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Future Evolution of the Human Brain

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Abstract

The past course of the evolution of the human brain indicates that its major feature was not so much anatomical change as the alteration of biochemistry and physiology through neurohormonal regulation and neurotransmitter alterations. In the recent, historical past, human brain size decreased during the period of the rapid development of technology and increasingly complex social organization. The human brain is now adapting to an environment dominated by human control. Future evolution of the brain will be a result of conscious manipulation and responses to changing technologies and social organization. Technologically-oriented transhumanists propose artificial enhancements to the biological structure of human brain based on information technology. The importance of brain physiology leads to attempts at chemical manipulation of brains. Pharmacological intervention in the cases of brain malfunction is well established, while the use of psychoactive substances has also produced a vast criminal industry. Systematic, controlled and ethically acceptable pharmacological intervention in human brain functions may provide an alternative, or a complement to information technology intervention into the operation of human minds. Whatever we do, we must recognise that natural forces shaping human brain have been significantly relaxed.

Keywords: encephalisation, ASPM, mind downloading, transhumanism, brain-machine interfaces, cosmetic neurology

Introduction

The evolutionary origins of the human mind and consciousness are amongst the central themes of anthropological research. They are undoubtedly related to the evolution of the biological properties of the brain. Since brains do not fossilize, hitherto two lines of approach to the subject were used: (1) study of natural or artificial endocasts from fossilized braincases and (2) comparative studies of animals, especially Primates.

In the first line of studies the size of the hominin brain played a dominant role (Gould, 1996; Tobias, 1971; Radinsky, 1975; Martin, 1990, 1998; Holloway, 1999; De Miguel, & Henneberg, 2001) complemented by the study of surface features – sulci and gyri – that were considered to be indicative of specific cortical areas related to function (Tobias, 1981; Holloway, 1984; Falk, 1985, 1991; Holloway et al., 2004). These studies followed two principles. The first, "bigger is better" used the concept of encephalisation (Bauchot & Stephan, 1969; Stephan, 1972; Jerison, 1973) assuming that the larger the brain size in relation to body size, the more complex are its functions. This principle holds in broad overview of vertebrates or mammals (Jerison, 1973; Martin, 1990), but its application to living humans repeatedly failed to indicate any strong straightforward correlation (Pearson, 1906; Passingham, 1979; Henneberg et al., 1985). Both the absolute brain size and the encephalisation quotients show strong and exponential increase within the human lineage (Tobias, 1971; Martin, 1990; Falk, 1998; Henneberg, 1987; De Miguel & Henneberg, 2001), but this was followed by the decrease in brain size during the Holocene (Schwidetzky, 1976; Henneberg, 1988). This decrease accompanied major developments in the sphere of culture: invention of food production, development of complex urbanized societies, democratic form of government, philosophy, science and industrialization.

Earlier researchers focused on the absolute size of the hominin brain steadily increasing from australopithecines through early forms of Homo to the Upper Palaeolithic. When, however, this increase in absolute brain size is compared with the increase of body size of hominins during the same period (Henneberg & de Miguel, 2004; Henneberg & Saniotis, 2009) it turns out that both processes were parallel and the increased encephalisation of humans is a result of increases in overall body size and reduction of the size of gastrointestinal system (Aiello & Wheeler, 1995; Henneberg, 1998).

In the absence of gross anatomical differences, besides simple quantitative differences, it must be the physiology of the brain that made human behavioural abilities unique. This physiological difference resides in the overall neurohormonal regulation of the body (eg. much higher in humans, compared to chimpanzees levels of thyroid hormone [Previc 2002]) and in the distribution and activity of neurotransmitters (Bradbury, 2005). Recently Previc (2009) has argued that humans have much evolved dopaminergic cortical systems. Understandably, since small molecules of neurotransmitters do not fossilize, there has been much less work devoted to this kind of human brain evolution.

In contrast to complex anatomical structure of the brain that is determined by numerous genes, evolutionary change of brain physiology may occur fairly simply because the number of genes controlling secretion of this particular hormone or neurotransmitter is small while consequences of altered neurohormonal regulation or neurotransmitter secretion may have profound influence on behaviours (Burki & Kaessmann, 2004). Simple lack of serotonin produces significant manifestations of depression, while stimulation of dopaminergic systems by common neurotropic drugs (eg. heroin) profoundly influences judgment and self-consciousness.

Human populations at present are still subject to the operation of general forces of biological evolution (Hawks et al., 2007) though natural selection has been greatly relaxed (Henneberg, 1976; Stephan & Henneberg, 2001) while the role of mutations and mixing of people from various genetic pools increased. A new element has been introduced into the operation of the forces of biological evolution on humans – our ability to manipulate gene pools by artificial selection and to offset unfavourable (maladaptive) biological traits by technology (eg. eyeglasses, insulin injections). It is inevitable that human brain and human mind will continue to evolve in the future. Although predicting the future is fraught with dangers of uncertainty and insufficient consideration of all possibilities, and thus it may be dangerous to deliberately indicate preferred outcomes of future changes in human brains, it seems necessary to explore possible directions of the evolution of human brains simply to be able to prevent maladaptive developments.

While the areas of cognitive science and neuroscience have been popularized in the last twenty years, due mainly to improvements in brain diagnostic methods and technologies, analysis of the future evolution of the human brain has tended to be expressed by mainly futurists and transhumanists. These two groups of thinkers have been able to explain at length possible future scenarios of the human brain which will access cutting edge technologies. The popularity of transhumanism, which is an ideological movement which encourages the modification and augmentation of the human body, may stem from the human desire to prolong youth and avert death. Noted transhumanists like Nick Bostrom, Ray Kurzweil and Hans Moravec offer several optimistic insights to how the human brain will be exponentially improved. These include the creation of nanotech brains and mind downloading into computers. While such technologies are yet to come into fruition, transhumanist ideas of brain augmentation deserve attention from the scientific community. One reason for this is because of science's exploration of virtual reality environments which are "creating intimate links between the external systems and the human user" (Sandberg & Bostrom, 2006, p.211). Current information technologies such as personal digital assistants (PDAs) are being worn by the human body and serving several purposes.

Converging cognitive technologies combining nanotechnology, biotechnology, information technology and cognitive science may be able to amplify or extend "core capacities" of the brain via augmenting neuronal networks (Sandberg & Bostrom, 2006, p.201). The current growth of these technologies has advanced the possibility of biological enhancements in the near future (Farah et al., 2004). Some thinkers contend that these technologies will enable human beings to tinker with their own evolution, a step which may affect natural selection.

In this section, we offer several areas which may inform future brain evolution. While the nuance of this analysis is speculative it provides ideas for further exploration in various areas of anthropology. Possible scenarios of future brain evolution which will be discussed are:

1. Abnormal Spindle-like Microcephaly (ASPM) and Microcephalin connection in brain evolution
2. Mind downloading and technological embodiments
3. Brain-machine interfaces (BMIs)
4. Cognitive enhancement and nootropic substances

ASPM and Microcephalin Connection in Brain Evolution

Evolutionary biologists argue that human evolution occurred much in the same way as the evolution of other species; that is, through the mutation of genes which enhanced an individual's adaptation to their environment. Recent findings in genetic evolution are challenging this idea of gradual evolution for a more rapid one. According to geneticist Professor Bruce Lahn from The University of Chicago, human brain genes have undergone a marked amount of evolution in a short period of time which has been much faster than the genes of other animals. Lahn also notes that human evolution is unique in the animal kingdom in its process of "acquiring new biological traits" which has privileged high intelligence (Gilbert et al., 2005). In short, the brain has experienced accelerated evolution.

However, this is not the full story. Lahn points out that there are two genes which regulate brain growth – microcephalin and ASPM (abnormal spindle-like microcephaly associated). Recent findings reveal that the microcephalin allele arose about 37,000 years ago, around the time which the popular scientist Jared Diamond calls the "Great Leap Forward" which saw the emergence of art and other modern human behaviours (Mekel-Bobrov et al., 2007; Mekel-Bobrov et al., 2005; Evans et al., 2005). In addition the ASPM allele arose approximately 5,800 years ago during the "Second Leap Forward" which led to the advent of writing, the formation of cities, complex societies, and civilisation. Phylogenetic research of ASPM suggests a positive selection in hominins leading up to *Homo sapiens* (Zhang et al., 2003; Evans et al., 2004), and that this has been ongoing over the last six million years (Mekel-Bobrov et al., 2005, p.1720).

Furthermore, the ASPM allele suggests that the human brain is still evolving. If scientists are correct, these two variants paved the way for intense brain evolution in humans. One may hypothesise here that nature took a gamble in conferring high intelligence to *Homo sapiens*, a trend which is ongoing.

Since genetic variation in brain regulation of present-day humans exists, theoretically it would be possible to apply longstanding in animal breeding, techniques of artificial selection to enhance mental abilities of people. This harkens back to the once much-debated concept of "eugenics" where individuals would be encouraged or discouraged to procreate depending on their intellectual characteristics. Besides ethical issues related to such situation, there would have to be sustained coherent effort extending over several generations before observable effects could bee seen. Moreover, since the nature of overall genetic regulation of mental abilities is not fully understood, selective artificial breeding could have undesirable side-effects. Because of human rights and logistical difficulties in sustained long-term breeding programs the eugenic approach to brain enhancement is neither ethically acceptable nor practically feasible.

If the human brain is undergoing evolution due to genetic components will the advent of new technologies work in tandem with the former? Will modifications and augmentations to the human brain trigger brain genes which would otherwise remain latent? These are questions which will need to be addressed. Genetic components to the human brain such as the ASPM gene still need to be clarified due to its complex and long coding sequence (Kouprina et al., 2004, p.2). Moreover, the ASPM gene sequence seems to have undergone accelerated evolution in the "African hominid clade" before the expansion of the hominin brain (Kouprina et al., 2004, p.1). While science is getting closer to understanding the genetic components of hominin encephalisation, there needs to be much more theoretical work on the neuro-hormonal systems of early hominin ancestors and to what extent these systems were informed by genes? For instance, to what degree did the dopaminergic and serotonergic systems play in 'humanising' the brain during the Paleolithic period?

Mind Downloading and Technological Embodiments

One possible scenario of future brain evolution relates to the increasing computational capacity of cybernetics. At the forefront of this has been engineer and inventor Ray Kurzweil. According to Kurzweil, computational capacity will grow exponentially in the 21st century. He predicts that by 2023 computers will "run more than a billion times faster than the human brain" (Kurzweil, 2000, p.103). Furthermore, by 2030 computer capacity will "simulate the brain power of a small village...the entire population of the United States by 2048, and a trillion human brains by 2060" (Kurzweil, 2000, p.105). Drexler (1992) proffers that future super computers will be the size of a sugar cube and capable of 10^{21} instructions per second. Similarly, Lloyd "calculates an upper bound for a 1 kg computer of $5*10^{50}$ logical operations per second carried out on ~10^^{31} bits" (Bostrom, 2003; Lloyd, 2000). The exponential increase in Moore's Law in the future will need at least 250 years to arrive at a 40 order performance magnitude between current computers that perform 10^{10} operations per second and the ultimate 1-kg laptop that would perform 10^{51} operations per second (Lloyd, 2000).

Increasing computational capacity at these exponential levels will be necessary in order to successfully implement mind simulations. Bostrom (2003) claims that the dissembling of brains, molecule by molecule, and then scanning them into the computer network may be possible in the future. The person's 'cybermind' would then be fitted to a robotic body. In this way, humans may achieve immortality without suffering the contingencies of the biological body.

> It thus seems plausible that the main computational cost in creating simulations that are indistinguishable from physical reality for human minds in the simulation resides in simulating organic brains down to the neuronal or sub-neuronal level. While it is not possible to get a very exact estimate of the cost of a realistic simulation of human history, we can use ~10^{33} - 10^{36} operations as a rough estimate (Bostrom, 2003).

In this equation, a planetary mass computer would be capable of 10^{42} operations per second. Such a super computer could "simulate the entire mental history" of humanity by using "less than one millionth of its processing power" (Bostrom, 2003).

A posthuman civilization could eventually create a multitude of such computers which could run "ancestor simulations". Such computers would be 'virtual machines' and would endow post humans with 'god-like' powers.

> In some ways, the posthumans running a simulation are like gods in relation to the people inhabiting the simulation: the posthumans created the world we see; they are of superior intelligence; they are "omnipotent" in the sense that they can interfere in the workings of our world even in ways that violate its physical laws; and they are "omniscient" in the sense that they can monitor everything that happens (Bostrom, 2003).

Transhumanists' claims of the possibility of mind downloading are seen as being untenable by neuroscience and for valid reason. Firstly, the kind of mind downloading which futurists envisage will need to replicate every neuron at an individual level (Cauller & Penz, 2003, p.257). This means individuating 100 billion neurons. It also neglects the neural matrix of the cerebral cortex which consists of as many as 100 trillion synaptic connections. Secondly, transhumanists ignore the complex neuro-hormonal systems and the fact that the human brain is veritably swamped by numerous neurological chemicals at any given time which are fundamental to brain/mind processes. How does the absence of such systems render any future semblance of brain/mind?

An alternative cognitive environment is presented by Gary Small (2008) in his tour of technology and its alteration of the human brain. Small claims that current technology is changing the human brain, a claim also argued by the noted neuroscientist Susan Greenfield (2004). Hominin evolution has been informed by technological usage since *Homo habilis* or perhaps earlier by the *Australopithecines*. Technological advancements such as the use of fire had the net effect of reducing hominin gastrointestinal tract and enabled hominins to consume more meat in their diets since fire chemically broke down raw foods (Henneberg, 1998, p.748). This change in the technological preparation of food also led to a reduction in tooth size, "masticatory skeleton", as well as, "the muscles and size of the stomach and the intestines" (Henneberg, 1998, p.748). Certainly, the increasing technologising of *Homo sapiens* has changed body size and has accelerated many endeavours in the fields of science and art (Pearson et al., 1995).

There is a growing body of research that is pointing to the direction that modern technological devices are altering the human brain. Small (2008) notes that human exposure to computers, twittering, and text messaging can accelerate learning by rewiring neural circuitry. He cites a recent UCLA study of internet searching by volunteer users between 55 and 76 years. Half of the volunteers were told to practice searching the internet while their other half were told not to search. Researchers used magnetic resonance imaging (fMRI) to scan the subjects' brains. They found that the subjects who used the internet had approximately twice the amount of brain activity than the non-user group. While more research is necessary to confirm the UCLA study results it does point to the neuroplasticity of the brain.

Any formulation purported by transhumanists must take into consideration present and future understanding of human consciousness. While science has deemed consciousness as "the hard problem", neuroscience, cognitive science and philosophy are rekindling this debate. On this theme, the work on consciousness produced by the Center of Consciousness Studies at the University of Arizona is insightful. In a recent conference conducted at the center, paper abstracts reveal a plethora of areas in consiousness studies including eastern schools of thought of consciousness, evolution of consciousness in *Homo sapiens*, consciousness and reality, panpsychism and consciousness, and metaphysics and consciousness. Both Peter Russell and Stanislav Grof, among others, have been leaders in consciousness studies. For Russell (2005) present day science is in a theoretical conundrum in trying to explain consciousness. He argues that there is a slow but inexorable paradigm shift occurring in science which will lead to an understanding of consciousness as something which is not contingent on brain processes, but rather as a principle immanent througout the universe. Grof, similarly contends that consciousness is not created by the brain but is rather modulated and amplified by the brain. Such a thesis resonates with Gregory Bateson's understanding of mind as underlying all cybernetic and organic processes in nature (Bateson, 2000, 2002). Bateson's ecology of mind challenges the quantifiable metaphors of science and draws our attention to the common processes that are immanent in biological and social systems (Saniotis, 2007). On this theme, the eminent systems theorist Ervin Laszo deserves mention in relation to his cutting edge notion of consciousness as being contingent upon the 'Akhashic field' or its scientific derivation – 'quantum vacuum'. According to Laszlo (2004, 2006) the quantum vacuum contains the physical universe and carries the "memory of the cosmos" at all levels of existence (Combs et al., 2006, p.77). In this sense, universal consciousness is constituted by coherency - the idea that the cosmos is interconnected from sub-atomic to galactical levels. As Laszlo claims, coherency is a precondition of life (Laszlo, 2006, p.7). In Laszlo's words "the relatively simple consciousness inherent in every human being in the planet becomes configured and integrated into the far more complex consciousness associated with the planet as a whole." (cited in Montecucco 2006, p.133). Such an understanding of consciousness poses several bioethical questions, an important one being to what extent is human consciousness being eroded by the loss of biodiversity? How can human consiousness endevour towards a rapproachement with the non-human world?

Other groundbreaking work in human consciousness has been produced by the Institute of Noetic Sciences which fouses on the interaction between mind-body and the non-local mind. For example, Radin (2008) notes that over the last sixty years there have been approximately 900 experiments conducted to measure whether observers can affect matter. Jointly, these experiments present "independently replicable evidence that observers can affect the behaviour of physical systems" (Radin, 2008).

Brain/Machine Interfaces (BMIs)

Recent advances in nanotechnology, information technology, neuroscience and biotechnology are leading towards the development of BMIs which promise cognitive and sensory enhancements. Recent animal research on BMIs supports the contention that humans are at the threshold of a "technological revolution" where artificial devices are integrated in the primate brain (Nicolelis & Srinivasan, 2003, p.252).

The use of neurological devices in order to enhance human performance will extensively grow in the forthcoming decades. Since 2002 there have been 59,000 human recipients of neurological devices, while 19 neurological devices were approved between the years 1994 and 2003 (Foster, 2006, p.185). One of the first neurological devices was an auditory brainstem implant which was used in 1979, and employed a speech precursor and microphone (Foster, 2006, p.186).

BMIs function by interpreting and translating neural activity into computers and prosthetic devices (Sanchez et al., 2004, p.943). BMIs use "primary motor, premotor, or posterior parietal cortices" firing patterns in order to simulate hand and arm movements (Sanchez et al., 2004, p.943). This necessitates that a BMI learns to interpret neural firing patterns and translate them "onto motor commands" (Sanchez et al., 2004, p.943; Chapin et al., 1999; Georgopoulos et al., 1986; Kim et al., 2003; Sanchez et al., 2003). The success of BMI neural algorithms is posited to their ability to extract information of neural activity in a chronological order (Sanchez et al., 2004, p.943). Quantifying neural activity for BMI applications is mainly in a research stage (Sanchez et al., 2004, p.944). A positive aspect of BMI modeling is that once developed the model can contain cellular information and how cells can be mapped (Sanchez et al., 2004, p.944). BMIs and brain-computer interfaces (BCIs) have the capacity of restoring abilities to individuals who have lost motor or sensory functions due to illness or trauma (Friehs et al., 2004, p.2702). The core of this technology envisions the ability to utilise "electrophysical methods" to obtain information about cerebral processes from the electrical activity of neuronal populations (Nicolelis & Srinivasan, 2003, p.252). Neuroscientific research indicates that there exists a biofeedback loop between humans and machines and that this opens the possibility for human-machine interfaces (Naam, 2005, p.189). Research also suggests that scientists can clinically simulate conditions under which "the brain undergoes experience-dependent plasticity", enabling robotic arms to "become an extra limb of the user" (Lebedev & Nicolelis, 2006, p.539; Nicolelis & Srinivasan, 2003, p.253).

Current BMI research consists of three areas: 1) data acquisition module; 2) data interpretation module; and 3) data output module (Friehs et al., 2004, p.2702). A promising area of BMI research is in restoring movement to people who have suffered brain stem stroke paralysis. In 2000 the neuroscientist Miguel Nicolelis implanted 100 wires into the cortex of a rhesus monkey. The monkey was placed before a monitor and given a joystick which sent signals to a computer. The computer, in turn, relayed a signal to a robotic arm which precisely simulated the monkey's arm movements (Baker, 2008, p.54).

In 2003 researchers implanted 700 electrodes in the cortices of rhesus monkeys which were trained to control a joystick via a robotic arm. The electrodes which were connected to a computer established the "neural encoding of motor control" (Naam, 2005, p.177). In 2008 Nicolelis implanted electrodes into the cortex of a rhesus monkey. During the experiment the monkey's neural signals were transmitted into the actuators of a robot named CB-1 (computational brain), enabling the monkey and CB-1 to move simultaneously (Naam, 2005, p.54).

Another BMI development consists in interfacing the nervous system parenchyma which is permeated by a rich and complex vascular bed which nurtures the cerebral cortex (Llinas & Makarov, 2003, p.244). In this schema, n-wires are fastened to an electronic main catheter which is spread out in a part of the brain's vascular system (Llinas & Makarov, 2003, p.244). Such a 'bouquet' configuration could support millions of probes (Llinas & Makarov, 2003, p.244). Each n-wire would record the electrical activity of small neuronal groups without breaching the brain parenchyma (Llinas & Makarov, 2003, p.245). This neurovascular approach would enable numerous n-wire electrodes to be connected via "amplifier-binary converter to a multiplex converter" allowing them to continuously switch electrical brain signals (Llinas & Makarov, 2003, p.246). The switching capacities of multiple amplifiers are exponentially faster than electrical brain signals (Llinas & Makarov, 2003, p.246). The use of conveying information to interface terminals would make such a neurovascular interface inexpensive. Another advantage of this system is its non-intrusiveness of cerebral "blood flow exchange of gases" due to its miniscule occupation in the vascular bed (Llinas & Makarov, 2003, p.245).

While most research into BMIs is currently therapeutically orientated, such developments, if widespread one day will eventually lead to a new generation of BMIs with various cognitive and sensory enhancing usages. Thinkers like Ray Kurzweil offer a future in which neural implants are so widespread in the human species to the point that they become necessary to future humans to function normally in a high tech world. In his seminal work *The Age of Spiritual Machines* (2000), Kurzweil discusses how the human brain will be comfortably tethered to computational devices to the point that it will become a normalized part of human existence. Brain enhancement will occur gradually but inexorably via direct interface with sophisticated machines until the architecture of human thinking becomes contingent on them (Kurzweil, 2000). Kurzweil predicts by 2029 that "direct neural pathways have been perfected for high-bandwidth connection to the brain" (2000, p.221). This would allow the bypassing of neural regions and augmenting or supplanting "the functions of these regions with computing performed either in a neural implant or externally" (Kurzweil, 2000, p.221). In Kurzweil's thinking visual, auditory and tactile implants will become so widespread in the 21^{st} century that BMI's will alter human evolution and lead humans at that period to become posthumans (Kurzweil, 2000, p.221).

> If we can provide the brain with speedy access to unlimited memory, unlimited calculation ability, and instant wireless communication ability we will produce a human with unsurpassable intelligence. We fully expect to demonstrate this kind of link between brain and machine (Baker, 2008, p.52).

Similarly, Clark believes that the human brain is suitable for various novel mergers with prosthetic devices with an onus on improving human health (2003, p.7). Neural implants, for example could probe the level of neurotransmitters and stimulate the secretion or retention of neurotransmitters at neural synapses. In this way, the neuro-hormonal system could work in an optimal manner, offsetting the onset of serious psychotic and depressive illnesses. In Clark's vision neural implants will have an impact on the way in which humans will interact with their environments or global positioning systems (GPS). The combination of GPS with various neural implants would have numerous everyday applications including driving, flying aircraft and finding one's direction. Clark also argues that the neuroplasticity of the brain will enable a comfortable accommodation of neural implants (2003, pp.115-116). To what extent BMIs will affect the neuro-hormonal system, as well as, higher order brain functions and affectivity is still unknown. We would argue that any long term implementation of BMIs needs to take into account for neuronal and neuro-hormonal complexity.

Cognitive Enhancement and Nootropic Substances

Humans have sought to improve their cognitive abilities since antiquity (Rose, 2002, p.975). For example, caffeine has been a popular stimulant for centuries, while herbs and other plants have been used for their nootropic and hallucinogenic effects (Mehlman, 2004, p.483). These substances included cannabis, peyote cactus (Lophophora williamsii), ayahuasca, Atropa belladonna, Papaver somniferium, Mandragora officinarum, alkaloid plants such as pomegranate (Punica granatum), henbane (Hyoscyamus niger), poppy (Papaver somniferium), Bacopa monniera Linn., Acorus calamas, Centalla asiatica Linn. (Brahmi) (Sharma, 1987), and Celastrus paniculatus (Wink, 1998, p.12-13; Mann, 1992; Gessner, 1974; Baumann, 1986; Stouch et al., 2008; Russo & Borrelli, 2005).

Modern day attempts towards cognitive enhancements via pharmacological substances are increasing rapidly in the western world. The aim of producing drugs in order to affect cognition dates back to Guirgea "who coined the term 'nootropic' in the 1970's" (Rose, 2002, p.975). According to Guirgea pharmacological interventions should not only be acceptable and feasible, but may expedite future brain evolution. As Guirgea notes:

> Man is not going to wait passively for millions of years before evolution offers hima better brain ... To develop a pharmacology of integrative action of the brain, in the nootropic sense, seems to me to have a place in this far-reaching human objective (Guirgea, 1972; found in Rose, 2002, p.975).

Guirgea's ideas intimate that nootropic substances can enhance human and sensory abilities. However, Rose correctly points out that memory function is complex, involving neuronal and neuro-hormonal systems and that the processes involving recall need further research (2002, p.976). Memory function in simple learning tasks is affected by various neurotransmitters (dopamine) (Mehta & Riedel, 2006), adrenaline (McGaugh and Roozendaal 2002), steroid levels (Sandhi & Rose, 1997) and glucose (Gold, 1986) (Rose, 2002, p.976).

A new genre of cognitive enhancement drugs are now widely available. These include nethylphenidate (Ritalin) for Attention Deficit-Hyperactive disorder (ADHD) (Saniotis, 2009; Farah et al., 2004; Diller, 1996), dextro-amphetamine and methylphenidate for maintaining alertness and as study aids (Farah et al., 2004; Babcock & Byrne, 2000), modafinil for improving attention span (Sandberg & Bostrom, 2006, p.204), the potential 'smart drug' adrenocorticotropic hormone (ACTH) and vasopressin (Rose, 2002, p.976; Burbach & Wied, 1993). Animal studies also indicate that brain-derived growth factors (Johnston & Rose, 2001) and "endogenous cerebral neuromodulators, neurosteroids (dehydroepiandrosterone)" (Migues et al., 2001) may "enhance long-term for weakly acquired stimuli" (Rose, 2002, p.976).

Oil of Celastrus paniculatus has been used by Indian students in order to enhance intelligence. Studies on rats indicated that the seed oil increased "the pentobarbifal-induced narcosis time" (Maciuk et al., 2002; Ahumada et al., 1991). The seed oil also seemed to increase myelinisation while the protein content decreased "dopamine turnover in rats" suggesting an increase in memory skills (Maciuk et al., 2002; Bidwai et al., 1987; Nauni et al., 1995).

Future pharmacological substances might be instrumental in enhancing cognitive potentialities and in the controlling of various addictions and phobias (Sandberg & Bostrom, 2006, p.204; Pitman et al., 2002; Hoffman et al., 2006). Cholinergic inhibitors have shown to have a positive effect on cognitive performance (Connemann et al., 2003). Research done on methylphenidate appeared to show improvements of spatial working memory among young volunteers. While these results have not been replicated by elderly volunteers they indicate increased "effects of "dopaminergic agonists" (Mitul & Riedel, 2006, p.2493). Evidence suggests that increased dopamine stimulation improves spatial working memory in people (Mitul & Riedel, 2006, p.2495). These results also conclude that more research needs to be conducted on the "cognitive effects of dopamine agonists" and the role of stimulant drugs such as amphetamine, methylphenidate and cocaine in dopamine transmission (Mitul & Riedel, 2006, p.2492, 2495). Future drugs may be able to prevent various addictions by manipulating and blocking dopamine reuptake. Previc's work on dopamine (2009), indicates that it was influential in human evolution and that dopamine was significant in the 'humanisation' of the cerebral cortex. For example, Previc suggests that dopamine is important in "promoting generativity" and improves human "fluency" (Previc, 1999, p.314). This means that dopamine promotes production of mental images and their processing. Thus, declines in dopamine levels may lead to deficits in "verbal and semantic skills that are found in aging" and the onset of dopaminergic deficit conditions such as Parkinson's disease, depression, Huntington's disease and phenylketonuria (Previc, 1999, p.314). If this is the case, then future drugs could be tailor-made in order to enhance attention, an important role of dopamine.

The seemingly increasing popularity of modafinil is a case in point. Originally developed for treating narcolepsy it is now recommended as a drug for improving attention span and alertness (Sandberg & Bostrom, 2006, p.204; Teitelman, 2001). It has also been found to increase reaction time in different memory tasks and spatial planning (Turner et al., 2003). Of course, such a drug could have many applications in assisting for workers in various backgrounds, including shift workers, doctors, truck drivers and aviators (Gill et al., 2006; Caldwell et al., 2000). Laboratory studies also show that modafinil increases executive functions in "rested healthy adults, particularly inhibitory control" (Greely et al., 2008).

Future pharmacological use may have widespread social ramifications which may eventually lead to changes in human social evolution. Firstly, if new generations of nootropics enhance human cognitive abilities then even non-users may be coerced into taking them in order to compete with the users of nootropics (Cakic, 2009). We predict that future societies will use nootropic substances concomitantly with virtual reality technologies in order to enhance cognitive abilities, as well as, intensifying experiences. In relation to children, the use of nootropics along with cybernetics may indelibly change their learning abilities in ways which we cannot foresee. According to Greenfield, the computer revolution is hardwiring children's brains in a negative way such as shortening their attention spans. She connects the increasing use of Ritalin for ADHD by children as a consequence of spending too much time in front of computers. Although Greenfield's views have not been verified by ongoing research they do provide possible future scenarios. Alternately, as scientists better understand the processes of addiction and their neuro-hormonal correlates nootropic substances could be strategically used. The development of nanotechnologies may also enhance nootropic molecules to be directly targeted to neural tissue, thereby enhancing cognitive abilities while diminishing unwanted side effects. In the future, "nanoscale materials" will be highly developed for therapeutic and diagnostic purposes (Khademhosseini & Langer; Langar & Tirrell, 2004; McCarthy et al., 2004).

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