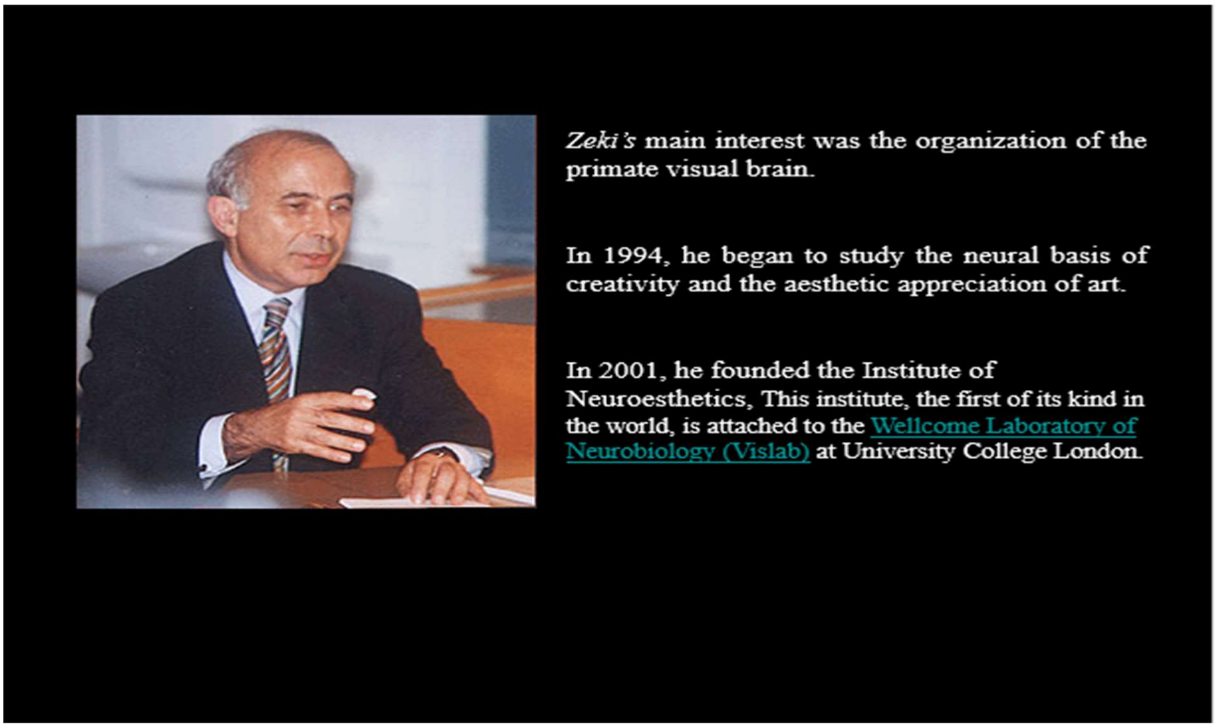
INTRODUCTION

Per Olav Folgerø

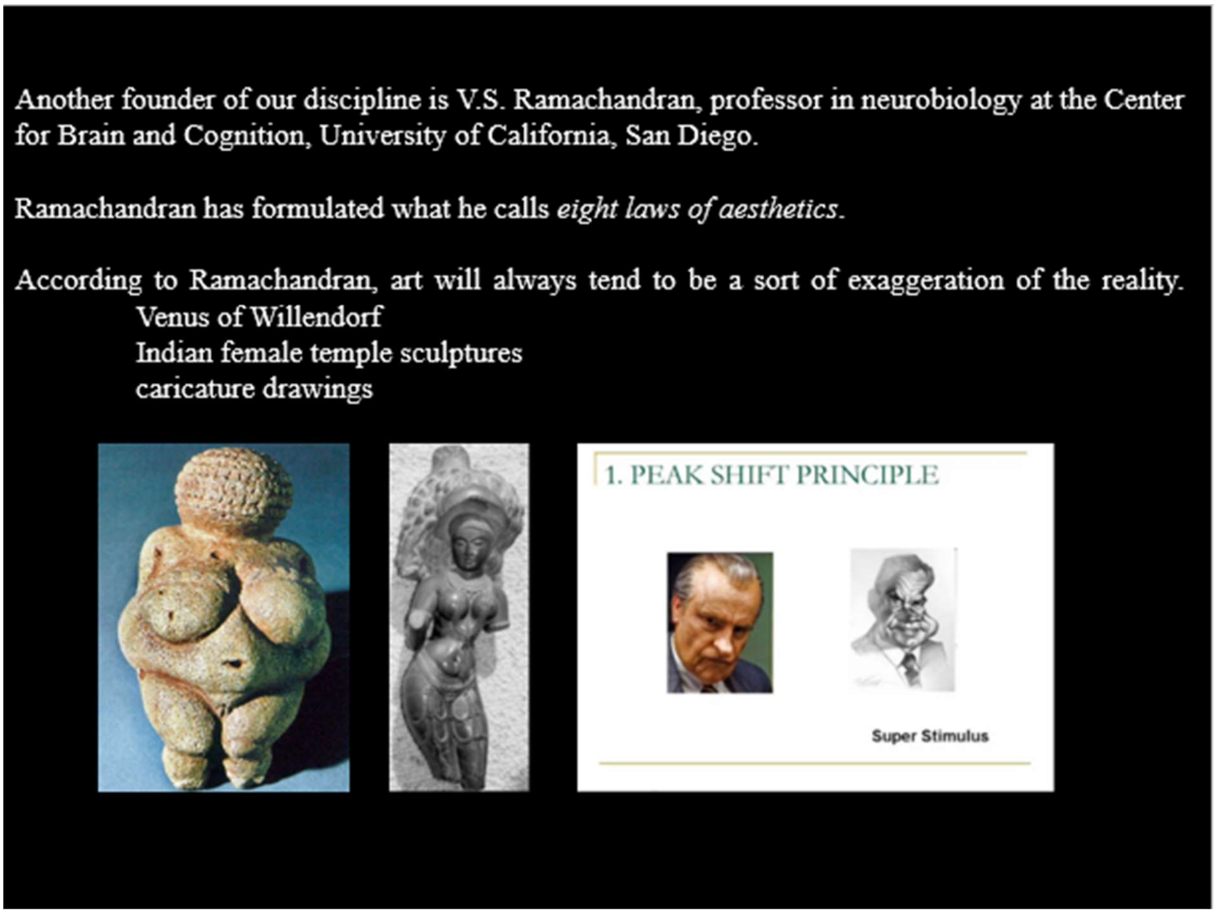
Welcome to Neuroaesthetics! This exciting, new, interdisciplinary field of research brings to dialogue disciplines as seemingly far apart as neurobiology and art history (Box 1). This Introduction is intended to provide insights into recent scientific works and methods in neuroaesthetics and whet your appetite for the lectures and lab work that will follow.

Box 1

The disciplinary field of ´neuroaesthetics` was mapped in 1999 by the neuroscientist Semir Zeki (Zeki, 1999), who is a professor at the Wellcome Centre for Human Neuroimaging, Department of Imaging Neuroscience, University College London. Hence, it is a relatively new discipline, and lies at the intersection between cognitive psychology, neurobiology and art. Neuroaesthetics uses models derived mostly from cognitive psychology and modern brain scanning techniques in order to study how the brain responds to aesthetic stimuli. Zeki's main interest is the primate visual brain system. From 1994 onwards, his studies also included the neural basis of aesthetic appreciation of art, and in 2001 he founded the Institute of Neuroaesthetics, the first of its kind in the world, at University College London (Box 2).


Zeki's main interest was the organization of the primate visual brain.
In 1994, he began to study the neural basis of creativity and the aesthetic appreciation of art.
In 2001, he founded the Institute of Neuroesthetics, This institute, the first of its kind in the world, is attached to the Wellcome Laboratory of Neurobiology (Vislab) at University College London.

Box 2


Another founder of our discipline is V.S. Ramachandran, professor in neurobiology at the Center for Brain and Cognition, University of California, San Diego.
Ramachandran has formulated what he calls *eight laws of aesthetics*.
According to Ramachandran, art will always tend to be a sort of exaggeration of the reality.
Venus of Willendorf
Indian female temple sculptures
caricature drawings
1. PEAK SHIFT PRINCIPLE
Super Stimulus

Box 3

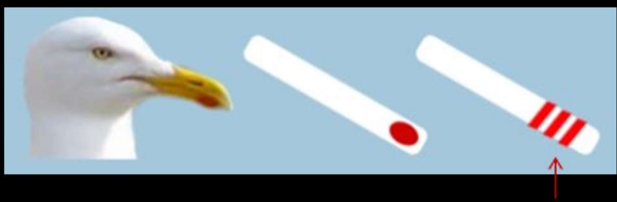
There is also another great neuroscientist who should be regarded as a founder of our discipline, namely Vilayanur S. Ramachandran, who is professor in neurobiology at the Center for Brain and Cognition, University of California, San Diego. Together with William Hirstein, he has formulated what he calls the 'eight laws of aesthetics' (Ramachandran & Hirstein, 1999). We will not go through each of these laws, but focus instead on only one in more detail, the one that provides a suitable starting point for discussing intersections of objective and subjective studies of art (Box 3).

According to Ramachandran and Hirstein, art will always tend to be a sort of exaggeration of the reality. As arguments in favour of their thesis, they draw on artifacts as diverse as the 28,000 years old so-called Venus of Willendorf (image on the left in Box 3), Indian female temple sculptures from the ninth century of our era showing exaggeration of female beauty (middle image in Box 3), and modern caricatures, such as the one of the American ex-president Nixon, which, as pointed out by Ramachandran, is more Nixon-like than the photo of the ex-President (image on the right in Box 3). Ramachandran labels this exaggeration of form in art as *the peak shift effect*. Interestingly, he finds the same mechanism at work in the animal world. There is, for instance, an interesting experiment on seagulls feeding their chicks. The beak of the seagull, which is yellow, has a red stripe on it, on which the chicken peck when they beg for food. If a yellow stick with a red patch on it is placed into the nest, the chicks will peck also at this stimulus. Now, if another stick with, say, three red stripes is placed into the nest, the chicken will peck even more vigorously. The stick with tree red stripes appears to be a 'Picasso in the world of chicks', says Ramachandran: being trained to respond to one particular stimulus will lead to a preference for an exaggerated or *peak shifted*-version of the same stimulus. This is, of course, interesting also in an evolutionary perspective on art (Box 4).

Ramachandran's point is that art will always tend to exaggerate reality. This leads to a most fundamental question in aesthetics: What is beauty? The question, debated for at least 2,500 years has been given a wide variety of answers. One can broadly distinguish three main positions:

- The *objectivist view*, which dates back to Plato, maintains that beauty is a property of an object that produces a pleasurable experience in any suitable perceiver;
- The *subjectivist view* dates back to the Greek philosophers known as the Sophists. They maintained that beauty is in the eye of the beholder, which means that taste cannot be debated;
- The *interactionist view* maintains that beauty is grounded in the processing experiences of the perceiver that emerge from the interaction of stimulus properties and the perceivers' cognitive and affective processes. Hence, this position appears as a golden middle between the objectivist and subjectivist positions.

According to Ramachandran, art will always tend to be a sort of exaggeration of the reality. Ramachandran labels this exaggeration *the peak shift effect*. He finds the same mechanism at work in the animal world. An interesting experiment has focused on seagulls feeding their chicks. The beak of the seagull, which is yellow, has a red stripe on it which the chicken peck at when they ask for food. In the words of Ramachandran: being trained to respond to one particular stimulus will lead to a preference for an exaggerated version of that same stimulus.

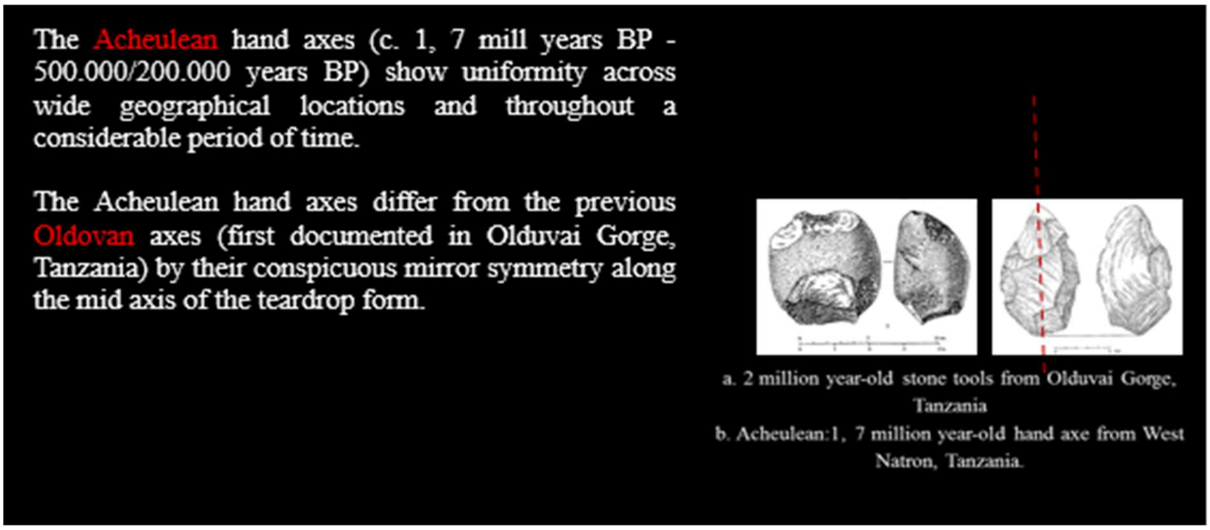


Box 4

The Objectivist View

The objectivist view. Among the identified features are balance and proportion, symmetry, contrast and clarity.

Objectivist criteria for beauty include balance, contrast and clarity, symmetry, and proportions. Among the first instances of intended symmetry in hominid evolution are the countless hand axes produced within the Acheulean stone industry, appearing about 1,7 million years before present (BP) and continuously produced until almost 200,000 years BP in a wide range of geographical locations. They differ from the previous Oldovan axes, first documented in Olduvai Gorge, Tanzania, by their conspicuous mirror symmetry along the mid axis of the teardrop form (Box 5).



Box 5

As the symmetry of late Acheulean tools goes far beyond functional requirements (Wymer, 1982), it has been assumed that an increased cognitive sophistication of hominines must have taken place during this period (Hodgson, 2009, p. 95). An 'awareness toward symmetry itself tended to now come to the fore' (Hodgson, 2011, pp. 39-40; as to the reasons for preference for symmetry, see Reber (2002), below, p. 25, note 1). Throughout the history of art, we find that symmetry is one of the leading principles. A surprising example is portrait painting: in 3/4 profile portraits, the symmetry line, in the majority of cases, passes through one of the eyes (Boxes 6 – 18).

Box 6

Box 7

Mother of God of Vladimir, painted in Constantinople A.D. 1131

Box 8

Mother of God, mosaic icon, 12th century, Constantinople,

Box 9

Master of Flemalle

Box 10

Box 11

Box 12

Box 13

Box 14

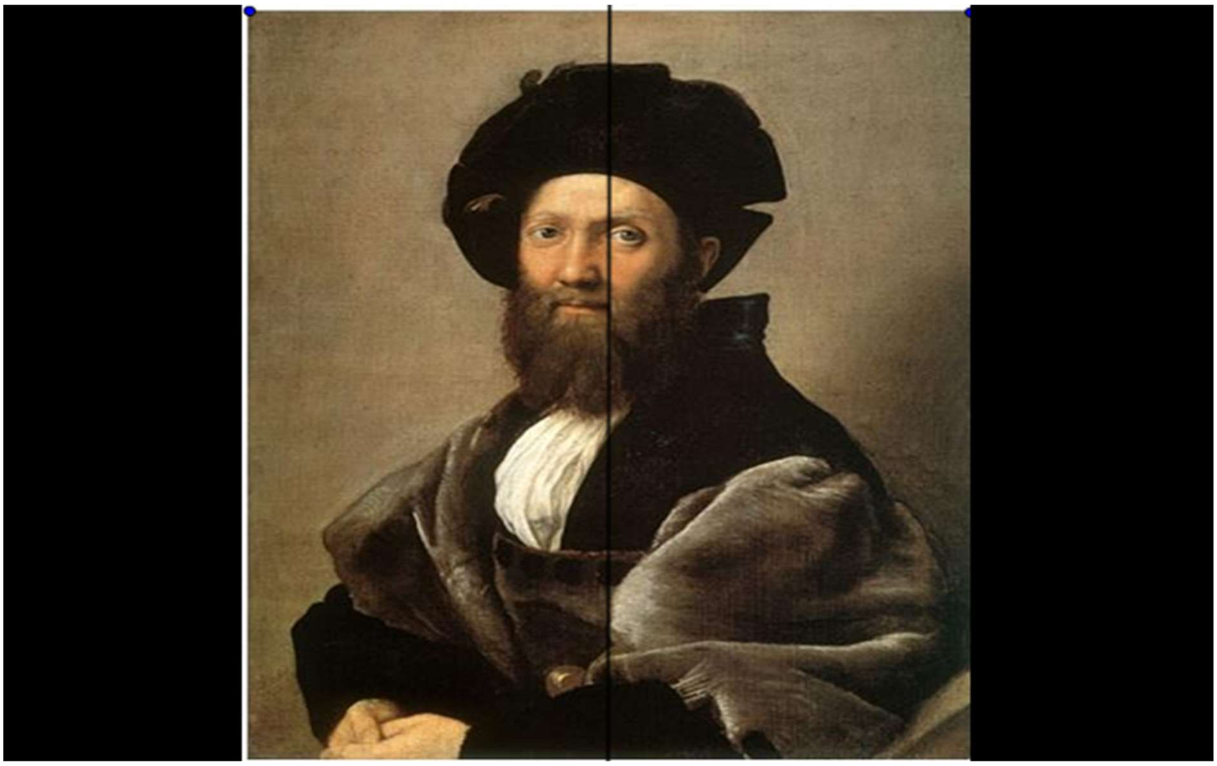
Portraits by Jan van Eyck

Box 15

Portrait by Rogier van der Weyden

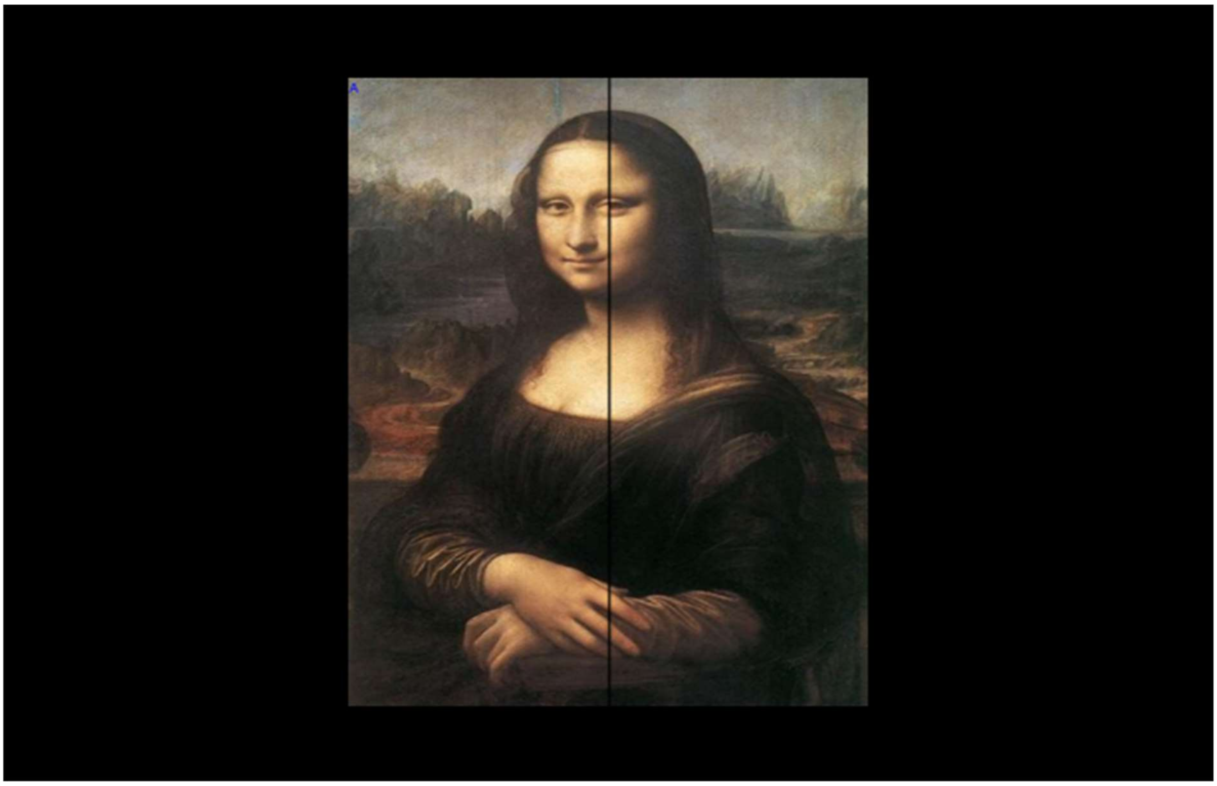
Box 16

Portrait by Tizian



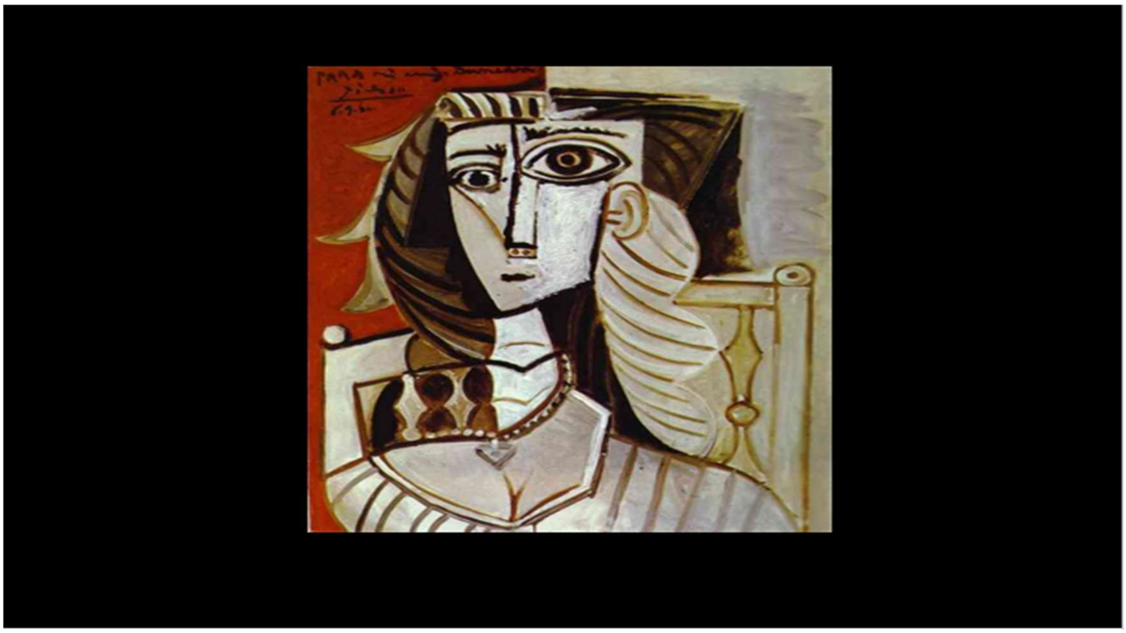
Box 17

Portrait by Rafael



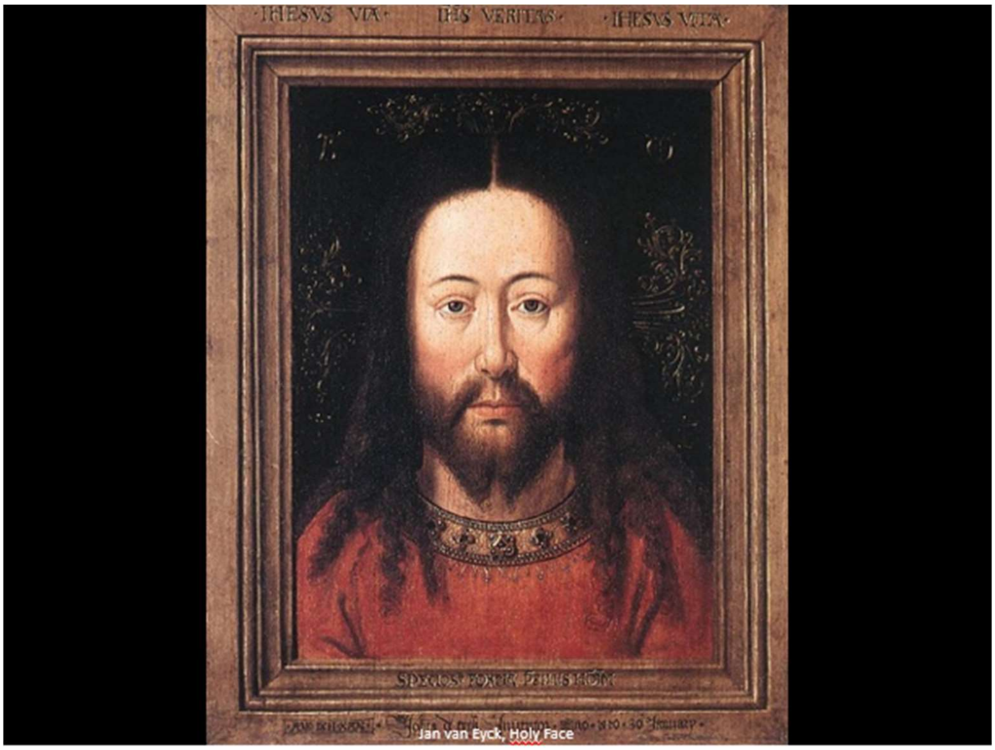
Box 18

Portrait by Leonardo DaVinci

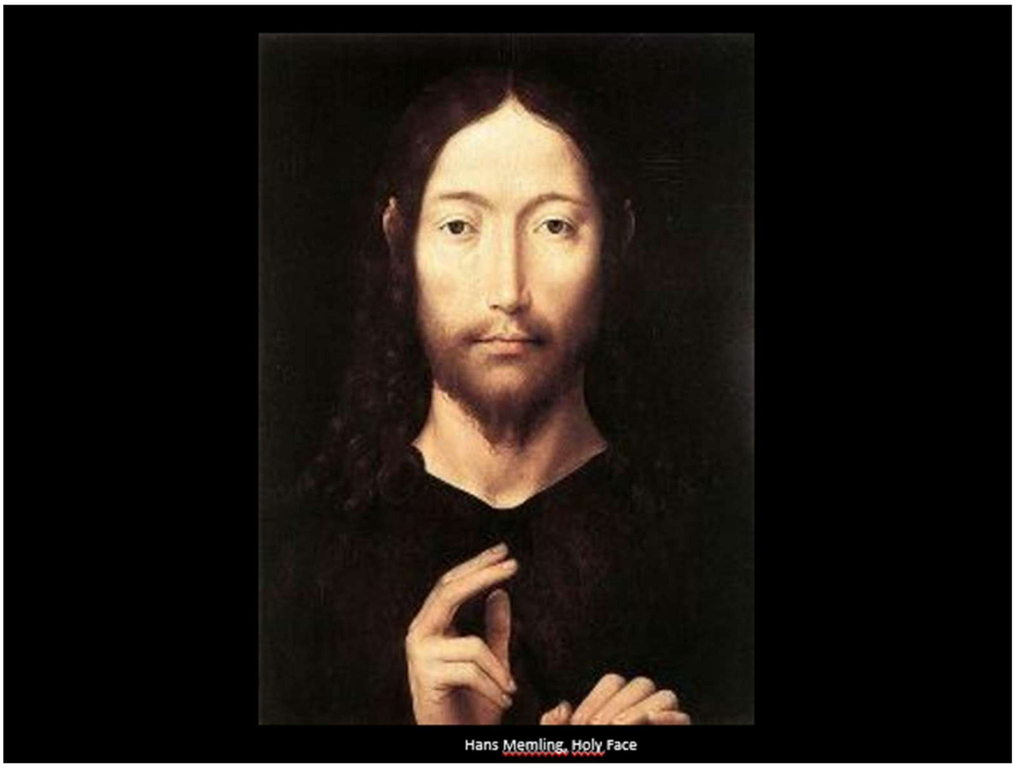


Box 19

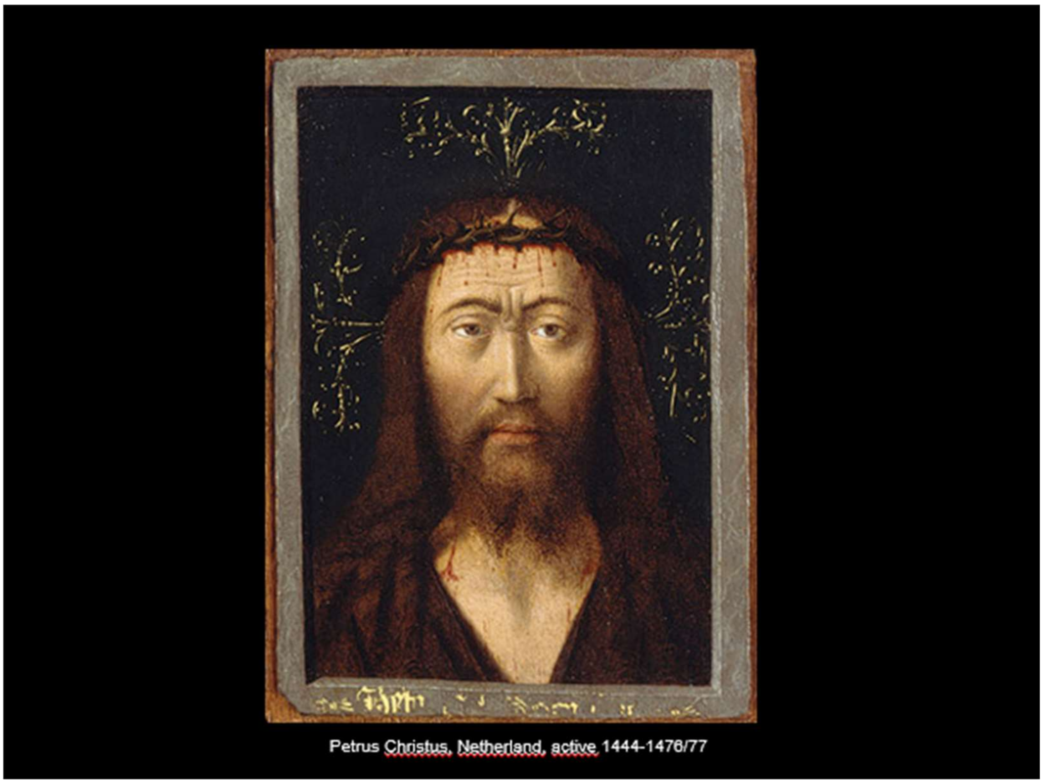
This holds even for Picasso's cubist paintings (Box 19). Talking about portraits, it is also remarkable that almost all 15th c. portraits are in profile, here represented by a self-portrait of Albrecht Dürer (Box 23), while all depictions of Christ, as the Holy Face, are *an face*. In portraits of The Holy Face, the gaze is frontally directed toward the beholder; hence, the face has an almost perfect symmetry (Boxes 20-22). This strongly indicates that *an face* and symmetry was the only acceptable way to represent Christ in this period of art history.



Box 20

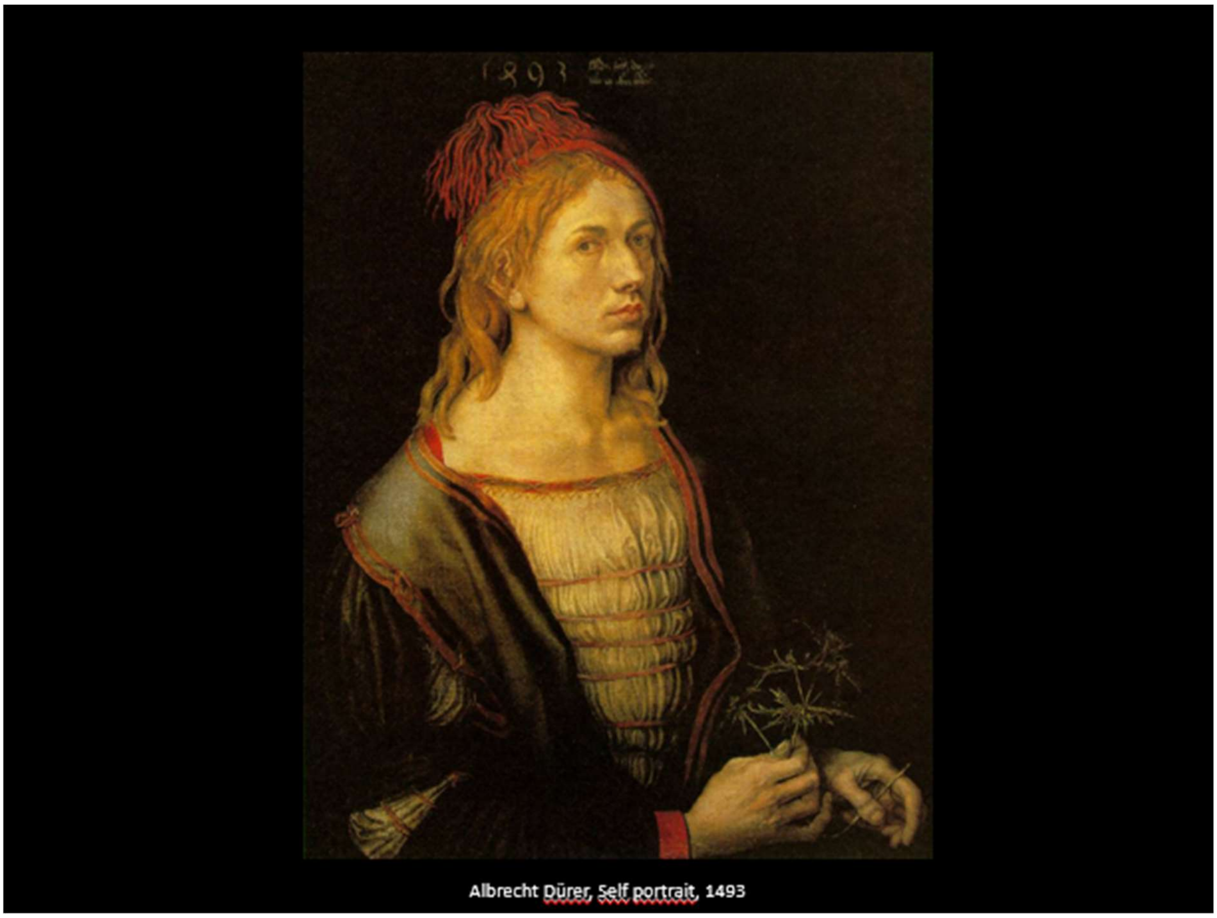


Box 21



Box 22

The question can be raised, as indeed we do in a research project on 'Symmetry in Art and Science', in which I cooperate: Is a symmetric face associated with divinity, and is it so because of qualities that lie in the symmetric form itself? Hence, does our biologically determined preference for symmetry imply that holiness must be represented *en face*, i.e. in the most symmetric manner? Or is it just a convention that determines that Christ shall be represented *en face*? Our research is based on a survey questionnaire where subjects look at faces with different orientation and with different gaze directions. Faces here presented are from busts of generals who took part in the manoeuvres of Garibaldi (photographs by Lasse Hodne, Boxes 24-27).



Box 23

The conditions are:

Box 24

en face and gaze directed at the viewer,

Box 25

en face with gaze to one side,

Box 26

¾ profile looking in same direction as head orientation, and

Box 27

¾ profile gazing at you.

Subjects are asked to read a list of adjectival allegations in a questionnaire and rate them from 0 to 10 according to how much they agree with them (Box 28). Examples of adjectival statements include:

The person is authoritarian
The person is including
The person is monitoring
The person is caring
The person is trustworthy
The person is intimidating
The person is harmonic

The following adjectival statements were used:

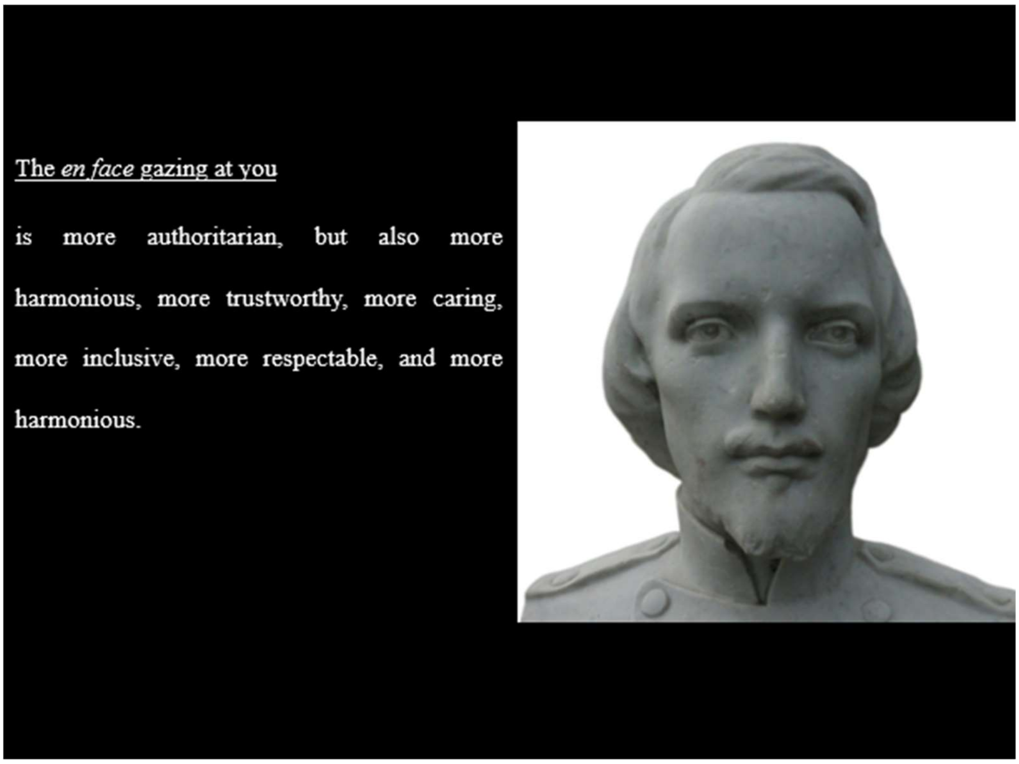
The person is harmonious
The person is trustworthy
The person is caring
The person is inclusive
The person is respectable

The person is authoritarian
The person is evasive
The person is intimidating
The person is monitoring
The person is dominant

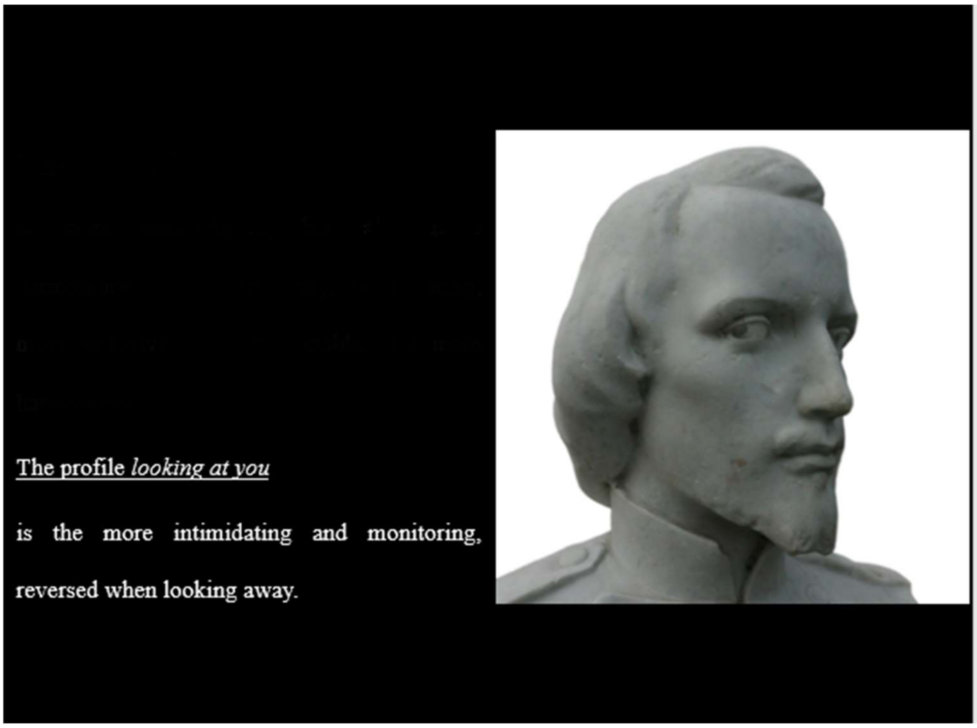
Box 28

So far, our results seem to indicate that:

1. The *en face* gazing at you is more authoritarian, but also more credible, more caring, more trustworthy, more harmonic, and more including (Box 29);
2. The profile looking at you is the more intimidating and monitoring, not so when looking away (Box 30).

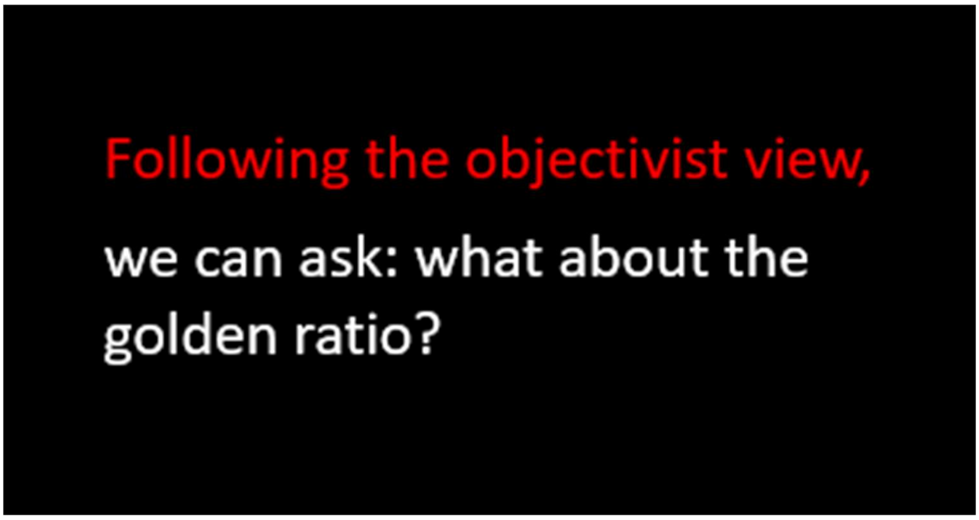


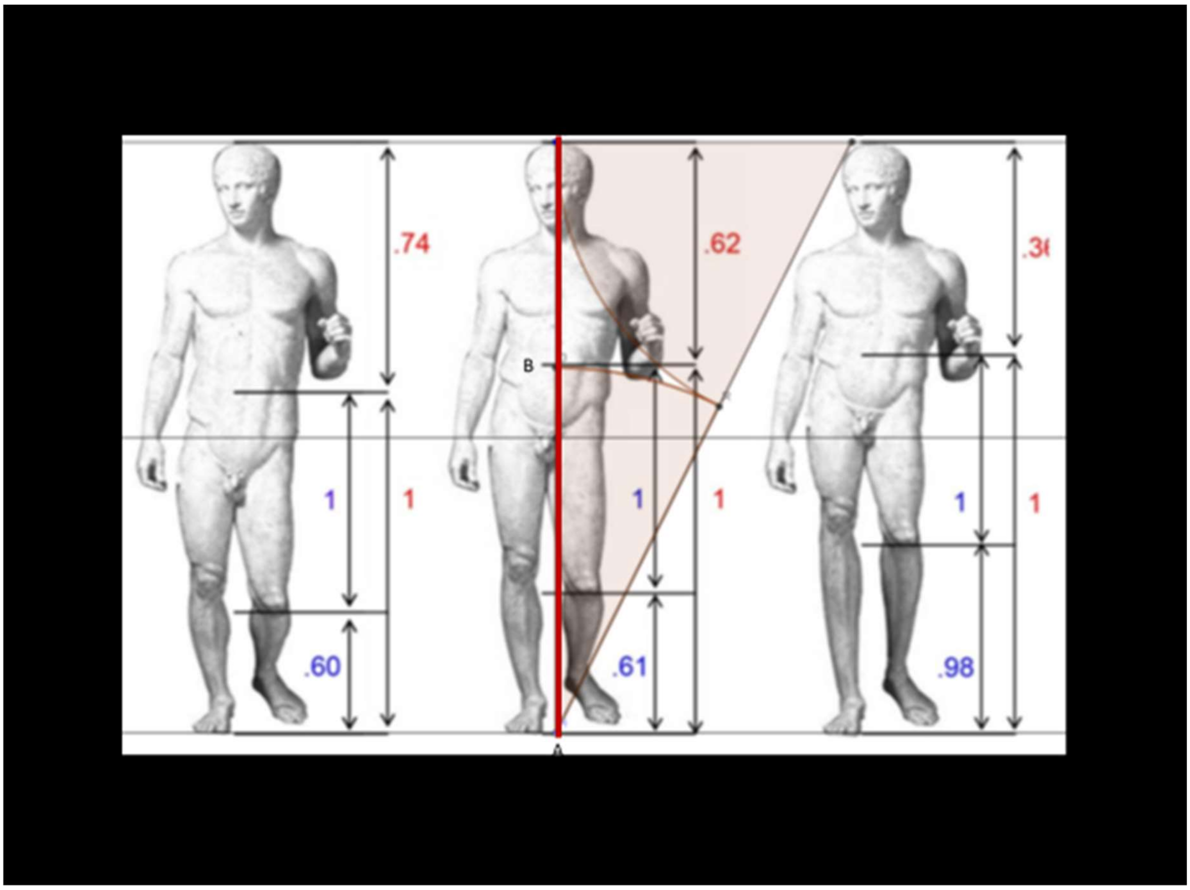
Box 29



Box 30

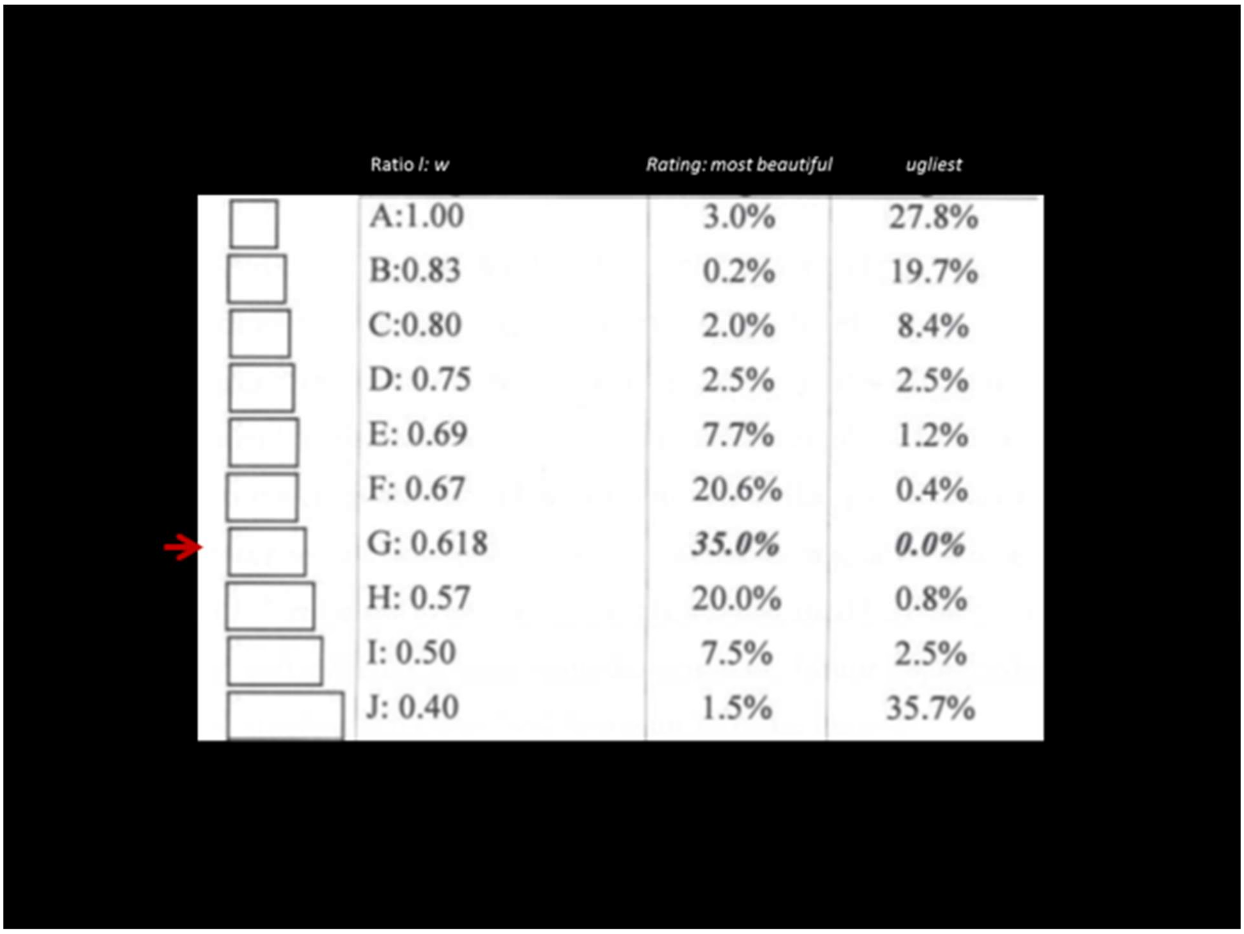
Our results, in fact, indicate that the frontal Holy Face is more than a convention. That is, it seems reasonable to suggest that there exist deeper biological and evolutionary reasons for such a convention and preference of facial symmetry (Folgerø et. al., 2016).





Box 31

In Box 31 we see the illustrated the proportions of the golden beauty. Modern research has significantly improved our knowledge on whether the golden beauty has a real and objective impact on the beholder. But let us start with a brief review of the first studies related to this topic in late 19th century, those of the German physiologist Gustav Theodor Fechner, published in the year 1876. Fechner demonstrated that subjects rated geometrical figures with golden proportions as more beautiful than other figures. In Box 32 we see that the golden rectangle form has been given the highest rating: 35% of the subjects, which were Fechner's students, rated the rectangle with golden proportions as the most beautiful. As you can see, the ratio between the width and the length of the rectangle is 0.618, which is the golden ratio.



Ratio l: w	Rating: most beautiful	ugliest
A:1.00	3.0%	27.8%
B:0.83	0.2%	19.7%
C:0.80	2.0%	8.4%
D: 0.75	2.5%	2.5%
E: 0.69	7.7%	1.2%
F: 0.67	20.6%	0.4%
G: 0.618	***35.0%***	***0.0%***
H: 0.57	20.0%	0.8%
I: 0.50	7.5%	2.5%
J: 0.40	1.5%	35.7%

Box 32

However, it has been strongly questioned whether a biological and inherited mechanism alone can explain these features, or whether they are the result of the frequent appearance in our culture of forms with golden proportions, ranging from huge aesthetic monuments, those of art and architecture, to the golden rectangle form of the credit cards of modern daily life.

In a brain scanning study on responses to Classical and Renaissance sculptures, an Italian group at the University of Parma led by Professor Giacomo Rizzolatti (Di Dio et al., 2007), demonstrated that subjects will rate sculptures following the Greek canon of beauty higher than those that are digitally manipulated. Those manipulated generally scored with a negative rating (Box 33). Moreover, the canonical sculptures increased activation in distinct areas of the cerebral cortex (Boxes 33, 34). As the frontal page (Box 33) of Di Dio et al.'s article indicates, the question is whether there are objective criteria for beauty, and whether the golden mean is such a criterion.

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The Golden Beauty: Brain Response to Classical and Renaissance Sculptures

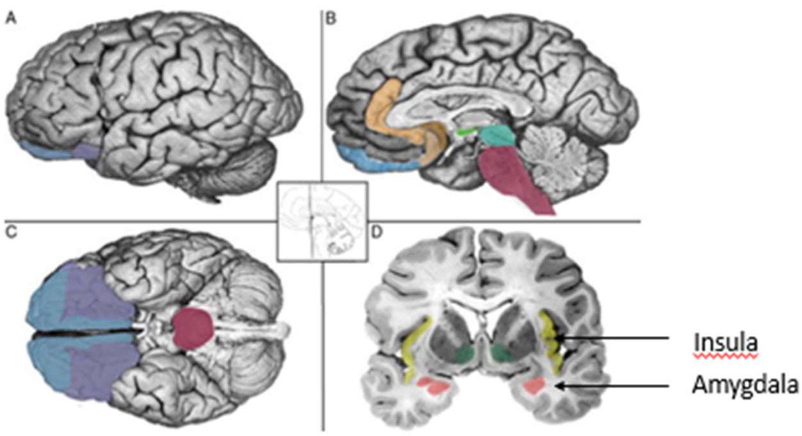
Cinzia Di Dio[1,2], Emiliano Macaluso[2], Giacomo Rizzolatti[1]*

1 Dipartimento di Neuroscienze, Università di Parma, Parma, Italy, 2 Fondazione Santa Lucia, Neuroimaging Laboratory, Rome, Italy

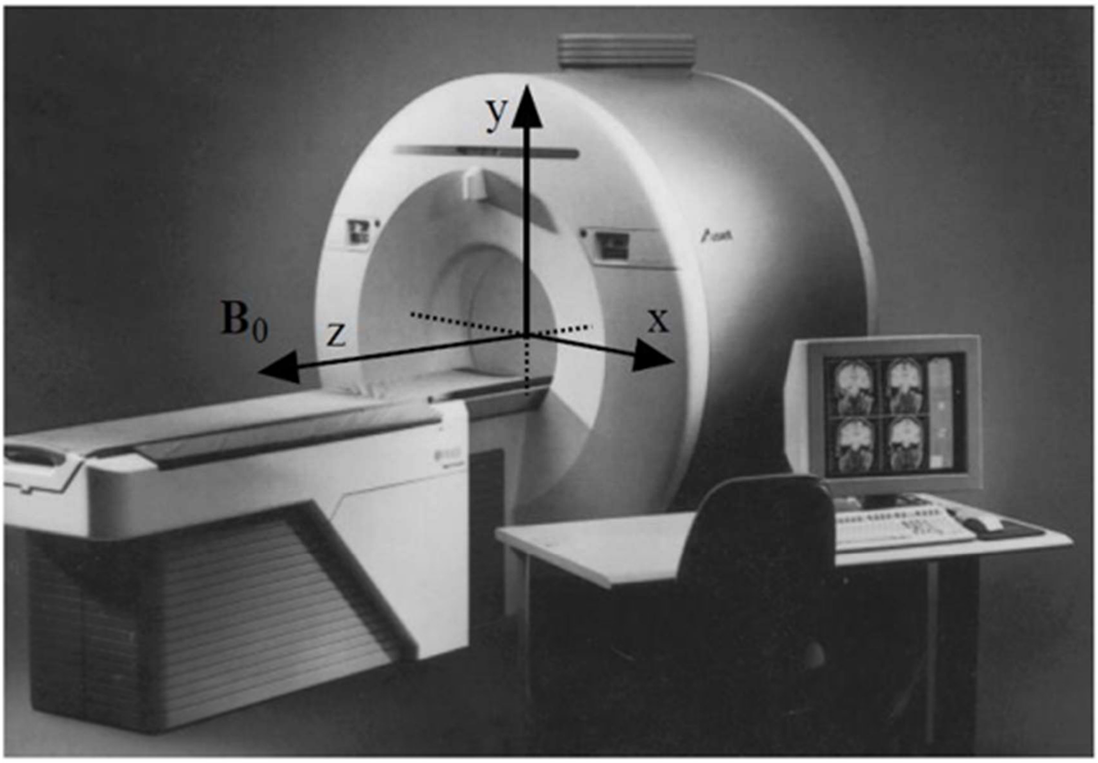
Is there an objective, biological basis for the experience of beauty in art? Or is aesthetic experience entirely subjective? Using fMRI technique, we addressed this question by presenting viewers, naïve to art criticism, with images of masterpieces of Classical and Renaissance sculpture. Employing proportion as the independent variable, we produced two sets of stimuli: one composed of images of original sculptures; the other of a modified version of the same images. The stimuli were presented in three conditions: observation, aesthetic judgment, and proportion judgment. In the observation condition, the viewers were required to observe the images with the same mind-set as if they were in a museum. In the other two conditions they were required to give an aesthetic or proportion judgment on the same images. Two types of analyses were carried out: one which contrasted brain response to the canonical and the modified sculptures, and one which contrasted beautiful *vs.* ugly sculptures as judged by each volunteer. The most striking result was that the observation of original sculptures, relative to the modified ones, produced activation of the right insula as well as of some lateral and medial cortical areas (lateral occipital gyrus, precuneus and prefrontal areas). The activation of the insula was particularly strong during the observation condition. Most interestingly, when volunteers were required to give an overt aesthetic judgment, the images judged as beautiful selectively activated the right amygdala, relative to those judged as ugly. We conclude that, in observers naïve to art criticism, the sense of beauty is mediated by two non-mutually exclusive processes: one based on a joint activation of sets of cortical neurons, triggered by parameters intrinsic to the stimuli, *and* the insula (objective beauty); the other based on the activation of the amygdala, driven by one's own emotional experiences (subjective beauty).

Citation: Di Dio C, Macaluso E, Rizzolatti G (2007) The Golden Beauty: Brain Response to Classical and Renaissance Sculptures. PLoS ONE 2(11): e1201. doi:10.1371/journal.pone.0001201

Box 33



Box 34



The functional magnetic resonance immagining fMRI scanner

Box 35

The studies were carried out using a *functional magnetic resonance imagining* (fMRI) scanner (Box 35). The most striking finding is the activation of the *right insula* in those cases when the subjects in the scanner viewed sculptures following Polycleitus' mathematical canon. This is important because the insula is a central structure in the emotional neural network of the brain, also called the limbic system. Observation of canonical sculptures will thus activate the emotional pathways, and these mechanisms seem to be biologically determined. The research shows how sculptures were modified in the case of the *doryphoros*, the Spear Bearer, of Polykleitos (Box 36). As you can see, the length of legs and thorax are manipulated, which results in great deviations from the proportions of canonical sculptures. In canonical sculptures, the golden mean divides the sculpture at the level of the navel (Box 37).

Two quantities are in the golden mean proportion if the ratio of the sum of the quantities to the larger quantity is equal to the ratio of the larger quantity to the smaller one. In our sculpture the sum of quantities is equal to the height of the sculpture, the line AC (Box 38). The larger quantity, AB, is the length from feet to navel. The golden mean is calculated thus: AC: AB = AB: BC = 1.618, the irrational number of the golden mean. (It will be 0.618 if you divide the smaller length with the longer, cf. the golden rectangle, Fechner, above).

Neural Bases of Aesthetics

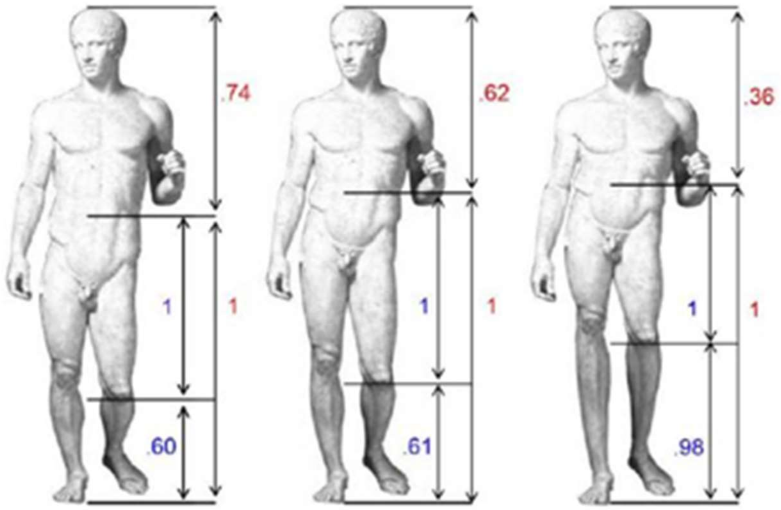
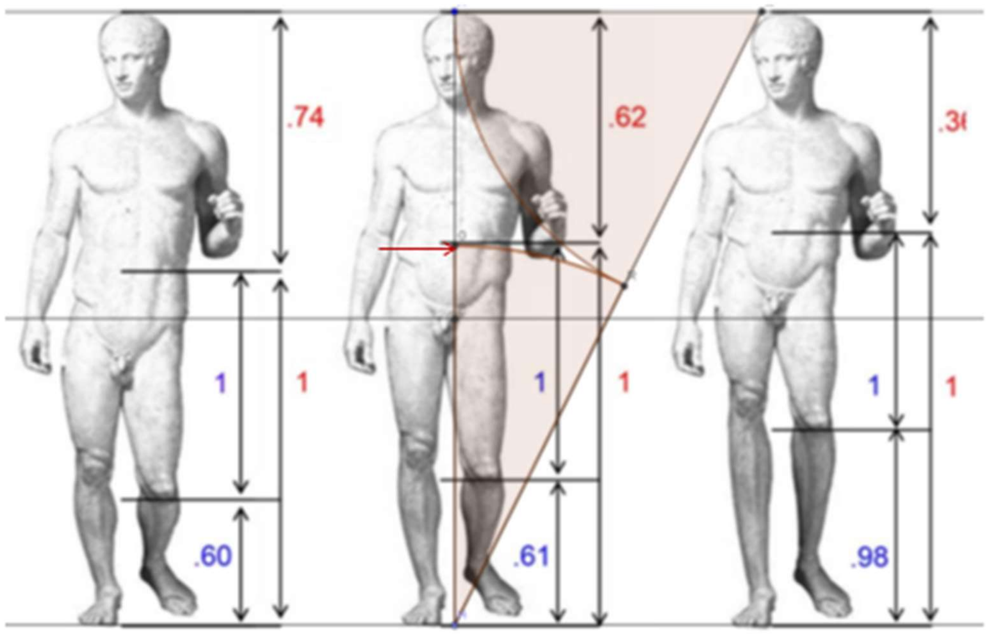


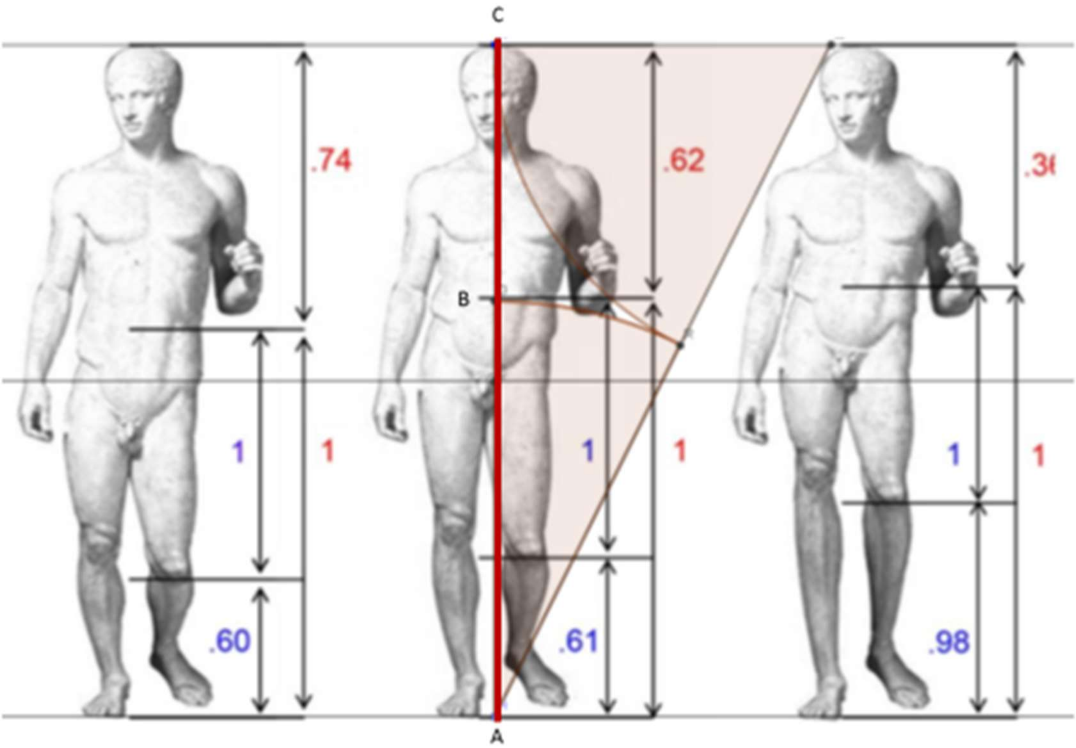
Figure 1. Example of canonical and modified stimuli. The original image (Doryphoros by Polykleitos) is shown at the centre of the figure. This sculpture obeys to canonical proportion (golden ratio = 1:1.618). Two modified versions of the same sculpture are presented on its left and right sides. The left image was modified by creating a short legs:long trunk relation (ratio = 1:0.74); the right image by creating the opposite relation pattern (ratio = 1:0.36). All images were used in behavioral testing. The central image (judged-as-beautiful on 100%) and left one (judged-as-ugly on 64%) were employed in the fMRI study.

doi:10.1371/journal.pone.0001201.g001

Box 36



Box 37



$$AC : AB = AB : BC = 1,618 \ldots.$$

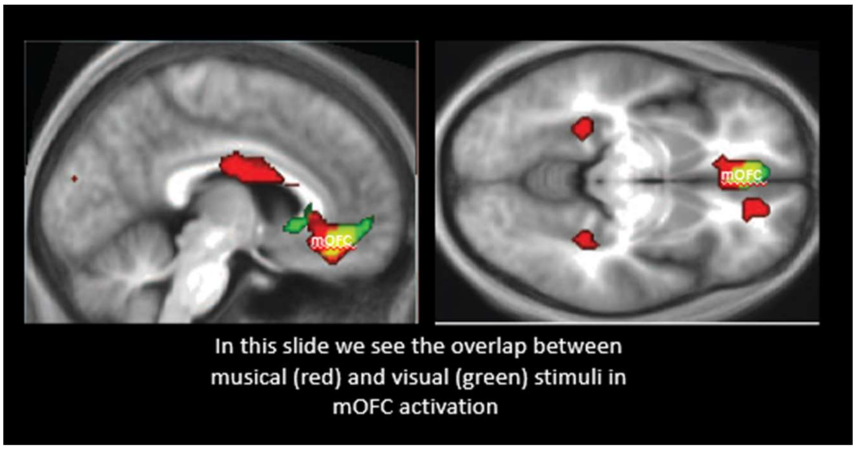
Box 38

Di Dio et al.'s results seem to indicate that the golden beauty is an objective and biological parameter that elicits activity in particular regions of the brain. Therefore, their results can be taken to illustrate what is meant by the *objectivist* view. However, this is not to say that this Italian group of researchers are pure objectivists when it comes to the question of beauty. It simply means that they have demonstrated how the golden mean affects beholders, that the golden mean seems to be universally and biologically determined.

The Subjectivist View

As we have already seen, the *subjectivist view* maintains that beauty is in the eye of the beholder, which means that taste cannot be debated.

In 2011, Semir Zeki's group in London documented that music and visual artworks, that are considered to be beautiful by subjects in a test group, in spite of the fact that what is beautiful for one person may be ugly for another, nevertheless will activate the same area in the brain, the area called the medial orbitofrontal cortex (mOFC). This has led the researchers to formulate a brain-based theory of beauty; I quote: 'Almost anything can be considered to be art, but only creations whose experience has, as a correlate, activity in mOFC would fall into the classification of beautiful art' (http://www.youtube.com/watch?v=NlzanAw0RP4). According to this definition of aesthetics, then, beauty is in the beholder's eye, which here actually means *the brain* of the beholder, within the structure of mOFC, localized frontally, towards the midline, right above the eyes and the orbits.

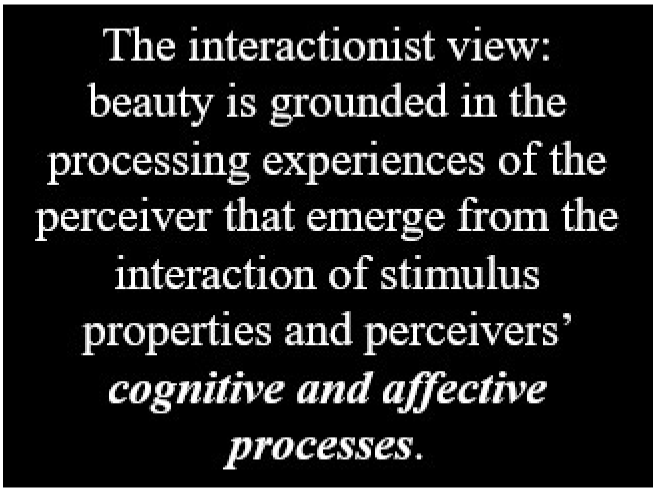


Box 39

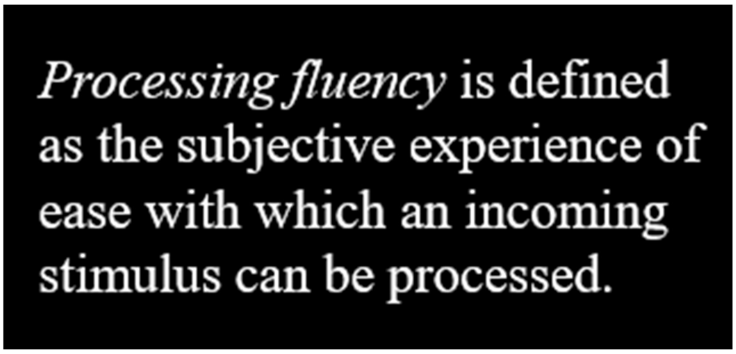
In Box 39 we see the overlap (yellow) between activation of mOFC as response to beautiful musical (green) and visual (red) stimuli. However, Zeki's position is not that there may be no objective criteria for beauty; what he argues is that if something is experienced (subjectively) as beautiful, the mOFC will be activated. This *universal* response to beauty may be regarded as an *objective* truth. The mOFC is part of our neurological reward network, and it is also a higher order cortex for smell and taste. This part of the brain is a phylogenetic old structure, and it is particularly significant in the life of lower animals.

The Interactionist View

In addition to the objectivist and subjectivist views of beauty, we have the so-called *interactionist* view, according to which beauty is grounded in the *processing experiences of the perceiver* that emerge from the *interaction of stimulus properties and perceivers' cognitive and affective processes*, in accordance with models deriving from gestalt psychology.



Research has documented that the feeling of pleasure in response to a stimulus is greater if the stimulus is easily processed, a process called *fluent processing*. *Processing fluency* is defined as the subjective experience of ease with which an incoming stimulus can be processed (Reber, Schwarz & Winkielman, 2004).



What increases the processing speed? The processing fluency increases if the stimulus is symmetrical[1] and if it has a high degree of contrast and clarity. Likewise, the processing fluency increases when we recognize the stimulus, ie if we have seen it before. We call it the mere exposure effect. The processing fluency will also be increased if the stimulus has been so frequently seen that it can be considered to be prototypical.

[1] In a Commentary to Wynn (2002), Reber (2002, p. 416) raises his doubts to the general opinion that the symmetrical hand axes were the result of the preference for symmetry *per se*. Contrary, the "preference for symmetry seems to be part of a broader preference for fluent processing of incoming stimuli".

The processing fluency increases if the stimulus is symmetrical and if it has a high degree of contrast and clarity.

Likewise, the processing fluency increases when we recognize the stimulus, i.e. if we have seen it before (mere exposure).

The processing fluency will also be increased if the stimulus has been so frequently seen that it can be considered to be prototypical.

An article by Piotr Winkielman et al. (2006) stresses precisely that prototypes are attractive because they are *easy on the mind*; our nervous system (Box 40) easily processes them.


Research Article

Prototypes Are Attractive Because They Are Easy on the Mind

Piotr Winkielman,[1] Jamin Halberstadt,[2] Tedra Fazendeiro,[3] and Steve Catty[2]

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ABSTRACT—*People tend to prefer highly prototypical stimuli—a phenomenon referred to as the* beauty-in-averageness *effect. A common explanation of this effect proposes that prototypicality signals mate value. Here we present three experiments testing whether prototypicality*

beauty-in-averageness effect is often theoretically explained as reflecting a biological predisposition to interpret prototypicality as a cue to mate value (Symons, 1979). For example, facial, as well as bodily, prototypicality may be predictive of current or prior health, lending individuals with a prototypicality prefer-

Box 40

Let us, for the sake of simplicity, take an example from everyday life: our preference for a familiar car model, the Volkswagen beetle (Box 41) with its classical round forms (Box 42).

Box 41

Box 42

In Box 42 we find a comparison between one of the newest models and an older one; the two forms demonstrate fairly well what is meant by prototypicality. So one of the reasons why Volkswagen, Fiat, or other successful car industries present their retro models is actually because we all have a preference for the prototypical, we want a car that resembles our beloved prototype.

We will now leave this discussion about objectivist, subjectivist and interactionist positions, to face another question, which has been hotly debated in modern art history: Is art foremost a stimulus for our cognitive processes, a position dominating in the art theory of the 20th century? For instance, the modernist art theoretician Clement Greenberg stressed the cognitive and analytical content of the pure picture plain. We hereby ask whether or not art has also a strong emotional impact? This question is among the subjects of the paper, 'Motion, Emotion and Empathy in Esthetic Experience', written by the art historian David Freedberg and the neurobiologist Vittorio Gallese (Box 43).

Opinion TRENDS in Cognitive Sciences Vol.11 No.5
ScienceDirect

Motion, emotion and empathy in esthetic experience

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The implications of the discovery of mirroring mechanisms and embodied simulation for empathetic responses to images in general, and to works of visual art in particular, have not yet been assessed. Here, we address this issue and we challenge the primacy of cognition in responses to art. We propose that a crucial element of esthetic response consists of the activation of embodied mechanisms encompassing the simulation of actions, emotions and corporeal sensation, and that these mechanisms are universal. This basic level of reaction to images is essential to understanding the effectiveness both of everyday images and of works of art. Historical, cultural and other contextual factors do not preclude the importance of considering the neural processes that arise in the empathetic understanding of visual artworks.

Introduction

> 'The painting will move the soul of the beholder when the people painted there each clearly shows the movement of his own soul...we weep with the weeping, laugh with the laughing, and grieve with the grieving. These movements of the soul are known from the movements of the body.' ([1], p. 80).

Although no consensus has been reached on how to define art, the problem of the nature of art (however so defined) has attracted the interest of cognitive neuroscientists who opened a field of research named 'neuroesthetics' [2,3]. Other attempts have been made to derive invariant universal perceptual rules to explain what art is, and what esthetic pleasures we derive from it, on the basis of psychophysical and neurocognitive knowledge of the visual part of the brain (see, for example, Refs [2,4–8]).

Here, we pursue a different strategy. First, we 'bracket' the artistic dimension of visual works of art and focus on the embodied phenomena that are induced in the course of contemplating such works by virtue of their visual content. We illustrate the neural mechanisms that underpin the empathetic 'power of images' [9] and show that embodied simulation and the empathetic feelings it generates has a crucial role (Box 1). Second, we address – within the same empathetic framework – one aspect of the effects of works of art, namely the felt effect of particular gestures involved in producing them.

Most spectators of works of art are familiar with feelings of empathetic engagement with what they see in the work itself. These feelings might consist of the empathetic understanding of the emotions of represented others or, most strikingly, of a sense of inward imitation of the observed actions of others in pictures and sculptures. These observations raise two questions: how relevant is empathy to esthetic experience, and what are the neural mechanisms involved?

Empathy in esthetic experience

We begin with examples of the ways in which viewers of works of art report bodily empathy. For instance, in the case of Michelangelo's *Prisoners*, responses often take the form of a felt activation of the muscles that appear to be activated within the sculpture itself, as if in perfect consonance with Michelangelo's intention of showing his figures struggle to free themselves from their material matrix (Figure 1). In looking at scenes from Goya's *Desastres de la Guerra*, bodily empathy arises not only in responses to the many unbalanced figures, where viewers seem to have similar feelings of unbalance themselves, but also in the case of the frequently horrific representations of lacerated and punctured flesh (e.g. Figure 2). In such instances, the physical responses seem to be located in precisely those parts of the body that are threatened, pressured, constrained or destabilized. Furthermore, physical empathy easily transmutes into a feeling of empathy for the emotional consequences of the ways in which the body is damaged or mutilated. Even when the image contains no overt emotional component, a sense of bodily resonance can arise. These are all instances in which beholders might find themselves automatically simulating the emotional expression, the movement or even the implied movement within the representation.

Simulation occurs not only in response to figurative works but also in response to the experience of architectural forms, such as a twisted Romanesque column [10]. With abstract paintings such as those by Jackson Pollock (Figure 3a), viewers often experience a sense of bodily involvement with the movements that are implied by the physical traces – in brushmarks or paint drippings – of the creative actions of the producer of the work. This also applies to the cut canvases of Lucio Fontana (Figure 3b), where sight of the slashed painting invites a sense of empathetic movement that seems to coincide with the gesture felt to have produced the tear.

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Available online 7 March 2007.

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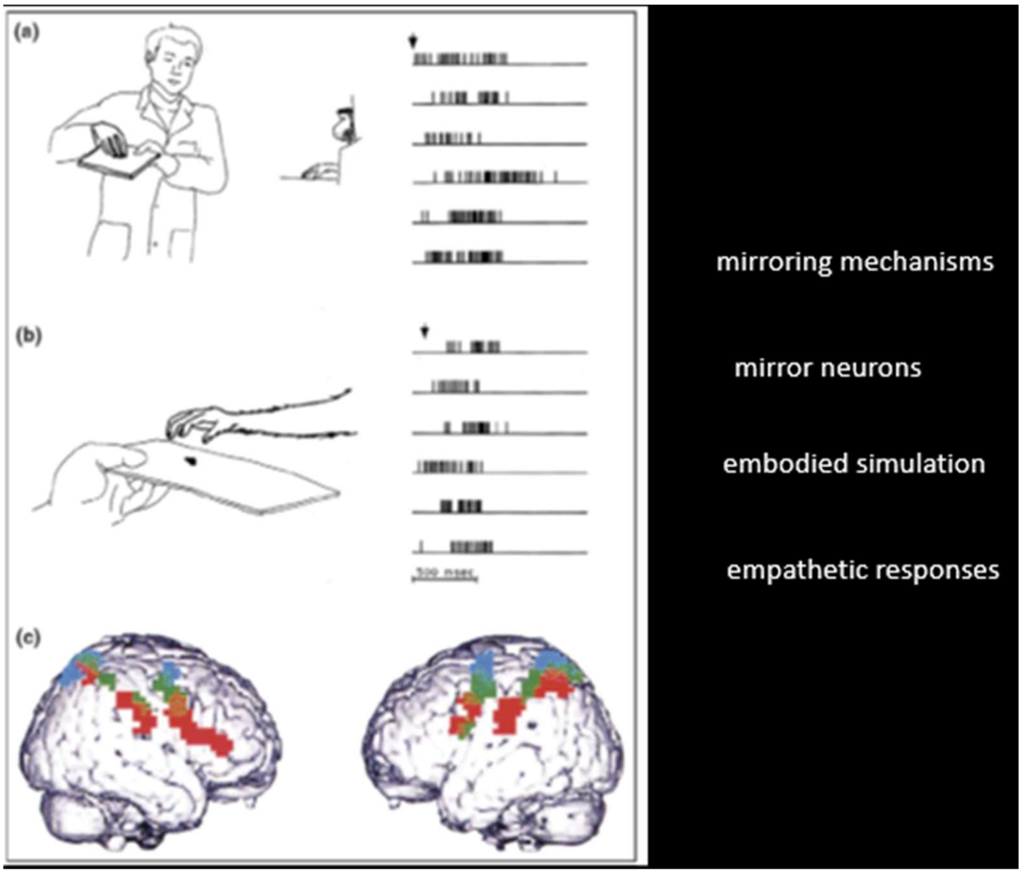
Box 43

Vittorio Gallese and David Freedberg address this issue and challenge the primacy of cognition in responses to art. They propose that a crucial element of aesthetic response consists of the activation of embodied mechanisms encompassing the simulation of actions, emotions and corporeal sensation, and that these mechanisms are universal.

An amazing discovery in neuroscience is the existence of the so-called *mirror neurons*. These nerve cells link *sensory* and motoric parts of the brain in a very particular manner, and they are found in monkeys as well as in humans. They respond to the visual input by activation.



Box 44

Box 44 illustrates a Macaque monkey looking at a man executing a grasping movement (a). In the brain of the monkey the mirror neurons are activated. The same neurons will also be activated ahead of a grasping movement done by the (grasping) monkey itself (b). The activation of the mirror neurons during pure observation of a movement will, however, not result in a real movement of the limb. What they do is react '*as if*' in movement (c). A most significant implication of the discovery of mirroring mechanisms is that the simulation of action by the mirror neurons, the embodied activation, leads to our understanding of a movement executed by others.

The mirror neurons can even interpret the final intention behind a movement, even when the concluding stages of the movement are hidden from vision. Significantly, this motoric understanding also leads to an activation of our emotional nerve networks, leading to empathetic responses to what we see, whether it is an action taking place here and now, or in a photo, or in a work of art (grasp whether this is true by looking at the image in Box 45). Vittorio Gallese and David Freedberg propose that a crucial element of aesthetic response consists of the activation of *embodied* mechanisms within the brain that are *simulating* actions, leading to corporeal sensations as well as emotions, and that these mechanisms are universal.

Box 45

Embodied simulation in esthetic experience: empathy for pain. The
viewing of images of punctured or damaged body parts activates part of the same network of brain centers that are normally activated by our own sensation of pain, accounting for the feeling of physical sensation and corresponding shock upon
observation of pressure or damage to the skin and limbs of others. Goya, Que hay
que hacer mas? (What more is there to do?), plate 33 from Los Desastres de la
Guerra (Disasters of War), etching, Biblioteque Nationale, Paris, France

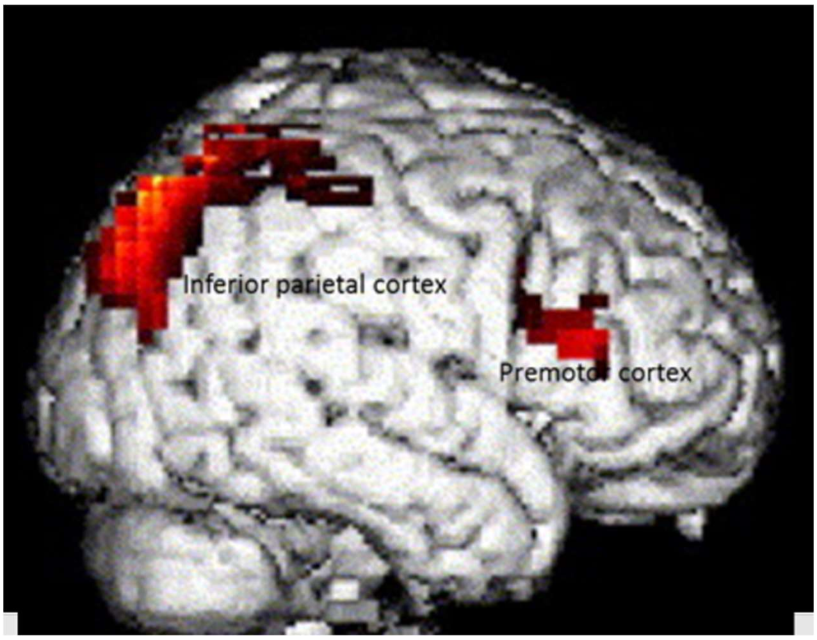
Embodied simulation in aesthetic experience will also explain our empathy for pain. As one of their examples, Freedberg and Gallese point to Goya's etching from *Los Desastres de la Guerra* (Disasters of War: Biblioteque Nationale, Paris, France) (Box 45). The viewing of images of punctured or damaged body parts activates part of the same neural network of the brain that is normally activated by our own *sensation* of pain. This accounts for the feeling of physical sensation and corresponding shock upon observation of pressure or damage to the skin and limbs of others, as in the very dramatic art performance captured in the image in Box 46.

Box 46

But they will also be activated when a ballerina watches the movements of another ballerina. The mirror mechanisms are localized in the *prefrontal cortex* and also in the *inferior parietal cortex*, as you can see on the brain image in Box 47.

Can we mirror the movements of others also when we simply see traces of these movements, as, for instance, in the paintings of Jackson Pollock that reflect the painter's dancing movements as he simulated Indian dance during the very act of painting? Or, to put it in another way: *Does one feel the movement of brushstrokes when looking at the completed work?* Vittorio Gallese proposes 'that even the artist's gestures in producing the artwork induce the empathetic engagement of the observer, by activating simulation of the motor program that corresponds to the gesture implied by the trace.' Gallese stresses that '*despite the absence of published experiments on this issue, the mirror-neuron research offers sufficient empirical evidence to suggest that this is indeed the case*' (Freedberg & Gallese, 2007, p. 202).

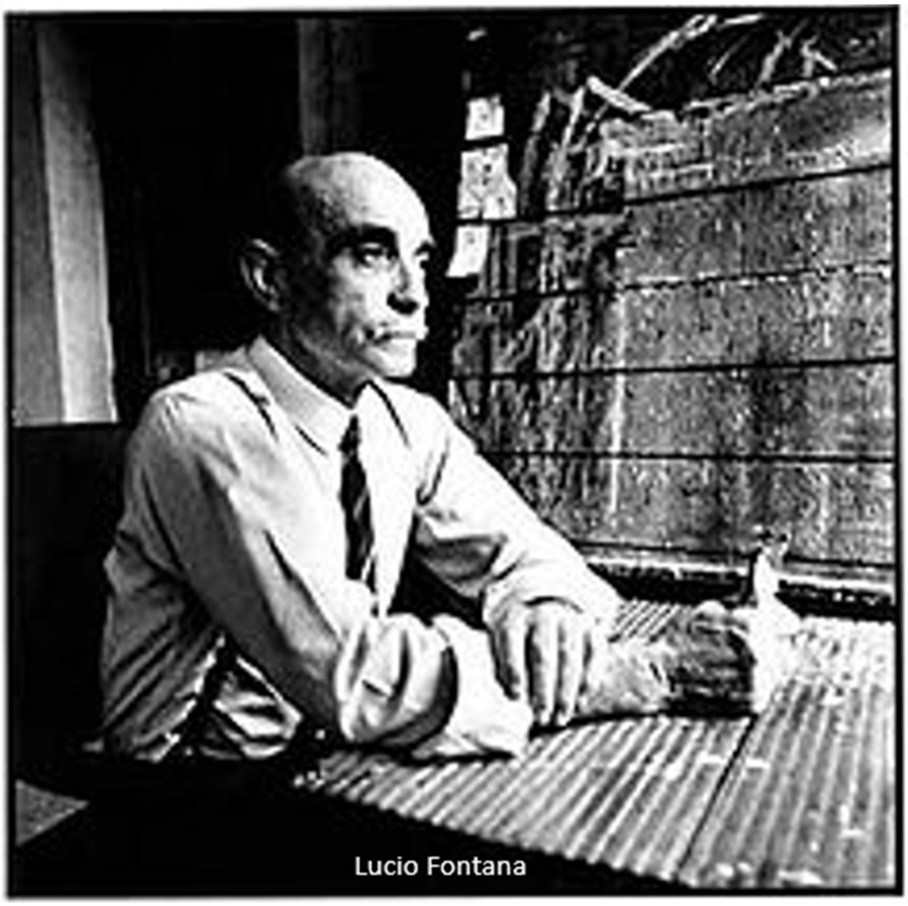
What about the pierced canvases of Lucio Fontana (Box 49)?



Box 47

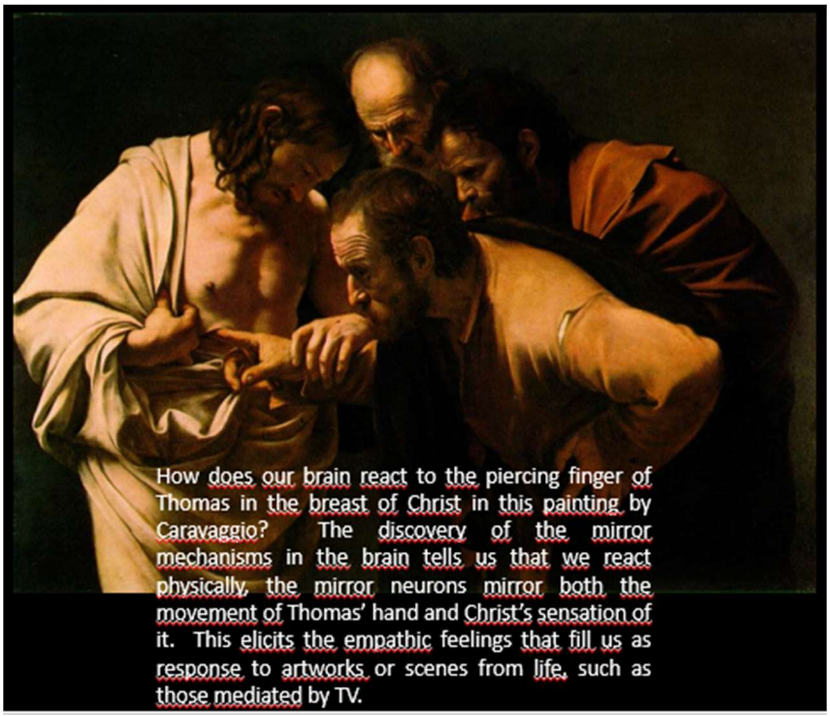
How do we react to the pierced canvases of Lucio Fontana?

Lucio Fontana, Concetto Spaziale (1960). Tate Gallery, London.



According to the mirror neuron data collected from other experiments, and in line with Freedberg & Gallese's (2007) arguments, it seems reasonable to suppose that neurons in the mirror system will activate, as if they were part of the motor act of cutting the canvas, in spite of the fact that the beholder stands still, merely looking at the artwork, not moving as little as a finger. This is now proved experimentally.

Box 49



Box 50

Moreover, how does our brain react to the finger of Thomas piercing the breast of Christ in this painting by Caravaggio (Box 50)? The discovery of the mirror mechanisms in the brain tells us that we react physically, the mirror neurons mirror the movements, those of Thomas, as well as the imagined *sensory* reaction of Christ; moreover, the mirror mechanisms are not isolated. In the dynamics of the brain, the activation of the mirror neurons will also lead to activation of emotional centres. Hence, observed motion will lead to emotion, and empathy (Freedberg & Gallese, 2007).

In this introductory lecture we have focused on different ways to define what beauty is, and discussed the objectivist view, the subjectivist view, and the in-between standpoint – the so-called interactionist view. Whether we prefer one of these views above the others, or adopt an intermediate position, we will ultimately have to deal with the fact that the sense of beauty involves our neurons, neuron networks, rewarding mechanisms, mirroring mechanisms, etc. Moreover, each region communicates with other regions by means of neural connections, for instance those complex interactions linking the cognitive and the affective and emotional neural mechanisms of the brain. Let us close by welcoming you to this new and fascinating discipline, neuroaesthetics, in the hope that you will find the journey ahead as exciting as we do!

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