Art and Neuroscience

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Social Brain

From neuropsychological viewpoint, we can take human brain as a machine allowing causality (A → B), symmetry (as opposed to asymmetry), consonance (as opposed to dissonance), harmony (as opposed to disharmony), pleasure (as opposed to threat and aversion), regularity (as opposed to irregularity), etc. It seems that rather than a consequence of bipedality freeing hands for work, neocortex, which distinguishes human beings from most species, developed as a consequence of a growing number of individuals in social groups. From this point of view, neocortex might be considered social brain, which does have connection with our mind and language, but primarily with development of social groups. We can assume from both neuroanatomical and archaeological connections that social groups of primates and hominids grew in size in course of the last three million years, with dramatic acceleration of the growth in the latest half million years (*figure 1, Dunbar 2003*). The group size seems to be directly proportional to the "social brain" size (*figure 2*). A social group is a set of individuals who can recognize each other as individuals. With modern people, such a group would be represented by a set of individuals we have in our address book, and their phone numbers stored in our mobile phone. Such a group would now have about 150–200 individuals. Social cohesion of a group of primates and hominids is primarily maintained with help of grooming. It is only logical that with group size growing, the grooming, which has a function of a "social adhesive", gets ever more time consuming. The larger the number of individuals that must be groomed in the interest of group cohesion, the larger portion of day time must be allocated to grooming. This cannot continue forever, as the growing time proportion, and the investment in grooming, gets in way of other activities of vital importance, such as livelihood, reproduction, territoriality, competition with natural enemies, etc. The maximum endurable time that can be devoted to grooming without adverse consequences, seems to be 30 percent of a day. Many findings prove that with a growing group size, the time proportion was exceeded in about half a million years ago (*figure 3*). This was a period in the development of hominids in which the group size laid demands on social cohesion that could not be met with grooming, thus most probably bringing about enormous strain on development of a "social adhesive", which would be more effective than physical grooming. We have a number of reasons to believe that in this particular time physical grooming was replaced by "social grooming", enabled through vocalizations and their modifications (rhythm, synchronization, melody), as a rudiment of singing. From vocalizations and their modulations, there is a mere little step to language. Let's notice that natural (Czech) language unwittingly acknowledges its original mission of social grooming, when using the word "drbat" (to pastime/gossip): the word is synonymous to the physical grooming or scratching, the way we can see primates in a zoo, as well as pastiming, or exchanging seemingly useless pieces of information, which, rather than solving an immediate issue, aims at maintaining social groups – most probably being just two different aspects of the same. This task of language (that of social grooming) was charmingly stressed by Jiří Fiala, a mathematician and philosopher, who referred correctly to the fact that language does not primarily serve to transferring important and meaningful information. He described an experience he once had in France. He was at a party where he knew practically nobody, and people were lively discussing things. When eventually leaving, the host shook his hand saying, "Well, what a pleasant talk we had." He had this feeling of a pleasant chat with Jiří

Fiala, although he recollected only saying three words in course of the evening, “Je suis d'accord.” We can see that what linguists call “communion mutuel” is actually the same thing as “social grooming”.

Perception

Our perception, of both images and sounds, is based on detecting contrasts (interface) and motion against motionless background. This is extremely important from developmental point of view, as detecting motion of an enemy, predator, or prey, is probably the most important to survive. If we place a baby, or a monkey, in between loudspeakers, and, in the stereo setting, move the sound source in the room, we can observe the head turning in the sound source direction. This is one of the examples of how perception works on the principle of contrasts, on the principle of distinguishing signal from noise, and foreground from background. From the viewpoint of development of music as modulations of vocalization, which probably appeared in evolution as a higher level of grooming, enabling to serve a number of individuals at a time, there are interesting archaeological findings of the first preserved musical instruments. A bone flute that dates to approximately 50,000 years ago during the middle Palaeolithic, which was found in a Neanderthal campsite in Slovenia, and which was made from the femur of a bear paw, has four holes. The distance between the second and the third holes of the flute is twice that between the third and the fourth holes, which is consistent with whole tones and half tones as we form them today, suggesting that musical scale then practically equalled the current one (*Kunej and Turk, 2000; figure 4*). Fundamental musical forms may be predestined by neurobiological substrate, which to a degree determines their form. Old Chinese flutes, which are actually the earliest well-preserved musical instruments, and which have been recently found at a Neolithic site in China, date to between 7000 and 5700 BC, were made from crane bones, and some of them have eight holes arranged in the same way as current fipple flutes. From the viewpoint of evolution, we can thus observe mind, language, music, and society from a single perspective. They have a common denominator in the social brain (neocortex). Thus, summarizing the above, we can see that about one half of a million years ago, size of primate and hominid social groups exceeded one hundred individuals, which represents a necessity to allocate more than 30% of time to physical grooming. At that time, strain emerges to develop a different mechanism of cohesion, i.e. vocalizations. Their modulations bring about prototype of singing, or music. This development of “social grooming” goes hand in hand with development of social brain (neocortex), and emergence of gene FOXP2, which is apparently connected with development of language. Evolutionary stability of social grooming, so important for social group development, is apparently secured through the integral mechanism of delightedness (experience of beauty, pleasure, and joy).

Beauty

Perception of beauty is presumably conditioned by symmetry with a pinch asymmetry, rhythm with a little bit of dysrhythmia, and harmony with a little bit of disharmony. In nature, symmetry is a symbol of beauty and harmony, and a correlate of good health (or fitness); thus it plays an important role in natural selection. Absolute symmetry, however, bears a notion of something technically sterile. Distinct asymmetry, on the other hand, is often a sign of illness, a signal of threat and danger, and results in flight or fight. Evolutionally, falsely positive estimation of a threat pays off much more than falsely negative underestimation of risk. Pleasure as a result of evaluation of small deviations from symmetry, harmony, and rhythmicity seems to have its neuronal correlates, which we can now study objectively. Statistical parametric maps (*figure 5*, adopted from *Kawabata and Zeki, 2003*), rendered on standardized brain with help of positron emission tomography, show activity specific for a decision between beauty and ugliness, beauty and neutral feeling, ugliness and beauty, and ugliness and neutral feeling. To start with, experimental subjects assessed on a subjective scale their feelings evoked by presented pictures (ugly – neutral – beautiful), and then their brain activity was scanned with PET, while the same pictures were presented. The pictures were not classified into categories such as landscape, still life, portrait, etc.

Similarly, we can now objectively detect neuronal basis of consonance, and its distinction from dissonance (*figure 6*). The figure shows waves of acoustic evoked potential recorded in Heschl's gyrus; when evaluated, frequency (Hz) and amplitude (μV) are plotted. When the experimental human subjects or primates are exposed to consonant chords (augmented fourth, major fifth, octave), the two curves go in parallel, while when exposed to dissonant intervals (minor second, major second, major seventh), "resonance" appears, called "locked in frequency" in electrophysiology.

Deconstruction of fine art and music in the 20th century

In the recent quarter of a million years, both vocal and graphical displays of human social brain activities seem to gradually grow in complexity, until the end of the 19th century. In Europe, music attained, among other influences under that of church dogma, monumental scale from Bach's baroque to Mozart's classicism and Beethoven to Dvořák's and Brahm's romanticism. Fine art moved from gothic Madonnas and religious iconography to hunting still life to realistic images of combat scenes. At the end of the 19th century, however, something significant heralded sharp turn in the development of both music and fine art. The big bang of a change was evoked by two inventions, that of daguerreotype and photography, which assumed the previous prominent task of fine art in depicting reality; and that of vax roller and gramophone, which made it possible to copy musical experience without the need of participants' active contribution. Liberated from formal bonds, 20th century music deconstructed in the direction from Wagner to Janáček, Schönberg and Boulez to a sort of atomic, "nuclear" music, and similarly fine art from romantic canvases of Delacroix to impressionists (Manet, Monet), to Cézanne, Braque, and Mondrian, to pop-art and Malewicz, that can be viewed as a sort of "nuclear" fine art (*figure 7*).

Music and language

Many neurophysiological findings suggest that Broca's area relates not only to language, but to musical syntax as well. Koelsch (*2000*) showed which parts of the brain activate with the so called false ending in music (*figure 8*). Moreover, other authors also showed which parts of the brain process both musical and verbal syntax. Brown et al (*2006; figure 9*) observed regional activities of various brain areas in course of melody and sentence completion task, such as, "August was the best month for them to take the Spanish course in Peru, because…." "… the weather is just fine in Peru at that time."). When generating melody, specific areas of BA44 and BA22 activated, while areas BA38, BA39/40, and others specifically activated when sentences were being generated. The other active areas were common for both tasks. Brown et al concluded that both music and language are on the level of sensorimotor kinaesthetic areas (primary auditory cortex and motor cortex) processed identically, on the level of combinatory processing of complex auditory structures (sensory BA22 and motor BA44/45) they are processed in parallel, and only on the level of semantic processing are they processed separately. In other words, "Bach speaks". Musical semantics thus show many more parallels with language than anyone expected. Music, similarly to language, is a hierarchic structure: elements → words → sentences → phrases → narratives → compositions. In similar hierarchy, problem solving and use of instruments are also built (*figure 10; Molnar-Szakacs and Overy 2006*).

Mirror neurons and play

Structural analysis of either musical or language signal presumably runs with the involvement of so called mirror cells, i.e. co-representation of intentional, hierarchically organized, sequential motor elements with auditory information. Mirror cells are cells that activate while we observe an activity. Brodmann's area 44 most probably plays an important role in the mirror system. The fundamental system of mirror neurons is frontal-parietal (MNS = Mirror Neuronal System). The frontal-parietal system of mirror neurons represents actions and intentions of others, across modalities, by recruiting one’s own motor system (*Iacoboni et al 2005*). Iacoboni et al (*1999*) showed the difference between activation of rostral parietal cortex and Brodmann's area BA44 when we observe motion of another person's fingers against control.

Similarly marked difference can be found between a person capable of, as opposed to a person not capable of playing the piano, when observing another person playing it. The same authors also show remarkable difference in the activation of frontal MNS if an experimental subject observes a hand grasping a cup in two different contexts. One of them suggested continuing breakfast (milk jar, sugar bowl, cookies, honey, tea pot), the other context suggested the breakfast was over (empty milk jar on its side, eaten cookies, open sugar bowl, empty tea pot). The two contexts bring about anticipation of two different actions. In the former case, the subject more or less expects the cup shall be brought to the person's mouth, while in the latter case the subject expects the cup shall be brought to a sink or dish-washer. The experimenters managed to filter off the effects of context, or to read and map just the difference in activation of mirror neurons reflecting the cup grasping as such, the activation of which is predestined by the context (*figure 11*). Thus, the mirror neuron system is an “interface” between perception and action, which means automatic and unconscious stimulation of neuronal structures, which reflect (and “understand”!) actions of others. This mechanism is extremely important in prediction of behaviour of others, which is a competence essential for survival, and its development represents an unquestionable selective advantage. Play (in both meanings, i.e. hide-and-seek as well as playing a musical instrument) is presumably the way this absolutely vital system develops, maintains, and trains.

The system of mirror neurons is connected with empathy (empathizing with others), with “the theory of mind” (social cognition), with language (!), and with distinction between self and non-self. If we understand schizophrenia as a disconnection syndrome, or an information processing disorder, it might be interesting to point out to the fact that people suffering from schizophrenia often (even pre-morbidly) lack “playfulness”, they lack empathy, their social cognition (and social adaptation) is disturbed; schizophrenic symptoms are to a large extent disorders of speech/language, and psychotic symptoms often include loss of distinction between self and non-self. Let's remind ourselves of Crow's remark that schizophrenia is a price we pay for the development of language.

Perception of a motor action, language, and music all use the same neural circuits, which are in human beings most probably related to the system of mirror cells. People seem to understand communication signals (visual or auditory, verbal or musical) based on comprehension of the motor act they represent, or even based on comprehension of intention (i.e. potential motor action) underlying the act.

Summary

Neurobiological hypothesis of the evolution of art assumes that it was the size of social groups which determined development of human frontal cortex. Social cohesion is secured with grooming. Cohesion of groups of hominids larger than 100 individuals could not be sufficiently secured with “face-to-face” grooming consuming about 20–30% of time available. More time, however, could not be devoted to grooming, because other activities, necessary for survival, would then be allocated dangerously inadequate period of time. Thus an effective way of maintaining social cohesion emerged, taking forms of vocalizations and drumming, which can be understood as “social grooming”. Direct line to singing and language can be traced from here. Acoustic rhythmization (drumming, chest drumming) serves in hominid groups the purpose of a synchronizer (*Zeitgeber*), as an important instrument of mobilization against external enemy. Some 500,000–200,000 years ago, gene FOXP2 emerged, which, together with neocortex (the social brain), and with social grooming, is a precondition to the development of language. To a significant degree, music and language employ the same areas of brain.

Play (in both meanings) activates mirror neurons. Mirror neurons (frontal-parietal system) enable prediction (of what follows), empathy in other people, and prediction of their behaviour. Prediction of other people's behaviour is a fundamental precondition of survival, and a significant selective advantage. Brodmann's area 44 is a common denominator of the system of mirror neurons. “Useless” children plays, tags, barley-breaks, ding-dongs, prattles, as well as adult pastiming and gossiping and “unproductive” activities such as playing music, singing, drumming, and dancing are all activities employing the vital system of mirror neurons, and developing our essential capacity for empathy and prediction.

Thus art and play are of crucial importance for the development of our abilities to empathize with others and to predict their behaviour, to recognize their emotions, to maintain social cohesion and alliances, and last, but not least to be capable of self-reflection. Art and play thus represent a common denominator for development of social dimensions of language, motions, and emotions; they train us in our ability to predict, and symbolize our significant selective advantage in the evolution.

Translation: Helena Hartlová

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