Neuroaesthetics, lecture 5, 02.10.13. Aesthetics and cognition in an evolutionistic perspective

In this lecture we will focus on the evolution of cognition. We will concentrate on neural structures involved in advanced cognitive tasks, as well as those activated during states of emotions - for instance the neural networks involved in aesthetic pleasure. We will draw on what we know about evolution of our brain structures and neural networks, as compared to archeological material that clearly shows traces of cognitive behavior and artistic production **(next)**.

The most astonishing archaeological records of art production is the Upper Paleolithic cave paintings of Southern Europe, most of them in France and on the Iberian Peninsula, dated from about 40.000 to about 15.000 years BP. The paintings which you can see here are from the Lasceux cave in Dordogne, France, painted about 10 to 15.000 years ago. We will, however, first take a brief regard on the evolution of our hominine ancestors until the art producing *H. sapiens* of Upper Paleoliticum.

About 90 million years ago **(next) (next)**, *anthropoids* and *prosimians* evolved as separate lines from a common ancestry among the so called *early prosimians*. The anthropoids were then split into four families: These were the **(next)** Old World monkeys, **(next)** New World monkeys, **(next)** Lesser apes, and **(next)** Great apes; the Great Apes includes our own species, the *Homo sapiens* as well as gorilla and chimpanzee. The splitting into these four families took place at about 40 million years ago **(next)**.

Fossil remains and molecular data indicate that the first of our human ancestors appeared about 6 or 7 million years ago, somewhere in the African continent. The earliest specimens have been attributed to three different species. These are: **(next)** *Sahelanthropos tchadensis,,* named tchadensis since it was discovered in Tchad **(next)** *Orrorin tugenensis*, and **(next)** *Ardipithecus ramidus* (4,4 million years before present (BP).

(next) as you can see in the reconstructed morphological traits of Ardipitecus ramidus, the medially located toe is separated from the other toas, an adaptation to climb in trees.

Given the fragmentary state of these remains, and the difficulties inherent in their comparison, there is, however, much discussion among the researchers as to the exact validity of their hominid status (M. Nadal, M. Capó, E. Munar, G. Marty, and C.J. Cela-Conde, 2009).

On the other hand, a study of the cranial features of Sahelanthropus, will seem to indicate that Sahelanthropus was bipedal. In this slide, **(next)** deriving from a publication by Christoph Zollikofer *et allia* and published in Nature 2005, you can see the angle between the plane of scull base and that of the orbital plane in **(next)** human, in **(next)** Chimpanzee, in **(next)** Australopithecus and in **(next)** Sahelanthropus.

In primates, the upper cervical vertebrae are oriented approximately 90 degrees to the plane of the scull base. As you can see the axis of vertebrae is almost parallel to the vertical plane in human **(next)** as well as in **(next)** Sahelanthropus.

This is very different from the situation in **(next)** Chimpanzee, which indicate that Sahelanthropus may have been able to walk on two feet.

The earliest *undisputed evidence* of completely bipedal hominids is close to 4 million years old when **(next) …** **(next)** the Australopithecus was the dominating species: *A. anamensis* and *A. afarensis* specimens are found in East Africa.

Until fairly recently, hominid evolution was conceived as a straight line where the different species did follow each other.

In the Kenyan Koobi Fora site, however, it was, by the end of the 1970ies, found new fossil remains that proved the existence of three different species with strongly deviating morphological traits living at the same time.

This shows that the evolution does not follow a single path; it surely followed *parallel paths*.

(next) The species belonging to the genus *Paranthropus* had a robust appearance and a small cranium.

The **(next)** *Homo habilis* and the **(next)** *H. ergaster* – on the other hand - had larger crania and were much more delicate.

The **(next)** *robust lineage*, to which the **(next)** *Paranthropus* belongs, was adapted to eat hard vegetables. They therefore developed **(next)**massive jaws and teeth. Climate changes led to their disappearance about 1 million years BP.

(next)*Homo habilis*, on the other hand, was the first hominid to develop a stone-tool industry, about 2, 5 million years ago, in the period called Oldovan. They represented the delicate or so called **(next)** *gracile lineage*, whose teeth were not so sharp and massive.

The reason for their success was that they developed a technology of knapping stone to form hand axes, which were used to crush their food into smaller pieces, easy to eat even without sharp and massive teeth.

Conversely, by 1, 7 million years ago, the successful *gracile lineage* had arrived at Asia and developed a new, more sophisticated and varied stone industry: the so called *Acheulean* culture.

These hominids diverged into 3 distinct species: in addition to the **(next)** *H. ergaster* in Africa, **(next)** *H. erectus* inhabited Asia, and H. *georgicus* (not depicted on this slide) settled in Caucasus.

The Acheulean stone industry produced hand axes with a conspicuous mirror symmetry, to which we will return later in my lecture.

From *H. ergaster*, a lineage leads to **(next)** *H. neanderthalensis*, appearing about 300.000 years BP, and to *H. sapiens*, 150.000 to 200.000 years BP.

The evolution of hominid cognition is traceable in artefacts with different levels of complexity, and belonging to different archaeological strata.

Significant are also reconstructions of hominid crania, and calculations of brain volumes and relative volumes between our early hominid ancestors, as well as in comparison to modern humans.

The evolution of species can be measured as an evolution towards larger and larger crania.

In **(next)** the genus *Australopetichus* , about **4** (4,2-2,5) million years before present, the cranial volume measured 400 ccm.

In **(next)** *Homo habilis*, about **2,5** (until 1,6 Ma BP), the volume of crania had increased to about 700 ccm. This was the time when the first stone industry appeared, i.e. the production of the irregularly formed hand axes within the period called Oldovan.

With the appearance of the ´symmetry-minded` **(next)** *Homo ergaster*, the cranial volume was further increased, now measuring about 950 ccm.

In **(next)** *Homo neanderthalis* and *Homo sapiens*, the cranial volume increases to 1 350 ccm; this is still the volume of modern human’s crania.

The degree of capacity to make and appreciate aesthetic objects must be regarded as a great hallmark of cognitive development in the evolution of the human mind. When this capacity first appeared is, however, a question of contention.

The artefacts are ´charged` with a symbolic meaning expressed through the complex semiotics of its lines, colours, degree of symmetry, three-dimensionality etc. Archaeologists are searching for its deeper meaning through a study of style, colour, composition, and iconography.

Any reconstruction of the neural networks required for production of the artefacts will, however, draw on models derived from archaeological material, cranial evolution, cultural factors and, not the least from modern neurobiological studies.

A very early example of what appears to be a product of rather complex cognitive mechanisms are the **(next)** strictly symmetrical Acheulean hand axes, manufactured, as we have seen, from 1, 7 mill years BP until about 200.000 years BP - and which show uniformity across wide geographical locations and throughout a considerable period of time.

The axes were surely made for utilitarian purposes but still they are witnessing the stone knapper's concern with *form apart from purpose*.

Another example of archaeological artifacts with traces of what may be designated as a complex level of symbolic or abstract thinking is the pieces **(next)** of incised animal bone found in the Kozarnika Cave in Bulgaria (Fig. 2a), dated to 1.2 million years BP.

"These lines were not from butchering; in this place (on the animal) there is nothing to cut. It can't be anything else than symbolism," says Dr. Jean-Luc Guadelli at the University of Bordeaux, in an interview with BBC News Online (http://news.bbc.co.uk/2/hi/science/nature/3512470.stm).

Even more complex than the incisions on the Kozarnika bones, **(next)** are the abstract patterns carved into pieces of ochre in the Blombos Cave, South Africa, dated to 70.000 years BP (Hensilwood *et. al*, 2002) (Fig. 2b) **(next)**.

The regularly carved **(next)** zigzag pattern of lines are the more interesting since we here find lines that are approximately parallel, and must surely have been intended to be so.

Another interesting feature is the carved parallel **(next)** horizontal lines; two of these are running through the apex points of the zigzag pattern.

A **(next)** third line is carved through the points of intersection of the oblique lines. Hence, the carved pattern of lines is organized *symmetrical* on each side of this midline.[1]

The sophisticated and strongly geometric regularity of the carved lines are remarkable.

(next) Also found in the Blombos Cave are shells of the species *Nassarius kraussianus*.

They were **(next)** stringed together in long pearl necklaces. This shows that human beings as early as about 70.000 years before present wanted to adorn themselves, or had particular ´dressing codes` in connection with ritual practices.

At another archaeological site in South Africa, **(next)** the Diepkloof Rock Shelter, Western Cape, are found fragments of engraved ostrich eggshells, dated to about 60.000 years BP (Teixer *et al.*, 2010).

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[1] The geometrical patterns on the ochre are organized in a manner called translational symmetry. The longitudinal form of the ochre and of the ornament will imply a longitudinal repetition of the geometrical patterns (translation and mirroring). In a mathematical language it can be said that the number of repetitions are unlimited even when the actual length of the artifact will restrict the space available (H. Weyl, pp. 52-54).

We will now return to the Acheulean hand axes and the preference for symmetry which they display.

(next) As noted above, the oldest known stone tools are 2,5 million years old.

Such artifacts (Fig. 7a), which show no signs of symmetrical patterns, belong, as we have seen, **(next)** to the Oldovan culture, first documented in Olduvai Gorge, Tanzania in the period dominated by *Homo habilis*.

About **(next)** one million years later, presumably by **(next)** *Homo erectus* and *Homo ergaster,* within the Acheulean culture, this technology was replaced by the production of the *symmetrical* tear drop formed hand axes.

Moreover, as the symmetry of late Acheulean tools purportedly goes far beyond functional requirements (Wymer, 1982), it has been assumed that an increased cognitive sophistication of hominines took place during this period (Hodgson, 2009).

With other words, it *was an industrial revolution* that took place with the appearance of H. erectus and its preference for symmetry;

”symmetry (even) became somewhat … detached from functional dictates in that an … *awareness toward symmetry* (came) to the fore” says Derick Hodgson (Hodgson 2011, p. 39). What were the selective pressures in evolution that led to this preference for symmetry?

It is strongly suggested that the recognition of the **(next)** bilateral symmetrical animal forms as opposed to the non-symmetrical form of inorganic nature would have been particularly relevant to the survival of homo - so it may well be that this sensitivity is related to the need to rapidly discern the predators' symmetry for the purpose of survival" says Derik Hodgson (Hodgson, 2009, pp. 93-97:94).

How can the sudden change from non-symmetrical tools to a production of tools with conspicuous bilateral (mirror) symmetry be explained? The answer has to be found within neurobiology and evolution.

How is symmetry processed by the brain, and how has these processing mechanisms evolved? To answer this question, our first concern will be the evolution of perceptual mechanisms, from the primary visual areas in the *occipital cortex* to the areas of the brain where the visual input is further processed for deeper cognition. So the question will be: how has our visual brain developed from the common ancestor for man and chimpanzee until modern *Homo sapiens*?

(next) Microscopic studies of primary visual cortex V1 and V2 have demonstrated that these areas are almost identic in man, monkeys, and apes; this means that cell morphology, and the organization of neural networks in this area in human brain is very close to that found in the visual cortex of apes.

What differs, however, is the great expansion that is found in humans in the areas that are processing visual input deriving *from* the primary visual cortices. **(next)** These are areas located within the so called "what system" in the ventral part of the brain, as well as in the so called "where system", located dorsally.

In the "what" system, objects are identified. There are, for instance, an area that can identify faces. The "what" system also contains higher order colour mechanisms. The "where system”, on the other hand, is occupied with processing of motion, depth perception, spatial organization, luminance contrasts, and figure/ground segregation.

From the time of the common ancestor to chimpanzee and man until *Homo sapiens*, there has been a relatively greater expansion within the ”where system” than in the ”what system”. This means that the system occupied with spatial processing has expanded more than the system telling us what exactly we are looking at.

The recognition of symmetry is a function within a network connected to the dorsal pathway (T. Jacobsen et. al., 2006; D. Hodgson, 2008/2011). This **(next)** “symmetry network” includes the higher order visual areas **(next)** V3A, **(next)** V4, and **(next)** V7 in *occipital cortex*, as well as some areas within the **(next)** *parietal* and **(next)** *premotor cortices*.

From the occipital areas, fibers are connected to the parietal cortex through the **(next)** *intraparietal sulcus*, which, as you can see here in this **(next)** transverse section from two locations of the parietal, cortex is a very deep groove; it connects the *occipital* and *parietal* areas. The *intraparietal sulcus* seems to have undergone enlargements in humans for the processing of 3D shapes.

Derik Hodgson has stressed that the fibre bundles from symmetry processing areas in occipital and parietal cortices will seem to interact with the **(next)** *mirror neuron systems* of the *inferior parietal cortex*, as well as that found in the *ventral premotor cortex* (BA44).

This intersection can be designated as an evolutionary success, an advantage for the production and use of more complex tools, including those with greater symmetry (Hodgson, 2011; cf. Fogassi & Luppino, p. 627)

Why is the anatomical co-localization of mirror neurons and the neurons occupied with depth perception, 3D, and symmetry so significant? It is significant because a form can elicit a motoric activation in the brain.

This is a so called *visuomotor activation* or *transformation*; it means that form perception will elicit a bodily action;

this action is, however, not a movement. It is just a triggering of the mirroring mechanisms, now acting as if a movement should be initiated; this activation can further stimulate other centers in the brain, for instance emotional networks within the so called *limbic system*.

It means that we, so to speak, can ´feel a form` emotionally.

The Acheulean hand axes are the first examples of an actual *manufacture* of tools with the symmetrical form. This suggests that there is an evolution toward an *intended manufacture of symmetry* within the Acheulean technology of *Homo ergaster*.

During the next million years there is a gradual perfection of the symmetrical form of the axes. A considerable quantity of this axe form has been found throughout the world, including Africa and the Middle East.

As hand axes represent the earliest material record of an interest in symmetry by the human lineage, they provide a particular position in the search for a reason why this kind of form, the symmetric one, came to be valued by later human groups, particularly in relation to ´art` (D.

Hodgson, 2011), as is very evident in the following three examples **(next) … (next) … (next)**.

It is commonly agreed that symmetric forms are generally considered to be more beautiful than asymmetric forms, i.e. that symmetry is an objective parameter for beauty.

This has also been scientifically proved. In a series of brain scanning studies, Thomas Jacobsen's group (2000, 2003, 2006), has demonstrated that degree of symmetry in an **(next)** abstract graphic pattern correlates positively in the judgment of beauty. This results in activation of **(next)** parietal areas, including the *intraparietal sulcus*.

Was it the preference for the aesthetics of the symmetrical form (i.e.: I like this symmetry) that led to the repeated production of **(next)** t**(next)** he symmetrical hand axes in more than 1 million years?

This, which is the most common opinion among researchers, is questioned by others, who maintain that it was not an **(next)** *intended manufacture of symmetry* per se, but a preference of a form that was easy on the mind, i.e. a form that was easy to process mentally, by our brain networks (i.e.: This form is easy to grasp mentally; it gives me aesthetic pleasure).

We will, however, leave this as an open question.

What was the selective forces driving the evolution? Recent studies in evolution stress that *cultural* factors is far more significant than previously expected. This process is called **(next)** *cultural evolution*. It works together with the pure *biological* evolution (for a recent review cf. Nadal *et al*., 2009).

It has been argued that paleo-tools were preserved and improved through succeeding generations, in a process of cultural evolution; the tools that are available within a culture constructs a so called “cultural niche” leading to *expression* of those genes that make the individual best fitted to make use of tools (Simão, 2002, p. 419).

Cultural evolution differs from Darwinian evolution in that it does not imply any changes in the DNA molecule. What changes is the degree of expression of particular genes, and this rendered gene expression can be transferred from parents to offspring.

To sum up, the sudden increase in human ability to make symmetrical tools during the archaeological period called the Acheulean has been related to the fact that hominine brain **(next)** evolution is characterized by a considerable expansion in the parietal areas, and also in certain areas of visual brain relaying information to the so called “where system”.

This path follows the nerve bundle called the superior *longitudinal fasciculus*, leading from the occipital to the parietal cortex through the *intraparietal sulcus*.

Symmetry is, as we have seen, extracted and processed within the occipital and nearly related parietal networks.

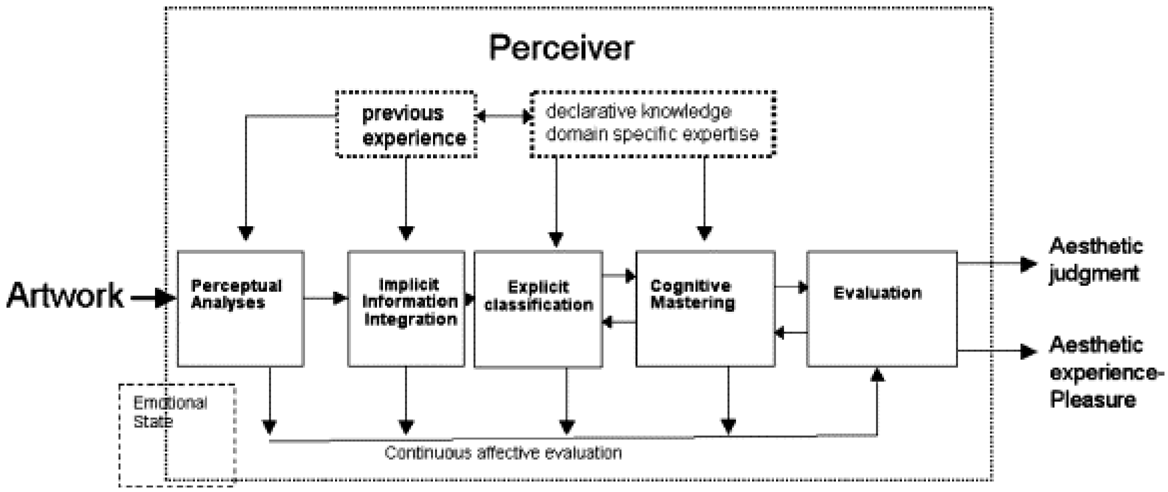
Working a symmetrical tool, such as a hand axe, strongly depends on a cognitive capacity for understanding the 3D form when seen from different angles, including those angles that make the tool transitively appear as two dimensional.

The process of tool making will also seem to have depended on mirroring mechanisms: an observation of the process of stone knapping is being mirrored in the brain of the apprentice by the mirror neuron system (Diane Humphrey, 2002).

The ability to create any intended beautiful form, such as a sculpture, and, not the least, to appreciate its beauty, will, ultimately, depend on the evolution of cognitive processes, such as those taking place within and in interaction with the parietal and occipital areas.

An aesthetic experience, the aesthetic pleasure, depends, however strongly on an affective and emotional activation, an activation of the neural networks within the limbic system.

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



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So long in this lecture we have mainly been restricted to the cognitive evolution in Early Paleoliticum, particularly the emergence of symmetric tools in the Acheulean culture, dominated by **(next)** *Homo erectus*, *Homo georgicus*, and *Homo ergaster*. The researchers dispute as to what extent the form of the axe should be accepted as the first true example of conscious interest in form springing from advanced cognitive processes.

Likewise it can be asked to what extent the engraved **(next)** ochre pieces from the Blombos cave constitute an irrefutable evidence for symbolic behavior.

But when it comes to the cave paintings and other artifacts of the **(next)** Upper Palaeolithic few people will question that human creativity and symbolic capacity have left an incontestable mark in the archaeological record.

We will now take a closer look at the archaeological remains in Upper Paleolithicum, first dominated by *H. neanderthalensis* and then by the early *H. sapiens*.

While the most impressive artworks from this period are the cave paintings, such as those seen here **(next)** from Lascaux and **(next)** Chauvet in France, a product of modern *Homo sapiens*, we will first take a brief review of some of the Neanderthal sites, and their artifacts **(next)**.

Neanderthals evolved from early *Homo* along a path similar to *Homo sapiens*, both ultimately deriving from a chimpanzee-like ancestor between five and 10 million years ago. Like *H. sapiens*, Neanderthals are, thus, related to *Australopithecus*, *Homo habilis*, and *Homo ergaster*; the exact descent remains, however, uncertain.

By 300,000 years ago, Neanderthals had settled in sub glacial Europe and the Middle East. Meanwhile, in warmer East Africa, our own species, Homo sapiens, was about to appear. The earliest exemplars of *Homo sapiens* are between 150,000 and 200,000 years old. This new species began sweeping across the old continents when temperature rose, about 70,000 years ago. They arrived in Australia probably about 50,000 years ago, and moved into Europe before 30,000 years ago, displacing the Neanderthals, and crossed the Bering Strait into America between 30,000 and 15,000 years ago.

The Neanderthal artifacts include pierced fox teeth and other sophisticated creations.

A recent **(next)** finding (2006) in the Gorham's Cave in Gibraltar shows Neanderthal related artifacts, suggesting that they lived there 25,000 years ago, and thus overlapped quite substantially with the abundant art-producing *Homo sapiens* (Dahlia W. Zaidel, 2009).

This long period of coexistence, including cohabitation in the Middle East and Europe, raises the intriguing possibility of *genetic admixture* between anatomically modern humans and archaic *Homo* populations, which could have resulted in contributions by these extinct lineages to the modern human gene pool.

It has been scientifically proved that sequences of the Neanderthal genome have been mingled with the gene pool of modern Homo sapiens **(next)**. The present slide shows that the Neanderthal nucleotide sequences are found in population so different as in **(next)** Western Europe, **(next)** in Asia, and in **(next)** Papuan-New–Guinea. The Neanderthal nucleotides are, however, wholly absent from the genome of populations **(next)** south of Sahara. The reason for this is that the intermingling of the Neanderthal and Homo sapiens took place after they both had left the African continent.

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The Chauvet **(next)** cave in southern France contains some of the earliest known cave paintings. Discovered on December 18, 1994, it is considered one of the most significant prehistoric art sites. It dates from approximately 30,000–32,000 years BP.

The majority of paintings in the cave represent animals **(next) … (next)**. Rather than depicting only the familiar plant eating animals that predominate in Paleolithic cave art, i.e. horses, cattle, mammoths, rhinoceroses, the walls of the Chauvet cave feature many predatory animals, such as, lions and panthers.

The paintings are sketchy, and strongly dynamic; you can sort of feel the animals running, some turning around, **(next)** rhinoceroses fighting, etc.

The morphology of the cave walls were frequently exploited in the depictions of animals. Niches and recesses were used in helping to position figures, **(next)** edges suggesting body shapes, virtually rendering drawings into sculptures. The incorporation of the rock face makes the imagery, so to speak, fluctuating between the two dimensionality –and that of the third dimension.

Based on paintings in the South African San Rock art, as well as knowledge about South African San culture and its shamanism, Professor David Lewis-Williams proposes that shamanism may have been a driving force also for the painting of the Upper Palaeolithic caves in Western Europe.

If this is correct, the paintings were executed under hallucinations, within a state of trance. The reason for setting forth this theory is that "among the engravings in the caves one finds images that conform closely to the kinds of so called entoptic phenomena established by laboratory research **(next)**.

Entoptic images have a physical basis within the retina, and have nothing to do with what we call optical illusions. One example is the lightings that appear when you push against the eyeball.

Some of us, including myself, have also experienced light in the form of zigzags, appearing suddenly, out of nothing, in the center of visual field, spreading then in the form of a Luna as it expands until, and after several minutes, the huge intensely pulsating lighting zigzag disappears out of the field of vision.

This particular percept is often followed by migraine attacks and is therefore well known to sufferers from that condition. In the cave, such zigzags can be found **(next)** separately or associated with images of animals, **(next)**zigzag formed horns etc.

This pre-hallusionistic stage leads into the so called tunnel vision, or vortex, the hallusionistic stage proer.

To quote Lewis-Williams, "the widespread occurrence of shamanism among hunter-gatherers, and formal parallels between elements of the mental imagery of altered states and Upper Paleolithic cave imagery … suggests that at least some – not necessarily all – cave wall paintings were probably associated with … hallucinations. In other words, it seems highly probably that some … forms of shamanism were present at, probably, all periods of the Upper Paleolithic Western Europe." – end of quotation.

Shamans spend hours dancing, drumming and chanting, often accompanied by assistants and the community. The shaman enters a so called *altered state of consciousness*, which provide their spiritual experience, experiences of death-rebirth, a journey of the soul, transformation into animals etc.

It includes a strong activation of the **(next)** *dopaminergic system*, which originates in the *ventral tegmental area* and the *substantia nigra* of the midbrain. Having a strong impact on our emotional nerve networks, the so called limbic system, including the cingulate gyrus, hippocampus and amygdala, the rendered consciousness leads to an integration of emotional and cognitive mechanisms; dreams mingle with reality (Winkelman, 199ff.).

The postures of the animals in Chauvet cave, their three-dimensionality, their´ movement`, like in a film, their overlap, reflect an artistic brain who fully understands the relation between 2D and 3D; the artist is sort of "playing" with the cavities and recesses in the wall, to exaggerate every movement of the animals.

If executed during hallucination, the memory mechanisms are fluctuating as during dreem sleep, where successive sequences of intense memory are being spliced and recombined, resulting in an incredible rhythm of pictures.

Mirroring mechanisms, i.e. the mirror neurons, within the artist's brain looking at the movements he or she had created, must certainly have led to a feeling of participation in the artistic world created.

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The acts of expressing and experiencing symbolic meaning through different artifacts were intimately related to social and cultural practices. Social dynamics require communication between people. Communication depends on a sort of language.

The language areas of the brain are localized within the **(next)** temporal lobe. «The amount of white matter in the human temporal lobe is greater than can be estimated from a general increase in body weight in humans as compared to chimpanzee, suggesting that temporal lobe connectivity patterns have undergone a certain amount of reorganization since the appearance of the human lineage … This reorganization might be related to the appearance and expansion of language related areas in the temporal lobe of humans, especially in the left hemisphere» (M. Nadal *et al*., “Constraining Hypotheses on the Evolution of Art and Aesthetic Appreciation”, i M. Skov og O. Vartanian (red.), *Neuroaesthetics*, New York 2009, pp. 103-129: 112).

Neuroaesthetics now agree that the area running around the lateral sulcus, also known as the Sylvian fissure, in the left hemisphere of the brain, has a neural loop that is involved both in understanding language (in Wernickes area) and in producing spoken words (in Broca’s area)/ At the frontal end of this loop lies Broca/s area, which is usually associated with production of language.

At the other end lies Wernicke/s area, which is associated with the processing of words that we hear being spoken, and the comprehension of their meaning. Broca/s area and Wernicke/s area are connected by a large bundle of nerve fibres, called the *arcuate fasciculus*.

Recent research (Catani and Mesulam, 2008, p. 958; Catani, 2007) indicates that the arcuate fasciculus is the “only direct connection between occipital and frontal cortex in the human brain”. Essentially, the pathway connects the visual ares of the brain (occipital cortex) with the areas which deal with higher order thinking within the frontal cortex. “The importance of this research is that converging evidence suggests that object drawing relies on cortical regions in frontal, parietal, and temporal areas which are interconnected by arcuate fasciculus, the bundle that will seem to be essential in the unique human ability: the ability to speak!

A comparison of human brain and the brains of apes shows that there is a particular high degree of folding, or gyrification, in the **(next)** temporoparietal art-and-language producing regions.

There is also another part of the brain that has a cell organization, unique to humans: This is the **(next)** anterior prefrontal cortex, Broadman's area 10. First, it is larger, both in relative and absolute terms, than that of other apes.

Although the absolute number of neurons is larger than in other apes, the neural density is the lowest among hominids, allowing greater space for connections within the same area, as well as with other higher order association areas.

Hence, it is not the number of neurons *per se* that is the critical factor determining the complexity of the neural network. It is the number of interconnections within, and between regions of the brain that is the very hallmark of advanced cognitive abilities.

Significantly, it has been demonstrated that Broadman area 10 is involved in the process of aesthetic judgment. This means that "aesthetic *judgment*s of beauty triggers activation in a brain network that generally underlies evaluative judgments, such as social and moral judgments" (Jacobsen et al., 2006, p. 284). Our ability to make such judgments is among the traits that make us human.

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(next) Concluding this lecture, one can say that the archeological record from a global, not just European, perspective suggest that the origin of art, symbols, and aesthetic appreciation, is diffuse, extending in space, and continuous in time, with deep roots in our Middle Paleolithic ancestors' cognitive and neural structures.

(next) Only by neglecting the African and Asian archaeological record, such as the Blombos Cave, is it possible to be surprised by the ”sudden” artistic explosion of the European

Aurignatian in Upper Paleolithic culture. This set of cultural manifestations had been gradually growing since the appearance of our own species and left some early samples, not in Europe, but in Africa.

(next) The murals found in Southern France and Northern Spain are sophisticated and beautiful manifestations of cognitive processes that were probably present at the dawn of our own species, such as in the symmetry-´loving` *Homo ergaster* and *Homo erectus*, some of which might even have been inherited from earlier ancestors.

(next) Artistic activities and aesthetic experiences, broadly conceived, seem to have evolved by integrating preexisting neural systems common to other primates with innovations that occurred throughout the human lineage. Such a process intertwined with the evolution of cognitive and affective processes linked to other human activities was the result of more than one selective pressure, and resulting in multiple adaptive advantages.