Neuroaesthetics, lecture 3, 27.09.13:

Neuroanatomical structures in aesthetic preference.

In this lecture we will take a closer look at four pioneer studies in Neuroaesthetics. We will again encounter the question whether there are objective criteria for beauty, or whether nothing about beauty can be discussed.

The articles are:

*O. Vartanian and V. Goel, ”Neuroanatomical correlates of aesthetic preference for paintings”, *NeuReport*, Vol 15 9. April 2004, pp. 893-897

*H. Kawabata, S. Zeki, “Neural Correlates of Beauty”, *Journal of Neurophysiology* 91,
2004, pp. 1699-1705. http://jn.physiology.org/content/91/4.toc

T. Ishizu, S. Zeki, “Toward a Brain-Based Theory of Beauty”, *PLoS ONE* 6 (2011), e21852.

*C.J. Cela-Conde, G. Marty, F. Maestú, T. Ortiz, E. Munar, A. Fernandéz, M. Roca, J. Roselló, F. Quesney, “Activation of the Prefrontal Cortex in the Human Visual Aesthetic Perception”, *Proc. Natl. Acad. Sci*. U.S.A. 101 (2004), pp. 6321-6325 (available online). http://www.pnas.org/content/101/16/6321.full.pdf+html

*T. Jacobsen, R. I. Schubotz, L. Höfel, D. Yves v. Cramon, “Brain correlates of aesthetic judgment of beauty” *NeuroImage* 29 (2006) pp. 276-285.

C.J. Cela-Conde, L. Agnati, J.P. Huston, F. Mora, M. Nadal, “The Neural Foundations of Aesthetic Appreciation, Progress in Neurobiology 94 (2011) pp. 39-48 (available online).

Before we go to the individual studies, however, we will give a brief presentation of some neuroanatomical structures in the brain that will stand central in these studies. These are brain areas localized within the prefrontal cortex and in the so called limbic system, our emotional nerve network.

(NEXT) In short, the prefrontal cortex is involved in complex cognitive processes, decision making, planning and execution of behavior, judgment processes about what is right or wrong, socially acceptable, morally good etc.

(NEXT) The limbic system is the set of brain structures that forms the inner border of the cortex. Paul Broca described this part of the brain *il grand lobe limbique*: the great limbic ring: cortex cinguli, hypothalamus, the anterior nuclei of thalamus, and the hippocampus form what is called the "classic limbic ring".

(NEXT) In the 1930s it was James Papez who first put forward the hypothesis that these structures were organized as a system of emotions. The limbic system was therefore also called "Papez circuit".

After these pioneering works, there has been intensive research on this system:

the **(NEXT)** amygdala, a network of nerve cells located anteriorly, i.e. in front of hippocampus is now considered to be one of the key structures of the limbic system, which moreover include the orbitofrontal cortex, the temporal pole, and parts of the basal ganglia, nuclei, or cell clusters located deep within the brain. Added to this, the cortex insula is included in the limbic system.

Or we can also present it **(NEXT)** in a way that more clearly show the difference between the phylogenetic new neocortex, and the phylogenetic elder paleocortex and archicortex. Within the neocortex we find the sensory, motoric, as well as the so called association areas.

As we go to the limbic system we find that the **(NEXT)** paleocortex includes the **(NEXT)** cortex cinguli, which clearly delineates the superior part of the limbic ring.

Moreover, we find the **(NEXT)** parahippocampal gyrus, encapsulating the hippocampus, and which contains areas for location and recognition of places, the so called parahippocampal place area.

(NEXT) Also the insula is a part of the paleocortex. Both cortex cinguli and the insula are activated during feeling of disgust, but also, in some cases, during feeling of pleasure, such as aesthetic pleasure. Disgust and pleasure activate, however, different parts of the cingulate cortex and the insula. Those of you following my first lecture may remember that the golden beauty in sculptures activated the insula.

(NEXT) The role of the *orbitofrontal cortex* in beauty judgments, as recorded in the fMRI scanner, has particularly been stressed by Kawabata & Zeki. We will soon turn to their study in detail.

Moreover, Nakamura *et. al.* (1998) has found a correlated increased activation of the orbitofrontal cortex in a study where male subjects made positive attractiveness judgments of female faces.

Another study of orbitofrontal cortex activation as response to faces was presented in my last lecture: Here it was the activation of orbitofrontal cortex and the insular cortex as response to the rating of attractiveness and goodness of faces. Faces that we rate as attractive will also be rated as good, and the more attractive, and good the rating is, the more is the activation of the orbitofrontal cortex. The inverse relationship for the insular cortex (T. Tzukiura and R. Cabeza, Shared Brain Activity for Aesthetic and Moral Judgments: Implication for the Beauty-is-Good stereotype SCAN (2011) 6, 138-148).

The **(NEXT)** archicortex is foremost represented by the extremely interesting structure, the hippocampus, which is a part of the classical limbic ring, and has a significant function in long time memory. In these slides **(NEXT) (NEXT) (NEXT)** you can see a section of the hippocampus with its one layer of cells, as opposed to the 6 layers found within neocortex.

How have these structures evolved? **(NEXT)** To answer this question we will take a closer look on the differences between the brains of amphibians, reptiles, primitive Mammalia, and progressive Mammalia, including the primates, to which we belong.

In the modern amphibians **(NEXT) (NEXT)** the gray matter is located deep to the brain surface, and consists of the so called basal nuclei (b), the paleocortex (p), and the archicortexarchicortex (a);

(NEXT) In a more progressive stage (C) the basal nuclei has moved inwards, and are located on the lower, or ventral, side of the brain.

(NEXT) In E, you can see a primitive mammalian stage, where the neocortex occupies the superior surface of the brain, separated from the paleocortex by the rhinal fissure. The ventrally located paleocortex becomes a primary olfactory cortex.

(NEXT) The archicortex is folded to become the hippocampus.

(NEXT) In advanced Mammalia (F), like the primates, the neocortex covers almost all the brain surface, and has become strongly folded.

(NEXT) Dorsomedially, we can recognize that the archicortex as the folded hippocampus.

The majority of studies in the fields of Neuroaesthetics are scanner *recordings* of immediate brain activation as a response to the viewing of artworks, and these observations are being compared with the reported *experiences and/or judgments* of beauty or ugliness by each individual subject.

Please mind the difference between *passive* experience of beauty and the aesthetic *judgment* task *per se*! In the aesthetic judgment, the question to be answered is the following: is this artefact beautiful or not?

We will primarily focus on the **(NEXT)** fMRI scanning method and its results. fMRI scanning is a neuroimaging technique that detects small changes in brain activity under certain conditions, which will always entail a change from one state to another. Hence, the brain dynamic which is recorded by the scanner is a result of the subjects' experience with contrasting stimuli presented in succession

(NEXT): *situation 1* versus *situation 2*. This is also called cognitive subtraction. It starts with a baseline condition, such as a passive viewing of a fixation cross. Then comes the experimental condition, for instance passive viewing of written words. This contrasting situation will result in a visualization of brain regions used for recognizing words.

Next, this will then function as the baseline condition for the next experimental condition which can be a reading of the written words. So in this contrast the scanner will illustrate which areas are activated during saying of words.

Finally, this will become the baseline condition for a new experimental setting where the subjects are asked to produce meaningful words, for instance to sayeat as a response to the picture of a cake.

An increase in activity within a particular brain area, will result in extra oxygen consume within that particular area.

Immediate drop in oxygen level will, however, be followed by an automatic dilatation of the small arterioles within this area, resulting in a surplus blood flow to the active area.

The fMRI scanner detects the difference in oxygen level within small brain cubes (say 3 *times* 4 *times* 6 mm) called voxels (comparable to pixels in the photo technology), calculating the difference between the activated and deactivated state within that particular voxel. The level of activity will be displayed on a computer screen, where the most active areas (the “hottest voxels”) are labeled with a particular colour, those of lesser activity with another colour. No activity change will generate no colour change on the display.

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Let us now take a closer look on the four pioneer studies in neuroaesthetics:

Common for the fMRI studies by **(NEXT)** Kawabata and Zeki, and **(NEXT)** Vartanian and Goel, both in 2004, and **(NEXT)** Jacobsen *et alii* in 2006, is that they demonstrate increased activity along with increased preference in the *limbic system* associated with *positive affect* and *reward* mechanisms: **(NEXT)** the orbitofrontal cortex (BA11) (Kawabata & Zeki), **(NEXT)** the anterior cingulate sulcus (BA32), the caudate nucleus (Vartanian & Goel), and the **(NEXT)** temporal pole (BA38) (Jacobsen *et al*.). This clearly underlines how aesthetic pleasure is processed within the neural networks for reward and emotion, within the limbic system.

In 2004, the same year when Kawabata and Zeki, and Vartanian and Goel published their results, **(NEXT)** Camillo Jose Cela-Cone *et alii* in Palma, Majorca, used the so called magneto-encephalography technique (MEG) to demonstrate that an activation in the prefrontal cortex precedes the activation in the emotional networks.

While the changes in blood flow recorded in fMRI takes 4-7 seconds to stabilize, the magneto encephalogram technique is sensible to changes taking place within milliseconds. Cela-Conde et alii were therefore able to demonstrate that a *conscious* activation in the cognitive systems precedes the emotional reaction detected by fMRI.

I quote from their abstract: **(NEXT)** Here we report the results of an experiment carried out with magnetoencephalography (MEG) which shows that the dorsolateral prefrontal cortex is selectively activated in humans during the perception of objects qualified as "beautiful" by the participants. Therefore, aesthetics can be hypothetically considered as an attribute perceived by means of a particular brain processing system, in which the prefrontal cortex seems to play a key role - end of quotation.

The study by Jacobsen *et al*. differs from all of the others studies that we concern here by the fact that their experimental paradigm enabled them to tap into the process of making *aesthetic judgments*: my judgment is that this artwork is good, or that it is ugly. This showed them that the neural networks for the aesthetic *judgment* task overlap with those working during moral and social judgments. The aesthetic judgment is a cognitive process relying on a network of reasoning; this network is localized within the prefrontal cortex, in BA9 and BA10.

A comparison between the four studies referred to above will underline how neural processing of aesthetics includes *affective* mechanisms, those activating limbic areas leading to *felt emotions*, as well as *cognitive* mechanisms involved in the *judgment* of beauty.

This is in full agreement with the model **(NEXT)** proposed by H. Leder *et al* (2004); in this model on brain activation in response to visual art, primary *perceptual* analysis leads, through implicit *memory* and classification, to *cognitive* mastering. Parallel to the cognitive analysis stream a *continuous affective evaluation* runs with reciprocal connections to the cognitive path. The two streams ultimately lead to an affective state, respectively cognitive judgment state of evaluation.

(NEXT) Kawabata and Zeki (2004) studied the neural correlates of beauty, i.e. what happens when we experience aesthetic pleasure. Let us briefly consider what is meant by *neural* correlates of *beauty*. The title of their paper tells us that the study investigates which neural mechanisms are activated as a response to the *experience* of beauty. Hence, it is *not a question of an aesthetic judgment* task per se. Kawabata and Zeki used fMRI technique, i.e. they let their subjects view the stimuli, paintings of different categories, while they were in the fMRI scanner.

Prior to scanning each subject had to view a large number of paintings and to rate them on a scale from 1 to 9. Scores of 1-4 were classified as “ugly”, 5-6 “neutral”, and 7-10 “beautiful”. They then viewed the same paintings in the scanner.

Before going into the neuroimaging data on the reactions to the beautiful versus the ugly and neutral, we will see that perception of different categories of paintings is associated with distinct and specialized visual areas of the brain. The four categories were portrait, landscapes, still-life and abstract paintings.

As previously noted, the fMRI scanner records the changes in brain activation from one condition to the next, reflected in the blood oxygen level changes within each voxel. This is the so called blood oxygen level dependent signal, or simply BOLD signal.

(NEXT)*Portraits vs. non portraits* gave activation in the fuciform cortex in Broadman's area 37 (BA37) within the temporal lobe. The exact locus for activation was the so called *fuciform face area,* known to respond to faces in general.

(NEXT) The contrast *landscape vs. non-landscape*, activated the so called *lingual gyrus*, which extends anteriorly within the temporal lobe in close connection to the hippocampal gyrus. The "hottest" voxels were found within the so called *parahippocampal place area*, used for orientation in space, connected with memory inputs from the hippocampus.

(NEXT) Contrasting *still lives with non-still lives* gave response in the extra striate visual cortex, within the part called V3. There were no signal changes following a contrast between abstract and non-abstract.

Kawabata and Zeki then contrasted BOLD signal changes for all categories of paintings (landscape, portrait, still-life and abstract) as measured on a scale from beauty to ugliness.

The following conditions were contrasted:

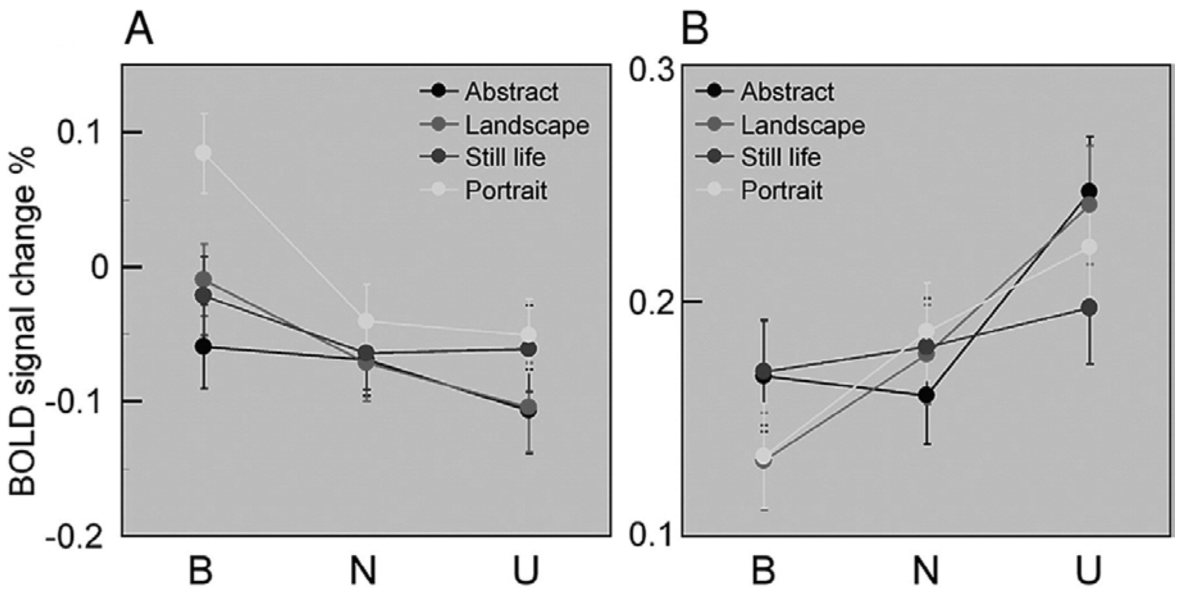
A contrast of **(NEXT)***beautiful vs. ugly* produced activity in the medial orbito-frontal cortex (BA11) alone. **(NEXT)**

Contrasting *beautiful versus neutral* produced **(NEXT)** activity in the orbito-frontal cortex (BA11) and also in the cingulate gyrus (BA32) and left parietal cortex (BA39). **(NEXT)**

A comparison of *ugly vs. beautiful* **(NEXT)** produced activity in the motor cortex (BA4) bilaterally, i.e. in both hemispheres **(NEXT)**. The contrast ugly versus neutral produced no relative activations.

As you can see in the diagram **(NEXT)** (quotation from article):"parameter estimates show that it is actually the change in <u>relative activity</u> in *the orbito-frontal cortex* that correlates with the judgment of beauty and ugliness. Much the same pattern, though in reverse order, is characteristic of the motor cortex", end of quotation (Kawabata and Zeki, 2004).

The more ugly, the less the activation of the OFC: inversely, the more ugly the more activation of motorcortex. One can ask wheter this has evolved in this way to enable us to run away from what is ugly.



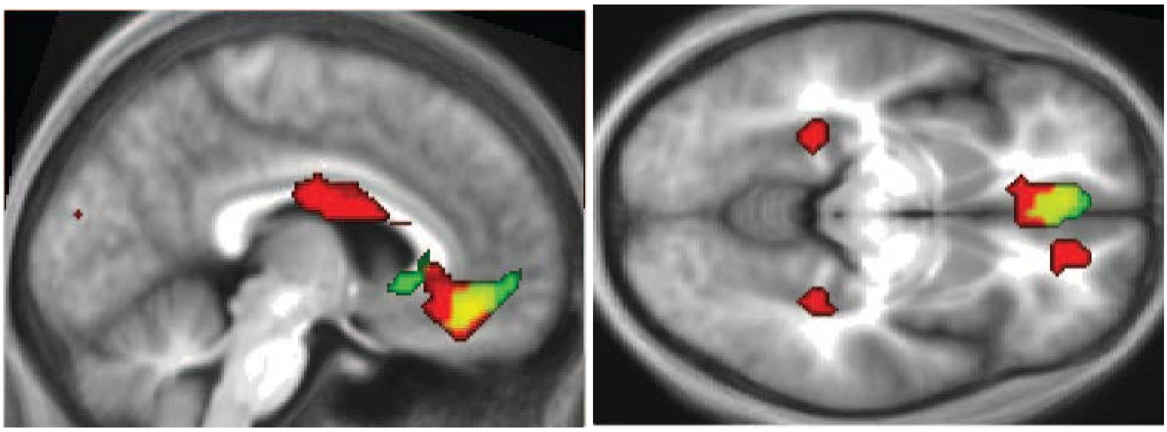
Orbito-frontal cortex (BA11)　　　　Motor cortex (BA4)

In a recent contribution **(NEXT)** with the title "Toward a Brain-Based Theory of Beauty", T. Ishizu and S. Zeki, ask whether different kinds of aesthetic stimuli activate different areas of the brain. Their experimental paradigm resembles that used by Kawabata and Zeki (2004) in that the subjects, prior to scanning, rate different painting categories and music styles.

In the scanner, the subjects are not required to make any judgments; they shall just look at the paintings and listen to the music: this means that it is not the cognitive task of aesthetic judgment that is recorded in the scanner. So what is recorded then?

The scanner records the areas that are activated as a response to the aesthetic pleasure. Ishizu and Zeki documented that music and visual artworks that by each person are considered to be beautiful (subjective beauty) activates the same area in the brain: the medial orbitofrontal cortex (mOFC) (BA11).

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» - end of quotation. (cf. also http://www.youtube.com/watch?v=NlzanAw0RP4).



(NEXT) On this slide you can see the overlap within mOFC between the activation as response to music (red) and to visual artworks (green).

The studies by Semir Zeki's group document the reactions to aesthetic pleasure within each subject. What one person like may differ considerably from what is beautiful for another. Hence, this may be said to mirror the so called subjectivist view in aesthetics: It maintains that taste cannot be debated: beauty is in the eye of the beholder, or, reformulated: beauty is in the brain of the beholder.

Mind, however, that it is not Zeki's position that there are no objective criteria for beauty; what he says, however, is that if something is experienced as beautiful, the mOFC will be activated. The OFC is part of our nerve network for reward, and it is also a higher order cortex for smell and taste. This corresponds to the fact that this part of the brain is a phylogenetic old structure, and that it is particularly significant in lower animals.

This point is also stressed by Steven Brown and Ellen Dissanayake, I quote: " The orbitofrontal cortex is one of the few areas that show consistent responsiveness to objects of both positive and negative valence. The orbitofrontal cortex is perhaps primarily a higher-level sensory cortex for smell and taste, serving as a secondary olfactory and gustatory cortex. …The importance of the *orbitofrontal cortex* for the appreciation of art objects like symphonies and sculptures may derive evolutionarily from the function of this part of the cortex in making appraisals of the olfactory and gustatory properties of food sources […]. " end of quotation.

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As in the study by Kawabata and Zeki, **(NEXT)** Oshin Vartanian and Vinod Goel (2004) investigated rating of paintings as *aesthetic preference* as viewed in the f-MRI scanner. **(NEXT)** Their results document rating according to a first-person point of view: The design allowed one to gain access to people's *subjective states of experience* by asking them how much they liked the painting.

-The most significant question in this study is whether aesthetic preference in art is characterized by a *cognitive stance,* or whether it is underwritten by an *emotional response* towards properties of artworks?

-The thesis is that if aesthetic preference is mediated by emotion, then it should involve brain structures that have been implicated in processing emotion (e.g. structures in the limbic system); otherwise, if aesthetic preference was primarily a cognitive process, then it should involve brain structures that have been implicated in evaluation under emotional neutral conditions.

The data **(NEXT)** demonstrate that activation in cortical structures implicated in processing *emotion* or *reward* co-varied as a function of *preference rating*; particularly important is the activation of the *caudate nucleus* and the *cingulate sulcus*, structures included in the limbic system.

f-MRI data corresponding to positive evaluation : **(NEXT)** this is beautiful activates the left *cingulate cortex*. The more ugly the paintings were rated, the lesser the activity **(NEXT)** within right *nucleus caudatus.*

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We will return to the study by **(NEXT)** Thomas Jacobsen et *alii*. in Leitpzig, Brain Correlates of Aesthetic Judgment of Beauty. "fMRI was used to investigate the neural correlates of aesthetic *judgments* of beauty of geometrical shapes. While they were in the scanner, participants performed evaluative aesthetic judgments (beautiful or not?) on the stimulus material. Symmetry was employed because aesthetic judgments are known to often be guided by criteria of symmetry.

(NEXT) Novel abstract graphic patterns were presented (instead of paintings) to minimize influences of attitudes of memory-related processes, such as subjective interest in the artworks, economic considerations on how much the works of art are worth in money etc. To switch over to abstract patterns is, hence, in terms with Immanuel Kant's definition of aesthetics: that it shall be disinterested, having nothing to do with desires to own, to sell etc.

The experimental setting is illustrated by **(NEXT)** this figure.

Behavioral results confirmed the influence of symmetry and complexity on *aesthetic judgments*: the more symmetric and more complex the stimuli are, the more beautiful were they judged to be.

Aesthetic judgment versus symmetric judgment resulted in strong activation within the **(NEXT)** frontomedian cortex (BA9/10) …, posterior cingulate cortex (BA23), left temporal pole (BA38) ….

(NEXT) In contrast, *symmetry judgments vesrsus aesthetic judgments* elicited specific activations in parietal and premotor areas, areas doing spatial processing tasks.

Interestingly, the judgment: this is beautiful enhanced BOLD signals not only in the frontomedian cortex (BA10), but also in the left *intraparietal sulcus* (BA7) of the symmetry network.

These findings indicate **(NEXT)** that aesthetic judgments of beauty rely on a network partially overlapping with structures underlying evaluative judgments of social and moral cues and substantiate the significance of symmetry and complexity for our judgment of beauty" (quoted from T. Jacobsen, "Neuroaesthetics and the Psychology of Aesthetics" in M. Skov and O. Vartanian (eds.) *Neuroaesthetics*, pp. 27-42: 39).

The evidence from Jacobsen *et al*. (2006) is in accordance with the results obtained from other studies. According to Zaidel and Nadal, "Neuroscience is now in a position to add to the centuries-old debates about beauty and the morally good in people, their actions, and objects, by showing that the bond between beauty and good may reside in the intimate neurobiological and evolutionary relations between the mechanisms we rely on to asses these values" (D.W. Zaidel and M. Nadal, "Brain Intersections of Aesthetics and Morals. Perspectives from Biology, Neuroscience, and Evolution", in *Perspectives in Biology and Medicine*, volume 54, number 3, 2011, pp. 367-380: 377).

In Antiquity and the Middle Ages, beauty, goodness and truth were conceived as almost interchangeable terms; hence, the link, demonstrated within the neurosciences, between beauty judgments and the moral judgments calls to mind the Greek *kalokagathìa*, the good and the beautiful combined, an aesthetic principle in Ancient Greek art as well as in Christian art of the Middle Ages (U. Eco, 1986, pp. 20-21).

It is, however, not possible to pinpoint exactly what kind of beauty is denoted by *kalokagathìa*. In Antiquity it mostly signified a unity of bodily sensuous beauty and morality, while the Christian Middle Ages moved from bodily beauty to the beauty of the soul, i.e. that the most beautiful person had the most beautiful soul.

As we have seen, modern studies on facial attractiveness clearly demonstrate that a physically attractive person generally will be regarded more positively then a non-attractive one. And we have seen how the goodness and beauty ratings confer to level of activity within the orbitofrontal cortex.

Needless to say, the close connection between our judgments of beauty and the morality judgments has some real frightening consequences. The physically attractive are considered to be more intelligent, better leaders, to have a stronger social integrity, to be better politicians, and professors. Indeed, physically attractive people are perceived both more <u>*positively*</u> and more <u>*accurately*</u> then those less attractive (Lorenzo *et. al*. 2010). It has even been demonstrated that physically attractive children are treated much better by the teachers in school than those that are not attractive.

To sum up

The neural processing of aesthetics includes *affective* mechanisms activating limbic areas, leading to felt emotions, as well as *cognitive* mechanisms involved in an objective judgment of beauty. In this model on brain activation in response to visual art, the primary perceptual analysis leads through implicit memory and classification to cognitive mastering.

Common for the fMRI studies by Kawabata and Zeki (2004), Vartanian and Goel (2004), and Jacobsen *et al*. (2006), is that they demonstrate increased activity along with increased preference in limbic structures associated with positive affect and reward mechanisms: the orbitofrontal cortex (Kawabata & Zeki), the anterior cingulate sulcus, the caudate nucleus (Vartanian & Goel), and the temporal pole (Jacobsen *et al*., 2006).

On the other hand, a MEG study by Cela-Conde *et al.*(2004) demonstrates increased activation within dorsolateral prefrontal cortex (dlPFC: BA10) when subjects viewed artworks judged as beautiful as compared to not-beautiful. Jacobsen *et al*. (2006) were able to demonstrate that the ´hottest` voxels for the judgment *beautiful versus ugly* were found in the medial dorsal premotor cortex within BA 10. The results from Jacobsen *et al.* and from Cela-Conde *et al.* (2004) correlate with the role assigned to the dorsal PFC in processing of information from external stimuli (Cela-Conde *et al*., 2011, p. 9).

The findings in the study of Jacobsen, that the aesthetic and moral judgments share neural substrate is very interesting. It has newly (February 2013) been published an article from M.

Avram and collegues in Munic, facing the same question. In this fMRI study, one-line verses from poems and short moral statements were used as stimuli. Their results suggest a common basis for the two judgment categories, revealing comparable neural networks mainly the orbitomedial prefrontal cortex. However, additional activations were found in the moral judgment condition, that is, in the posterior cingulate cortex, the precuneus, and the temporoparietal junction. These regions have been related to understanding the minds of others.

It can be concluded that neurocognitive research shows results indicating that certain objective factors may determine what we judge as beauty. In my first lecture we saw that Cinzia Di Dio *et alii.*(2007) demonstrates that the golden mean may be such a factor; that symmetry is also an objective factor is demonstrated by Jacobsen *et alii* in Leiptzig

On the other hand Semir Zeki's group has demonstrated that the *mediale orbitofrontal cortex* is activated when subjects find something beautiful, whether it is so called popular art or classical art, visual as well as music (Kawabata anbd Zeki 2004; Ishizu and Zeki 2011).

Finally, when it comes to the interaction of subjective and objective criteria for beauty, we can, for instance, say that a symmetric stimulus which is found to be beautiful, will activate the medial orbitofrontal cortex. We find it beautiful because of the objective criterion: symmetry.

Moreover, a symmetric stimulus is also more easy to conceive, it is easier on the mind: our nervous system is processing it more fluent. Hence, a symmetric stimulus leads to increased *processing fluency*, and a subjective feeling of pleasure. Some studies on processing fluency involves fMRI. It is interesting that also in these studies, it is the OFC that shows activation, here when a stimulus is being fluently processed.