Prospects for a Cognitive Neuroscience of Visual Aesthetics

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Abstract

The neural basis for visual aesthetics is largely unknown. Yet, murmurings within cognitive neuroscience suggest this will soon change. In this review, I suggest several ways in which cognitive neuroscience might contribute to studies in aesthetics. First, I present a framework, adapted from the cognitive neuroscience of vision, from which hypotheses about neuroaesthetics might be tested. Following that, I outline several ideas advanced by prominent neuroscientists that are provocative, but in need of experimental testing. Then I point to the effects of brain damage on artists, as contributing to our understanding of the neural bases of artistic production. Finally, I mention recent functional neuroimaging studies that are relevant to aesthetic concerns. These studies examine the neural response to beautiful faces and its relationship to affective systems within the brain. While it is too early to be sure, programmatic research in the cognitive neuroscience of aesthetics promises rich rewards by bringing new ways to approach empirical aesthetics. However, much work remains to be done.

Prospects for a Cognitive Neuroscience of Visual Aesthetics

The cognitive neuroscience of aesthetics is in its infancy. Despite a recent spate of writings on art by neuroscientists, relatively little empirical work has been conducted. There are no central tenets from which cognitive neuroscientists can draw inspiration. With rare exceptions, it is not even clear that neuroscientists consider aesthetics a proper domain of inquiry. (Some aestheticians probably consider neuroscientific inquiry into aesthetics an abomination.) This is the "state of the art" vis-à-vis the cognitive neuroscience of aesthetics. Yet, there are reasons to be optimistic about prospects for a cognitive neuroscience of aesthetics.

In this review, I start with a general framework from visual cognitive neuroscience that is relevant to visual aesthetics. This framework provides a context within which empirical questions might be asked and hypotheses about neuro-aesthetics might be tested. Following the framework I will outline recent ideas advanced by prominent neuroscientists that are provocative, but need experimental grounding. Next, I touch on ways in which the neuropsychology of visual artists contributes to our understanding of artistic production. I will then mention several neuroimaging experiments that are relevant to neuro-aesthetics, before making some concluding comments.

A Framework from Visual Cognitive Neuroscience

The process by which humans visually recognize objects offers a framework from which to consider visual aesthetics. Such a framework, adapted from cognitive neuroscience, rests on two assumptions (Chatterjee, 2002a). First, visual aesthetics, like vision, has multiple components. Second, an aesthetic experience is not a response to a single component. Rather, it is derived from responses to different components of a visual object. Investigations can be focused on any of these components or on their combinatorial properties.

Beyond perceptual and cognitive aspects of visual aesthetics are the emotional ones. The aesthetic experience has long been described as one of "disinterested interest," or one in which the viewer experiences pleasure without obvious utilitarian consequences of this pleasure. This experience contrasts with those to other visual objects that might give pleasure by appealing to basic drives such as the desire for food or sex. Aesthetic objects presumably give pleasure without evoking additional desires, although the boundaries between the two emotional experiences may not always be clear (Santayana, 1896). The process by which humans react to stimuli and engage neural circuits that respond to pleasing or rewarding stimuli may offer a probe into the neural basis for "liking without wanting."

The nervous system processes visual information both hierarchically and in parallel (Farah, 2000; Van Essen, Feleman, DeYoe, Ollavaria, & Knierman, 1990; Zeki, 1993). The levels of this processing can be classified as early, intermediate and late vision (Marr, 1982). Early vision extracts simple components from the visual environment, such as color, luminance, shape, motion and location (Livingstone & Hubel, 1987, 1988). These components are processed in different parts of the brain. Intermediate vision segregates some components and groups others together to form coherent regions in what would otherwise be a chaotic and overwhelming sensory array (Biederman & Cooper, 1991; Grossberg, Mingolla, &

Ros, 1997; Sajda & Finkel, 1995). Intermediate vision proceeds automatically, seemingly without effort. Late vision selects which coherent regions to scrutinize. It also evokes memories from which objects are recognized and meanings attached. In the aftermath of object recognition, emotions may be evoked and decisions about the objects (e.g., I will eat it., or I will grasp it.) can be made.

Individuals with brain damage may have selective deficits in any of these levels of visual processing. Thus, damage to parts of the occipital cortex can produce complete blindness or blindness for sectors of the visual field or blindness for selective elements of early vision, such as color or form or movement. Damage to intermediate vision results in an inability to group visual elements (Vecera & Behrmann, 1997). Such a person is overwhelmed by the experience of confronting a visual environment that cannot be organized (Ricci, Vaishnavi, & Chatterjee, 1999). Damage to late vision takes varied forms. In some disorders, such as spatial neglect, some visual objects are simply not selected for further processing because of their spatial location (Chatterjee, 2003). In others, such as associative visual agnosias, even when the visual percept of the object is discerned, the patient does not recognize the object (Farah, 2000). The percept is "stripped of meaning" as it no longer makes contact with the person's memories attached to that percept. This evidence for different levels of visual processing from human neuropsychological studies is corroborated by neurophysiologic studies.

How is this view of levels of visual processing reflected in empirical aesthetics? The distinction between form and content common in aesthetic writings (e.g., Russell & George, 1990; Woods, 1991) is paralleled by the observations that early and intermediate vision process form and later vision processes content. Figure 1 shows a working model of how the
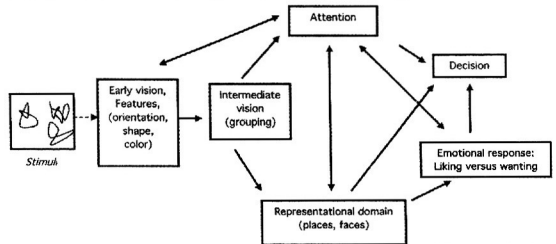

Figure 1. A general framework for the neural underpinnings of visual aesthetics guided by visual neuroscience.

neuroscience of visual aesthetics might be mapped. The early feature of an art object might be its color, which would be processed in parts of the occipital cortex, such as areas V4. Early features would be grouped together to form larger visual units by intermediate vision. The neural basis of grouping is not well understood, but it likely involves extra-striate cortex (Biederman & Cooper, 1991; Grossberg et al., 1997; Sajda & Finkel, 1995).

The process of grouping gives "unity in diversity," a fundamental feature of compositional balance, which itself is a central idea about the formal structure of aesthetic objects. If compositional form is apprehended automatically by intermediate vision, then sensitivity to such form should also be automatic. Subjects are sensitive to form "at a glance" with exposures as short as 50 msec (Locher & Nagy, 1996). Furthermore, preference for form predominates when images are shown over short exposure times. By contrast, preference for detail (which requires serial attentional processing) predominates when images are shown for slightly longer times (Ognjenovic, 1991).

As a tentative proposal, I suggest the following sequence of processing within the nervous system. The visual attributes of art work initially are processed like any other visual object. Various combinations of early and intermediate visual properties (e.g., color, shape, composition), especially if they are balanced, engage frontal-parietal attentional circuits. These attentional networks continue to modulate processing within the ventral visual stream (Humphreys, Riddoch, & Price, 1997; Motter, 1993, 1994; Pessoa, Kastner, & Ungerleider, 2003; Shulman et al., 1997; Watanabe et al., 1998). This further modulation likely contributes to a more vivid experience of the stimuli, both its attributes, such as colors or form as well as its content, such as faces or landscapes. Thus, a feed forward system is established in which the attributes of an aesthetic object engage attention, and attention further enhances the processing of these attributes. Aesthetic objects are probably one example of a class of objects that engage such a feed forward system. Any object that is experienced vividly, such as an

emotional face, is probably mediated similarly. These other objects are distinguished from aesthetic objects by the structural properties of the object itself and the subsequent emotional responses to them.

The emotional experience of viewing an aesthetic object is central to the aesthetic experience. Considerable evidence from neuroscience suggest that the anterior medial temporal lobe, medial and orbitofrontal cortices and subcortical structures mediate emotions in general, and reward systems in particular (Breiter, Aharon, Kahneman, Dale, & Shizgal, 2001; Delgado, Nystrom, Fissell, Noll, & Fiez, 2000; Elliott, Friston, & Dolan, 2000; O'Doherty, Kringelbach, Rolls, Hornack, & Andrews, 2001; Schultz, Dayans, & Montague, 1997). Recently, the distinction between "liking" and "wanting" has gained prominence in investigations of the neural bases of emotions (Berridge, 1996; Wyvell & Berridge, 2000). Wanting or the desire for rewards seems to be mediated by dopaminergic circuits including the ventral striatum and the nucleus accumbens. There is a long-held notion that a quintessential aesthetic experience involves disinterested interest. That is, the object gives pleasure but not for utilitarian reasons. The neural mediation of such an emotional experience, of liking without wanting, has not been worked out. (Judgments about an aesthetic object might be considered outside the core aesthetic experience following the logic of disinterested interest. However, they feature prominently in experimental aesthetics in which subjects state preferences or make decisions about objects. These judgments are likely to engage widely distributed circuits, most importantly the dorsolateral frontal and medial frontal cortices.)

Cognitive neuroscience, for the most part, focuses on properties of the nervous system that are shared rather than those that vary. What are we to make of the amazing diversity of art from different cultures and time periods? Can one sort universal aspects of neuroaesthetics from cultural ones? The analogous question of distinguishing universal from cultural aspects might be asked of vision. Is vision universal or relative? Early and intermediate vision are almost certainly universal. For example, individuals respond to the same light frequencies to perceive colors and group visual elements similarly. These processes are presumably "hardwired" in the brain. No amount of experience or cultural exposure will make a human perceive infrared light. Similarly, grouping mechanisms, such as seeing illusory contours, are likely to be obligatory. Later vision is different. Although the process of selecting and recognizing visual objects (linking the percept to memories and meanings) is likely to be universal, the specific memories and meanings evoked by visual percepts vary. For example, what is the
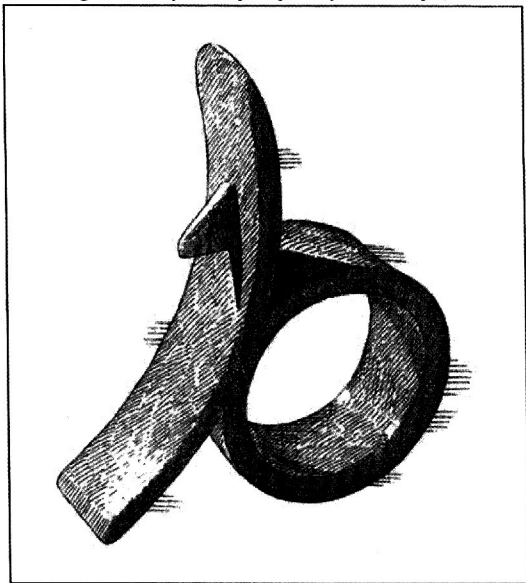

Figure 2. A visual object that would be difficult to recognize by most viewers. This is an example of a percept stripped of meaning.

object in Figure 2? While the percept may be clear, without some knowledge or memory of the class of which this object is a member, recognition is at best a guess. Across cultures, individuals with similar brain

damage are likely to have object recognition deficits. However, their culture affects which objects they do or do not recognize.

As in object recognition, aesthetic objects are likely to evoke both universal and relative responses to different components of the object. Responses to early and intermediate visual components of an art object are likely to be universal. Thus probes for preferences for early visual elements, such as color (Eysenck, 1941) or compositional form (Goetz, Borisy, Lynn, & Eysenck, 1979), which unifies diverse elements, are likely to be universal. By contrast, probes for preferences for aspects of later vision, such as the content of an image are likely to be relative (Gombrich, 1960).

Recent Comments on Art by Cognitive Neuroscientists

Recently, the relationship between the biology and beauty of vision has captured the imagination of prominent vision neuroscientists. Zeki (1999a, b) argues that no theory of aesthetics is complete without an understanding of its neural bases. He suggests an important parallel between the goals of the nervous system and that of artists. Both are driven to understand essential attributes of the world. The nervous system decomposes visual information received through the retina into different components, such as color, luminance and motion. Similarly, many artists, particularly within the last century have honed in on different visual attributes, such as color by Matisse or motion by Calder. Zeki suggests that artists, like visual neuroscientists, endeavor to discover attributes of the visual world, which correspond to processing components of the visual brain. With respect to the general framework described in the previous section, Zeki highlights the importance of the modular nature of early vision in its role in visual art, and the way in which elements from early vision evoke aesthetic experiences.

Livingstone (Livingstone, 2002) focuses on artists' use of interactions between the dorsal (where) and the ventral (what) visual stream. The distinction between dorsal and ventral processing is central in visual cognitive neuroscience (Ungerleider & Mishkin, 1982). The dorsal stream is sensitive to contrast differences, motion and spatial location. The ventral stream is sensitive to simple form and color. Livingstone suggests that the shimmering quality of water or the sun low on the horizon seen in some impressionistic paintings (e.g., the sun and surrounding clouds in Monet's *Impression Sunrise*) is produced by isoluminant objects distinguishable only by color. The dorsal stream is insensitive to isoluminant color differences of the image. Since the dorsal stream identifies motion (or the lack thereof) and spatial location, Livingstone argues that this is why these isoluminant forms 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 can use contrast to produce shapes, leaving color for expressive, rather than descriptive purposes (as in Derain's portrait of Matisse). Like Zeki (1999b), Livingstone also focuses on features of early vision, but highlights their interactions. Artists use these interactions as part of their tool-kit to achieve specific aesthetic effects.

Ramachandran and Hirstein (1999) propose several perceptual principles underlie aesthetic experiences. Of this list of perceptual principles, they emphasize the "peak shift" phenomena as offering insight into the aesthetics of abstract art and rely on Tinbergen's (1954) work. Tinbergen demonstrated that sea gull chicks beg for food from their mothers by pecking on a red spot near the tip of the mother's beak. It turns out that 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 underlying primitives of that form even when the subject is not aware of the primitive. Their insight is that abstract art may be tapping into such visual primitives, although they are not specific about the neural mechanisms that might account for this intriguing hypothesis.

These three attempts to link visual neuroscience and aesthetics reflect the emerging recognition by neuroscientists that visual aesthetics are an important part of human visual experience. As such, visual aesthetics ought to conform to principles of neural organization.

The Neuropsychology of Visual Artists

If visual aesthetics conform to principles of neural organization, what happens to artists with brain damage? Several factors make it difficult to know what to make of the art produced by brain-damaged individuals. The data are observational rather than experimental. Artists vary in their talents, raising questions of whether general principles can be extracted from something that is already so variable across individuals. Beyond the question of talent lies the problem of artistic styles and content which may change with brain damage. When considering different artistic tradi-

tions, is the same kind of behavior even being scrutinized? Despite these limitations, I suggest that the neuropsychology of artists contributes to the empirical studies of the arts. I have developed this thesis in detail elsewhere (Chatterjee, submitted). Here, I focus on three questions. Because of specialized visuo-motor skills, are artists spared the kind of visual deficits seen after brain damage in other people? Does brain damage alter artists' styles? Can brain-damaged artists contribute to our understanding of the roles of "knowing" and of "seeing" in producing art?

Artists with brain damage that affects their visual system do not appear to be spared deficits experienced by others. Rather, because of their skills they often express their deficits with particular eloquence. Sacks (1995) described an artist with achromatopsia, a selective loss of color perception. Before the traumatic brain injury, which produced this deficit, the artist painted colorful abstractions. Following his brain injury, everything appeared "dirty gray" to him. Initially he applied color in a haphazard manner, before resigning himself to black and white renderings. Eventually he reintroduced color to his paintings, but with an extremely limited palette. Thus, this patient's achromatopsia changed how he painted, but did not prevent him from continuing to be a successful artist.

Unilateral spatial neglect is a disorder in which individuals appear to be unaware of objects or images in space contralateral to their brain lesion (Chatterjee, 2003). This disorder is more common following right than left brain damage. Several successful artists, including Lovis Corinth, Anton Rädersheidt, Reynolds Brown and Loring Hughes all developed neglect following right brain damage (Heller, 1994; Jung, 1974; Schnider, Regard, Benson, & Landis, 1993). These artists demonstrate dramatic contralesional neglect in their paintings, with minimal brush strokes and detail in contralesional space. The great Italian film director, Fellini, developed left neglect following a right hemisphere stroke (Cantagallo & Sala, 1998). Fellini was also an accomplished cartoonist, and his spontaneous cartoons demonstrated left-sided neglect (Figure 3). Some patients with neglect can
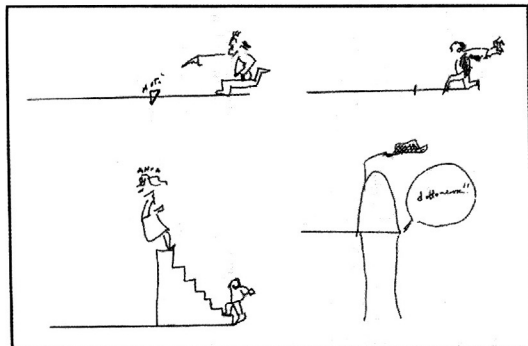

Figure 3. An example of Fellini's spontaneous cartoons when asked to bisect lines. As can be seen he drew his adornments on the right of the line even as he mis-bisected the line to the right of true center. Reprinted with permission (Cantagallo & Sala, 1998).

process left sided stimuli to some degree short of full awareness. Fellini demonstrated such partial awareness in some of his drawings. For example, he drew a cartoon (Figure 4) of an elephant on the left asking the question of a doctor behind a desk on the right, "Can I stay here, doctor?"
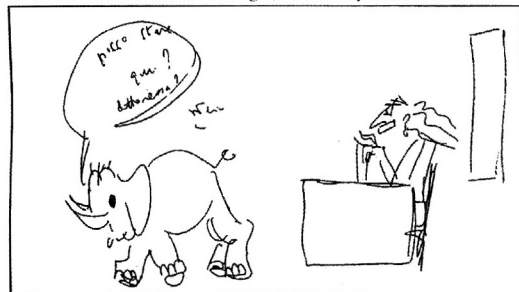

Figure 4. A cartoon drawn by Fellini showing an elephant on the left asking if it can stay there. Reprinted with permission (Cantagallo & Sala, 1998)

Visual agnosias are disorders in which patients are unable to recognize objects visually. Lissauer (1890), at the end of the nineteenth century made the classic distinction between apperceptive and associative agnosias, to highlight the fact that a patient might not identify an object because of a deficit anywhere along a perceptual to conceptual continuum. Apperceptive agnosics have deficits that lie closer to perceptual processing (De Renzi & Lucchelli, 1993; Warrington & James, 1988). Whereas associative agnosics deficits lie closer to conceptual knowledge of objects (Riddoch & Humphreys, 2003). The few artists with visual agnosias who have been described demonstrate problems of either apperception or association in their art. Wapner and colleagues (Wapner, Judd, & Gardner, 1978) described an artist, JR, with an apperceptive agnosia. JR's drawings after his stroke retained some of his premorbid techniques, such as the use of shadows and perspective. However, he often lost his place in the middle of drawings. Because he could not recognize his own drawing, he often omitted some details and elaborated others. Sometimes he redrew features, such as five legged rhinocerous or a plane with many propellers. At times he would use a conceptual strategy to guide his drawings. For example, in drawing a telephone, he would say "It needs a base for it to stand on, a place to speak into, something to hear with a wire to plug in for communication and place to dial." This strategy was not particularly effective. His piecemeal vision was accompanied by a fragmented approach to his drawings. He drew features accurately, but did not fit these features into an overall composition.

JR's deficits contrast with those of two other artists, who had similar associative agnosias (Franklin, van Sommers, & Howard, 1992; Schwartz & Chawluck, 1990). The quality of their drawings varied dramatically depending on the context in which they drew. When presented with a rich visual model, such as a picture or actual person, their drawings remained remarkably skilled and beautiful (see Figure 5). However, associating a

Figure 5. A drawing copied from an example by a patient with an associative visual agnosia. Reprinted with permission (Franklin et al., 1992).

word to a visual form proved to be very difficult, and this difficulty was expressed in their art. When given names of objects to draw, their drawings became simple, crude and sometimes unrecognizable.

While artists are not spared the kinds of deficits experienced by others following brain damage, sometimes the changes in their artwork can be surprisingly appealing. Brain damage that renders accurate depiction difficult can sometimes free artists to be more expressive. The artist Loring Hughes had trouble with spatial relationships of lines after she suffered right brain damage. Heller (1994) described Hughes' experience as follows: "…after damage to her brain…two things contributed to a new found freedom from inhibition. First, her difficulties with spatial relationships made it impossible for her to replicate the world on paper, and this forced her to accept and explore the world of her own emotions…she gave up trying to reproduce things and turned, instead to her imagination…. To her surprise, when she did start showing, the feedback from the artistic community was much more encouraging than before. Her paintings 'deliver an emotional wallop' according to art critic Eileen Watkins." Similarly

Reynolds Brown and Lovis Corinth were judged to be more expressive in their paintings after their right brain damage. They used bolder strokes and less detail. The critic Alfred Kuhn (quoted in Gardner, p. 23, 1975) characterized Corinth after his brain damage as having "shifted from the ranks of the great painters into the circle of great artists."

DeKooning is perhaps the best-known artist whose style changed following neurologic disease (Garrels, 1995; Storr, 1995). He developed Alzheimer's disease, probably in the late 1970s. With the help and support of his ex-wife and assistants, he continued to paint until 1988. There is general agreement among experts that this late period, exhibited in San Fransisco in 1996, constituted a new and coherent style. These paintings were abstract and successively simpler, using mostly primary colors such as reds and blues on white. Gary Garrels (1995), senior curator at the San Francisco Museum of Modern Art comments: "In the 1980s works, the essential procedures and techniques were not changed, but simplified, and the vocabulary of forms was retained but clarified. Particularly in the works from 1984, the results are paintings of an openness and freedom not seen before, paintings that are extraordinarily lyrical, immediately sensual, and exhilarating."

Do artists produce what they apprehend directly, or do they produce what they think is true of the world? Gombrich (1960) underscores the importance of this question in the history of Western art when he explores reasons why styles of representation have changed dramatically over the years. He suggests that artist bring tremendous top-down information to bear on their perceptions. Sensations trigger hypotheses about what it is they are seeing. In turn, the hypotheses are based on internal representations. Consequently, artists are more often aware of their own internal representations than they are of their direct sensations. An exaggerated example of this point is evident in the drawings of children. Children draw roads receding into the horizon with parallel lines rather than lines converging into the vanishing point because they know that the sides of the road are parallel and do not meet in the distance. This perceptual hypothesis testing occurs automatically, and artists need considerable practice to better "see" the world. What happens when artists have impoverished internal representations? Germane to this question are observations of autistic children with exceptional drawing skills.

About 10% of autistic children have islands of exceptional skills (Rimland & Fein, 1988). Some of these skilled children are gifted visual artists. Selfe (1977) reported the first detailed description of such a child, Nadia. Nadia had several developmental abnormalities. She did not respond to her mother and she lacked expressions of social sympathy. As she got older, her relationships with other children seemed like an obsessive concern for their presence, rather than consisting of any substantial interpersonal interaction. Her language development was delayed and her speech was frequently echolalic and ritualistic. Despite these abnormalities, she was amazingly skilled at drawing. At three and a half years of age she was drawing remarkably life-like horses in perspective (see Figures 6 and 7). Unlike other children, she did not go through a stage of drawing simplified schematic
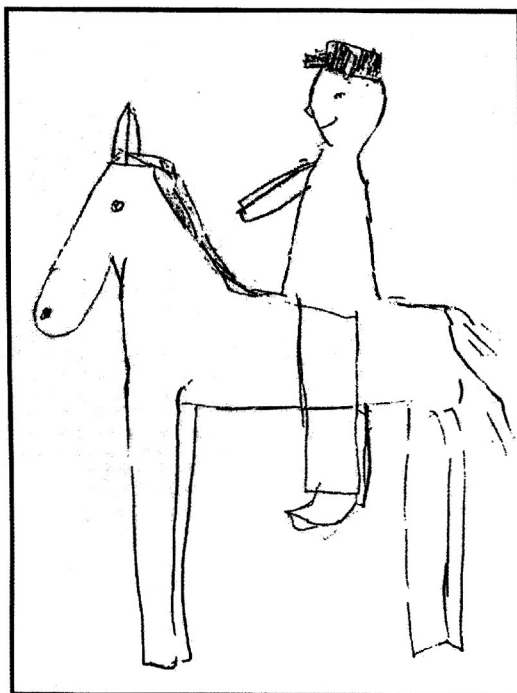

Figure 7. A typical drawing of a person on a horse that by a six year old child. Reprinted with permission (Selfe, 1977).

over time, her abilities themselves did not improve substantially. Her movements when drawing were deft, rapid and without hesitation. She drew intensively for a few minutes at a time and produced line drawings without any interest in color. She tended to draw specific subjects like horses and riders and she seemed oblivious to the boundaries of the page. Her drawings were modeled after other drawings. However, she did not copy the models. Rather, her drawings were often composites of previous images she had seen, and sometimes had subtle shifts in their orientation. She never looked at the original once she started to draw.

While Nadia was exceptional, she is not unique. Other such autistic artists have been reported. Thus, in the setting of impoverished conceptual development, but preserved or superior visuo-motor skills, children can produce remarkable drawings with depth, rather than the simplified symbolic drawing produced by most children. Consistent with the view that Nadia drew what she saw rather than what she knew, she would sometimes begin her drawings at bizarre points, such as at the neck of a horse and not its head where most people start. If language development is a marker for conceptual development, then it is especially intriguing that Nadia's drawing skills became prosaic as she acquired more language.

It is worth repeating that inferences made from the neuropsychology of artists must be made with considerable caution. Nonetheless, these examples of the dramatic phenomenology seen in artists with brain damage show that such patients contribute to our understanding of visual aesthetics.

Functional Neuroimaging and Visual Aesthetics: The Example of Beautiful Faces

Functional magnetic resonance imaging (fMRI) techniques are likely to advance our understanding of the neural underpinnings of perceptual and emotional aspects of aesthetic experiences. fMRI uses changes in blood flow in response to stimuli or cognitive processes to make inferences about the relevant underlying neural activity. The inferential logic in fMRI studies can be complicated (Aguirre & D'Esposito, 1999). If one knows the components of a cognitive operation which can be isolated, then one might test hypotheses about which parts of the brain are engaged by this component. Alternatively, if one has a clear sense of the function of a particular region of the brain, then one can test the hypothesis that a cognitive process includes that function. Domains of inquiry that are relatively early

Figure 6. Drawing by the autistic child, Nadia, when she was 3 and a half years old. Reprinted with permission (Selfe, 1977).

images of horses before drawing them more realistically. Her skills were highly developed at the outset, and although the objects she drew changed

in their evolution, such as neuro-aesthetics, pose challenges to testing hypotheses using fMRI. Currently, the specific components of a process (the aesthetic experience) may not be isolated and knowledge of relevant brain functions might not be sufficiently worked out.

Despite these limitations, a few recent fMRI studies relevant to the cognitive neuroscience of beauty, particularly in the context of faces, have been reported. Faces are a category of visual objects with special saliency within the nervous system. Faces convey tremendous amounts of information, such as identity, emotion, personal and cultural attributes and so on. Patients with focal brain damage, usually to the occipital-temporal junction can have a disorder called prosopagnosia, a selective inability to recognize faces (Young, Newcombe, de Haan, Small, & Hay, 1993). fMRI studies have shown that in most normal individuals a region within the fusiform gyrus is more responsive when subjects look at faces than when they look at other objects such as houses (Allison, McCarthy, Nobre, Puce, & Belger, 1994; Kanwisher, McDermott, & Chun, 1997). The importance of faces for humans is also reflected in art. There is a long history of portraits being used to communicate information about the individual depicted (Chatterjee, 2002b).

The fMRI studies in facial attractiveness focus on the difference between an aesthetic judgment of the beauty in faces and the degree to which they are desirable. Aharon and colleagues (2001) studied young heterosexual men's responses to attractive and average male and female faces. These subjects also indicated how long they wished to view a face by repeated key-presses. This procedure allowed the investigators to distinguish between an aesthetic judgment and the desire to keep looking at the face, because they found a dissociation of attractiveness rating and key press across gender. These young men chose to view attractive women longer than average looking women, but did not choose to view attractive men longer than average looking men or average looking women. The main finding in the study was that the desire to keep looking at faces correlated with activity within the nucleus accumbens and closely related subcortical structures. These structures are postulated to be part of a more general reward circuitry, associated with monetary, drug and homeostatic rewards and thought to be mediated by dopaminergic systems. While the neural structures activated by aesthetic judgments per se were not identified, the authors suggest that judgments of attractiveness and the pleasure derived from attractive objects might be neurally dissociable.

In a related study, Kampe, Frith, Dolan, and Frith (2001) found that direction that attractive faces were gazing also modulated activity within reward circuits, close to the nucleus accumbens. Again, they did not find neural effects of the perception of attractiveness per se, but they did find attractiveness when paired with eye contact activated the ventral striatum. They postulate that in the setting of social contact, the return of eye-gaze from an attractive face is rewarding, and consequently activity of dopaminergic reward systems are enhanced. By contrast, O'Doherty and colleagues (2003) found that attractive faces activated the medial orbitofrontal gyrus even when subjects made an unrelated judgment of the faces, in this case gender. They also found that this activity was further enhanced if the face was smiling. Unlike the two previous studies, they did not find significant activity within the nucleus accumbens or the ventral striatum. They speculate that the orbitofrontal activation reflects the direct affective response to beautiful faces and not expectations of rewards that might be mediated by the circuits involving the nucleus accumbens and the ventral striatum.

These studies are cited as an example of how functional neuroimaging might contribute to empirical studies in aesthetics. There is something paradoxical about them, with respect to aesthetics. These studies use attractive faces as a probe to understanding the neural bases for rewards. Such studies are critical to understanding drives in normal and pathological states. The focus is usually on wanting rather than liking. In some conditions, such as in drug addiction, one might find wanting without liking. It is precisely the converse of this, liking without wanting, if such circuitry could be delineated, that would be of most interest to empirical aesthetics.

Conclusions

The prospects for a cognitive neuroscience of aesthetics is promising. Adapting ideas from visual neuroscience may help guide testing of hypothesis about the perceptual, cognitive and affective aspects of neuro-aesthetics. Intriguing ideas proposed by prominent neuroscientists are poised to be tested empirically. Insights into artistic production can be gained by observations of artists with brain damage. Hopefully, new observations will continue to educate us in this regard. These observations need to be accompanied by experimental work in patients with brain damage. Patient based studies can be used to test hypotheses of the functional organiza-

tion of aesthetic reception and production and their neural underpinnings. Functional neuroimaging studies complement lesion studies, and can be used to probe large scale neural activity underlying the aesthetic experience. Faces, in the form of portraits have long had a central position in art. The neural response to attractive faces is beginning to uncover circuits that mediate emotional responses to beauty. Similar investigations will hopefully be conducted with other stimuli, such as landscapes and abstractions. Such methods from cognitive neuroscience offer the promise of sorting out the perceptual and cognitive aspects of aesthetic viewing as well as the emotional response to beauty. Perhaps most intriguing, these studies may help uncover the neural bases for disinterested interest, or the pleasure in an aesthetic experiences that is self-contained, without utility outside of itself.

References

Aguirre, G., & D'Esposito, M. (1999). Experimental design for brain fMRI. In C. Moonen & P. Bandettini (Eds.), *Functional Magnetic Resonance Imaging* (pp. 369-380). Berlin: Springer-Verlag.

Aharon, I., Etcoff, N., Ariely, D., Chabris, C., O'Connor, E., & Breiter, H. (2001). Beautiful faces have variable reward value: fMRI and behavioral evidence. *Neuron, 32*, 537-551.

Allison, T., McCarthy, G, Nobre, A. C., Puce, A., & Belger, A. (1994). Human extrastraite visual cortex and the perception of faces, words, numbers, and colors. *CVerebral Cortex, 5*, 544-554.

Berridge, K. (1996). Food reward: brain substrates of wanting and liking. *Neurosci Behav Rev, 20*, 1-25.

Biederman, I., & Cooper, E. (1991). Priming contour-deleted images: evidence for intermediate representations in visual object recognition. *Cognitive Psychology, 23*, 393-419.

Breiter, H., Aharon, I., Kahneman, D., Dale, A., & Shizgal, P. (2001). Functional imaging of neural response to expectancy and experience of monetary gains and losses. *Neuron, 30*(619-639).

Cantagallo, A., & Sala, S. D. (1998). Preserved insight in an artist with extrapersonal spatial neglect. *Cortex, 34*, 163-189.

Chatterjee, A. (2002a). *Universal and relative aesthetics: a framework from cognitive neuroscience*. Paper presented at the International Association of Empirical Aesthetics, Takarazuka, Japan.

Chatterjee, A. (2002b). Portrait profiles and the notion of agency. *Empirical Studies of the Arts, 20*, 33-41.

Chatterjee, A. (2003). Neglect: A disorder of spatial attention. In M. D'Esposito (Ed.), *Neurological Foundations of Cognitive Neuroscience* (pp. 1-26). Cambridge, MA: The MIT Press.

Chatterjee, A. (submitted). The neuropsychology of visual artists.

De Renzi, E., & Lucchelli, F. (1993). The fuzzy boundaries of apperceptive agnosia. *Cortex, 29*, 187-215.

Delgado, M., Nystrom, L., Fissell, K., Noll, D., & Fiez, J. (2000). Tracking the hemodynamic responses for reward and punishment. *Journal of Neurophysiology, 84*, 3072-3077.

Elliott, R., Friston, K., & Dolan, R. (2000). Dissociable neural responses in human reward systems. *Journal of Neuroscience, 20*, 6159-6165.

Eysenck, H. J. (1941). A critical and experimental study of color preference. *American Journal of Psychology, 54*, 385-391.

Farah, M. (2000). *The Cognitive Neuroscience of Vision*. Malden, MA: Blackwell Publishers.

Franklin, S., van Sommers, P., & Howard, D. (1992). Drawing without meaning?: dissociations in graphic performance of an agnosic artist. In R. Campbell (Ed.), *Mental Lives. Case Studies in Cognition* (pp. 179-198). Cambridge, USA: Blackwell.

Gardner, H. (1975). *The Shattered Mind. The Person After Brain Damage*. New York: Alfred A. knopf.

Garrels, G. (1995). Three toads in the garden: line, color, and form. In *Willem de Kooning. The Late Paintings, The 1980s* (pp. 9-37). Minneapolis: San Franscisco Museum of Modern art and Walker Arts Center.

Goetz, K. O., Borisy, A. R., Lynn, R., & Eysenck, H. J. (1979). A new visual aesthetic sensitivity test: I. Construction and psychometric properties. *Perceptual & Motor Skills, 49*(3), 795-802.

Gombrich, E. (1960). *Art and Illusion*. Princeton: Princeton University Press.

Grossberg, S., Mingolla, E., & Ros, W. D. (1997). Visual brain and visual perception: how does the cortex do perceptual grouping? *Trends Neurosci, 20*, 106-111.

Heller, W. (1994). Cognitive and emotional organization of the brain: Influences on the creation and perception of art. In D. Zaidel (Ed.), *Neuropsychology* (pp. 271-292). New York: Academic Press.

Humphreys, G. W., Riddoch, M. J., & Price, C. J. (1997). Top-down processes in object identification: evidence from experimental psychology, neuropsychology and functional anatomy. *Phil. Trans. R. Soc. Lond. B, 352*, 1275-1282.

Jung, R. (1974). Neuropsychologie und neurophysiologie des konturund formsehens in zeichnerei und malerei. In H. Weick (Ed.), *Pyschopathologie Mususcher Gestaltungen* (pp. 27-88). Stuttgart: FK Shattauer.

Kampe, K., Frith, C., Dolan, R., & Frith, U. (2001). Reward value of attractiveness and gaze. *Nature, 413*, 589.

Kanwisher, N., McDermott, J., & Chun, M. (1997). The fusiform face area: a module in human extrastriate cortex specialized for perception of faces. *Journal of Neuroscience, 17*, 4302-4311.

Lissauer, H. (1890). Ein Fall von Seelenblindheit Nebst Einem Beitrage zur Theori derselben. *Archiv fur Psychiatrie und Nervenkrankheiten, 21*, 222-270.

Livingstone, M. (2002). *Vision and art: The biology of seeing.* New York: Abrams.

Livingstone, M., & Hubel, D. H. (1987). Psychophysical evidence for separate channels for the perception of form, color, movement, and depth. *The Journal of Neuroscience, 7*, 3416-3468.

Livingstone, M. & Hubel, D. (1988). Segregation of form, colour, movement, and depth: Anatomy, physiology, and perception. *Science, 240*, 740-749.

Locher, P., & Nagy, Y. (1996). Vision spontaneously establishes the percept of pictorial balance. *Empirical Studies of the Arts, 14*(1), 17-31.

Marr, D. (1982). *Vision. A Computational Investigation into the Human Representation and Processing of Visual Information.* New York: WH Freeman and Company.

Motter, B. C. (1993). Focal attention produces spatially selective processing in visual cortical areas V1, V2, and V4 in the presence of competing stimuli. *Journal of Neurophysiology, 70*, 909-919.

Motter, B. C. (1994). Neural correlates of attentive selection for color or luminance in extrastriate area V4. *J. Neurosci., 14*, 2178-2189.

O'Doherty, J., Kringelbach, M., Rolls, E., Hornack, J., & Andrews, C. (2001). Abstract reward and punishment representations in the human orbitofrontal cortex. *Nature Neuroscience, 4*, 95-102.

O'Doherty, J., Winston, J., Critchley, H., Perret, D., Burt, D., & Dolan, R. (2003). Beauty in a smile: the role of orbitofrontal cortex in facial attractiveness. *Neuropsychologia, 41*, 147-155.

Ognjenovic, P. (1991). Processing of aesthetic information. *Empirical Studies of the Arts, 9*(1), 1-9.

Pessoa, L., Kastner, S., & Ungerleider, L. (2003). Neuroimaging studies of attention: from modulation of sensory processing to top-down control. *The Journal of Neuroscience, 23*, 3990-3998.

Ramachandran, V. S., & Hirstein, H. (1999). The science of art: a neurological theory of aesthetic experience. *Journal of Consciousness Studies, 6*, 15-51.

Ramachandran, V. S., & Hirstein, W. (1999). The science of art: A neurological theory of aesthetic experience. *Journal of Consciousness Studies, 6*(6-7), 15-51.

Ricci, R., Vaishnavi, S., & Chatterjee, A. (1999). A deficit of preattentive vision: experimental observations and theoretical implications. *Neurocase, 5*(1), 1-12.

Riddoch, M., & Humphreys, G. (2003). Visual Agnosia. *Neurol Clin, 21*, 501-520.

Rimland, B., & Fein, D. (1988). Special talents of autistic savants. In L. Obler & D. Fein (Eds.), *The Exceptional Brain* (pp. 474-492). New York: Guilford.

Russell, P. A., & George, D. A. (1990). Relationships between aesthetic response scales applied to paintings. *Empirical Studies of the Arts, 8*(1), 15-30.

Sacks, O. (1995). The case of the color blind painter. In *An Anthroplogist on Mars* (pp. 3-41). New York: Alfred A. Knopf, Inc.

Sajda, P., & Finkel, L. H. (1995). Intermediate-level visual representations and the construction of surface perception. *Journal of Cognitive Neuroscience, 7*, 267-291.

Santayana, G. (1896). *The Sense of Beauty. Being the Outline of Aesthetic Theory.* New York: Dover Publications, Inc.

Schnider, A., Regard, M., Benson, D. F., & Landis, T. (1993). Effect of a right-hemisphere stroke on an artist's performance. *Neuropsychiatry, Neuropsychology, & Behavioral Neurology, 6*(4), 249-255.

Schultz, W., Dayans, P., & Montague, P. (1997). A neural substrate of prediction and reward. *Science, 275*, 1593-1599.

Schwartz, M., & Chawluck, J. (1990). Deterioration of language in progressive aphasia: a case study. In M. Schwartz (Ed.), *Modular Deficits in Alzheimer-Type Dementia* (pp. 245-296). Cambridge, MA: The MIT Press.

Selfe, L. (1977). *Nadia. A case of extraordinary drawing ability in an autistic child.* New York: Academic Press.

Shulman, G. L., Corbetta, M., Buckner, R. L., Raichle, M. E., Fiez, J. A., Miezin, F. M., et al. (1997). Top-down modulation of early sensory cortex. *Cerebral Cortex, 7*, 193-206.

Storr, R. (1995). At last light. In *Willem de Kooning. The Late Paintings, The 1980s* (pp. 37-79). Minneapolis: San Franscisco Museum of Modern art and Walker Arts Center.

Tinbergen, N. (1954). *Curious Naturalist.* New York: Basic Books.

Ungerleider, L. G., & Mishkin, M. (1982). Two cortical visual systems. In D. J. Ingle, M. A. Goodale & R. J. W. Mansfield (Eds.), *Analysis of visual behavior* (pp. 549-586). Cambridge: MIT Press.

Van Essen, D. C., Feleman, D. J., DeYoe, E. A., Ollavaria, J., & Knierman, J. (1990). Modular and hierarchical organization of extrastriate visual cortex in the macaque monkey. *Cold Springs Harbor Symp Quant Biol, 55*, 679-696.

Vecera, S., & Behrmann, M. (1997). Spatial attention does not require preattentive grouping. *Neuropsychology, 11*, 30-43.

Wapner, W., Judd, T., & Gardner, H. (1978). Visual agnosia in an artist. *Cortex, 14*, 343-364.

Warrington, E., & James, M. (1988). Visual apperceptive agnosia: a clinico-

anatomic study of three cases. *Cortex, 24*, 13-32.

Watanabe, T., Sasaki, Y., Miyauchi, S., Putz, B., Fujimaki, N., Nielsen, M., et al. (1998). Attention-regulated activity in human primary visual cortex. *Journal of Neurophysiology, 79*, 2218-2221.

Woods, W. A. (1991). Parameters of aesthetic objects: Applied aesthetics. *Empirical Studies of the Arts, 9*(2), 105-114.

Wyvell, C., & Berridge, K. (2000). Intra-accumbens amphetamine increases the conditioned incentive salience of sucrose reward: enhancement of reward "wanting" without enhanced "liking" or response reinforcement. *Journal of Neuroscience, 20*(8122-8130).

Young, A. W., Newcombe, F., de Haan, E. H. F., Small, M., & Hay, D. C. (1993). Face perception after brain injury: Selective impairments affecting identity and expression. *Brain, 116*, 941-959.

Zeki, S. (1993). *A Vision of the Brain.* Oxford: Blackwell Scientific Publications.

Zeki, S. (1999a). Art and the Brain. *Journal of Consciousness Studies, 6*, 76-96.

Zeki, S. (1999b). *Inner Vision: An Exploration of Art and the Brain.* New York: Oxford University Press.

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Music and Neuroimaging: Technical Aspects

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Abstract

Due to technical advances, a significant number of researchers have become interested in the potential of neuroimaging to gain an understanding of the complex brain – music interactions. Animal models generally fail to answer questions specific to human musical processing. Both structural MRI and functional MRI have been employed over the last years to investigate brain – music relationships. Here structural MRI and functional MRI are examined in terms of more technical aspects. Employing both structural MRI (Keenan, Thangaraj, Halpern, & Schlaug, 2001) and functional MRI example (Gaab, Keenan, & Schlaug, 2003), the underpinnings of these methods are examined. The elucidation of methodological limitations will aid in both the understanding and construction of neuroimaging and music – brain relationships.

Neuroimaging and the Brain

Discovering the brain correlates of music would provide significant insight into both the workings of the brain and the basic components of musical processing. Further, such discoveries would add to our understanding of memory, language and cognitive categorization. Given these