Aesthetic Science

CONNECTING MINDS, BRAINS, AND EXPERIENCE

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Neuroaesthetics

GROWING PAINS OF A NEW DISCIPLINE

Anjan Chatterjee

Introduction

Does neuroscience have anything useful to contribute to aesthetics? Neuroaesthetics is a new field that is gaining momentum. The field falls directly on the borders of art and science and brings with it the inherent tensions between these two human endeavors. Unresolved is the question of whether neuroaesthetics can be both true to its scientific roots and relevant to aesthetics. At this early stage it is worth examining the current state of neuroaesthetics while keeping in mind the principles that underlie this practice. In this chapter, I review briefly writings that fall under the rubric of neuroaesthetics. I offer suggestions of what might be needed if the field is to take itself seriously as a science, particularly as an experimental science. I then conclude with some cautionary notes about challenges that neuroaestheticians face.

The term *aesthetics* is used broadly here to encompass the perception of, production of, and response to art, as well as interactions with objects and scenes that evoke a response that might be considered aesthetic. I also restrict my comments to visual aesthetics, but the general principles would easily apply to music, dance, and literature. At the outset, I should be clear that neuroscience is not likely to offer much to discussions about definitions of art.[1] Some philosophers have claimed that defining art with necessary and sufficient conditions is not possible.[2] In response to such claims, recent theoreticians have defined art by its social and institutional[3] or its historical context.[4] Neuroscience is unlikely to address sociological or historical conceptions of art with any specificity. Neuroscientists are likely to avoid definitional issues and focus on accepted examples of artwork or properties of these works as probes for experiments.

Observations on Parallels Between Art and the Brain

With rare exceptions, most neuroscientists do not consider aesthetics worthy of inquiry. And some aestheticians probably consider neuroscientific inquiry into aesthetics trivial at best and more likely an abomination. Only recently has neuroscience joined a tradition of scientific inquiry into aesthetics dating back to Fechner in the 19th century.[5] There have been attempts to link aesthetic experiences to its biological underpinnings in the past. For example, Berlyne[6] emphasized the role of physiological arousal in aesthetic experiences. Similarly, Rentschler, Herzberger, and Epstein[7] edited the first book that explored links between beauty and the brain. However, it is the recent spate of writings on parallels between art and how the brain is organized that have garnered wide interest.

Zeki[8,9] argued forcefully that no theory of aesthetics is complete without an understanding of the role of the brain in aesthetics. He suggested that the goals of the nervous system and of artists are similar: both are driven to understand visual properties of the world. The nervous system decomposes visual information into attributes like color, luminance, and motion. Similarly, many artists, particularly within the past century, isolate and enhance different visual attributes. For example, Matisse emphasized color and Calder emphasized motion. Zeki suggests that artists endeavoring to uncover important distinctions in the visual world end up discovering modules that are recognized distinctly by the visual brain. Cavanagh[10] has similarly claimed that the artists' goals follow strategies used by the nervous system in enabling our perception. He observes that paintings often violate the physics of shadows, reflections, colors, and contours. Rather than adhering to physical properties of the world, these paintings reflect perceptual shortcuts used by the brain. Artists, in experimenting with forms of depiction, revealed what psychologists and neuroscientists are now identifying as principles of perception.

Livingstone[11] and Conway[12] focused on how artists make use of complex interactions between different components of vision in creating their paintings. The dorsal (where) and ventral (what) processing distinction is a central tenet in visual neuroscience[13] (see Shimamura, Chapter 1 in this volume, for a description of these processing streams). The dorsal stream responds to contrast differences, motion, and spatial location. The ventral stream responds to simple form and color. Livingstone suggests that the shimmering quality of water or the sun's glow on the horizon seen in some Impressionist paintings (e.g., the sun and surrounding clouds in Monet's *Impression Sunrise*) is produced by objects that can be distinguished only by color and not by contrast differences. The dorsal stream is not aware of color differences. Since the dorsal stream senses motion (or the lack thereof) and spatial location, Livingstone argues that forms that reflect the same amount of light or have the same degree of contrast are not fixed with respect to motion or spatial location and are experienced as unstable or shimmering. Conversely, since shape can be derived from luminance differences, she argues that artists often use contrast to produce shapes, leaving color for expressive rather than descriptive purposes. Livingstone highlights the way that visual attributes combine in the construction of our visual perception. Artists make use of these combinations to produce specific aesthetic effects.

Ramachandran and Hirstein[14,15] proposed a set of perceptual principles that might underlie aesthetic experiences. For example, they rely on Tinbergen's[16] work to emphasize the "peak shift" phenomenon as offering insight into the aesthetics of abstract art. Tinbergen demonstrated that seagull chicks beg for food from their mothers by pecking on a red spot near the tip of the mother's beak. A disembodied long thin stick with three red stripes near the end evokes an exaggerated response from these chicks. Ramachandran and Hirstein propose that neural structures that evolved to respond to specific visual stimuli respond more vigorously (a shift in their peak response) to stylized versions of these stimuli. These stylized forms are referred to as "primitives." Their insight is that abstract art might be tapping into the responses to such visual primitives even if the viewer might not even be aware of the original stimulus from which the primitive is derived.

These examples of neuroaesthetics writings reflect recognition by neuroscientists that visual aesthetics are an important part of human experience. As such, this experience ought to conform to principles of neural organization. Intriguing parallels exist between the techniques and output of artists and the organization of the visual brain. The challenge for this approach to neuroaesthetics is to convert these observations into a systematic program of research. Can such observations motivate future experimental work? What would constitute falsifiable hypotheses?

A Framework for Neuroaesthetics

A cognitive neuroscience research program in visual aesthetics rests on two principles.[17] First, visual aesthetics, like vision in general, has multiple components. Second, an aesthetic experience arises from a combination of neural responses to different components of a visual object, along with the meanings and associations evoked by the image. The process by which humans visually recognize objects offers a framework from which to consider these components (Fig. 12.1). Investigations can focus on these components and on how they combine.

The nervous system processes visual information both hierarchically and in parallel.[18–20] The levels of this processing can be classified as early, intermediate, and late vision.[21] Early vision extracts simple elements from the visual environment, such as color, luminance, shape, motion, and location.[22,23] These elements are processed in different parts of the brain. Intermediate vision gives structure to regions in what would otherwise be a chaotic and overwhelming array of sensations. This structure is given by separating some elements and grouping others together.[24–27] Late vision scrutinizes these coherent regions as objects are recognized, meanings attached, and memories evoked.[20,28] These levels interact considerably, and the boundaries between higher levels of visual perception and conception may be not be completely clear-cut. However, these distinctions offer a framework from which to think about different aspects of artwork and our responses to them.

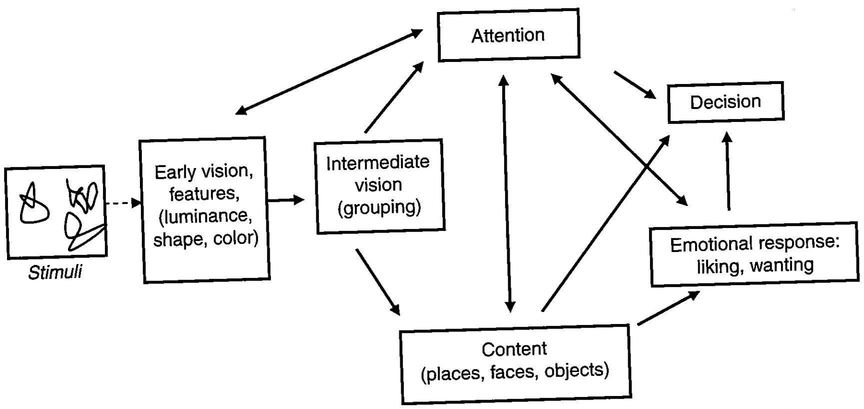

FIGURE 12.1 *A general information-processing model to guide research in neuroaesthetics. (Adapted from[29].)*

This way we process visual information is likely to be reflected in aesthetics[29] (for related models that include broader cultural concerns, see [30] and [31]). Any work of art can be decomposed into its early, intermediate, and late vision components. Aesthetic writings commonly distinguish between form and content (e.g.,[32,33]). Similarly, scientists observe that early and intermediate vision process form and later vision processes content. By *content* I mean the semantic content of an object—that is, its recognizable visual form as well as what the object is and the kinds of information it brings to mind and with which it is associated.

Figure 12.1 shows a model of how the neuroscience of visual aesthetics might be mapped. The early features of an art object might be its color and its spatial location. These elements would be grouped together to form larger units in intermediate vision. Such grouping occurs automatically. The neural basis of grouping is not well understood but likely involves extra-striate cortex (structures that are adjacent to cortical areas that first receive visual information from the eye).[24,25] Grouping creates "unity in diversity," a central notion that underlies compositional balance.

If compositional form is apprehended automatically by intermediate vision, then one might reasonably hypothesize that sensitivity to such form is also automatic. It turns out that people are sensitive to compositional form "at a glance" with exposures as short as 50 milliseconds.[34] Intriguingly, preference for form predominates when images are shown for short durations, while preference for detail predominates when images are shown for slightly longer times.[35] Combinations of early and intermediate visual properties (e.g., color, shape, composition) engage circuits in the frontal and parietal cortices that mediate attention. Attention modulates activity in early visual cortices[36–39] and is likely to contribute to a more vivid experience of the stimulus. The recognition of the object by higher vision then evokes its semantic associations.

Beyond perception and conception in visual aesthetics, two other aspects of aesthetics are important. The first is the emotional response to an aesthetic image; the second is the process of making aesthetic judgments. Parts of the temporal lobe (anterior medial) and frontal lobe (orbito-frontal) and other structures deep in the brain mediate emotions in general, and reward systems in particular.[40–45] Aesthetic judgments about images are likely to engage neural circuits that are distributed widely, particularly within the dorsolateral frontal and medial frontal cortices.

Empirical Evidence: Lesion Studies

Investigations of patients with brain damage have contributed greatly to our understanding of cognitive and affective systems. This approach offers substantial promise in advancing neuroaesthetics. Diseases of the brain can impair our ability to speak or comprehend language, to coordinate movements, to recognize objects, to apprehend emotions, and to make logical decisions. By contrast, while damage to the brain can certainly impair the ability to produce art, paradoxically in some cases art abilities seems to improve. Brain damage can create a disposition to produce visual art (for interesting speculations on how brain damage may have contributed to the oeuvre of the 19th-century photographer Muybridge, see[46]), provide artists with a unique visual vocabulary, add to artists' descriptive accuracy, and enhance their expressive powers. These paradoxical improvements offer unique insights into the creative underpinnings of artistic output, as reviewed elsewhere[47–50] (also see Chapter 15, this volume).

Studies of people with brain damage also can advance our understanding of the perception and experience of art. Some people with brain damage probably do not perceive art in the same way that non–brain-damaged individuals do, and their emotional responses to artwork may differ from those of people without brain damage. However, neuropsychological investigations of aesthetic perception to date are nonexistent. There are no adequate instruments to provide basic quantitative assessments of a person's apprehension of artwork. We have recently developed such a tool, The Assessment of Art Attributes.[51] This assessment assumes that the perception of art can be organized along different perceptual and conceptual attributes (Table 12.1). Using such an assessment, we have begun to investigate groups of patients to ascertain the relationship of brain damage to selective deficits or enhancements in art perception. Much remains to be learned if we can develop adequate methods and measurements for this line of inquiry.

Empirical Evidence: Imaging Studies of Beauty

Beauty is central to most people's concept of aesthetics.[52] Of course, not all art is beautiful and artists do not always intend to produce beautiful things.

TABLE 12.1 Form versus Content

Form	Content
hue	depictive accuracy
saturation	animacy
stroke/contour	emotionality
depth	abstraction
balance	fantasy
complexity	symbolism

A pervasive concern in empirical aesthetics has been distinguishing between form and content of artwork. This list of attributes represents one version of how this distinction might be made in experimental studies.[51]

Current discussions by art experts rarely make mention of beauty (see Chapter 6, this volume). But beauty remains a central concept in lay discussions of aesthetic experiences. Understanding the neural basis of the apprehension of and response to beauty might offer insight into the apprehension of and response to visual art. Facial beauty has received most attention.

The response to facial beauty is likely to be deeply encoded in our biology. Cross-cultural judgments of facial beauty are quite consistent.[53–55] Adults and children within and across cultures agree in their judgments of facial attractiveness.[56] Similarly, infants look longer at attractive faces within a week of being born, and the effects of facial attractiveness on infants' gaze generalize across race, gender, and age by 6 months.[57,58] Thus, the disposition to engage attractive faces is present in brains that have not been modified greatly by experience. Some components of beauty are undoubtedly shaped further by cultural factors,[59] but the universal components are likely to have a common neural basis.

Several studies report that attractive faces activate reward systems in the brain. These systems include parts of the frontal cortex (orbito-frontal) and structures deep within the brain (the nucleus accumbens, the ventral striatum, and the amygdala).[60–65] Neural activity in these areas is interpreted as reflecting our emotional reactions to attractive faces.[66] The particular emotional reactions involve the desire to satisfy appetites. The notion that attractive faces are rewarding to look at, at least for men, is evident behaviorally. Heterosexual men are quite willing to sacrifice higher future rewards for smaller immediate rewards when looking at attractive female faces.[67] Presumably the patterns of neural activation to attractive faces are part of a system that helps us select mates.[63]

Perceptual features of faces, such as averageness, symmetry, the structure of cheekbones, the relative size of the lower half of the face, and the width of the jaw, influence people's judgments of facial beauty.[68–70] Winston and colleagues[65] found that activity in parts of the brain where the left occipital and temporal lobes meet was enhanced by facial attractiveness. Similarly, Kranz and Ishai[64] found more

activity in a part of the ventral occipito-temporal region (the lateral fusiform gyrus) for attractive female faces than for unattractive female faces.

We conducted a study in which people looked at faces, and in one condition they judged the attractiveness of faces and in another they judged the identity of pairs of faces. Attractiveness judgments produced neural activity in a distributed network involving ventral visual association cortices and parts of posterior parietal and frontal cortices.[71] We suggested that the parietal and frontal activations represented the neural correlates of attending to faces and the process of deciding which faces they liked. We also found more neural activity within the insula (a structure underneath the frontal, parietal, and temporal lobes) and less activity within the anterior and posterior cingulate cortex (parts of the medial frontal lobes). We thought that these patterns represent the emotional reactions to attractiveness. Most important in this study, we found attractiveness continued to evoke neural responses in occipital lobe visual areas, even when subjects were judging the identity of faces and not their attractiveness. The degree to which these areas responded was no different than when they were considering beauty explicitly. We proposed that this visual region of the brain responds to beauty automatically.

Facial attractiveness is apprehended automatically[72,73] and has pervasive social effects beyond its specific role in mate selection. Attractive individuals are considered intelligent, honest, pleasant, natural leaders[74–76] and are viewed as having socially desirable traits, such as strength and sensitivity.[77] The cascade of events in the brain that end up with a bias in social judgments is likely to be triggered by an early perceptual response to attractiveness. We proposed that neural activity in ventral visual cortices that we found responding to facial attractiveness serves as the initial trigger for this cascade. The fact that this region of activation extended beyond parts of visual cortex especially sensitive to faces *per se* raises the possibility that this area may be responsive to attractive objects more generally.[71]

While studied less often than faces, human bodies also range in their beauty. Furthermore, many body proportions, such as the ratio of hip to waist diameter, can be quantified. People are quite consistent in the relative body proportions that they consider beautiful. This consistency gives rise to the idea that evolutionary selection pressures contribute to our standards of beauty.[78] Di Dio and colleagues[79] used images of western classical and Renaissance sculpture in an fMRI study to investigate neural responses to bodily beauty. They found that the right ventral occipital regions, parts of the frontal lobes, and the right insula were activated by images of the sculptures in their original form as compared to distorted views in which the proportions of the body were altered. Explicit judgments of beauty by the participants activated the right amygdala, an area deep in the anterior parts of the temporal lobe that has long been associated with emotional processing. The authors propose that the insula is responding to objective parameters of beauty (although a similar claim could be made for the ventral occipital regions that they found active, and we found active in our study on facial beauty described above) and the amygdala might be responding to subjective responses to beauty.

Empirical Evidence: Imaging Studies of Art

Very few studies have used art to examine the neural bases of aesthetics (see Chapters 13 and 14, this volume). While the goals in many of these studies are similar, their experimental approaches differ and the results at first glance appear bewilderingly varied. Kawabata and Zeki[80] asked participants to rate abstract, still-life, landscape, and portraiture paintings as beautiful, neutral, or ugly. The participants then looked at the same images in the scanner. Not surprisingly, they found that looking at portraits, or landscapes, or still-lifes evoked different patterns of activity within different parts of the ventral visual cortex. These patterns of activity represent different responses to the different content of these images. In contrast to these visual regions, they found more activity for beautiful than for ugly or neutral images in the undersurface of the frontal lobes (the orbito-frontal cortex). In the anterior cingulate and left parietal cortex, they found more activity for beautiful than for neutral stimuli. Only activity within the orbito-frontal cortex increased with the beauty of all the painting types. The authors interpreted this activity as representing the neural underpinnings of an aesthetic emotional experience of these paintings.

Vartanian and Goel[81] used images of representational and abstract paintings shown in different formats in an fMRI study. The images were of the originals, or they were altered or filtered. Each painting was presented in each of the three formats and participants reported their preferences for each image. In general, representational paintings were preferred over abstract ones. Representational paintings produced more activity than abstract paintings in the ends of the occipital lobes, the precuneus (a part of the parietal lobe that lies between both hemispheres), and the posterior middle temporal gyrus. Participants also looked longer at the images that they preferred. The authors also found more activity in the occipital gyri on both sides and the left anterior cingulate for images they liked. They also found that activity in the right caudate nucleus (a deep structure that is part of a neural system referred to as the basal ganglia) decreased as their liking for paintings decreased.

Cela-Conde and colleagues[82] used magnetoencephalography to record event-related potentials when participants viewed images of artworks and photographs. Magnetoencephalography is a technique of recording brain waves across different parts of the brain while a person is engaged in a specific task. In their study, participants looked at different kinds of art images, including abstract art, classical art, Impressionist art, post-Impressionist art, and photographs. They judged whether or not each of these images were beautiful. Beautiful images produced more neural activity than not-beautiful images over the left dorsolateral prefrontal cortex in a period of 400 to 1,000 milliseconds after the images were viewed. The authors infer that this region is involved when people make aesthetic judgments.

Jacobsen and colleagues[83] used a different strategy to investigate the neural correlates of beauty in an fMRI study. Rather than use actual artworks as their stimuli, they used a set of geometric shapes designed in the laboratory. Participants judged

whether the images were beautiful or whether the images were symmetrical. Participants in general found symmetrical patterns more beautiful than non-symmetrical ones. When they made aesthetic judgments, the medial frontal cortex, the precuneus, and the ventral prefrontal cortex were active. Parts of the left parietal cortex (the intraparietal sulcus) were engaged by both symmetry and beauty. Both beauty and complexity of the images evoked activity in the orbito-frontal cortex. In a follow-up study using the same stimuli,[84] they found that beauty generated a brain wave, the lateral positive evoked potential, 360 and 1,225 milliseconds after they saw these images.

One might be disheartened that these studies investigating aesthetics report different patterns of activation. However, Nadal and colleagues[85] propose that the results of these studies are compatible within the general model (see Fig. 12.1) I proposed.[29] Engaging visual properties of paintings increases activity within ventral visual cortices.[81] Aesthetic judgments activate parts of dorsolateral prefrontal and medial prefrontal cortices.[82,83] And emotional responses to these stimuli activate the orbito-frontal[80,83] as well as anterior cingulate cortices.[80,81,86]

Why Aesthetics? A Neurobiological Proposal

Why are aesthetic experiences such a central feature of our lives? Any answer to such a question is necessarily speculative. I suggest that a drive to beauty and the propensity towards an aesthetic attitude might underlie the universality of making and appreciating art. Evolutionary biology may offer a general framework from which to consider why humans seem to be engaged in what seems to be such a pointless pursuit.

DRIVE FOR BEAUTY

Most people are drawn to beauty. As we have suggested in our own work, neural responses to attractive faces occur automatically, even when people are not explicitly judging beauty.[71] Three kinds of evolutionary arguments are made for the attraction to beauty. The first and most obvious is the way that beauty influences mate selection. With faces and bodies, the link between mate selection and beauty is clear.[87] Attractive features are physical attributes that are desirable in selecting mates, because they are clues to genetic health.[53,70,78,88–90] On this view, the nervous system has evolved to be attracted to specific configurations of facial features that signal "good genes." We have come to regard these features as beautiful. A variation of this view is the "costly signal" proposal.[91] Male birds attract female birds by using extravagant plumage or elaborate songs. These displays appear to be maladaptive insofar as they interfere with movement and attract predators. The costly signal proposal is that such displays advertise the unusual vigor of the displayer: he can afford these maladaptive indulgences because he is so fit to begin with.

Art-making requires considerable time and effort and, like a costly display, would similarly advertise one's fitness in the competition for mates.

Others have argued that thinking that art is derived from how we select mates is too narrow a view of how art might have evolved. Dissanayake[92] gathers considerable evidence for art's role in promoting social cohesion. She rejects relatively recent ideas that novelty or individual creativity is all that important. Rather, she takes an ethnographic view of the evolutionary significance of art to humanity. For her, the behavior of "making special" is critical to art. Ordinary objects, movements, patterns, and sounds are transformed into something extraordinary by exaggeration, repetition, embellishment, and so on.[93] This stylizing of visual forms is reminiscent of the peak shift idea emphasized by Ramachandran and Hirstein[14] in their discussions of the biology of aesthetics. Beauty, virtuosity, costliness, and emotional investment are all ingredients in the process of making something special. By focusing on the ritualistic nature of making and appreciating art she emphasizes the importance of art in enhancing cooperation and encouraging cohesion within local societies.

A different kind of argument for why we have come to regard things as beautiful has to do with how easily we apprehend objects.[94] On this account, preferences are a byproduct of a general information-processing mechanism. As mentioned before, one idea around for such a mechanism is the extraction of a prototype, or a typical member of a category. People prefer prototypes of different kinds of stimuli, such as color[95] and music.[96] Faces would presumably be another category of stimuli subject to this biased preference for prototypes.[97] A variation on the information-processing account for preference is the idea that people prefer to look at things that are processed "fluently." Fluency is the ease with which one processes objects. Specific physical features of objects themselves and their conceptual characteristics contribute to fluency. Features of the object, such as symmetry, and figure–ground relationships as well as the experiences of the viewer influence fluent processing. The important point is that processing fluency is associated with aesthetic pleasure.[98,99] People like what they see and recognize easily. Thus, familiarity as established by mere exposure, and as it contributes to processing fluency, influences people's preferences for simple displays in laboratories.[100] These influences also extend beyond the laboratory. Familiarity also influences which Impressionist paintings are regarded highly.[101]

Given that specific configurations of physical objects contribute to the experience of beauty, regardless of whether this contribution is driven by mating desires and rituals, promotes social cohesion, or facilitates processing, how do these experience relate to the aesthetic experience? Herein lies a paradox.

THE AESTHETIC ATTITUDE

Evolutionary arguments for the importance of beauty emphasize its significance in how humans have adapted to their environment. Mate selection, social cohesion, and better information processing all have utility. The point of adaptation is to be useful in propagating the species. This utilitarian view of aesthetics is at odds with an idea proposed in the 18th century[102] that the aesthetic attitude is one of "disinterested interest" (see Introduction, this volume). While Kant's idea is by no means agreed upon by all aestheticians, I base my speculations on its importance. Aesthetic pleasures are self-contained; they do not intrinsically evoke additional desires. That is not to say that an artwork cannot evoke utilitarian desires, such as the desire to own it or to display it to impress others. However, these rewards fall outside the aesthetic experience.

Tommaso and colleagues[86] found that gazing at beautiful paintings raised pain thresholds and at the same time inhibited a brain wave referred to as the P2 evoked potential. The P2 potentials are generated by the anterior cingulate cortex. These results suggest that beautiful paintings, even in the artificial laboratory setting, engage people enough to distract them from unpleasant experiences. This phenomenon may be related to the kind of aesthetic experience in which one is completely absorbed by the image, with little regard for anything else.

Can neuroscience contribute to a further understanding of disinterested interest? Berridge and colleagues have drawn a distinction between "liking" and "wanting" that may be relevant to this question.[45,103] Liking and wanting depend on different neural structures and different neurotransmitters. Liking seems to depend on specific parts of our rewards circuits (the nucleus accumbens shell and the ventral pallidum that uses opioid and GABA-ergic neurotransmitter systems) that differ from those structures on which wanting or satisfying our appetites depend (the mesolimbic dopaminergic system, which includes the nucleus accumbens core). Cortical structures such as the cingulate and orbito-frontal cortex further modify these liking and wanting experiences. This distinction between liking and wanting is made in rodents with experiments that use sweet and bitter tastes. Whether the organization of these neural systems also applies to humans and in response to visual images remains to be seen.

The idea that part of our reward systems are cleaved off those that deal with our appetites could be the neural basis for aesthetic disinterested interest. Perhaps the neural circuitry for liking grew out of more prosaic utilitarian reward systems—that is, liking was co-opted within our reward systems that began with clear utilitarian wanting to satisfy appetites. Perhaps the liking system evolved to allow humans to maintain some distance from the objects of desire and has now come to serve the aesthetic attitude. The fact that liking involves the opioid system might be a clue to the "inward" nature of the pleasurable experience.

Cautionary Coda

The neuroscience of visual aesthetics is in its infancy. With a field so wide open, progress in any direction would be an advance. However, I suggest that practitioners of neuroaesthetics should keep some concerns in mind. None of these concerns is unique to neuroaesthetics; rather, they have arisen in other domains within cognitive neuroscience. Neuroaesthetics can profit by being sensitive to these concerns as it matures.

1. RISKS OF REDUCTION

I argue that experimental neuroaesthetics needs to adhere to the constraints of any experimental science. In other words, experiments motivated by general frameworks are needed. And experiments should test falsifiable hypotheses. Such experimental work usually has two properties. First is that the domain in question can be broken down into more manageable components. Second is that the observations can be quantified. The analysis of specific components means tackling relatively narrow aspects of the broader universe of aesthetics. Such a componential approach is no different than how one tries to tackle any complex domain like language, or emotion, or decision-making. The complexity of the domain needs to be simplified in a way that offers some experimental control. While qualitative analyses can certainly provide important empirical information, quantification more easily provides ways to test hypotheses rigorously.

The risk of decomposition and quantification is that such reduction actually misses the very thing we are most interested in studying. Take the example of the aesthetic responses to beauty. Experimental aesthetics often addresses this issue by obtaining preference ratings from participants. In such a research program, one might ask methodologic questions about how best to capture people's preferences. One might ask whether judgments of interestingness are the same as judgments of preference. Or one might explore the relationship of complexity to either preference or to interest. These are all legitimate and important questions to be pursued. However, the pursuit of such questions might easily obscure the basic question of the relationship of preference to the aesthetic experience. Is preference simply a diluted version of the former? Or is that deeply moving experience that one might consider aesthetic qualitatively different? What do neuroscientists make of notions like the "sublime"? The sublime is a very special emotional experience and is mentioned frequently in aesthetics.[102] And yet, sublime is not talked about in affective neuroscience. When we reduce aesthetics to components that can be quantified we risk being diverted from the targets of our investigation.

A different risk of reduction is that what we study is simply not of much relevance to aesthetics. In other words, neuroaesthetics, by focusing on the perceptual and affective properties of artwork, misses what is most germane to contemporary discussions of art (see Chapter 6, this volume). Current discussions of art by critics make little reference to beauty. As I mentioned at the outset, neuroscience is less likely to contribute much to cultural and sociological aspects of art. This challenge might mean that the divide between what neuroscience can deliver and what is most important to aestheticians is too wide to traverse, and after a brief

handshake, as represented by this volume, the disciplines will go their separate ways. In my view, such a conclusion would be premature: these are early days in a new discipline and future directions are difficult to predict. Nonetheless, neuroscientists should be sensitive to the proverbial problem of looking for the dropped coin under the lamp because that is where things are visible, even if the real action is elsewhere.

2. IS AESTHETICS USED AS A PROBE TO UNDERSTAND THE BRAIN, OR IS THE BRAIN USED AS A PROBE TO UNDERSTAND AESTHETICS?

Fechner, in *The Elements of Psychophysics*, distinguished between an outer psychophysics and an inner psychophysics. Outer psychophysics is the study of the relationship between human psychology and the physical properties of stimuli. This kind of study has been the main approach of empirical aesthetics over the past one and a half centuries. Inner psychophysics is the relationship between human psychology and the physical properties of the brain. Fechner recognized that such an inner psychophysics was possible in principle. We are now in a position to pursue an inner psychophysics. Modern neuroscience tools such as fMRI, ERPs, and transcranial magnetic stimulation do exactly that. However, it is worth being explicit about the triangular interactions between psychology and outer physics and inner physics.

Research that probes the relationship between outer and inner psychophysics without direct recourse to psychology is possible. In such experiments, finely controlled stimuli are related to the response properties of neurons in specific regions. Thus, one might find that parts of the ventral surface of the brain (the parahippocampal gyrus) respond preferentially to landscape depictions. Here the landscape images are being used to probe the properties of the brain. Do parahippocampal neurons simply classify images, distinguishing between landscapes and other visual stimuli like objects and faces, or do they also evaluate images? Are they tuned to whether the landscapes are appealing or not? Such an experiment might teach us something important about the brain. Here, aesthetic objects are being used to probe properties of the brain, rather than the brain being used to probe the psychology of aesthetics.

A danger in experiments that relate inner and outer psychophysics is that one might think that they now know something about psychology without adequately investigating the behavior itself. This general problem in cognitive neuroscience is referred to as the reverse inference problem.[104] Thus, one takes the location of neural activation as an indication of underlying psychological process. For example, if one found activations in areas that control our motor systems in response to attractive stimuli, one might plausibly think that attractive stimuli encourage us to approach the stimuli. Such an inference is valid as a conclusion if and only if these motor regions are active in approach behaviors and none other. Such unique correspondences between regional activity and mental operation are rare in the brain.

The proposal that activations to attractive stimuli represent approach behaviors is better considered a hypothesis that is generated by the data rather than data that are confirming a hypothesis. The challenge for the investigator is to then design a follow-up experiment that would confirm or disconfirm this hypothesis.

3. WHAT IS THE ADDED VALUE OF NEUROSCIENCE?

This question, in my view, is the most important challenge for neuroaesthetics. If the goal is to understand aesthetics (as distinct from understanding the brain), what does neuroaesthetics deliver? When does neuroscience provide deeper descriptive texture to our knowledge of aesthetics, and when does it deliver added explanatory force? Knowing that the pleasure of viewing a beautiful painting is correlated with activity within very specific parts of the reward circuits adds descriptive texture to our understanding of aesthetic experiences. A new layer of description is added to how we think of this reward. However, such a study would not have taught us anything about the psychological nature of that reward.

To return to the question posed at the beginning of the chapter, does neuroscience have anything useful to say about aesthetics? To answer this question, we need to take the possibility of an inner psychophysics seriously. In other words, what is the relationship between the physiological properties of the brain and the psychology of aesthetics? But more specifically, when does neuroscience add something to the understanding of the psychology of aesthetics that cannot be discovered by behavioral studies alone?

These are early days in a field that may well generate considerable enthusiasm. As a field, neuroaesthetics is likely to draw interest from psychologists, philosophers, artists, art historians, art critics, and the lay public. It is up to neuroscientists to distinguish hype from hope. It is also up to neuroscientists to take seriously what art experts have to say about art when constructing their experiments and theories.

These cautionary notes should not be construed as causes for pessimism. Rather, they are laid out because neuroaesthetics is gradually coming of age. Neuroaesthetics may be ready to take itself seriously.

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Endnotes

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