3D Space Perception as Embodied Cognition in the History of Art Images

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Abstract

Embodied cognition is a concept that provides a deeper understanding of the aesthetics of art images. This study considers the role of embodied cognition in the appreciation of 3D pictorial space, 4D action space, its extension through mirror reflection to embodied self-cognition, and its relation to the neuroanatomical organization of the aesthetic response.

INTRODUCTION

Pictorial Space and Embodied Cognition

Depth perception and the evocation of a sense of space has a long provenance in the history of images, especially in the context of the perspective representation of distance through size recession and the solidity of protruding objects through shading, shadows and highlights. A goal of these depth representation techniques is not simply accurate 3D representation but also to give the viewer a sense of direct involvement with the objects depicted in the scene. This kind of involvement may be conceptualized as a form of mental function termed "embodied cognition", or experiencing a depicted scene as though one is a physical participant rather than just intellectually understanding the nature of the scene being depicted. The operation of embodied cognition gives extra vividness to the aesthetics of art appreciation.

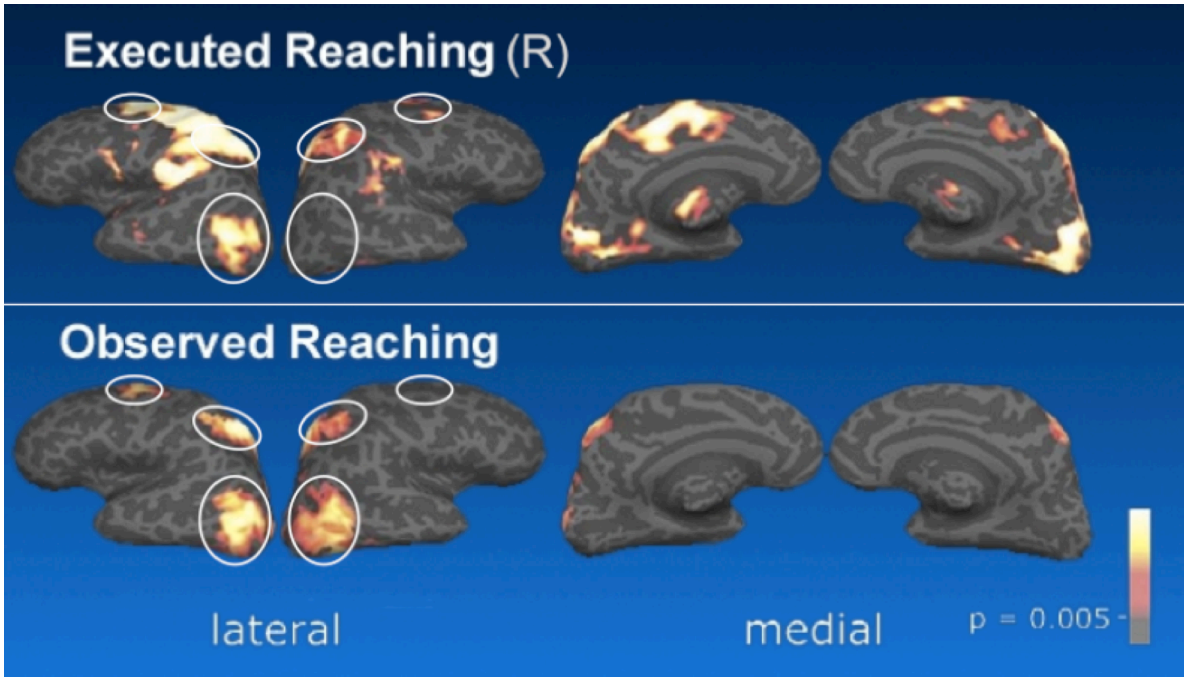

Fig. 1. A study of the mirror neuron regions of the human brain (Filomon et al., 2007) depicted on the lateral (left images) and medial (right images) inflated surfaces of the brain. Three regions are designated by ellipses in each hemisphere: the motor hand area (upper ellipses), the parietal reach areas (mid-height ellipses) and the lateral occipital complex (LOC, lower ellipses). Activation, biased to the left hemisphere for this right-hand reaching task, would be reflected to the opposite hemisphere for left-hand reaching. Note lack of medial activation for observed reaching, implying that none of the medial activations for reaching are mirror regions.

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In the context of art appreciation, embodied cognition usually means the sense of 'feeling' the artwork in relation to your own body (Merleau-Ponty, 1945; Freedberg & Gallese, 2007). Embodied cognition is usually framed in terms of action observation, in the sense that observing the actions of others is experienced similarly to performing the action oneself, and numerous studies have shown corresponding similarities in the patterns of brain activation in the two situations. This reciprocity is often associated with 'mirror neurons' (Rizzolati et al., 2001), which are neurons in the respond similarly when watching an action and when performing the action oneself. This reciprocity implies bidirectional transmission of the information, either out from the control centers to the limbs for one's *own* action, or inward from the image or scene into the control centers in the case of the *observed* action.

Embodied Cognition in Art Appreciation

Paintings are often analyzed in terms of the pictorial space that they depict (cf. Tyler & Ione, 2001), and often in terms of the dynamic forces of the action (e.g., Arnheim, 1949; Loran, 1985), but painting is less often discussed in terms of an action space. This is the 4D space-time generalization of the 2D structural space, the 3D pictorial space and the 2D space of action forces that are often used in art criticism. The dynamic forces, balance and tension are forces of potential action within the space of the painting. With the right technique, the potential actions can be turned into real perceived actions, ripples of movement, gestures and expressions that are experienced as actual movements to the receptive viewer. These are particularly enhanced when the viewers feel not as though they are observing an action as an outsider, but transport themselves into the action space of the painting and experience it as though they themselves are involved in the action.

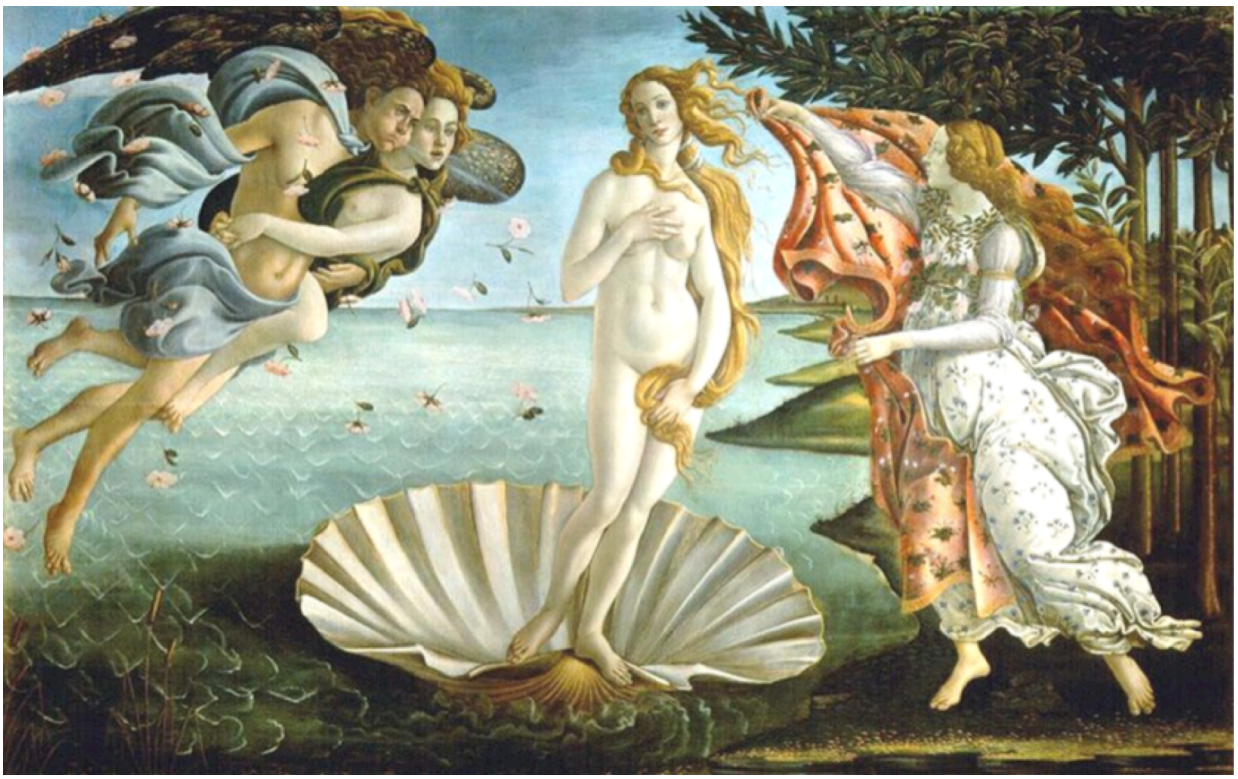

Fig. 2. "Birth of Venus" by Sandro Botticelli (1486)

Historically, paintings have not simply depicted static structure, but have conveyed an action space in which a drama (typically a mythical, religious or otherwise symbolic event) takes place. The appreciation of such an action space is thus quite different from a geometric figure. In order to appreciate it as such, the viewer has to mentally project their body into to the depicted space and imagine the possibilities of action within it. For the successful evocation of such action space, a painting recruits the perceptual processes of spatial appreciation through the full array of Gibsonian depth cues, in a form that is generally understood as providing an allocentric sense of the 3D space within the image. However, the level beyond the perceptual appreciation of 3D space as such is the sense of being drawn into the pictorial space to participate as a player in the depicted

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scene. This is a form of embodied cognition different from the identification with an observed action; rather than identifying one's body with the body depicted in the image, it is more a question of identifying the action space surrounding one's body with the space depicted in the image. The experience of the depicted space then becomes one of the egocentric space inhabited by one's own body, with its limitless array of action possibilities. This may be considered a spatial form of 'situated cognition' in which the cognition, instead of being situated in the context of the real objects being cogitated, is projected into the artificial pictorial space of the image.

One of the most iconic paintings in history is that of the Birth of Venus by Botticelli (Fig. 2). We may ask what it is about this particular painting that make it so memorable. Is it just the colors and forms that carry the day, i.e., the static structure of the composition? Armed with the twin concepts of action space and embodied cognition, we can perhaps gain a deeper understanding of the potency of this work. It is hard to see the figures as static forms. Although the composition as a whole has classical balance, each of the figures has an unstable posture so that we literally feel their movement. The zephyrs at left are wafting in with (and creating) the breeze, totally unsupported in open space. The handmaiden at right is balancing on tiptoe, partially buffeted by the same breeze as she leans forward to wrap Venus in a silken cloak. And Venus herself is pitched forward by the motion of the scallop shell, which seems to have been wafted across the waves and is just about to touch the shore. While the zephyrs move upward, Venus and the handmaiden move obliquely towards each other in the 3D action space of the shoreline. As a study in the action space of painterly movement, it exhibits supreme skill quite distinct from many others of Botticelli's works.

Fig. 3. 'Judith Beheading Holofernes' by Artemisia Gentileschi (1612)

The other aspect of the painting is how it not only depicts a sense of dynamic movement, but a sense of the elevation of the spirit as though we ourselves are being wafted in the breeze as we participate in the scene. This is the experience of embodied cognition, as though we are physical participants in the actions depicted in the painting. We can view it in a flatfooted manner, resisting any tendency to be involved, or we can allow ourselves to be drawn into the action and gain a richer experience of the imaginary world of the artist's creation.

The opposite kind of experience is obtained when viewing the later painting of Artemisia Gentileschi, one of the very few female painters of the Renaissance/Baroque era (Fig. 3). Here we feel the downward thrust of the two women of the startled general, the thrust of the knife, the spatter of the blood, and his desperate shove to try to stave off his demise. In fact, in its violence, its compositional inversion and its conscious violation of balance, I have suggested that this painting was a harbinger of the modern (20th century) era, to which many stylistic innovations could in principle be traced. The point of its introduction here is to emphasize the dark side of embodied cognition, the almost visceral sense of repulsion we feel on viewing this work, in which the head is caught at the moment of the maximum sense of the pain of sword slicing through the neck (so

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different from the calm sense of achievement of David with the head of Goliath in works by Verrocchio and Caravaggio).

Bringing the issue up to recent years, further example of the operation of embodied cognition can be seen in the works of Jackson Pollock (Fig. 4), whose action paintings were produced by the technique of splattering paint on the canvas straight from the tubes. Despite not depicting any recognizable objects, the paintings vividly capture the energy of the splattering movements, and evoke the same experience in the receptive viewer (and incidentally hark back to the splatter of the blood in the Gentileschi painting). Thus, embodied cognition can operate equally effectively in abstract works as in the representational ones.

Fig. 4. 'One: Number 31' by Jackson Pollack (1952)

Embodied Cognition and the Action Space

The concept of a 4D action space leads to the issue of the spatial experience of embodied cognition and its relation to the ecological optics of J.J. Gibson (1979). This view introduces the concept of a static three-dimensional 'ground' as the stage for the 'figure' of the participants depicted in the image, and the spatiotemporal action(s) that they are portrayed as carrying out. In this sense, the pictorial space of the image is the 'negative space' of the figural actions. Negative space is often conceptualized as the 2D shape of the background that is not usually perceived as having a shape because the shape analysis is focused on the boundaries of the elements perceived as figures. Classically, figure/ground categorization is typically considered as a two-dimensional categorization problem, in which one region of an image is identified as the figure of current interest and the remainder of the image territory is categorized as ground. The categorization is well-known to be a transient, attention-driven process that can rapidly fluctuate among different figural elements and their components, as in the classic Rubin face/vase alternating image.

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It is also well-known that there is a surface continuity property to the ground assignment, which is perceived to continue behind the figure in a separate 2D layer (known as 'amodal completion'). Thus, the classical figure/ground conceptualization, although usually cast as a 2D analysis, has a proto-3D aspect to it in terms of the relative depths of the assignation of figure as foreground and the ground as background (although this can be reversed in the case of depictions of holes). In this assignation, little attention is usually paid to the structure of the perceived background beyond this aspect of the continuity of the amodal completion behind the figure.

Fig. 5. 'Miracles of St Peter' by Masolino da Panicale (1424). Upper: detail of figures; lower: perspective construction of the 3D space.

If we apply these considerations to the depiction of pictorial space in the history of art images, however, they reveal that the figure/ground relationships in elaborated scenes incorporate a full 3D component in the figure/ground assignment. The image region designated as 'figure' is perceived as a solid object with depth structure that is completed by the amodal completion process. That is, the invisible rear side of a protruding

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object is understood to have a 3D structure dictated by the configuration of the visible front side, a form of 3D amodal completion. Similarly, the continuity of the background behind this 3D figure is understood to be a continuation of the depth structure of the visible regions of the ground. Rather than being simply the uniform plane of the typical figure/ground demonstrations, the backgrounds in art images form courtyards, rooms, landscapes, and so on, with elaborated 3D structure. In this way, the figure/ground assignment is applied to provide a full sense of the 3D configuration of the pictorial space.

The important aspect of this conceptualization is that the 3D spatial structure of the ground is maintained in the form of the pictorial space even though the ground is de-emphasized by the figure/ground assignment process. There is thus a tension between the background region considered as 'negative space', or non-processed territory, and the background region considered as the extended 'lebensraum' that forms the pictorial space occupied by the 3D figure(s). Although it is well-understood that the boundary between figure and ground is perceptually 'owned' by the figure and dissociated from the ground, it can now be seen that this does not imply that the ground is free of properties. Under the new interpretation, the term 'negative space' is a serious misnomer: the ground is negative in terms of *figure* but positive in terms of *space*, and should in fact be termed 'negative figure'. Indeed, space is itself a negative concept in 3D terms, receding rather than advancing, concave rather than convex, but, *qua* space, it opens up a wide range of possibilities for figure placement, even when totally empty. Whereas the figure crystallizes a particular action, space represents the limitless possibilities for action. In the elaborated usage through the history of art, pictorial space may contain an array of structures, from valleys to colonnades that provide a more structured concept of the available space, without reaching the level of figural objects. This elaborated, even theatrical, concept of space may appropriately be termed 'action space'.

On of the earliest depictions of an accurate 3D pictorial space was by Masolino da Panicale (Fig. 5), long before most of well-known artists of the high Renaissance. In a rather literal rendition of the figure/ground concept, he portrays the figures of St Peter and acolytes healing a lame man and resuscitating a dead woman. The figures stand out strongly relative to the earthen background due to the expert shadowing, and do so far more effectively than anything by his better-known collaborator, Masaccio. In terms of figure/ground completion, you perceive the figures as being clothed in the same gold, pink of green damask robes on their far sides as on their near sides. Even the stone on the dirt floor of the piazza are given a vivid three-dimensionality by the strong shadowing, unique in this era of flat-wash frescos.

In viewing the full work (Fig. 5, lower), however, we become aware of the extended 3D structure of the scene, with part of the action taking place inside a loggia at the right. Part of the success of this spatial representation is that it is one of the very first paintings in history to have achieved an accurate perspective construction of the 3D structures throughout the scene. This is shown by the perspective construction lines, which all project to a single vanishing point at the center of the fresco. The white construction lines are for the nearer structures as the right and left of the piazza, while the black ones are those at the rear of the scene. Masolino has integrate not only the foreground structures but also the far background structures running away down the street behind the piazza into a unified 3D composition. Earlier artists had achieved correct perspective for single structural elements, such as the ubiquitous pavimenti forming the floor structure, but had not understood the necessity to harmonize all aspects of the 3D scene into a singe vanishing point.

It is worth commenting that this implication of his use of a single vanishing point is not just a geometrical inference. One can ask how such an accurate perceptive geometry could have been achieved in a fresco 6m in width. It is generally understood that Renaissance artists employed chalk-laden strings attached to a nail for this purpose. When the taut string was plucked, the vibrations would deposit a line of chalk-dust on the wall to guide the perspective lines. Remarkably, if one examines the fresco with the knowledge of where the vanishing point should be, I can verify that there is still a hole in the plaster at the precise location where the nail would have been. (This is all the more remarkable, since the fresco has been restored no fewer than five times over the centuries, so each of the restorers must have been aware of the significance of this hole, and left it unfilled in acknowledgement of its significance in the history of perspective.) Incidentally, the piazza depicted in the scene can be identified as the Piazza Signoria in Florence, the three-bayed arcades now being the site of the most renowned sculptures of the Renaissance.

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A B C

Fig. 6. Aspects of self-reflection evoking embodied cognition in art. A. Narcissus admiring his own reflection, by Caravaggio (1609). B. Norman Rockwell's portrait of himself painting a self-portrait (1960). C. A reproduction of Magritte's paradoxical 'La Réproduction Interdite' (1937), depicting a man contemplating his head from the rear, and perhaps projecting into his brain processes.

Mirror Reflection and Embodied Cognition

The concept of 'mirror neurons' mirroring the actions of others as though they are our own actions, forming a neural basis for the operation of embodied cognition, is reflected in range of paintings exploring the role of mirroring in the aesthetic experience. Three examples illustrating different aspects of this exploration are assembled in Fig. 5. Caravaggio's 'Narcissus' draws us into the circle of contemplation of the reflection as we feel the attraction of the youth to his own reflection. In Rockwell's multiple self-portrait, we feel ourselves leaning forward to examine the mirror reflection that is his subject, tiling sideways in an unstable posture that is itself reflected the tilt of the glass of Coke sliding off the book of (presumably) famous self-portraits. In Magritte's paradoxically non-inverted mirror-reflections, we imagine the mind of the observer boggling at the unexpected mirror-reversal of his head, evoking the concept of him considering the working of his brain as it views itself in this fashion. Thus, these three examples are not simple mirror-reflection of the subject of the painting, but evocative explorations of the philosophical implications of mirror reflection and self-identity, drawing us in to experience the scenes not just through a bodily sense of embodied cognition but through a challenge to our identities as viewers, in what might be called 'embodied self-cognition'.

Fig. 7. Human skull and brain drawings by Leonardo da Vinci (~1500)

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One form of self-reflection is the reflection of one's mortality in terms of skull containing the remnants of one's identity. The Renaissance master of skull drawings was Leonardo da Vinci (Fig. 7), one of the first artists to emphasize the importance of a detailed appreciation of anatomy. Less well-known are his explorations of neuroanatomy in the form of drawings of an exploded view of the brain with its cranial nerves, and what is probably the first depiction in history of the cortical convolutions of the human brain. (For those weak on history, it is worth noting that this brain was drawn several decades before Vesalius' classic text on anatomy.) The Renaissance style of including the individuality of the face in the exploded figure of the head gives these admittedly analytic drawings a personal dimension, such that the viewer feels a form of uncomfortable identification with the images.

Leonardo da Vinci pursued investigations deeper into the brain by making wax casts of the ventricles (Fig. 8), which he thought housed the vital spirit of consciousness. This conception may be viewed as a precursor to the modern understanding of the core brains structures of the limbic system, adjacent to the ventricles, which are understood to play a central role in the flux of emotions at the core of our being. Modern depictions of the limbic system available on the Internet are shown to the right of d Vinci's drawings in Fig. 8. The limbic system may be viewed as a natural work of sculptural art in its own right, evoking a certain visceral aesthetic response. Moreover, it is interesting to ask whether our response to these images has an embodied cognition component of our limbic system as it recognizes the depiction of its own structure in a form of embodied emotional cognition.

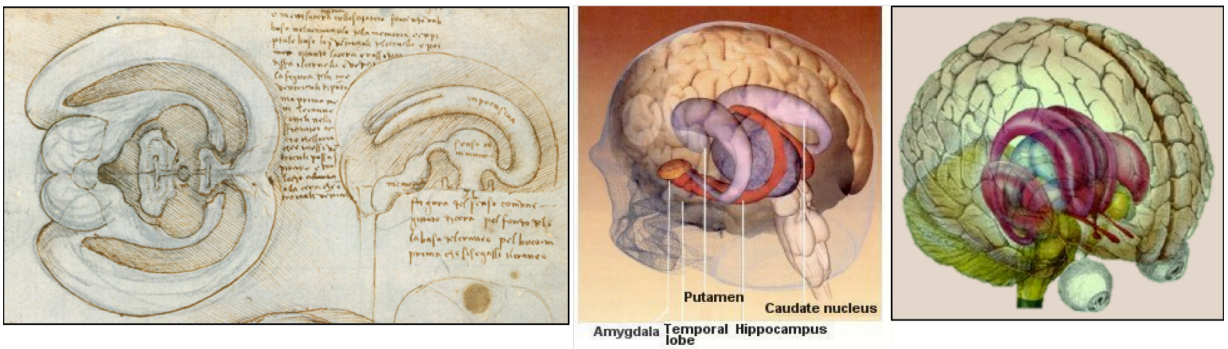

Fig. 8. Subcortical brain structures by Leonardo da Vinci (~1500) compared with modern depictions of the limbic

The Aesthetic Response

One field of study related to artistic process is that of aesthetics. Aesthetics is the study of art creation and appreciation, the choice of elements to include in an artistic composition and the judgment of the success of works of art as evoking effective responses in the viewer (in the case of visual artworks). The aesthetic response is thus the form of cognition involved in the artistic process, and intersects with the domain of embodied cognition to the extent that the response has a visceral component.

Though limited, there is an increasing corpus of studies of the aesthetic response of the brain to works of art (Bartels & Zeki, 2004; Vartanian & Goel, 2004; Kawabata & Zeki, 2004, 2008; Tsukiura & Cabeza, 2011). The most recent, by Ishizu & Zeki (2013) emphasized the activation of core brain structures. Their paradigm was to have subjects perform the aesthetic judgments of the relative beauty of pairs of artworks. This process thus involves the appreciation of beauty and the process of making a comparative judgment. As a control for the judgment process, participants performed simple judgments of the relative brightness of the works. The differential activation for the aesthetic judgment involved the limbic system component of the amygdala, the subcortical structures of the globus pallidus, putamen and cerebellar vermis, the anterior ventral cortical regions of the medial and lateral orbitofrontal cortices, and the dorsal cortical region of the supplementary motor areas. The amygdala is typically associated with negative emotions and the orbitofrontal regions with positive emotions (O'Doherty et al., 2003; Kringelbach, 2005; Winston et al., 2007; Zeki & Romaya, 2008; Liang, Zebrowitz & Zhang, 2010; Grabenhorst & Rolls, 2011); the globus pallidus and putamen with judgment processes (Eslinger et al., 2009), and the supplementary motor area and vermis with coordination of the eye

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movements and attention required for comparing the pairs of images (Ernst & Paulus, 2005). These areas thus constitute a plausible neuroanatomical basis for the aesthetic judgment process.

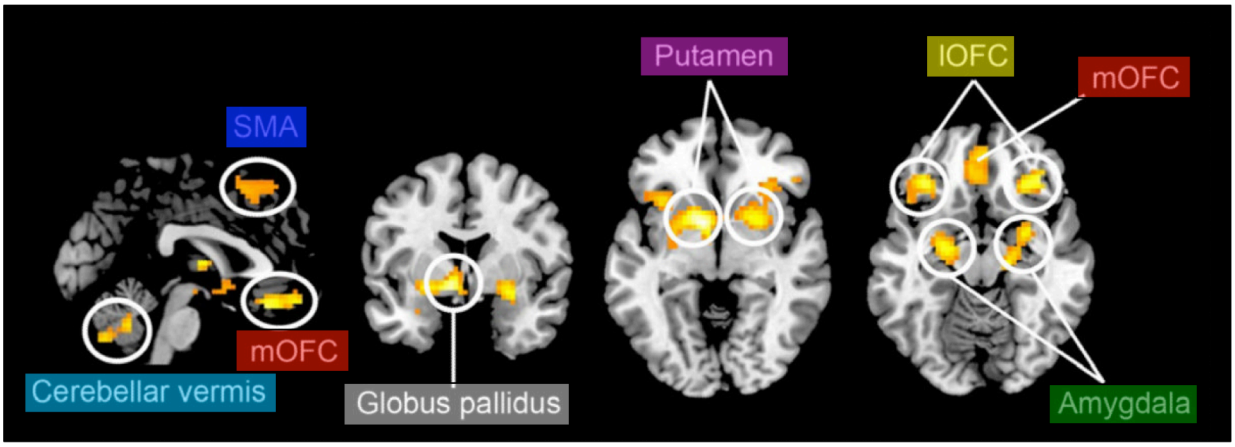

Fig. 9. Brain areas activated by the aesthetic judgment of beauty. (from Ishizu & Zeki, 2013)

It may be commented, however, that the reported activations seem to elucidate the organizational aspects of the process more than the aesthetic aspects – they shed little light on what factors are involved in making one image appear more beautiful than another. Correspondingly, they leave unresolved the issue of how beauty *per se* is encoded in the human brain, beyond the expression of the positive and negative affect evoked by these images. It may be that this is a function of the extensive activation of the putamen, which is typically associated with motor coordination in complex tasks. In the context of aesthetic judgments, aesthetics consists of factors such as the coordination of shapes and colors into an integrated composition, and appreciation of the tensions between different aspects of the depicted actions. These seem sufficiently similar to its classical roles to account for the unusually extensive activation throughout the putamen in this aesthetic task, which corresponds to the ancient Greek concept of '*symmetria'* or goodness of form. This interpretation goes some way beyond the inferences drawn by previous authors, and is intended as a working hypothesis for the neural instantiation of the core processes of aesthetics (as opposed to those of complex judgment in general, which may not have been fully controlled by the simple judgment of brightness employed as a control by Ishizu & Zeki, 2013). This hypothesis, of the putamen as the specific locus for the registration of goodness of form, may be tested in future brain imaging studies by a comparison between aesthetically pleasing and unpleasing compositions that are similar in other respects. If the study is performed with compositions of live figures rather than geometric ones, it may be expected to involve a substantial embodied cognition component.

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