The neural circuitry of visual artistic production and appreciation: A proposition

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Abstract

The nondominant inferior parietal lobule is probably a major "store house" of artistic creativity. The ventromedial prefrontal lobe (VMPFL) is supposed to be involved in creative cognition and the dorsolateral prefrontal lobe (DLPFL) in creative output. The conceptual ventral and dorsal visual system pathways likely represent the inferior and superior longitudinal fasciculi. During artistic production, conceptualization is conceived in the VMPFL and the executive part is operated through the DLFPL. The latter transfers the concept to the visual brain through the superior longitudinal fasciculus (SLF), relaying on its path to the parietal cortex. The conceptualization at VMPFL is influenced by activity from the anterior temporal lobe through the uncinate fasciculus and limbic system pathways. The final visual image formed in the visual brain is subsequently transferred back to the DLPFL through the SLF and then handed over to the motor cortex for execution. During art appreciation, the image at the visual brain is transferred to the frontal lobe through the SLF and there it is matched with emotional and memory inputs from the anterior temporal lobe transmitted through the uncinate fasiculus. Beauty is perceived at the VMPFL and transferred through the uncinate fasciculus to the hippocampo–amygdaloid complex in the anterior temporal lobe. The limbic system (Papez circuit) is activated and emotion of appreciation is evoked. It is postulated that in practice the entire circuitry is activated simultaneously.

Key Words

Art and neurology, artistic production, artistic appreciation

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In this essay, the author would like to hypothesize on the likely neural circuitry involved in visual artistic production and appreciation. The propositions presented are based on established and previously conceived concepts relating to the cognitive neuroscience of creativity, principles of visual science, principles of functional neuroanatomy and, lastly, the neurology of centers of appreciation of art and beauty.

Proposed Neural Circuitry of Visual Artistic Production: Background

The cognitive neuroscience of creativity

The concept of creativity in general is an abstract one and simply speaking it involves doing something novel that ultimately proves to be good to the human society. Artistry is indeed a creative endeavor as art imparts knowledge and pleasure to the viewer. Many create art or music and, logically, all may be considered creative. What then differentiates a Leonardo or Michelangelo or Mozart from the rest? Nancy Andreasen had written about ordinary versus extraordinary creativity.[1] But, what determines this extraordinary creativity is not exactly known. Andreasen[1] suggests that extraordinary creative people probably have an extra degree of connectivity in their brains or perhaps harbor an unusual type of connectivity. This is difficult to prove as, of all the extraordinary creative individuals that we know of, only Albert Einstein's brain had been subjected to histological studies, but that too in a very limited fashion. Einstein's brain seemed to have an altered white/grey matter ratio,[2] which was later conceived as suggestive of an extra degree of connectivity.[3] Although creativity is likely to be a phenomenon of mind and hence somewhat abstract, it is indeed a brain phenomenon.

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Patients with brain injuries perform poorly on creativity tasks. But, where then lies the "Seat" of creativity in the brain? We do not know. Arne Detrieich in a recent review has discussed the current thoughts on the cognitive neuroscience of creativity, summarizing the vast literature on functions of individual brain areas and observations made on brain-injured patients.[4] The role of the prefrontal lobe has been much stressed, although it is far from clear whether it can be called the seat of creativity.

Seat of artistic creativity?

The brain is incredibly elegant but remains very mysterious. There are several areas of the brain that can be associated with the ability to produce art. Because frontal lobes are highly developed in humans compared with nonhuman primates who can not produce art, it might be reasonable to deduce that art arises from these structures. However, it seems more likely that the posterior parietal lobe, in particular on the nondominant side, is central to the ability to produce art. Visual artistic production involves a high degree of visual spatial skill. Following McDonald Critchley's observation that lesions in the nondominant posterior parietal lobe or parieto-occipital region causes significant visual spatial motor skill derangement,[5] it is reasonable to suggest that this region of the brain is ultimately associated with artistic production. It has been known for over a century that injuries to the right posterior parietal lobe cause loss of artistic ability. This decline in ability had been detailed in a patient who suffered a series of strokes.[6] Furthermore, visuospatial function has been localized in the nondominant inferior parietal lobe by neuroimaging studies.

On the other hand, some patients with predominantly left brain lesions (frontotemporal dementias, autism) may show unmasking of artistic creativity stored in the right parietal lobe.[7] This somewhat paradoxical observation can be explained on the basis of the theory of "paradoxical functional facilitation" proposed by Kapur.[8] This is thought to occur as a compensatory augmentation occurring as a specific manifestation of central nervous system plasticity. The present author had referred to this earlier as Reverse Diaschisis.[9] In diaschisis, as first described by von Monakow in 1914, reduced function of one brain area leads to reduced function of a remote brain area to which it is anatomically connected. The reverse occurs here. The localization of artistic creativity in the right intraparietal sulcal region has been further suggested by the report by Seeley *et al*.[10] of a patient with primary progressive aphasia (due to corticobasal degeneration) who showed unusual transmodal creativity (auditory to visual). The lady had a fairly circumscribed atrophy of her left inferior frontal – anterior temporal cortex, but seemed to have an excess of grey matter in the right intraparietal sulcal region. This lady, on being fascinated by Maurice Ravel's composition of Bolero, painted the "music" beautifully in an art form.

And, this phenomenon of development of *de novo* creativity is not just limited in the field of visual art but had been observed in fields of music and literature as well.[11] On the other hand, this hemispheric model is undoubtedly a simplification. Lythgoe *et al*.[12] reported on a patient who, in contrast to Frontotemporal Dementia patients, developed a prolific visual artistic output in the context of a preserved language function that also enabled a prolific written poetic output. The subject had bilateral middle cerebral artery aneurysms.

Conversely, Drago *et al*.[13] reported in an artist with Parkinson's disease whose artistic qualities significantly deteriorated following left subthalamic nucleus (STN) deep brain stimulation (DBS), suggesting the role of the dominant hemisphere in art production that may be more than simply a deficit of motor executive function. The problem certainly is more complex in patients with bihemispheric dysfunction. The contribution of both hemispheres in creative cognition is exemplified in split-brain subjects with incomplete surgical division of corpus callosum as suggested by the lack of creativity in these subjects[14] probably because they cannot transmit nonverbal or emotive signals from one hemisphere to the other.[15] These studies however do not definitely suggest that the "seat" of artistic creativity is in the right inferior parietal lobe, but can only point to the significant role that this area plays in visual artistic production.

Role of prefrontal lobe in creativity

Arne Deitriech summarized the vast amount of literature that exists in relation to functions of the prefrontal lobe, specially those related to creativity.[4] However, again, it is far from clear that this too can be called the "seat" of any creative process. The prefrontal lobes however control imaginative thinking and the final expression of emotion – functions needed in visual artistic appreciation (to be discussed later). The prefrontal lobe can be considered to have two distinct parts – the ventromedical prefrontal lobe (VMPFL) and the dorsolateral prefrontal lobe (DLPFL). These two parts are phylogenetically different – the VMPFL is developed from hippocampal tissue and does not possess any extensive cortical connectivity except perhaps with the anterior temporal lobe structures through the uncinate fasciculus (vide infra). It has been suggested that the process of creative cognition (including artistic creative conceptualization) starts at the VMPFL and is then transferred to the DLPFL, which, because of its wide connectivity, activates other necessary cortical areas (in both hemispheres) to determine the final creative output. Visual artistic production would be no exception.

The concept of two visual systems

Ungerleider and Mishikin[16] and later Goodale and Westwood[17] conceived of the existence of two cortical visual systems. The ventral stream connects the occipital with the anterior temporal lobe and is called the "what" system. The dorsal stream connects the occipital lobe to the frontal and parietal cortices, and can be called the "where" system. For example, if one views a car, the image is formed in the visual cortex on the occipital lobe. This information is transmitted through the ventral stream to the anterior temporal lobe where the perceived image is matched with the stored memory in the hippocampal region, and one identifies the object of vision as a "car." But, where is the car? Transfer of information from the occipital to the parietal lobe through the dorsal stream would tell one where exactly is the car – in the garage or in the street. These two visual systems are intimately involved in both visual artistic production and appreciation or painting meaningful art. This has been demonstrated in disorders involving these visual pathways (e.g., sementic dementia,[18] Balint syndrome[19]). With semantic dementia, it is possible to generate beautiful paintings with the more posterior portion of the brain without being able to olace meaning onto what has been painted. For example, a patient can draw a bird, but lack the formal word knowledge about how a bird differs from another animal.[18] Smith and his colleagues[19] described a patient in whom temporary dysfunction in the dorsal stream led an artist to simplify visually rich paintings into paintings that captured only small pieces of an object. When her vision returned, the full internally generated pictures returned.

But, what are the gross neuroanatomical equivalents of these conceptual systems?

Neuroanatomical correlates of two visual systems

Different cortical areas in each cerebral hemisphere are interconnected with each other through a series of well-defined and dissectible bundles of white fibers [Figure 1]. The arcuate fibers are curved bundles that connect adjacent cortical areas. The superior longitudinal fasciculus (SLF) connects the occipiral lobe with the parietal and frontal cortices curving over the corpus callosum. The inferior longitudinal fasciculus (ILF) connects the occipital lobe to the anterior temporal lobar structures, including the hippocampo–amygdaloid complex. The SLF can be considered to be the gross anatomical counterpart of the "dorsal stream," and the ILF as the anatomical counterpart of the "ventral stream" of the two visual systems concept detailed earlier. There is yet another major white fiber tract not much discussed in the cognitive/visual neuroscience literature. This is the uncinate fasciculus (UF) that loops round the sylvian fissure and connects the anterior temporal lobar structures to the frontal cortex. As would be detailed later, this fasciculus is likely to be intimately connected with artistic activity as it connects the emotional and memory brain to the frontal lobe, specially the VMPFL.

Of course, emotions are mostly mediated through the Papez circuit of the limbic system connecting the amygdala and the hippocampus through the fornicial system to the mammilary bodies and then on to the anterior nucleus of thalamus and further on to the frontal cortex to determine the final expression of the emotion.

Based on these established and long-conceived neuro-anatomical pathways, cognitive neuroscientific principles and principles of visual science and systems, I would now proceed to speculate on the neural pathways (circuitry) of both visual artistic production and appreciation.

The Hypothesis: Neural Circuitry for Visual Artistic Production

The present author's hypothetical neural circuitry for visual artistic production is shown schematically in Figure 2.

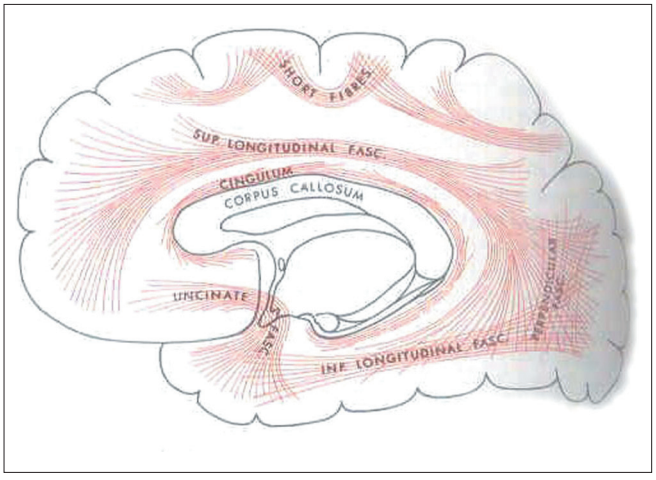

Figure 1: Major intrahemispheric white fiber tracts in the brain (adapted from Gray's Anatomy 1995)

The author suggests that when an artist conceptualizes a visual scene that he wishes to paint or sculpture, activation first occurs in the VMPFL, which, as discussed earlier, is the site of origin of creative cognition. This activation, which results in the cognition of the visual image, is influenced by inputs to the VMPFL from the memory brain (memory of witnessing similar situation in the past) in the hippocampal region of anterior temporal lobe through the uncinate fasciculus. The VMPFL activity is also influenced by the emotion of the artist in relation to the perceived concept of the visual scene, carried from the emotional brain (amygdalo–hippocampal complex also in anterior temporal lobe) through the fornicial system of fibers constituting the limbic system pathway (Papez circuit). Once the concept of the art to be created in formed in the VMPFL, information is transferred to the DLPFL through the arcuate association fibers for the executive planning of the art work. The DLFPL performs this by transferring the concept to the visual brain in the occipital lobe (through the SLF or dorsal stream of visual system) to form the visual image to be painted. Bidirectional impulse transmission through the SLF allows constant modification of the visual image of the concept till it is finalized. This process is also influenced by feedback from the anterior temporal lobar structures (memory and emotional brain) to the occipital lobe through the ILF (the ventral stream of visual system). The information regarding the concept of the art work, as also of the visual image being formed, traverses to the inferior parietal lobule (IPL) (the storehouse of artistic creativity) as the SLF relays through the parietal cortex on its passage while connecting the frontal and occipital cortices. The IPL gives artistic coloring to the visual image till the final form is reached. Once the final form of the visual image to be painted or sculptured is formed, the information is finally "handed over" to the DLPFL through bidirectional pathway in the SLF. The DLPFL, being well connected to the other areas in the frontal and parietal lobe, transfers the information to the motor cortex for final execution of the art work – the artist puts the brush and paint on the canvas or the chisel and hammer on a piece of stone. As the art work is being formed, it is constantly viewed by the visual brain (occipital lobe) and information is sent and exchanged with the artistic creativity area in the IPL and the memory and emotional brains in the anterior temporal lobe through the bidirectional network in SLF and ILF. Modifications perceived are finally transferred to the DLPFL for final execution. It is suggested that the process in essence is not a stepwise one as described but works in unison and is not rested till the final art work is completed.

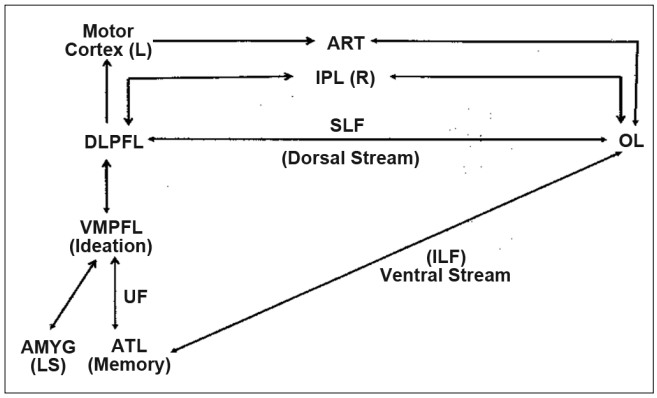

Figure 2: Proposed neural circuitry for visual artistic production

Proposed Neural Circuitry for Visual Artistic Appreciation: Background

The neurology of artistic appreciation (visual or otherwise) is an utterly complex process. This involves principles of neuroaesthetics, a new subspecialty of neurosciences. The subject had been exhaustively discussed in a recent monograph.[20]

The author does not wish to go into the details of neuroaesthetic principles but would simply like to highlight the brain areas that are implicated in aesthetic experience of visual art. In fact, technically, it is easier to map brain areas (by functional MRI technology) involved in art appreciation than locating areas concerned in artistic production – as artists cannot be asked to create art while lying inside a MRI gantry but a subject can surely look at and appreciate a piece of art projected before his eyes through a mirror system in the gantry.

Chatterjee[21] suggested that the involvement of the visual brain region in processing aesthetic stimuli is the same as in the processing of any other kind of visual stimuli. What sets aesthetic preference apart from other cognitive processes involving visual stimuli is precisely the engagement of additional nonperceptual processes such as emotions and decision making. These nonperceptual processes ultimately evoke the feeling of appreciation (the "Ah" experience) or perhaps feeling of rejection in the mind of the viewer. Recent neuroimaging studies have revealed a basic picture of the neural correlates of these cognitive and affective processes. Affective processes involved in aesthetic appreciation seem to be mediated by the orbitofrontal (or ventromedial prefrontal – VMPFL) cortex,[22] caudate nucleus, anterior cingulated cortex and strengthening of early visual processes in the occipital cortex.[23] Recognition and meaning attribution in aesthetic appreciation seem to be related with activity in the temporal pole,[24] and decisions seemed to be mediated by the lateral prefrontal cortex (DLFPL) and the frontal pole.[24,25] The prefrontal lobe thus appears to be pivotal in art appreciation, just like as discussed before, in art production. Activity in the orbitofrontal or ventromedial prefrontal cortex was identified by Kawabata and Zeki[22] while participants decided (decision making function as mentioned earlier) about the beauty of diverse artistic visual stimuli. The fact that many studies have observed activity in this region in association with primary and abstract rewarding stimuli suggests that its role in aesthetic preference might be to represent the reward value of each visual stimulus. On the other hand, studies carried out by Cela-Conde *et al*.[25] and Jacobsen *et al*.[25] revealed that rating the beauty of visual art works and geometric designs engages the lateral prefrontal cortex (DLFPL).

The Hypothesis: Neural Circuitry for Visual Artistic Appreciation

The author would now proceed to hypothesize on the neural circuitry involved in artistic appreciation in a somewhat stepwise manner [Figure 3], although the author believes that the entire circuitry is activated simultaneously and not exactly in a stepwise manner (described here only to put a complex concept in a simple and easily understandable fashion).

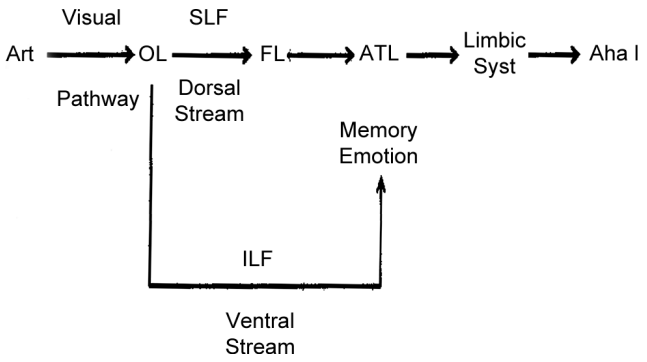

Figure 3: Proposed neural circuitry for visual artistic appreciation

When an art work is viewed, the image is formed in the visual brain. Many visual areas in the occipital lobe are activated to appreciate the shape, size, form and color of the art work. Activation of the fusiform gyrus would occur if familiar faces or buildings are visualized and would evoke a different kind of emotion.

The visual image from the occipital lobe is then transferred both to the frontal and to the parietal lobes (through the dorsal stream or SLF – the "where" system) as also to the anterior temporal lobe (through the ventral stream or ILF – the "what" system). At the anterior temporal lobe, activation leads to evoking memory and emotion. These are then transferred to the frontal lobe (bothVMPFL and DLPFL) for appreciation of beauty (as discussed earlier) as also for imaginative thinking, and may evoke a "conflict" (as discussed later).

Information relating to the final result of this integration at the prefrontal lobar level is finally again transferred back to the emotional brain (amygdalo–hippocampal complex) in the anterior temporal lobe through the uncinate fasciculus. The final result is activation of the limbic system through the Papez Circuit and the "Ah" experience.

Further Thoughts

Two other functions in relation to artistic appreciation may be ascribed to the prefrontal cortex. Firstly, this is the site of imaginative thinking and hence must be activated when subjects view unfinished art works and imagine how the art work would have looked if finished (e.g., many of the sculptures by Michelangelo) and also to appreciate elements of movement or dynamism in a static art form as discussed by the present author earlier.[26] Imaginative thinking on the part of the viewer is also involved in appreciation of both abstract and symbolic arts.

Secondly, the prefrontal cortex is also engaged in the phenomenon of "frontal lobar conflict" when an art work viewed is "mentally" compared with similar images and visual scenes previously perceived and stored in the memory brain of the anterior temporal lobe. The information from the latter area is transferred to the prefrontal lobe through the uncinate fasciculus as had been conceived earlier in this article. This gives rise to heightened activation in the prefrontal lobe, which, then being transferred to the anterior temporal lobe again through the uncinate fusciculus, activates the limbic system to evoke emotion of appreciation

(the "Ah" experience). Support for this hypothesis comes from the work of Zeki and colleagues,[27] who showed, by functional neuroimaging, that there occurs greater frontal lobar activation when subjects viewed objects dressed in unnatural colors than in their usual ones. The reason, of course, is the conflict between the perceived image and the image stored in memory from previous experience. The phenomenon obviously comes into play when subjects appreciate innovations made by the artist, for example, in impressionist art forms.

Future Perspectives and Concluding Remarks

So far, our present day concepts of the brain areas involved in either artistic production or appreciation of art and beauty are based on observational studies made in patients (often artists) where the diseased part of the brain could be localized with reasonable accuracy using sophisticated neuroimaging means or subjecting control subjects with various visual stimuli (e.g., beautiful art works) presented before their eyes using a mirror from a TV screen as they lie in a functional MRI or Positron Emission Tomography scan gantry. Such techniques, although useful, seem to be very basic in relation to the complexity of the subject under study. What is needed is actually to study the brains of artists as they work or a common man as he stands before a masterpiece. Currently available technologies are far from achieving these targets. Perhaps, someday, we may hope to have functional MRI/Positron Emission Tomography done by more refined machines with wider gantry when it would be possible to actually visualize brain area activation in artists engaged in painting or a common man enjoying a beautiful art work. What had been hypothesized here regarding the possible neural circuitry for artistic production and appreciation is a very simplistic version of an utterly complex process. The proposed hypotheses are entirely conceptual needing experimental proof through available and yet to develop more sophisticated neuroimaging and electrophysiological techniques. However, the hypotheses are indeed based on established principles of neuroanatomy, cognitive neurosciences and deductions from described case studies in cognitive neurology. The author would stress again that nothing in reality occurs in a stepwise fashion, the whole circuitry involved is activated simultaneously and continues to remain so long after an artist creates an art or a viewer views a masterpiece. "Art is the expression of the inner world of an artist." It is highly unlikely that principles of gross anatomy would ever be able to decipher the mysteries of this "inner world."

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