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REVIEW

Art and brain: insights from neuropsychology, biology and evolution

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Abstract

Art is a uniquely human activity associated fundamentally with symbolic and abstract cognition. Its practice in human societies throughout the world, coupled with seeming non-functionality, has led to three major brain theories of art. (1) The localized brain regions and pathways theory links art to multiple neural regions. (2) The display of art and its aesthetics theory is tied to the biological motivation of courtship signals and mate selection strategies in animals. (3) The evolutionary theory links the symbolic nature of art to critical pivotal brain changes in *Homo sapiens* supporting increased development of language and hierarchical social grouping. Collectively, these theories point to art as a multi-process cognition dependent on diverse brain regions and on redundancy in art-related functional representation.

Key words aesthetics and brain; attraction and hormones; beauty and brain; brain damage in artists; language and art; mate selection and art; neuroscience and art.

Introduction

The enormous variety of art created in human societies throughout the world expresses a multitude of ideas, experiences, cultural concepts, creativity and social values. The arts – paintings, sculpture, theater, poetry, film, music and dance to name but a few – form a communication system between artist and viewer, represented in a manner not afforded by language alone. Whereas nearly everyone can use language, only a few can create art compositions with qualities that elicit reactions of pleasure and appreciation for subsequent centuries and millennia. Because the compositions seem to incorporate unique understanding, their neuroanatomical basis is a challenge. Clues and insights can be obtained from several sources including the study of established artists with brain damage, the times of early humans when art practice began, evolution of *Homo sapiens* and immediate ancestors, as well as discussion about biological motivation, such as mate selection strategies in animals, and diverse fields such as archaeology, anthropology and the fossil record (see Fig. 1).

Several factors have simultaneously shaped the search for the elusive underpinnings of art in the brain, namely its ubiquitous presence in human societies, in contradistinction to its absence in animals, art's symbolic and representational essence, its seeming lack of functionality and its relatedness to pleasure. Three theories, which can be

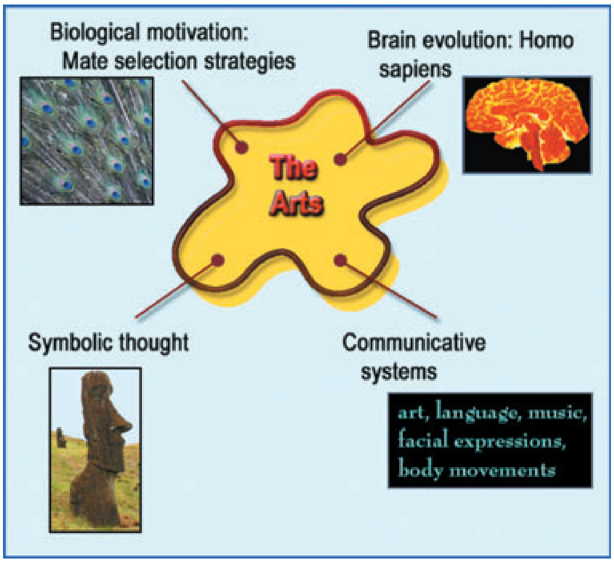

Fig. 1 Diagrammatic illustration summarizing factors that contribute to the uniqueness of art practice in human societies. The fundamental cognition behind the arts concerns symbolic and abstract cognition. The biological motivation theory and brain evolution in *H. sapiens* contributed to the emergence of the arts and are discussed in this work. Art is viewed here as a form of a communicative system between artist and viewer.

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roughly grouped together into the localized brain regions or pathways, biological motivation of courtship displays and evolutionary explanations, have been proposed. The background and sources of evidence for these art and brain theories, particularly the visual arts, are described in this work (for general music and brain reviews see Peretz, 2006; Patel, 2007). The localized brain regions theories focus on specific brain areas, pathways and physiological responses (reviewed in Zaidel, 2005). The biological theories link art to mate selection (sexual selection) strategies in animals (Miller, 2000), whereas the evolutionary theories tie art to critical alterations in the behavior of *H. sapiens* such as the use of symbolism (d'Errico et al. 2003; McBrearty & Stringer, 2007) or a sudden emergence of modern language around 45 000 years ago (Klein, 1999). With regards to the evolutionary association of language and art, the key argument concerns the precise art shapes, marks and forms that appeared around 45 000 years ago and such precision is interpreted by some scholars as being associated with precise words, formal structure and meanings (Wade, 2006). Evidence for the practice of art prior to the emergence of *H. sapiens* is sparse, even as immediate ancestors such as *H. erectus* or *H. habilis* produced numerous types of stone hand tools. It would seem that the practice of art in all of its manifestations is a late event in the *Homo* line.

Brain regions and art

Brain damage in established artists

In neuropsychology and neurology, the relationship between brain structures and their functions is traditionally inferred from behavioral effects of damage in regional brain areas. Alterations, if any, in artistic production in established artists following the damage is of great interest because they provide a strong basis for linking art to neural regions. As the complexity of art itself defies breakdown into easily definable elements, the focus is mostly on general artistic categories. Thus, the quest addresses region- or pathway-specific disruptions of general categories such as skill, technique, style, talent and creativity, and, whenever possible, the disruption of specific artistic components. Unlike the fixed meaningful units of language (the words), units of art such as brush strokes have no meaning outside the context in which they are used. Absence of art-related alterations following brain damage in artists would imply both a redundancy in functional representation and multi-regional processing.

Historically, in 1948 the neurologist Théophile Alajouanine published the first neurological paper devoted to a description of the consequences of brain damage in three artists; their virtuosity spanned painting, music and writing (Alajouanine, 1948). They suffered from left hemisphere damage and varying levels of aphasia. In contrast to the writer whose art relied exclusively on intact left hemisphere functioning (language is principally specialized in the left cerebral hemisphere), the musician and painter continued to be productive (Boller et al. 2005). In the context of their post-damage productivity, discerning or classifying their creations is problematic and not easily given to fine analysis. Since Alajouanine's publication, however, other neurological cases have been reported for established visual artists; the majority of cases are reviewed in several publications (Rose, 2004; Bogousslavsky & Boller, 2005; Zaidel, 2005). Typically, individual cases are the main source of such information. The cases represent a wide gamut of etiology and damage localization, ranging from unilateral stroke and tumor in the left and right hemispheres to various progressively dementing diseases such as Alzheimer's disease, Pick's disease and fronto-temporal dementia. The range is informative to the understanding of the extent of loss and preservation of artistic abilities.

The critical comparison concerns pre- vs. post-damage output and what the comparison shows, by and large, is that artists go on producing art post-damage (Zaidel, 2005). Reviewing the case studies of established artists indicates that artistic skill – in painting, drawing or sculpting – is largely preserved, regardless of the laterality of the damage or its etiology. Thus, neither the functional specialization of the left nor the right hemisphere, nor any specific lobe or one brain region, can explain art-related cognition. Similarly, talent and creativity are unaltered in non-demented cases with unilateral damage (typically due to stroke or tumor). Even with artists suffering from dementing diseases, where the neurodegenerative damage is extensive, the skills appear to persevere for many years into the illness, even after cognitive functions undergo severe deficits (Miller et al. 1996, 1998; Fornazzari, 2005; Drago et al. 2006; Cummings et al. 2008). However, toward the end of the illness they do cease to produce art, largely because extensive and widespread neuronal connectivity is lost. With regard to individual techniques applied by artists pre-damage, they are either minimally or not changed at all post-damage. The personal artistic style within a genre practiced in the pre-damage period appears unchanged. (Genre here refers to an art movement or school, as in abstract art, surrealism, realism, etc.; style here refers to individual artistic expression within the genre.) Some artists have experimented with a variety of genres in their life-long careers but it is the one that immediately preceded the damage that is adhered to afterwards. The weight of the evidence therefore favors art as a multi-process activity, one that depends on several brain regions and on redundancy of art-related functional representation rather than on a single cerebral hemisphere, region or pathway.

Some seemingly art-related deficits that emerge following brain damage are not specific to artists. Rather, they reflect perceptual and cognitive specialization in the human brain (Zaidel, 2009). For example, deficits in spatial layout depiction can follow right hemisphere damage, particularly when the right parietal lobe is involved. Spatial perception and topographical memory are specialized in the right parietal lobe (De Renzi, 1982). Similarly, right hemisphere damage sometimes leads to hemi-neglect of the left half of space; artists and non-artists do not complete, i.e. 'neglect', drawings in the left half of the page (Zaidel, 2005). In the majority of cases, the hemi-neglect dissipates within the first couple of months post-damage. In one interesting outcome involving an artist, the neglect was not manifested in the outline drawing itself (it was complete on both sides) but rather in the application of the colors to the drawing; the left half of the drawing was left uncolored, whereas the right was colored (Blanke et al. 2003). A rare case of a writer with left hemisphere damage suffering from aphasia described by Alajouanine (1948) was unable to write again because of the strong specialization of language in the left hemisphere. Ultimately, the brain regions that give rise to these deficits do not control the essence of art expression under normal, intact conditions.

Additionally, no systematic data are available on the extent of the perceptual and cognitive deficits in artists as a group, i.e. we do not yet know how severe or mild these deficits are following brain damage in artists vs. non-artists. There is every reason to suppose that, as a group, artists would have 'resistance' to some of the deficits. For example, given that visual artists generally develop a trained 'eye' through a lifetime of detailed observations, the practice should contribute to redundancy in brain functional representation, one that transcends normal hemispheric or regional specialization.

Preference responses to paintings measured with neuroimaging

Neuroimaging studies concerning brain activation and art works have focused principally on viewers of art rather than on artists themselves, and mainly on aesthetic preference. With neuroimaging techniques (commonly functional magnetic resonance imaging), subjects view art works and indicate their preference while their brains are scanned (reviewed in Nadal et al. 2008). Vartanian & Goel (2004) found that subjects shown both representational and abstract paintings had increased activation in the right caudate nucleus as well as increased activation in the bilateral occipital gyri, left cingulate sulcus and bilateral fusiform gyri as a function of increased preference for the paintings. Kawabata & Zeki (2004) found that viewing beautiful vs. ugly paintings differentially involved the orbito-frontal cortex and motor cortex, and that different categories of paintings yielded distinct patterns of brain activation. Although neuroimaging techniques can potentially reveal a great deal about the nature of art from the viewer's perspective (Jacobsen et al. 2006), the challenge remains the brain of the artist and that is difficult to achieve with the limitations of current techniques and methodologies.

Colors and visual processing

Colors have a significant, though not critical, role in visual art. In prolific artists, visual sensory deficits arising from eye defects illustrate the separation between talent and skill from the choice or use of colors *per se* (Nathan, 2002; Ravin, 2008). Visual artists with color blindness are not hampered by their color deficiency in the sense that they nevertheless go on producing art (reviewed in Zaidel, 2005). Human central processing of color vision is in the occipital lobs, in the area equivalent to the V4 of animals, as determined by brain damage and neuroimaging studies. Damage in the area results in a deficit known as central achromatopsia (Zeki, 1990). Color knowledge and color meaning are linked to the lingual gyrus, which transverses the medial inferior occipital and temporal lobes (Meadows, 1974; Miceli et al. 2001). This is separate from object knowledge, which involves knowing many other properties about the object, including identity, shape and utility (Miceli et al. 2001). In the eye, it is the specialized neurons in the retina known as cones that are critical for viewing objects in daylight or artificial light and for seeing color. Under normal circumstances the choice of colors chosen by artists are determined by both the physiological status of the eye and color-specializing regions in the brain. However, this still leaves the question of special talent for colors in art unanswered.

The biological underpinning of art

Artists rarely produce works for their own private viewing. Exhibiting to others is a principal feature of art and it is the display aspect that has recently led to the postulation of an interesting biological association between art and animals' courtship displays (Zahavi, 1978; Miller, 2001). Charles Darwin distinguished between survival of the fittest and sexual selection, arguing that animals' natural ornaments (e.g. colorful plumage) and other forms of animal displays are a product of evolutionary forces specifically promoting means of sexual attraction (with an eye to procreation), as opposed to survival *per se* (Darwin, 1871). In nature, mate attraction strategies are a dominant motivational force involving exhibiting one's multiple endowments particularly with regards to health, genetic quality and fertility (Cronin, 1992). The exhibiting of feathers, furs, lung capacity and physical acrobatics are all types of advertisements designed to attract a mate. The classic example is that of the peacock's tail. It is too elaborate to be used effectively to escape predators or to fly and yet it serves as an instrument for advertising the various fitness qualities (and, possibly, beauty). Mate selection strategies, in both animals and humans, reflect the brain of the organism with all of its capabilities and limitations. The inference with art is that the display signals the intelligence, cognition, physical strength, skill, creativity and talent of the artist (Miller, 2000).

Attraction: hormones

Hormones play a critical part in the mate selection process. The hypothalamus is the major neuroanatomical site for producing hormones and modulating their levels. Courtship signals are triggered by hormonal secretion and perceived by observers, be they potential mates or rivals, whose own behavioral repertoire is stimulated and altered by hormones. Artists use multitudes of techniques to draw attention to their composition and the degree of attention given to the art might depend on hormonal levels in the viewer. In the visual arts, for example, size, color, contents, symbolic message, material and context are but a few attention-seeking techniques. In this context, one hormone to consider is oxytocin. It is a hormone (and a neurotransmitter) identified as promoting attachment, bonding, approach-to-the-other, trust and positive social behavior. It is produced in the hypothalamus and secreted into the vascular system by the pituitary gland. In empirical research involving humans, manipulating levels of oxytocin has been shown to alter levels of trust in males engaged in a financial game (Damasio, 2005; Kosfeld et al. 2005; Zak et al. 2005). In a speculative vein, oxytocin levels in the brain of the viewers might also be part of the neural mechanism involved in attracting viewers to art displays. What the triggers in the artwork might be remains to be resolved. Future research could focus on its role in this regard.

Attraction: aesthetics of art

In ways that have not yet been deciphered (scientifically, philosophically or any other way), the symbolism in art and aesthetics seem to be intertwined. Physiologically, experiential pleasure is linked to increased levels of dopamine, GABA and various neuropeptides (Burgdorf & Panksepp, 2006) but what triggers the increase in the context of art is not known. The role of aesthetics in art can be regarded as follows: The symbolic content of a work of art draws the viewer's attention through its aesthetics. The latter is not deliberately 'placed' by the artist in the composition but rather reflects the sum total of the artistic virtuosity itself and an emergent 'aesthetic' property distilled in the mind of the viewer. In other words, the cues for the aesthetic contents are extracted by the mind of the viewer. The extent to which the artist's mind engages (communicates) with the viewer's mind is gauged by the amount of aesthetics in the work. Even so-called ugly works attract attention and elicit aesthetic-related responses. Abhorrent subject matter can be displayed and yet viewers regard the work as exceedingly beautiful. With attraction to the artistic display comes the contemplation of the artistic message, be it a face, historical event, nature scene, innovation, mere ideas or concepts, color combinations, etc. Artistic content varies across cultures but not the role of aesthetics in the art of the culture, if we regard the aesthetics of art to have biological underpinnings (as described above). Why else would art created in distant lands influence Western artists at the end of the 19th and beginning of the 20th centuries? Van Gogh, Degas, Picasso, Modigliani and many others in their circle were greatly influenced by Japanese, African and Pacific Islands art without ever visiting those lands or speaking their language. Similarly, non-artists today are attracted to art works produced in distant times and locales without the benefit of knowledge of the contexts in which those works were created. Biological and neuroanatomical underpinnings in the attraction process, in artists and non-artists alike, could be regarded as the common denominator.

Aesthetics and pleasure: some neural underpinnings

Aesthetics are associated with a continuum of pleasure-related responses but those are most likely to be associated with motivational neural systems. As described above, only a few functional neuroimaging studies measuring preference for art works have been published, and with mixed findings (Zaidel, 2005; Nadal et al. 2008). Research on animals, mostly rats, suggests that experiential pleasure is phenomenologically and physiologically complex (Phillips, 2003), and this could partly explain the lack of consistent findings in the human neuroimaging studies as well as the paucity of such studies. The work of James Olds in the 1950s on rats initiated the search for the anatomical underpinnings of pleasure following observations suggesting a 'pleasure center' in the hypothalamus (Olds, 1956). Subsequent research linked pleasure in animals with motivational behavior, including appetite, survival and goal attainment. The 'reward pathway' consisting of the medial forebrain bundle, especially parts that include the lateral and posterior hypothalamus, the ventral tegmental levels and the neurotransmitter dopamine has been linked to pleasure (Leknes & Tracey, 2008). For a while dopamine was regarded as the principal pleasure-related neurotransmitter. Currently, however, there is agreement that neither the 'reward pathway' alone nor dopamine alone explains the nature of pleasure, liking or preference (Berridge, 2003). Other brain areas such as subcortical regions are critically involved with pleasure-related experiences (Panksepp, 2005; Burgdorf & Panksepp, 2006), as are the orbitofrontal cortex regions (Rolls & Grabenhorst, 2008) and the limbic system. In addition to dopamine, the opiates, GABA and various neuropeptides are now considered crucial in pleasure-related experiences (Burgdorf & Panksepp, 2006; Leknes & Tracey, 2008). Clearly, refining our understanding of the neural basis of the aesthetic response to art remains a serious challenge.

Evolutionary theories of art and brain

Of major interest is the early beginning of art. When did humans first practice art and how tightly was the practice linked to a specific pivotal point in *H. sapiens* brain evolution? The fossil record suggests that anatomically modern humans arose 200 000–150 000 years ago in Africa and about 100 000 years ago began expanding through migration to other parts of the world (Wood & Collard, 1999; Relethford, 2008). One key issue is the long time gap between when *H. sapiens* arose and the subsequent appearance of multiple art objects and abundant art practice. The archaeological evidence points to the Upper Paleolithic, around 45 000–35 000 years ago (a period known as the Transition), in Western Europe when active, consistent and abundant art appeared. The Western European locale is intriguing because *H. sapiens* also expanded to Asia, the Middle East and Eastern Europe. Fine hand tools, small statuettes made from ivory, tusks, bones and stone as well as beads and pendants were created in the Upper Paleolithic. This, together with evidence for body paint decorations and jewelry, is viewed as early signs of stratified status in social groups (Lewis-Williams, 2002). The identification of socially-related levels within social groups and communities would have been aided by the use of visual symbolism, as in personal ornamentation. Thus, according to this view, the pivotal circumstances behind the purpose and use of ornamentation by early humans are linked to group identity levels rather than to the production of 'beautiful objects' for personal decoration or to make one appear attractive *per se* (Bahn, 1998; Lewis-Williams, 2002). Art practice gradually changed, evolved and progressed to be much more than a group identifier, transforming instead to the virtuosity of individual artists admired for their talent and serving a cultural purpose.

Only a trickle of art-related artifacts has been unearthed from earlier periods and this raises the issue of symbolic cognition and its expression in the *H. sapiens* living prior to the Transition. One clue might lie in what happened to the *H. sapiens* who did not migrate out of Africa 100 000 years ago (Behar et al. 2008). From archaeological findings it is suggested that they evolved advanced cognition in isolated regions along the seacoasts in South Africa and Eastern Africa, harvesting and consuming seafood (to compensate for chronic drought conditions lasting many thousands of years in Africa) that could have had altering effects on the brain (Mellars, 2006). Beads created from seashells, animal teeth, ivory and other materials were used for ornamentation as early as 70 000 years ago in South Africa. It is these human groups that, around 60 000–65 000 years ago, migrated out of Africa and spread more widely in the rest of the world, including Western Europe, than did those in the first migration. However, it should be mentioned that red ochre and other coloring sources, crude markings on pieces of clay and crude figures have also been unearthed in earlier human habitats throughout the world, signifying the existence of symbolic cognition prior to the two major migrations from Africa (McBrearty & Brooks, 2000; McBrearty & Stringer, 2007).

Its symbolic nature notwithstanding, no one would suppose that the practice of art seen in the Transition period commenced suddenly in human existence but rather that it reflects millions of years of evolutionary events and adaptive responses to the interweaving of genomic, environmental, climatic and social factors. Most scholars would agree that a gradual development, rather than an abrupt leap, contributed to the consistent practice of art (Morgan & Renne, 2008). At the same time, symbolic behavior is not unheard of in animals (de Waal & Tyack, 2003; Addessi et al. 2008) and yet animals do not produce art. The key question that needs to be addressed concerns the critical difference in the brain between animals, early humans and *H. sapiens* in particular to explain the practice of art. The answer lies in the brain's neuroanatomy and biochemistry, increase in regional specialization such as hemispheric asymmetry in humans, interconnectivity between specialized regions, and the interaction between neuronal densities and brain size, all of which control various behavioral developments in humans, not only art production. In addition, the formation of tight interdependent social groups might have been more pivotal in increased art practice than anything else.

Both art and language rely on symbolic and referential cognition. Critical positive changes in the brain that have been attributed to full-fledged art production by anatomically modern early humans have also been attributed to the simultaneous evolutionary development of language. McNeill (1992) has suggested that planned meaningful hand gestures are speech related and Corballis (2003) has suggested that both hand gestures and facial expressions provided the initial jumping board for language development. Lieberman (2007) proposed that upright walking provided the critical adaptive change that promoted human language as well as pivotal anatomical changes in the human sound-producing structures in the throat and mouth. The genetic mutation of the FOXP2 gene in the anatomically modern *H. sapiens* has also been suggested as jump-starting language development but there is debate and controversy about any unique role of FOXP2 in human language (Hauser & Bever, 2008). Importantly, precursors for combinatorial syntactical language (the hallmark of human language) were already in place in monkeys and apes (Carstairs-McCarthy, 2004), which could imply readiness of the brain to develop art. Despite the precursors there is no evidence for anything even remotely resembling art in non-human primates. And, yet, they do have extensive sound-based and vision-based communication. One could argue that a critical 'symbolic capacity threshold' with genetic and cognitive underpinnings should be reached to produce art.

Art and language, despite heavy reliance on symbolic and referential cognition, need not have arisen from a single process; separate evolutionary paths could have shaped them. Reasons to suppose that art and language rely on separate brain pathways can be inferred in several ways. First, artists with aphasia following left hemisphere damage continue to produce art without compromising the essence of their pre-damage creations; symbolic thought is not lost. (Similarly, artists with right hemisphere damage do not lose their pre-damage artistic abilities.) Second, language is heavily dependent on highly specialized neuronal regions and circuitries principally in the left hemisphere, and is tightly defined by its output, namely speech, comprehension, writing and reading. In contrast, art's communicative power is infinite, its combinatorial powers ranging broadly in form and expression; it is frequently ambiguous and lacks 'rigid' meaning units (Langer, 1962). Third, although practically everyone can speak and use language to communicate, only a few possess the kind of art-related intelligence required to produce and exhibit art. In sum, not all communication systems employed by humans need share the same neural underpinnings (Hauser & Bever, 2008).

In view of the foregoing, one could argue here that art is a 'higher' representation of the human mind than language. Their evolutionary emergence could well have been staggered, where art followed language rather than preceded it or depended on it. After all, examples of vocal and non-verbal language communication in monkeys and apes abound, and they are based on neuroanatomical underpinning that has evolved for some 40 million years, while not giving rise to any art.

Conclusion

Several relevant disciplines contribute to understanding the link between neuroanatomy and art. Here we explored the consequences of brain damage in established artists, the biological motivation in courtship displays and its relationship to the display and aesthetics of art, and the beginnings of art in the early life of *H. sapiens*. In evolutionary terms, we can only speculate on the selective pressures that have shaped the human brain in a direction that forged the practice of art. Art and language share a reliance on symbolic cognition but they could have developed and been selected through staggered and separate evolutionary paths. With the available data, no single brain region, pathway or cerebral hemisphere can explain the brain/art relationship. By contrast, it has been possible to ascertain language localization in the left hemisphere. This is partly due to the fact that art is a complex system where single definable units are not amenable to formulation, unlike those of language. Nevertheless, review of the current evidence from artists with brain damage suggests that artistic talent, skill and creativity are supported by wide brain areas, and are greatly resistant to brain damage. Future consistent interdisciplinary research and detailed descriptions of artists with brain damage should greatly enhance the intersection of art, biological motivation, neuropsychology and the brain.

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