroscience of aesthetics, and one of the major sources for criticism of neuroaesthetics, has been characterization of aesthetic experience—its very object of study. This might seem alarming and unprecedented, but it is not uncommon in the history of science. At one stage, biology had to grapple with the question of what life is, and physics with the question of what matter is. In their foundational book on computational neuroscience, Churchland and Sejnowski (1992) faced the similar problem of defining what computation is—a fundamental concept in this nascent field.

[Precise definitions] become more convincing, meaningful, and interconnected as the empirical discipline matures and gives more ballast to the theory. . . . It is not, however, that one must say *nothing*—in that event, one could not get the science started. The point rather is that the theory outlining the elementary ideas of the discipline gradually bootstraps itself up, using empirical discoveries as support, and kicking away old misconceptions in the haul. (p. 61)

A precise characterization of aesthetic experience requires acknowledgment of the cultural and historical constitution of this concept. Current conceptions of aesthetics and aesthetic experience owe much to the thinking of 18th century European philosophers such as Shaftesbury (1711/1995) and Kant (1795/1914). This was a period in which art became separated from other spheres of human experience; a move that was accompanied by the peeling of aesthetic interests away from general-purpose and everyday pleasures. Disinterested contemplation came to be considered as the appropriate way of engaging with art: “To assure the autonomy of art from everything else, aesthetic experience is defined as something utterly apart from every conceivable purpose” (Carroll, 2008, p. 152). In contrast, in non-Western societies, aesthetics generally encompasses a broader range of activities and objects than in Western societies, and it is more closely related to the communication of spiritual, ethical, and philosophical meaning than in the Western tradition (R. L. Anderson, 1989). For instance, for the Huichol people of Mexico, beauty is a measure of the

extent to which something incarnates the character of the deity it is meant to represent. Thus, Huichol aesthetics and ethics are inextricably bound together: "Aesthetics is not concerned with passive reflection, but with an active attitude to maintain or adjust a system of ethics, inherited from their ancestral deities, which organizes the world and defines appropriate activities and relations with it" (Shelton, 1992, p. 241).

Aesthetic experience also varies throughout time and among historical periods. The history of Western art alone is replete with examples of artworks that were popular in their day, but whose reputation has since withered into obscurity. On the other hand, many examples of artworks that have caused outrage at their unveiling because of their audacious departure from convention have since become much admired staples of the repertoire (e.g., Beethoven's Symphony No. 9, Stravinsky's *Le Sacre du Printemps*, or the impressionist style in visual arts), as cultural conventions have shifted or expanded to accept these transformatively creative works.

If the aim of research in the cognitive neuroscience of aesthetics is to characterize the biological and cognitive substrates of aesthetic experience, then a strict focus on an 18th century Western conception of aesthetic experience, understood as a dispassionate, purposeless, and decontextualized engagement, is likely to be inadequate. As Carroll (2008) argued, "The standard characterization of aesthetic experience is effectively useless from the point of view of empirical research" (Carroll, 2008, p. 158). The cognitive neuroscience of aesthetics must be able to account for varieties of such experience across cultures and historical periods.

A broader and less historically and culturally biased notion of aesthetic experience can be found in Shusterman's work (Shusterman, 1997; Tomlin, 2008). He defined three crucial features in aesthetic experience: An aesthetic experience has an evaluative dimension, in the sense that it involves the valuation of an object; it has a phenomenological or affective dimension, in that it is subjectively felt and savored, drawing one's attention; and, finally, it has a semantic dimension, in that an aesthetic experience is a meaningful experience, not mere sensation. One aspect that seems to distinguish the affective component of aesthetics is that the associated emotional states lack the motivational drive to act that is common in other rewarding affective states (Chatterjee, 2014b; Scherer, 2004). Chatterjee (2014b) has suggested that the emotions involved in aesthetic experience might be related to a reward system of liking or pleasure (subserved by opioid and cannabinoid neurochemical systems) rather than a reward system related to wanting to satisfy desires (subserved by dopaminergic neurochemical systems; Berridge, Robinson, & Aldridge, 2009). In this way, it might be possible to be disinterested and emotionally invested at the same time.²

From this perspective, research in the cognitive neuroscience of aesthetics aims to understand the biological and cognitive mechanisms that enable humans to have perceptual experiences that are evaluative and affectively absorbing (though possibly not satisfying particular motivational desires), in individually and culturally meaningful ways. Conceiving aesthetic experience in this manner has the virtue of connecting with the philosophical tradition and the study of art and aesthetics in non-Western societies (R. L. Anderson, 2004). Moreover, it converges with Chatterjee and Vartanian's (2014) notion of the aesthetic triad derived from their review of research in neuroaesthetics. They argued that when examined together, brain lesion and neuroimaging evidence suggests that aesthetic experiences arise from the interaction among neural networks involved in sensory-motor, emotion-valuation, and meaning-knowledge processing.

This point brings us to the second issue: how aesthetic experiences relate to brain activity. Some commentators have characterized the goal of neuroaesthetics research as finding a "beauty center" in the brain (Conway & Rehding, 2013). However, the vast majority of theoretical and empirical research in neuroaesthetics points to a range of cognitive processes and several brain networks being involved in aesthetic experience (Chatterjee, 2014a; Leder et al., 2004; Nadal, 2013; Nadal & Pearce, 2011). Indeed, cognitive models of aesthetic experience typically stress the involvement of basic perceptual processes, memory, attention, emotion, social cognition, and other cognitive processes, each associated with several underlying brain regions and networks (e.g., Brattico & Pearce, 2013; Leder, 2013). Moreover, using the methods of cognitive neuroscience to understand these cognitive processes in terms of brain function is not to discount the importance of subjective experience. It is simply one more tool (although an especially powerful one if used skillfully) to go alongside phenomenology, experimental psychology, computational modeling, and other methodological approaches to understanding the mind, each with its own strengths and limitations.

Finally, we consider the characterization of neuroaesthetics (and other branches of aesthetics) as a search for rules connecting objective properties of artifacts (including artworks) with aesthetic experiences (Conway & Rehding, 2013). In line with other areas of psychology and cognitive neuroscience (e.g., emotion: Scherer & Zentner, 2001; memory: Hupbach, Gomez, Hardt, & Nadel, 2007), aesthetic experiences surely arise from a complex interplay of factors related to the object, the individual, and the context (Jacobsen, 2006). Research on frisson experienced during musical listening, for example, often entails listeners self-selecting music that gives them chills and using other listeners' selections for the control condition (Blood & Zatorre, 2001; Salimpoor,

Benovoy, Larcher, Dagher, & Zatorre, 2011; Salimpoor & Zatorre, 2013). This procedure moves the focus firmly onto the listener's individual musical experience and away from objective properties of the music. Other research has shown that semantic and physical contexts influence the subjective experience and neural processes in response to works of art (Brieber, Nadal, & Leder, 2015; Brieber, Nadal, Leder, & Rosenberg, 2014; Kirk, Skov, Hulme, Christensen, & Zeki, 2009; Lengger, Fischmeister, Leder, & Bauer, 2007). Although it is important to understand the role of object properties, a focus on the object itself can have several negative consequences, not the least of which is that it encourages cherry picking a few choice artworks that happen to corroborate the theory (Hyman, 2010) and ignoring the many that fail to do so, which in turn hampers the goal of putting together a coherent research program with testable hypotheses (Chatterjee, 2011).

Neuroaesthetics sometimes has been criticized precisely for treating the object and the person out of context: "Paintings are treated as mere isolated stimuli or sets of stimuli . . . The works and our experiences of them are divorced from their cultural context and from the viewer's individual history" (Tallis, 2008, p. 20). This criticism might have been more true in 2008 than it is today. Serious research is being performed outside the laboratory, avoiding the separation of object, experience, and context noted by Tallis (2008). For instance, the neural correlates of dance appreciation have been studied using live performances and on-line measures (Jola, Abedian-Amiri, Kuppuswamy, Pollick, & Grosbras, 2012; Jola & Grosbras, 2013; Stevens et al., 2009), the physiological concomitants of the aesthetic appreciation of paintings have been examined in actual museum visitors (Brieber et al., 2015; Brieber et al., 2014; Tschacher et al., 2012), and physiological affective responses to music have been studied in audiences at live concerts (e.g., Egermann et al., 2013).

What Can Cognitive Neuroscience Add to Our Understanding of Aesthetics?

Criticisms of scientific aesthetics from the humanities

Dickie (1962) claimed that psychology had little to contribute to aesthetics, either in terms of understanding aesthetic experience or in terms of clarifying concepts and methods in the study of aesthetics. Although not all philosophers share this extreme position (Beardsley, 1966), neuroaesthetics has continued to be criticized in the humanities because of its failure to produce interesting results about art itself. Some even go as far as claiming that neuroaesthetics is, in principle, unable to contribute

to knowledge about art (Massey, 2009; Tallis, 2008). There are at least three cogent responses to these criticisms that demonstrate that cognitive neuroscience can and does contribute to the understanding of aesthetics (which, as we have argued earlier, is not limited to art).

First, taken at face value, these criticisms seem to imply that the brain is not involved in the production or appreciation of art, so that any understanding of the neural basis of these abilities is irrelevant. Second, they seem to deny that any scientific approach to aesthetics could contribute to the aspects of art those critics are specifically interested in or to the sorts of issues they are concerned with, including the concept of the aesthetic, the definition of art, the ontology of art, the identification of what makes a good artwork, and so on (Levinson, 2003). It seems, however, unfair to judge the merits of the cognitive neuroscience of aesthetics based on how much—or how little—it contributes to resolving philosophical or art-critical questions, such as the greatness (or otherwise) of particular works of art. (Tallis, 2008). The cognitive neuroscience of aesthetics is concerned with people's behavior, cognition, and experience in relation to aesthetics. The aim is not necessarily to provide answers to philosophical questions about art, nor, certainly, is it to replace philosophical aesthetics.

Third, the relevance of cognitive neuroscience to aesthetics and art should be evident because *art* and *aesthetics* are often defined in cognitive terms. Notice how often such terms appear, for example, in Beardsley's (1969) definition of aesthetic experience:

A person is having an aesthetic experience during a particular stretch of time if and only if the greater part of his *mental activity* during that time is united and made *pleasurable* by being tied to the form and qualities of a *sensuously* presented or *imaginatively intended* object on which his primary *attention* is *concentrated*. (p. 5, emphasis added)

Levinson's (1996) more recent conception of aesthetic pleasure also relies on psychological processes: "*Pleasure* in an object is aesthetic when it derives from *apprehension* and *reflection* on the object's individual character and content, both for itself and in relation to the structural base on which it rests" (Levinson, 1996, p. 6, emphasis added). Cognitive neuroscience has much to contribute regarding pleasure, sensation, imagination, attention, apprehension, and reflection, and the processes by which they interact (see, for instance, Vessel, Starr, & Rubin, 2012). Thus, the cognitive neuroscience of art and aesthetics can help to unravel the psychological and neural processes involved in phenomena that were formulated in philosophical conceptions of art and aesthetics.

Science and the humanities as complementary approaches to aesthetics

The concern has been expressed that in attempting to create general predictive models of aesthetic experience, we may lose the quintessential essence of those experiences: their unique, privileged, and individual quality (Tallis, 2008). It is important to acknowledge a genuine tension here between an approach often taken in the humanities in which a given artifact is studied in detail, relating it to the particular historical circumstances in which it was created and experienced, and that of the sciences, where the tendency is to pose and corroborate general predictive models of a given phenomenon.³

However, one must not confuse a theoretical stance on a phenomenon (aesthetics in this case) with a method for studying it. As shown previously, the scientific approach to aesthetics need not imply a focus on objective properties of the stimulus (Conway & Rehding, 2013) or necessarily on generalizing across individuals as illustrated by various neuropsychological case studies of artists (Chatterjee, Bromberger, Smith, Sternschein, & Widick, 2011; van Buren, Bromberger, Potts, Miller, & Chatterjee, 2013; Zaidel, 2005). Furthermore, the scientific approach need not entail a sharp distinction between phenomena that are aesthetic and those that are not (Conway & Rehding, 2013). Aesthetics is likely to resemble other complex phenomena in psychology and neuroscience, such as autism (where a spectrum of conditions result from a complex interaction between genetic and environmental factors; Persico & Bourgeron, 2006) or color perception (where the relation between frequency and perceived color categories varies as a complex function of context as well as individual and cultural experience; Roberson & Hanley, 2007; Zeki & Marini, 1998). Therefore, we posit a *spectrum* of different aesthetic experiences depending on the individual (affected by experience, stable traits, and current motivational and emotional states), the context, and the object.

These considerations mean that scientific and humanistic approaches can share the same theoretical stance while taking different methodological approaches to studying the phenomenon, each with potentially complementary strengths and weaknesses. The enlightenment philosopher John Locke (1690/1997) portrayed philosophy as a kind of servant to science, clarifying concepts and assumptions and interpreting results. We suggest that rather than playing a subordinate role, philosophical and scientific approaches can fruitfully complement each other, operating hand in hand. Examples of such complementarity are not hard to come by, even in the fields of art and aesthetics. For instance, Darwin (1871/1998) is usually credited with the original observation that aesthetic features and the affective responses they elicit play

a crucial role in mate choice. However, Joseph Addison (1712) and Thomas Reid (1785) had already stressed this adaptive role of natural beauty: “There seem likewise to be varieties in the sense of beauty in the individuals of the same species, by which they are directed in the choice of a mate, and in the love and care of their offspring” (Reid, 1785, p. 744). Thus, Darwin’s (1871/1998) great accomplishment was to propose a natural mechanism—sexual selection—that explained observations made by earlier British empiricist philosophers. Analogously, the scientific evolutionary approach to aesthetics is not opposed to the philosophical approach, but a natural extension of it.

Moreover, and contrary to suggestions of territorial squabbles between scientists and humanists (Hutton & Kelly, 2013), current research in the cognitive neuroscience of aesthetics is essentially interdisciplinary. In fact, projects bringing together philosophers, architects, art historians, psychologists, neuroscientists, and physicists (Brieber et al., 2014; Brinkmann, Commare, Leder, & Rosenberg, 2014; Cela-Conde et al., 2013; Huang, Bridge, Kemp, & Parker, 2011; Kozbelt & Seeley, 2007; Vartanian, Navarrete, et al., 2013) have shown just how much there is to be gained from a closer partnership between C. P. Snow’s *two cultures* (Snow, 1964).

What Can the Cognitive Neuroscience of Aesthetics Contribute to the Understanding of Human Cognition?

The cognitive neuroscience of aesthetics has also been viewed on occasion with suspicion from within scientific disciplines. There are three main reasons for this. First, some view art and aesthetics as limited to museum exhibitions, concert halls, and other sophisticated leisure activities rather than as a fundamental feature of the behavioral, cognitive, and neural constitution of *Homo sapiens* (e.g., only humans produce art spontaneously). They therefore see little interest in the scientific understanding of such “elitist” activities, accessible in some cases only to the more privileged. Second, others are wary of the subjectivity involved in the appreciation of art and aesthetic experience. Third, one might question why a biological theory of aesthetics is needed in addition to a psychological one. In this section, we briefly address these three issues, remembering first that we argued for a conceptual distinction between the aesthetics and art (and the subfields of cognitive neuroscience investigating these phenomena).

Pervasiveness of aesthetic cognition

Regarding the first concern expressed, art and aesthetics are not restricted to few exclusive occasions, contexts, and social classes; they are ubiquitous manifestations of

human neurocognitive capacities. The vast majority of humans, to a lesser or greater degree, engage routinely in some form of art:

We are accustomed to understand art to be only what we hear and see in theatres, concerts, and exhibitions; together with buildings, statues, poems, novels . . . But all this is but the smallest part of the art by which we communicate with each other in life. All human life is filled with works of art of every kind from cradle-song, jest, mimicry, the ornamentation of houses, dress and utensils, up to church services, buildings, monuments, and triumphal processions. It is all artistic activity. (Tolstoy, 1904, p. 51).

Thus, understood in this broader sense, aesthetics is intrinsic to some of the activities people hold most dear to them. In fact, as argued by Dissanayake (1988, 2009), art is a vital component in such activities, contributing to heighten the uniqueness and specialness of the object, activity, or occasion. Artistic and aesthetic production and appreciation are an integral part of natural human behavior (Lorblanchet, 2007). Therefore, knowledge about their cognitive and neural underpinnings is of interest to cognitive science and cognitive neuroscience: “Art, as any other activity of the mind, is subject to psychology, accessible to understanding, and needed for any comprehensive survey of mental functioning” (Arnheim, 1966, p. 2).

Subjectivity of aesthetic experience

The second concern expressed by scientists regarding the cognitive neuroscience of aesthetics is not very different from the one originally directed at the study of consciousness. It refers to its personal and subjective nature: science cannot deal with the eminent subjectivity of aesthetic experience and its individual uniqueness. This critique is not new, for even the early proponents of scientific aesthetics had to deal with it (Munro, 1928), and it can be understood in three different but related ways.

In one sense, the subjectivity criticism expresses the concern that aesthetic experience cannot be measured independently from the experiencing subject: It is a subjective state that is not directly linked to a concrete property of an object in the world and therefore lies outside the scope of science. However, this argument is only an apprehensive rehashing of one of the early realizations of cognitive psychology. Just as memory is not a faithful store of events that can be played back, perception is not a photographic recording of the properties of objects. It is an active process of constructing a meaningful representation of the world and therefore susceptible to transient contextual features and events and to personal goals and intentions: “whether beautiful or ugly or just

conveniently at hand, the world of experience is produced by the man who experiences it” (Neisser, 1967, p. 3). However, this fact has not prevented psychology and cognitive neuroscience from developing a multitude of methods to measure implicit processes in subjective experiences, from which the cognitive neuroscience of aesthetics has profited greatly. For instance, Chatterjee et al. (2009) were able to show that even when participants did not explicitly attend to the attractiveness of a series of faces they were viewing and were not required to provide any sort of explicit attractiveness assessment, the ventral occipital cortex was still responsive to this facial feature.

In a second sense, the subjectivity criticism seems to suggest that there is no way aesthetic experience can be studied scientifically because subjective states vary from moment to moment and from person to person. An aesthetic experience is like a snowflake: On the whole, it is similar to any other; in the details, it is unique, ephemeral, and unrepeatably. No two aesthetic experiences are the same. Thus, how can something as elusive as an aesthetic experience be pinned down with general principles? Additionally, this elusiveness makes definition difficult, and this is one of Conway and Rehding’s (2013) main critiques of neuroaesthetics: “the lack of a cogent, universally accepted definition of beauty” (Conway & Rehding, 2013, p. 4).⁴

It might seem that the lack of a universally accepted definition of the aesthetic experience should warrant skepticism toward scientific aesthetics and its achievements. But what about other branches of psychology and cognitive neuroscience that also deal with elusive phenomena and lack broadly shared definitions of key concepts? Take emotions, for instance. People differ greatly as to what it means to experience happiness, what it is like to be in love or to feel rejected, and the degree to which different objects and situations elicit different kinds of emotions. However, this does not preclude scientists from studying emotion. It only means that scientific research on emotion—and on aesthetic experience—must determine the factors that explain the differences among individuals and differences within individuals at different moments and in different circumstances. In fact, findings from several studies have shown that these differences can be accounted for and, moreover, that they can be used to model brain activity related to aesthetic experience (Chatterjee et al., 2009; Vartanian, Lam, Fisher, Granic, & Goel, 2013). Not only are emotions, like aesthetic experiences, phenomenologically elusive; they also defy clear, precise, and widely agreed definitions: “‘Emotion’ has no generally accepted definition” (Izard, 2010, p. 369). Thus, even 130 years after William James (1884) asked “What Is an Emotion?” there is substantial disagreement among emotion researchers regarding such important issues as the function of emotions, the

specificity of the physiology of emotion, the difference between emotion and mood, or the role of cognitive processes in emotion (Ekman & Davidson, 1994). However, the cognitive neuroscience of emotion has managed to develop successfully despite such disagreements. It is reasonable to expect the same from the cognitive neuroscience of aesthetics.

Finally, the subjectivity critique might also relate to dissatisfaction with the absence, in the domain of aesthetics, of correct and incorrect responses that would allow a standardized measure of aesthetic performance. Such assessments do in fact exist (Barron & Welsh, 1952; Child, 1962; Götz, Borisy, Lynn, & Eysenck, 1979; Wilson & Chatterjee, 2005), but they provide a relative, rather than absolute, measure that compares an individual's performance to that of a reference group. However, it is worth remembering that such objective measures are useful only to the extent that they capture the important properties of subjective aesthetic experience.

In summary, the critique of the subjectivity of aesthetic experience is a manifestation of what Santayana (1896, p. 4) called "man's prejudice against himself": the devaluation of the product of mental processes in favor of objects and laws that are independent of humankind's own nature:

We have still to recognize in practice the truth that from these despised feelings of ours the great world of perception derives all its value, if not also its existence. Things are interesting because we care about them, and important because we need them. Had our perceptions no connexion with our pleasures, we would soon close our eyes on this world . . . A judgment is not trivial, however, because it rests on human feelings; on the contrary, triviality consists in abstraction from human interests (Santayana, 1896, pp. 3–4).

What is gained by understanding brain mechanisms?

Finally, it is pertinent to ask why a cognitive neuroscience of aesthetics is needed when there is a healthy tradition of psychological research in empirical aesthetics. There are at least two reasons—one methodological, the other theoretical—that we come to below.

As a preliminary, we note that scientific psychology in general and empirical aesthetics in particular have always been coupled to the study of the brain. William James (1890) wrote that

[psychologists] must be "cerebralists," to the extent at least of admitting that certain peculiarities in the way of working of their own favorite principles are explicable only by the fact that the brain laws are a codeterminant of the result. (p. 4)

This is not to say that psychology can be reduced to or abandoned in favor of neuroscience. Searching for neural mechanisms underlying psychological processes

does not make the psychologist a physiologist, for precisely the same reason that the physiologist need not become a cytologist or biochemist . . . [T]he psychologist is interested in physiology to the extent that it contributes to his own task" (Hebb, 1949, p. xv).

Reflecting the general case, empirical aesthetics has aspired, both in its inception (Fechner, 1876) and in its modern reformulation (Berlyne, 1971), to explain the neural foundations of aesthetic behavior and cognition. As noted earlier, Fechner saw the outer psychophysics upon which he based empirical aesthetics (Fechner, 1876) as an approximation to charting directly the relation between mental and neural processes (Scheerer, 1987). Berlyne (1971) also firmly believed that psychological explanation was incomplete if it lacked biological foundations:

Every form of behavior must depend on bodily structures, including characteristics of the human nervous system . . . This must hold for aesthetic activities as well as for any others, so that *the psychological study of art must include a search for the biological origins of art.* (p. 8, emphasis added)

Thus, explaining the relation between aesthetic experience and brain function has always been central to empirical aesthetics.

What is gained by doing so? First, from a methodological perspective, the cognitive neuroscience of aesthetics provides a whole new suite of research tools and methods to the armory of the empirical aesthetician. In this sense, the contribution of the cognitive neuroscience of aesthetics to psychological aesthetics is no different from the contribution of the cognitive neuroscience of language to psycholinguistics, for instance. Generally speaking, the tools of cognitive neuroscience have helped psychologists (a) to understand how cognitive processes are related to underlying neural mechanisms, (b) to study cognitive or affective processes (or aspects of those processes such as their temporal course) that are not accompanied by overt behavioral responses, (c) to determine whether two tasks rely on common or different mechanisms, and (d) to constrain cognitive theories and models (Mather, Cacioppo, & Kanwisher, 2013; Poldrack, 2006; White & Poldrack, 2013). Examples of all four contributions exist in the cognitive neuroscience of aesthetics. Neuroimaging and neurophysiological methods have been used to show, for instance, that (a) aesthetic experiences are related to activity of large-scale neural

networks rather than specific regions (Cela-Conde et al., 2013; Vessel et al., 2012); (b) facial attractiveness is processed even when people do not explicitly attend or overtly respond to it (Chatterjee et al., 2009) and aesthetic judgments involve two distinct stages: an early impression formation and a subsequent evaluative categorization (Cela-Conde et al., 2013; Jacobsen & Höfel, 2001, 2003); and (c) aesthetic experiences of music and painting rely partly on common affective processes (Ishizu & Zeki, 2011). Finally, (d) results from such studies have challenged and complemented cognitive models of aesthetic appreciation and therefore contributed to refinement and reformulation of them, as discussed by Brattico, Bogert, and Jacobsen (2013); Leder (2013); and Leder and Nadal (2014). For example, neuroimaging studies showing that beliefs about the authenticity or authorship of artworks have an impact on how rewarding the artworks are perceived to be (Kirk, Skov, Hulme, et al., 2009), and that this impact occurs at early processing stages (Huang et al., 2011) have prompted a strengthening the role of semantic context in a widely used model of the aesthetic experience of art (Leder & Nadal, 2014).

Second, from a theoretical perspective, neuroaesthetics augments empirical aesthetics with the general conceptual framework of cognitive neuroscience. A good example is the centuries-long debate on the manner in which aesthetic experience and pleasure are related, discussed earlier in the Conceptual Foundations section. Burke (1757) made one of the most singular contributions to this debate by arguing that aesthetic feelings, such as beauty and the sublime, arise from the same neural processes that cause pleasant and unpleasant emotions, such as love and fear. His views became the cornerstone of some of the early psychological approaches to aesthetics (Allen, 1877; Marshall, 1894) and persisted during the behaviorist heyday as a factor explaining choice (Beebe-Center, 1932). The idea that aesthetic appreciation relies on the neural substrates of pleasure and pain even constituted the central theoretical pillar of Berlyne's (1971) new experimental aesthetics, in which the hedonic tone of aesthetic experiences was proposed to result from the combined activity of brain systems related to reward and aversion.

However, the notion that brain activity related to reward underlies aesthetic appreciation remains somewhat toothless without a detailed empirical understanding of the reward system itself and how it is involved in human aesthetic experience. It is here that the cognitive neuroscience of aesthetics has made two of its most substantial contributions to experimental aesthetics. First, it has offered a thorough description of the brain's reward system participating in aesthetic appreciation: (a) it has pinpointed the brain regions

and neurotransmitter systems involved; (b) it has characterized the temporal dynamics of neural activity in these regions and systems (e.g., Salimpoor et al., 2013); and (c) it has shown how these systems and dynamics are modulated by intrinsic and extrinsic factors (for reviews, see Chatterjee & Vartanian, 2014; Nadal, 2013; Skov, 2010). One of the major insights that emerge is that the valuation of art, music, and other cultural objects, such as money, relies on the same neural mechanisms that mediate reward derived from food or drink, thus contributing to the notion of a "common currency" for choice (Batra, McGuire, & Kable, 2013; Brown et al., 2011; Levy & Glimcher, 2012; Sescousse, Caldú, Segura, & Dreher, 2013). Second, the conceptual apparatus of cognitive neuroscience permits a fruitful reanalysis of the debate about what kinds of pleasure are aesthetic and what distinguishes aesthetic pleasure from other sorts. As noted in the Conceptual Foundations section, Berridge et al.'s (2009) distinction between two forms of reward—liking and wanting—allows the characterization, in principle at least, of aesthetic pleasure as "liking without wanting," as a reward that is unrelated to the satisfaction of desires. Additionally, relying on the notion of functional connectivity and advances in its estimation, recent studies show that aesthetic pleasure is characterized by the tight coupling of activity in reward brain regions and sensory brain regions.

Let us consider two specific examples. Using a combination of ^{11}C -raclopride positron emission tomography scanning, functional magnetic resonance imaging, and behavioral measures, Salimpoor et al. (2011) found that peak musical experiences (pleasurable chills to familiar self-selected musical excerpts) were associated with dopaminergic activity in the caudate nucleus while the nucleus accumbens was involved in the anticipation of the peak experience. Thus, the experience itself and its anticipation appear to be served by dopamine release in distinct regions of the striatal system, again underlining the important role of individual beliefs and expectations. In a subsequent study, Salimpoor et al. (2013) 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.

These studies show that pleasurable musical experiences involve dopaminergic activation in distinct areas of the reward system, which is functionally connected to sensory processing (see also Lacey et al., 2011). This

accounts for motivation to repeat or continue the experience of listening to a piece of music, but it cannot, in and of itself, explain the pleasure associated with the experience. However, striatal dopamine systems are intricately and reciprocally connected with opioid systems in the nucleus accumbens and ventral pallidum thought to underlie pleasure (Salimpoor, Zald, Zatorre, Dagher, & McIntosh, 2015). Understanding in more detail the relations between these systems and the extent to which they can be activated in isolation provides a compelling and rigorous empirical pathway toward distinguishing different varieties of (aesthetic) pleasure.

Looking Ahead

In response to commentaries on the cognitive neuroscience of aesthetics from both those in the humanities and the sciences, we have argued for a conception of the field that applies beyond art to a wider range of sensory phenomena and encompasses a greater variety of sensations than beauty. We have encouraged an interdisciplinary approach that incorporates biology, neuroscience, psychology, and the socially embedded nature of aesthetic experiences that is wide enough to include differences between cultures and over time. We have argued strongly for a sophisticated scientific approach involving the investigation of a spectrum of aesthetic experiences depending on the interaction of the individual and the context as well as properties of the objects forming the focus of an aesthetic experience. The goal is to understand the psychological and neural processes of an individual having an aesthetic sensory experience in a given context, not to place a value on its object. Aesthetic experiences engage a wide range of cognitive processes and networks of brain regions. We believe the methods of cognitive neuroscience extend the toolbox of the empirical aesthetician in useful ways, rather than replacing traditional experimental and nonexperimental methods.

Looking ahead, we believe that this vision suggests a multidisciplinary approach to understanding aesthetic experience at a number of levels ranging from subjective experience, through cognitive processing and systems neuroscience, to cellular and genetic factors using a range of different methods, each with complementary advantages and disadvantages. For example, lab-based studies with artificial stimuli allow great experimental control but lack ecological validity, so they should be complemented by studies of people in genuinely aesthetic situations (Brieber et al., 2015; Brieber et al., 2014; Egermann et al., 2013; Jola & Grosbras, 2013; Jola, Pollick, & Grosbras, 2011; Stevens et al., 2009; Tschacher et al., 2012) that have high ecological validity but may suffer from the presence of additional noise. Furthermore, since aesthetic episodes can have transformational

effects, it also would be important to investigate the consequences of aesthetic experience on cognitive, emotional, and social function (Wang, Mo, Vartanian, Cant, & Cupchik, 2015). We look forward to decades ahead in which the cognitive neuroscience of aesthetics, neuroaesthetics, develops into fully productive scientific maturity, integrated with its parent disciplines of empirical aesthetics and cognitive neuroscience.

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Notes

1. We use the term *art* to refer to the full range of visual and performing arts including painting, printmaking, sculpture, photography, music, dance, literature, drama, architecture, and so on.
2. It should be noted that although this is consistent with the general idea of disinterested interest understood, in a broad sense, as a pleasure without incentive or inclination, it does not necessarily correspond to Shaftesbury's or Kant's notions of disinterested interest, given the clear differences in terms of the specific conceptual understanding of art, aesthetics, and mind within which those philosophers expressed their ideas.
3. Following the principle of Ockham's razor, scientists seek simple theories with general coverage, but a theory must, first and foremost, account for the phenomena, and there may be aspects of individual aesthetic experiences that are genuinely unique and require individual treatment.
4. Note also our earlier argument that beauty is not synonymous with aesthetics.

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