Neuroaesthetics: An Introduction to Visual Art

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Neuroaesthetics is the study of how aesthetic perception, production, judgment, appreciation, and emotional response are produced and experienced from a neurobiological basis. While this area of study is relatively new to the field of neuroscience, this review will look at proposed theories behind aesthetic processes in the brain and existing experimental research implicating neural substrates behind these theories. The neurobiological basis of perception and interpretation of visual art is discussed. More specifically, we review the visual system and visual reward, and the evolutionary theory of visual perception. Among several findings of this review are examples of artistic manipulation of the two-stream hypothesis of visual processing. Manipulations of the ventral tegmental area (VTA) and nucleus accumbens (NAc) through transcranial direct current stimulation (tDCS) have been shown to increase aesthetic appreciation. Evolutionary theories rooted in survival are thought to govern the human appreciation for landscape art. While these findings are significant, they are only the beginning for a field with an immeasurable future.

Abbreviations: fMRI – Functional Magnetic Resonance Imaging; lDLPFC – Left Dorsolateral Prefrontal Cortex; NAc – Nucleus Accumbens; PFC – Prefrontal Cortex; tDCS – Transcranial Direct Current Stimulation; VTA – Ventral Tegmental Area

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Introduction

Neuroaesthetics refers to the study of aesthetic stimuli and the aesthetic experience from a neurobiological perspective. Since the birth of neuroaesthetics with psychophysicist Gustav Theodor Fechner's 1876 publication "*Vorschule der Aesthetik*" (Preschool of Aesthetics), the field has operated under one unifying principle: that the perception of a stimulus is directly related to the physical properties of that stimulus (Fechner, 1876). Specifically, Fechner's law states the subjective perception of a stimulus is proportional to the logarithm of the stimulus intensity. From an evolutionary perspective, this claim seems apparent. For an organism to make any sense of its environment, its perception of a stimulus must be informative of the physical properties belonging to the source of the stimulation. However rudimentary this may be, Fechner's underlying principle gave way to the study of perception and, in recent decades, neuroaesthetics.

The field of neuroaesthetics is relatively new to neuroscience, with its formal definition stated as "the scientific study of the neural bases for the contemplation and creation of a work of art" in 2002, with the founding of the Institute of Neuroaesthetics by Dr. Semir Zeki (Douchová and Nešetřil, 2010). Several terms in this definition allow for a broad range of interpretations, causing neuroaesthetics to become a broad field. Neuroaesthetics is not only concerned with the perception and corresponding neural activity in those viewing or experiencing art, but also that of the artist. By studying the creation as well as the contemplation of art, neuroaesthetics allows for a greater understanding for art's timeless existence, as well as its origin. This also leaves the formal definition of the work of art open to interpretation. When contemplating this term, common media, such as painting, music, and dance come to mind. But as this review will further explore, the unifying theme that allows a stimulus to be called 'art' is its ability to evoke an emotional response in its audience on a simply aesthetic level. It is important to distinguish stimuli from aesthetic stimuli when defining art, as most stimulation affects emotional processing. For example, it is not the content of a soccer match that gives it the name "the beautiful game," but the arc of the ball, the movement of the players, and other aesthetic simplicities of the game. Whether entirely abstract, or rife with symbolism and meaning, all visual art necessarily recruits aesthetic properties in its endeavor for emotional response.

This review will examine both the creation and contemplation of visual art popularized in contemporary culture. We begin with the neural basis for the production and perception of visual art by first detailing the visual system, discussing the neurobiological basis for appreciation, examining evolutionary theories behind appreciation, and finally exploring new theories for conceptual art.

Methods

References were selected as part of an independent study course offered by the Psychology Department at Sewanee: The University of the South. The selection criteria for articles were minimal in order to allow for selection of a wide variety of work, including historical and pioneering papers such as Fechner (1897). As the literature in this area of neuroscience is relatively minimal, we did not want to exclude any articles on the neuroaesthetics of visual art. All research articles included were deemed to have adequate controls and utilized sound neuroscience methodology. Aside from historical articles in neuroaesthetics, research articles selected were published within the last twenty years, were found through PubMed, and were published in English.

Visual Art

For the perception of visual art, there are parallels between the organizational properties of art and organizational principles of the brain. As art is produced for the purpose of being perceived, it can be assumed that artists, knowingly or not, uncover evidence for the neural underpinnings for aesthetic perception (Chatterjee, 2011). Just as the nervous system dismantles visual information into specific attributes such as color, shape, and motion, artists isolate and make use of such attributes to create aesthetically pleasing, as well as displeasing, works of art. However, visual artists often produce recreations of the visual world, a unique trait to their medium. Art, as a visual representation of reality, is incredibly useful to neuroaesthetics, because it encourages artists to discover new techniques to enhance the representation, often making use of perceptual shortcuts that our brains cannot differentiate from reality (Zeki, 1999). For example, using a darker shade of color on one side of an object gives the impression of a shadow. Optical illusions such as this serve to uncover distinct traits of the visual system and how visual information is processed.

Before we can understand the various ways in which artists manipulate the visual system, we must first have a basic understanding of the distinct stages of visual processing. The primary visual cortex is the first area of the brain where visual information is processed. This area of the brain contains neurons that detect lines and corners. After identifying lines and corners in the visual field, information is relayed along two distinct yet interconnected pathways to ventral and dorsal areas of the brain involved in visual processing (Milner and Goodale, 2008). The ventral stream, also known as the *what* stream, processes information related to shape, color, and object identification in general. This neural pathway extends from the primary visual cortex to the inferior temporal lobe. The dorsal stream, also known as the *where* or *how* stream, is involved in localizing the object within the entire field of vision. Identifying attributes such as luminance, motion, and spatial location help the dorsal stream in this task (Chatterjee, 2011). The dorsal stream is also involved in performing visuomotor tasks such as grasping an object (Goodale and Milner, 2006). This stream extends from the primary visual cortex to the posterior parietal lobe.

While the dorsal and ventral streams are likely interconnected at numerous locations, their distinct functions allow for artistic manipulation. Chatterjee (2011) reveals how artists utilize complex combinations of different aspects of vision to manipulate components of one or both streams, creating visual effects in their works. For example, Monet's *Impressionist Sunrise* is a landscape painting that theoretically should make little use of the dorsal stream, other than placing objects in relation to the painting's environment. However, the varying luminescence in the brush strokes of the sun's reflection on the water mimics the light-bending effects of rippling water, contributing to the "shimmering" quality of the image. To the viewer, the image is a skilled representation of the real world.

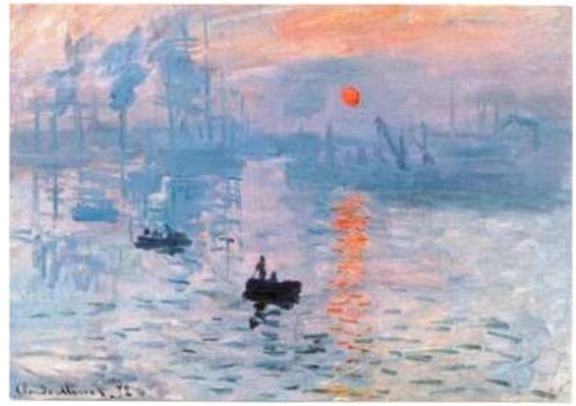

Figure 1: *Impressionist Sunrise*, by Claude Monet

Most research aimed at uncovering neural substrates for aesthetic appreciation centers on the reward circuitry of the brain. The mesolimbic dopamine pathway, comprising the dopaminergic projections from the ventral tegmental area (VTA) to the nucleus accumbens (NAc), is the main backbone of the brain reward pathway. When a favorable behavior or stimulus occurs, this reward pathway increases activation, creating pleasure and the experience of reward. Projections from the VTA to the hippocampus, amygdala, cingulate cortex, and the prefrontal cortex (PFC), are also involved in reward processing and behavioral reinforcement (for a review, see Ikemoto, 2007). In projecting to these areas, the reward circuit involves and incorporates other functions, such as emotion and memory.

Reward center manipulation has also been shown to improve aesthetic appreciation. A 2014 study was performed to see if transcranial direct current stimulation (tDCS) to the left dorsolateral prefrontal cortex (lDLPFC), a location projected to from the VTA, would improve aesthetic appreciation (Cattaneo et al., 2014). They succeeded in showing a causal relationship between lDLPFC activity and visual aesthetic appreciation. Participants with tDCS applied to the lDLPFC reported higher affinity for art images than the control group (Cattaneo et al., 2014). While the lDLPFC has previously been implicated in aesthetic appreciation, this research pioneers evidence for a causal relationship (Cela-Conde et al., 2004). Unsurprisingly, the ventral striatum (which includes the NAc) has also been implicated as central to aesthetic perception processes. Functional magnetic resonance imaging (fMRI) studies have shown that activity in the reward pathway is highly correlated with viewing art images (Kirk et al., 2009; Lacey et al., 2011). It is clear from these studies that reward processing is vital to experience pleasure from visual art.

While most behaviors or stimuli that activate the reward pathway have a clear evolutionary purpose, the purpose of reward activation upon the perception of artistic visual stimuli is not so clear. While an all-encompassing explanation is nonexistent, there have been theories put forth to explain human appreciation of some artistic representations of the world. For aesthetic appreciation to be considered biologically inherent to humans, it must be proven cross-culturally to control for developmental differences and experiences with regard to environment. Luckily, such studies exist and offer overwhelming evidence that some aesthetic stimuli are inherently appreciated regardless of culture. Studies have shown that when adult participants from different geographical locations are given several normalized landscape photos to indicate preference from, all but barely habitable climates (i.e., desert) are chosen equally. However, when the same experiment was performed with young children across the world, there was a marked preference for a savannah landscape with trees, mirroring the East African landscape where human civilization originated (Orians and Heerwagen, 1992). The same study noted a general preference for habitats that include a body of water (for drinking), a variety of open and wooded spaces (for living and hiding), and trees with low hanging branches (for gathering fruit and escaping). This evidence not only suggests humans have evolved a biological predisposition to habitable climates, but also that we have the evolutionary ability to identify key aspects of landscapes that add to or subtract from our preference. The artistic representations of these preferred landscapes are found in calendars, screen savers and murals worldwide (Dutton, 2003).

The evolutionary explanation for aesthetic appreciation is not limited to realistic representations of potential habitats, but applies to other areas of aesthetic production, judgment, and appreciation as well. The peak shift phenomenon is a neuroaesthetic theory that states that an organism that is either instinctively or conditionally trained to respond to a stimulus will respond more vigorously to more extreme versions of that stimulus (Ramachandran and Hirstein, 1999). For example, if a rat is rewarded for selecting a rectangle instead of a square, its response will scale in intensity with longer, skinnier rectangles. This phenomenon has also been seen in sea gull chicks. It has been observed that sea gull chicks will beg for food by pecking on the red spot near the tip of the mother’s beak. However, by using a long stick with three red spots near the end, researchers were able to produce more vigorous pecking responses from the chicks than could their mother (Chatterjee, 2011). Ramachandran and Hirstein (1999) hypothesize that this phenomenon could be the link between evolutionary neuroscience and the widespread appreciation of abstract art. Perhaps there are underlying neural substrates evolved to respond positively to lines and colors in the first stage of visual processing. In 1993, artists Vitaly Komar and Alexander Melamid hired a public polling agency to collect data from ten countries across five continents (excluding Australia and Antarctica) about artistic preferences. In each geographical location, blue was the reported favorite color, with green in second place (Dutton, 2003). While this is not sufficient evidence by itself that our appreciation for abstract art stems from the peak shift phenomenon, it does suggest that visual features such as color are more important to us than we may realize. It appears that even before the brain sends visual information from the second stage (forming shapes from color and lines) to the third stage of visual processing (identifying meaning and emotional response), there are some perceptual judgments made about parts of the visual information.

The emergence and continual growth of conceptual art in modern society must also be acknowledged from a neuroaesthetics perspective. The term conceptual art is used here to describe the cognitive processes called into action, other than simply the perception of aesthetically pleasing lines and colors. An example of conceptual art is René Magritte's *Treachery of Images* in which he has painted a tobacco pipe with the caption "This is not a pipe." The brain does not find appreciation in the rendition of the pipe by itself, but in the meaning of the caption. The viewer clearly sees a pipe, yet is told by the artist there is no such pipe. This produces a stark contradiction in the viewer's mind, which is alleviated in realizing there is no pipe, but only an image of one (Minissale, 2012). This realization absolves the individual of contradictory stimuli, giving conceptual art its leg to stand on in the world of art.

Figure 2: *Treachery of Images*, by René Magritte

Minissale (2012) argues that the pleasure received from conceptual art, proven by its entrance and continued habitation in pop culture, comes from human's intrinsic pleasure from solving puzzles. Although there is no external motivation, such as monetary reward, puzzle games such as Sudoku are successfully marketed to people worldwide. Why would people spend time and energy completing these seemingly arbitrary tasks? The answer lies in the reward pathway. Puzzle-solving has been shown to increase activity in the VTA and striatum, intrinsically motivating puzzle-solving behavior (Aarts et al., 2008; Albrecht et al., 2014). When examining the fundamental principles of puzzle-solving, one can see similarities to other aspects of life that are also intrinsically motivated. A puzzle serves as a specific dissonance with a certain conclusion we are not yet aware of, but we know exists. Until the conclusion is discovered, the dissonance is psychologically troubling in the same way as Magritte's *Treachery of Images.*

Conclusion

While it is likely unsurprising that the reward centers of the brain are at the heart of aesthetic appreciation, the numerous ways in which they are activated likely are. Artists make use of the separate visual processing streams to imply motion; neuroscientists can increase affinity for art through tDCS of the lDLPFC; appreciation for landscape art likely has roots in evolutionary neurobiology; neurological substrates of conceptual art appreciation likely mirror substrates behind the motivation to solve puzzles. Visual art is an immense subject with an equally immense amount of neurological methods and theories for artists to use.

The research in the field of neuroaesthetics also suggests that emotions are at the core of the aesthetic experience. Whether it is seeking out the best works of art or simply enjoying the view, it seems that the associated emotional response is the ultimate reward. The neural activity of areas implicated in emotional processing of both positive and negative calibers, such as the NAc, PFC, and amygdala, among others, transcends artistic mediums. By broadening the number of art forms studied through neuroscience, the functions that these regions display may solidify even further. Perhaps the future of neuroaesthetics will uncover more about the origin and evolution of art than it will about our neurological reactions to it.

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