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Chapitre 9

COGNITIVE ENHANCEMENT, HUMAN EVOLUTION AND BIOETHICS*

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"An important reason for the persistence
of the idea of the universality of human dignity
has to do with what we might call the nature
of nature itself" (Fukuyama, 2002,156)

This article has three goals. The first is to explore the relations between the properties designated by the terms "human", "post-human," "Trans-human", and to clarify the corresponding "isms". The reason why we need to provide this clarification is that the present ethical debates are more or less implicitly associated with certain views about human evolution. It is therefore useful to

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dispel some usual confusions about the use of these terms, and about the normative intuitions they convey. Our second goal is to scrutinize the current techniques for cognitive enhancement in order to assess, first, their relation with the three categories just mentioned, and, more generally, with specific ethical issues. We will focus on techniques aiming to modify human sensory and cognitive abilities – leaving to others the task of exploring the no less crucial role of genetic technologies in the evolution of the species. Do they deeply affect our mental and bodily integrity, to the point of creating a break in the dynamics of human evolution: do they affect "the nature of our nature"? Our third goal is to briefly examine whether general ethical principles could be invoked either in favor of, or against, the normative proposals of post-and trans-humanism, and to consider how compatible the types of enhancement presently developed are with respect to these principles.

I - HUMANS, POST-HUMANS AND TRANS-HUMANS

At first, one might be tempted to see these three categories of beings as defined by a process of speciation. Roughly speaking, a post-human species would be a natural or artificially engineered lineage that diverges from homo *sapiens sapiens* in several features, first and foremost in its reproductive mechanisms. A trans-human species might be a particular form of post-human species, where a combination of systematic genetic modifications, neural implants, organism-machine hybridization and adaptive training is supposed to elevate the transformed entities to a new realm of achievement and dispositions.

The difference between post- and trans-humans thus seems, at least prima facie, to be a matter of how biologically distant the products of selection are from the original human genome– the minimal distance between them being their incapacity to interbreed. Is this definition empirically and conceptually acceptable?

Speciation: a biological path to post-humanity?

In biology, speciation is the evolutionary process by which new living species appear and develop. Speciation occurs at varying speeds, but it normally requires a time scale of several hundreds of thousands of years. Contrary to Nietzsche's interpretation of Darwin, a species does not emerge "in order to overcome itself": speciation tends rather to result from new or more specialized selective pressures. As a consequence, certain mutations will spread in the population. Speciation is completed when these mutations prevent interbreeding between the original and the mutant populations.

Among the variety of speciation scenarios, two cases are particularly frequent in nature. In 'allopatric' speciation, populations diverge because they have been geographically isolated. Galapagos finches are a classical example explored by Darwin. In 'sympatric' speciation, populations diverge under the influence of selective pressures unique to some particular ecosphere. For example killer whales are subdivided into two non-interbreeding populations, resident and nomadic. Granting a global exchange of goods and persons as we know it, however, sympatric speciation in humans looks highly unlikely as long as humans live on the same planet.

Artificial selection

If post-human speciation has any chance of occurring, it thus does not seem very likely that it would be a consequence of *natural selection*. An obvious alternative is that it might result from man-engineered, *artificial selection*. Although the genome is constantly mixed, one might aim to select, within a population, individuals having desired traits (an eugenic practice that is currently found ethically unacceptable for humans), or directly insert new genetic material in a host genome. A genetically modified monkey was produced in 2001[1], in order to help develop new treatments against Alzheimer's disease or certain cancers. Although ethics committees currently limit genetic engineering to such purposes, genetic engineering could, in a not very distant future, be applied to human individuals, in order to serve socially meaningful goals, such as enhancing their attentional abilities (capacities that are known to be efficient in inhibiting dispositions to violent behavior). Note, however, that beings enhanced in one of their properties do not automatically qualify as post-humans. A post-human must be genetically different from all current and past humans. Furthermore, an enhanced mutant population (supposing that the acquired genes spread to a sufficient number of individuals) would only count as 'post-human' once interbreeding becomes only possible among mutants.

Granting this, however, helps bring to the fore a more important point: being post-human in the literal sense of speciation does not capture the meaning intended in a philosophical or ethical discussion of post-humanism. If interbreeding was no longer possible among enhanced people from human ascent, it might add to the difficulties in finding one's mate; but it would not affect

1 *Science*, 2001, 291, 309-312.

the representations that bind humans together. Being human is not defined only by the extent to which one is able to fulfill common bodily or mental dispositions – for one rightly considers as fully human those who have lost, or failed to express, them, for instance the congenitally blind. Being human seems rather to be rooted in our representations of the norms, values and obligations that are attached to the human condition, and that contribute to regulate social interactions independently of ability, ethnic origin, socio-economic level, etc.

This normative dimension is present in the distinction between the positions associated with humanism, post-humanism and trans-humanism. In fact, in contrast with a merely biological or biotechnological definition of three categories of entities, these three positions can be seen as embedding an implicit type of ethical stance about the future of mankind.

The cultural import of "isms"

What is post-humanism?

Post-humanism is a value system that aims to supplant that of humanism. Nietzsche's *Zarathustra* exemplifies this position when he criticizes humanism for promoting man's domestication. Although contemporary post-humanists follow Nietzsche in his diagnosis about the insurmountable weaknesses of humanism, they differ in their critical foci. The humanist claims for equal dignity and equal value are not called into question. Rather, humanism is criticized for its inability to convert these claims into facts. Various explanations have been offered for this inability.

In his *Letter on Humanism* (1946), Martin Heidegger offers two reasons which, according to him, turns humanism into "the agent of non-thinking". On the one hand, humanism endorses Aristotle's definition of man as a rational animal. Human nature, however, should not, according to him, be defined in a zoological or biological perspective. Language is supposed to introduce a radical discontinuity between animal and human nature. On the other hand, humanism places uncritical trust in science and technology. Technology, however, often serves the ends of violence and domination by some men over others. All the values that humanism openly claims to promote, such as moderation of one's impulses, equal distribution of wealth, trustworthy exchanges, respect of others, are overwhelmed by such technological changes as deadly weapons, tools for social manipulation, and mass production of useless objects. Humanism is also blamed for not having foreseen the consequences of the gradual disappearance of traditional religious or cultural references. Technology, as a direct expression of the ‘animal will’, is to blame. In sum, Heidegger diagnoses the error of humanism as rooted in an uncritical fascination for technology, which is, itself, a direct expression of the animal will. Post-humanism, from a Heideggerian viewpoint, is based on the proposal that culture, language and education should be substituted to technology as the main goals to be reached, in conformity with human nature, now severed from animal will.

In a controversial paper entitled “Rules for the Human Park”, Peter Sloterdijk offers an alternative diagnosis. He proposes revising Heidegger’s diagnosis of the humanist failure. The problem does not have to do with a mistaken, continuistic definition of man as a rational animal, but rather with the fact that all the consequences of this definition fail to be drawn. What humanism fails to reflectively consider is not its relation to language, but its own animal essence. According to the author, sedentary men are tamed by their own house, in the same way as they are themselves taming (training, breeding) their domestic animals. Sloterdijk emphasizes, as post-humanists generally do, that a species is mainly shaped by its *socio-technical* environment. Humanism has fostered an environment dominated by a division of labor between the literate and the illiterate: thus was “created a gulf between them so wide that they almost turned into two different species”. In Sloterdijk’s opinion, however, in vivid contrast with Heidegger, it is not only through literary education that mankind can be educated. An anthropo-technology (including genetic engineering) is necessary to “domesticate” men, reduce their violent behavior, and promote peaceful cooperation between people.

Post-humanism and trans-humanism

With this last claim, Sloterdijk occupies an intermediate position between post- and trans-humanism. Trans-humanism is less centered on a philosophical critique of the nature and scope of humanism, than on the hope that new techniques (genetic engineering, nanotechnology, robotics and virtual reality) will help humanity to overcome the limitations inherent in its biological evolution (aging, suffering, reproduction, etc.). The influential authors for this trend of thought, such as Nick Bostrom, David Pearce, Ray Kurzweil, and Hans Moravec, are computer scientists or roboticians who intend to “improve” (or “meliorate”) the bodily, emotional, or cognitive human dispositions. Melioration here does not mean merely restoring health or optimal functioning in natural bodily and mental functions. More radical trans-humanists plead for a replacement of humans by robots with some preserved human features. In spite of the science-fictional tone of this kind of goal, trans-humanists detect some signs that the mutation they are calling for is under way. We will offer a concrete example shortly.

In spite of its emphasis on technological utopia, the normative dimension is prominent in the trans-humanist credo: the final aim is not merely instrumental – curing diseases, suppressing handicaps, or regulating social interactions. It is, rather, to allow humanity to have access to a higher form of consciousness and ethical status, to be sensitive to goals and values that are beyond the reach of natural humans.

The case of Kevin Warwick

The research conducted on himself by the computer scientist Kevin Warwick is one of the signs that might foreshadow the new hybrid entities that, according to trans-humanism, harbinger the future of mankind. His "Cyborg" Project aims to promote the fusion of the organism and the machine. Human beings, when equipped with a pacemaker, a cochlear implant, a joint prosthesis, are on their way to becoming cyborgs. A "real" cyborg, however, is not merely an agent whose physical substrate is hybrid: it is a biological brain that controls robots, and thus is able to use artificial extensions of its bodily and mental systems.

Kevin Warwick (University of Reading (UK), was implanted in 2002 with a microchip in the median nerves of his left arm. This microprocessor, being connected to a radio transmitter, is designed to allow his nervous system – or rather, the motor subsystem controlled by the nerves of his left arm, to be sensitive to the motor commands issued by distant computers or by a human being. Warwick has thus managed to couple his own arm (both as a an agentive medium and as a sensory receptor), with the arm of a distant robot. Warwick reported feeling in *his* own fingers, the shape of objects manipulated by the distant robot on the basis of *his own* intentions. He could also "allow" the distant robot to form the intention to move his own fingers. Warwick's next attempt was to connect his own motor system to another agent's via microprocessors: his neural activity is now spreading to the other's system, namely his wife Irena, even when she is not physically present. Warwick has called Techlepathy "this new form of telepathy enabling agents to directly communicate information from one nervous system to the other. According to Warwick, techlepathic technology could one day become the main form of human communication.

The Cyborg Project is thus not merely a matter of extending human capacities; it aims to promote communication, make it more immediate and felt "in one's bones". As observed above, trans-humanism, and post-humanism, reflect implicit ethical choices. Heidegger's argument was that technology missed the true, language- and reason-bound, "good" nature of man. Heidegger's post-humanism thus consisted in returning humanity to its essence, supposed to have been obliterated by the animal will. This ethical position qualifies as a "bioconservatism.[2] Sloterdijk, in contrast, aims to use technology to help humans achieve their own essence as rational animals. His position is echoed in the "liberal" conception of bioethician John Harris (Harris, 2007), who takes enhancement to be "right ethically" "personally prudent", and in agreement with moral and political considerations. Finally, trans-humanists represent a radicalization of the liberals, in that they consider that hybrid entities are bound to supplant, and finally replace *homo sapiens sapiens*. They see hybridization as an expression of individual freedom, and offer ethical reasons against banning enhancement, which possesses, in their view, its own intrinsic ethical value.

II - ADVANCES IN NEUROTECHNOLOGY

The baroque experiments by Kevin Warwick give us a foretaste of the new possibilities offered by the emerging field of neuroinformatics. In order to assess the ethical relevance of enhancement research, we will present the state of the art, limiting ourselves, as announced earlier, to the techniques aiming to modify or extend an individual's sensory or cognitive abilities – leaving aside genetic manipulation techniques, and the use of psychotropic drugs. The set of enhancement techniques has grown considerably in the last fifteen years, but still remains poorly known to the general public: it involves costly prototypes, often developed as part of specialized remediation or military engineering. The fact remains that this sector has huge potential implications for the future of individuals and societies.

A- Sensory substitution systems

The first set of techniques aims to provide subjects who are deprived of a sensory modality with the information that this modality normally provides, in a format that they are able to decipher. Take the example of Braille alphabet. Each character, or *cell*, is made up of six dot positions, arranged in a rectangle. This alphabet allows a visually impaired agent to convert written words into finger-touched words. A written text, whether in Braille or in other formats, has the disadvantage of being non-modifiable: the blind can only read texts translated

[2] The tripartition between conservatives, liberals, and transhumanists, is borrowed from . Missa & Perbal, (2009, 9).

into tactile signals. The principle of a tactile vision substitution system (TVSS), first developed by Paul Bach-Y-Rita (1998) consists in providing a disabled perceiver more autonomy in the collection of sensory information. The TVSS automatically performs the conversion of information from one modality – such as vision – to another, such as the tactile modality. To do this, sensors collect signals in the impaired modality, for example through a camera attached to the head; a coupling system then converts the signals into stimulations in another modality, such as sounds or tactile stimulations. The inner thigh, the abdomen, and finally the tongue, much more innervated, were successively used as a "visuo-tactile screen". The pixel-based visual image is thus converted in points on a vibrotactile screen in contact with the skin (on the back, abdomen, or forehead). Equipped with this apparatus, a blind subject quickly learns to identify objects and to track their trajectories. This sensory substitution technology has been successfully applied to visually impaired babies, whose cognitive development and socio-emotional maturation benefited immensely from this (non-invasive) equipment.

It is no exaggeration to say that the TVSS allows the blind to "see" the world. This is made possible, inter alia, by the fact that information as collected on the skin does not compete with the proprioceptive information that is present in the area where the equipment is located. As is well known, the blind person who uses a cane to get an echo from the environment does not perceive the tip of the cane or the vibrations of her ears. She perceives, rather, the objects that surround her. The same holds for subjects equipped with a TVSS: they "see" the objects *of the outside world* – and not the stimulations on their skin. They are thus able, after some training, to interact with the outside world: return a ball, or engage in minute electronic assembly.

Who among normal seers is not persuaded that vision is a source of infinite and varied pleasures? Paul Bach-y-Rita, however, discovered that being equipped with a TVSS does not automatically bring pleasure to the person so equipped. From congenital cataract surgery, it had already been found that some patients prefer to return to auditory exploration rather than live in a visual world. Contrary to what one might expect, receiving sensory information does not automatically make it attractive, or even bearable by a perceiver. To love to see, hear, or touch, one must have learned to do so at an early age at which emotions colored sensations. A blind baby equipped with a TVSS will love to have a tactile feel of the objects around him because he experiences the pleasant emotions of discovering the world in an autonomous way. This may not be the case for more mature visually impaired individuals with an established practice of auditory exploration. This finding deserves attention in a world where neurotechnologies are assessed for their ethical value. This value has to be assessed contextually and individually, rather than as a matter of general principle.

New applications of sensory substitution systems are now under study: they are used to allow surgeons to guide their actions according to a pre-planned trajectory in the intervention areas that are not accessible to vision (Robineau et al., 2007). Others are used to transform vestibular into tactile information (Brainport, Paul Bach-Y-Rita). A third group of applications concern the military; they aim to improve the quality of night vision by extracting thermal infrared information. The thermal stimuli can be converted into tactile stimulations, or can directly affect retinal implants. Here a second issue is one of "fairness". Is it fair to use cognitive enhancement in a military attack, when the enemy does not even know that new tracking methods are available? Is not, generally speaking, equality of access a precondition for the ethical use of new enhancement techniques? We shall return to this issue in the last section.

Let us now turn to the present state of the art in neuromotor enhancement.

B – Neuromotor substitution systems

Sensory substitution systems rely on brain plasticity to establish intermodal equivalences in order to allow a perceiver to have access to information in a modality that is impaired or unavailable to him. Similarly, neuromotor substitution systems aim to offer agents a form of mobility that is no longer, or was never, naturally available to them. The Australian artist Stelarc, has been one of the first to emphasize the relatively contingent character of the human limbs. He conducted various types of intervention on his own body, at the juncture of the "body art" and the "performance art" traditions. He added a third upper limb, which he called 'The Hand': this robotic manipulator was controlled by electromyographic signals recorded on the abdominal muscles and thighs. In a more recent performance, Stelarc manipulates a six-legged exoskeleton controlled by its own body. His credo seems typically trans-humanist. "Our biological body with its particular form and its particular functions becomes inadequate in the context of technological high-precision machines. This does not mean that we can do without it. But the body could for example be technologically augmented or genetically meliorated, it could be reprogrammed or redesigned. *(Libération,* October 12, 2007).

Stelarc aims to reprogram his body. The scientist Miguel Nicolelis demonstrates that the body and an external robot are, for the brain, *equivalent* tools or instruments for acting. In a series of fascinating experiments, Miguel

Nicolelis and his colleagues, specialists in neuro-engineering at Duke University (Nicolelis et al., 2000), connected a small nocturnal monkey, the douroucouli, to a computer, itself connected to a robot. The monkey's cortical (frontal and parietal regions) were implanted with electrodes that sent signals to the computer and thereby, to the robot; this device is called a "brain-machine interface closed loop" or BMIC How does the animal learn how to maneuver the robot in order to obtain food? He must discover, in a practical way, what "thought" is able to activate the remote robot. A practical and not a theoretical discovery, for the animal does not know what thought is and obviously cannot theorize about the relationship between its brain and the robot. Note that in this strange situation, the arms are useless, since they cannot reach the food: the animal realizes this quickly and does not try to use them. In a BMIC, one must act in a mental way in order to change the world. How then does the animal manage to move the robot? In the absence of any proprioceptive feedback (since no movement is made by the animal), the vision of the effects of its thoughts on the robot delivers the only data providing the feedback needed to select the proper commands. To use them, it must have somehow reprogrammed itself. This may have seen as natural to it as, in humans, the fact of driving a car, which momentarily becomes their own body. As natural as Stelarc's third arm. If this is true, then conservative ethicists' concern for true human nature may appear misplaced: humans are, like other primates, highly plastic, and naturally open to any form of enhancement (at least, when the conditions listed above are present).

Neurotechnology has exploited Nicolelis' and others' findings in order to develop neurotechniques for coping with tetraplegia. Tetraplegics with preserved ocular motility can produce a text simply by directing their gaze at the keys they want to strike, and thus communicate with their environment. But some of the patients with Locked-in Syndrome are not able to move their eyes. Two types of Neurotechniques now allow them to mentally concentrate on the letters presented on the screen to convey their messages. The first is invasive: silicon electrodes are implanted permanently in the premotor and motor cortex. They send "volitions" to a brain-machine interface, which transmits them to a robotic limb (a neuromotor prosthesis) or to a computer screen (Hochberg et al. 2006). These techniques allow patients to recover a minimal autonomy, and to have exchanges with their loved ones; they also present serious problems associated with brain surgery and rapid tissue decay around the electrodes.

A second group of techniques is non-invasive. An EEG helmet placed on the patient's scalp can detect differential neuronal activity produced at any given time. The mental effort required from the patients is much greater here, however, since they must focus their attention exclusively on what they want to do, in order to create a frequency signal dense enough to be decrypted by cortical EEG. Hitachi has been marketing another type of non-invasive system called *Optical Topography:* This technique can identify the brain areas where blood flow is maximal with a light near the infrared. These measures can be used, as in the previous case, to extract information about brain activity in order to control a robot. Unlike invasive techniques, non-invasive methods require a fairly long learning phase, everyday use, and a good ability to concentrate. They are too tiring for the patients to use the devices constantly.

Are these technologies ethically sound? The supplementary neuromotor techniques, as well as the substitute sensory systems, seem to fall unambiguously into the category of the ethically acceptable. Thanks to them, subjects confined in a paralyzed body, or deprived of a form of perception, are allowed to enjoy a form of autonomous agency and communication. Even conservative ethicists might welcome such therapeutic enhancements. This liberal view about neurotechnology, however, is confronted with two objections.

As noted above for the case of Kevin Warwick, there is no reason why neuromotor technology, in both its invasive and non-invasive forms, or the use of TVSS, should be limited to situations of motor or sensory disability. It could be developed for other purposes, be they commercial, recreational, artistic, or military. Just as sensory perception may be artificially increased by the extraction of modal information that would otherwise be unavailable, such as thermal or magnetic information, actions can be performed remotely, made more precise, more informed, more sensitive to the group. For example, it will soon become possible to share motor intentions with one or more other agents without having to pass through an external signal. One can imagine applications of such devices for military purposes, or for organized crime.

The second objection is that the high cost of these alternative technologies is, at least in the immediate future, a serious concern for the principle of the equal dignity of humans. Offering motor autonomy to a tetraplegic is so expensive that only wealthy individuals can afford it (about thirty-five to date). This also applies to the various ways rehearsed above of artificially enhancing sensory awareness or motor ability. Why should public-funded research benefit only a happy few? Note that this situation is not unique to biotechnology, nor even to the present stage of technological development. Technical innovations of all kinds have always been first enjoyed by those who could afford them. Writing and reading, for example, for centuries remained a private competence of the ruling classes and the clergy, before spreading to the general population. The present concern, however, is that the "gulf between literates and illiterates" could now be transferred to one between artificially enhanced and natural humans: why should the former be offered opportunities denied to the latter? This is a serious debate that involves political premises as well.

C – Cognitive enhancement devices

Pedagogy, school organization, educational curricula, and academic tests can be seen as aiming at a *quantitative* augmentation of knowledge (although they also bring qualitatively new types of cognitive abilities having to do with self-regulation, this is not, admittedly, their explicit function). *Cognitive* enhancement, however, goes beyond a merely quantitative increase in knowledge. It rather aims mostly to develop qualitatively new skills (whether epistemic, affective or conative). Reading and writing, for example, qualify as a qualitative cognitive enhancement. The human brain does not come with reading as a natural ability. At present, two types of technology-based qualitative cognitive enhancement need to be distinguished, as they seem to raise different ethical problems. Non-invasive interventions – whether educational or regulatory – seek to develop capabilities in children or adults that they would fail to acquire otherwise. Invasive interventions, in contrast, aim to add or foster a missing or poorly developed cognitive capacity by directly modifying the subject's nervous system.

1) Non-invasive techniques of cognitive enhancement

Research in this area has been inspired by the observation that brain development depends on both genes and training. Because of this dual influence, humans differ in how they use their brains for a single task, a difference that is evidenced by brain imaging techniques. The expression of genes is itself modulated by prenatal and postnatal environment (again, this article does not consider the possibility of manipulating the genes themselves). Some of the events that contribute to genetic modulation have now been identified: for example, early separation from the mother can result in significant cognitive deficits in offspring and, in particular, attentional ones (Tremblay, 2008). If there is no such thing as a standard learner, it becomes necessary to offer educational and training facilities adapted to each particular brain. Two ethical principles seem to clash in this case: a popular rule is that school children should be treated in the same way: any discrimination or "stigmatization" among them would be detrimental to their self-image. Another principle, however, consists in responding differentially to the cognitive and emotional needs of children. If these needs are different, as is now established, then the children should also be offered different forms of help: for some, it will be the traditional forms of educational training; for others, it will be cognitive enhancement. The "stigmatization" rule seems to have to yield: it has little weight when one considers what children have to gain from receiving the kind of help they need; furthermore, being offered a diversified type of training does not have to be associated with undergoing discriminative or derogatory attitudes.

It is in the field of attentional training that enhancement research has mostly been developed. Voluntary mobilization of attention is the key to academic success and, more broadly, to social learning. The effects of attention training on the development of individual intelligence were recently experimentally tested by Michael Posner. After a 5-session training course consisting of video games designed to develop their executive memory, 4 year-old children were found able to reach by 6 years the attentional abilities typical of non-trained 8 year-olds (Rueda & Posner, 2005). Minimal attentional training thus seems to have a deep influence on development and benefit the child's insertion at school and in other social settings.

Here again, applied ethics recommends helping each child develop or enhance her own cognition to a level compatible with the child's well-being, while political philosophers and social scientists emphasize that the problem is of a social rather than a psychological origin. They often object that "individualist" methods of training are not a panacea: the social and emotional environment of a young child (family, living space) are crucial dimensions of their cognitive and attentional development. The quality of these inputs depends in turn on a multiplicity of socio-economic and cultural factors such as the stability of a family's resources, its integration into the social fabric, and parents' sensitivity to the emotional and cognitive needs of their children.

This objection, actually, does not diminish the importance of Rueda & Posner's results. The reason is that, independently of the sources of attentional difficulties in children (genetic, environmental, social), mental and emotional autonomy can be made available to children who, left to themselves, would not be able to acquire it. As emphasized by Posner & Rueda, subjects with attention deficit hyperactivity disorder (ADHD) are a primary target population for attention-enhancing videogame training (It is estimated that at least 5% of children, and 4% of adults present this problem).

An alternative, more costly, method is also explored, based on the non-invasive EEG feedback methods presented earlier (Fuchs et al. 2003, Strehl et al., 2006). An EEG helmet collects neural activations in various portions of the scalp, while the child is playing a video game. A neurofeedback training is actually occurring through this videogame, for the player is asked to reach target values embedded in the game (for example, the relative speed of an aircraft correlates with the activation of a neural structure involved in attention). Granting that the observed values are distinctively modulated by arousal and focused attention, children here learn how to attend through mere biofeedback activity, and to resist their impulses. Widely used in North America, this technique has been found to allow ADHD children to progressively stop using Ritaline. The price of an EEG helmet for therapy purposes (around 3000 $), however, raises, again, ethical issues: why should low-income families be denied access to neurofeedback?

Another socially relevant, bioethically sensitive, issue concerns the application of neurofeedback to emotional development. Here again, the ethical question is associated with bioconservatist norms: should one allow natural differences to remain, even if they are associated with considerable difficulties for the individuals, their families and society at large? Or should technology-based self-reshaping be allowed and encouraged? Collective interest suggests that this course of action would be a more socially responsible one. Take, for example, the case of emotional impairment. Psychopathy refers to an impaired development of emotion, which results in a lack of moral awareness, and an unwillingness to postpone the satisfaction of one's desires, in particular those of a violent or sexual nature. Many psychopaths end up living in jail for substantial parts of their lives. Why are psychopaths vulnerable to criminality and violence, poverty, and relational difficulties? It is now known that reactivity to aversive stimuli, such as the expression of pain in others, or the image of mutilated or bleeding bodies) is a causal factor in social learning. Psychopaths lack such reactivity; the so-called "fear-circuit" (a set of brain areas involving the insula, the anterior cingulate and the amygdala), in their case, fails to be activated (Blair et al., 2005, Birbaumer et al., 2005). Some neuroscientists have been attempting to use neurofeedback to restore activity in the fear-circuit in volunteer psychopaths (Caria et al. 2007). An fMRI device is used to record in real time the blood flow in the patients' insula. Patients can, again, visualize their insula activity and reach a target value, on the basis of neurofeedback, as described above. The same kind of technique can be used (mutatis mutandis) to diminish insula activity (in the case of hyper-anxious patients). After a few sessions, normal values are reached. A remaining problem, however, consists in stabilizing the therapeutic effect across new contexts. More research, then, is necessary before such treatments may become available. Before assessing neurofeedback as a general way of manipulating one's emotions or one's attention, let us turn to an alternative technology, of an invasive kind.

b) Invasives techniques of cognitive enhancement

As in the cases of similar techniques discussed in sections A and B, invasive techniques for cognitive enhancement were originally designed to remedy neural impairments. Two types of cases have been particularly suggestive about the potential of these methods. First, there is deep brain stimulation (DBS): this involves implanting a brain pacemaker, a device comprising three components: 1) a generator emitting electrical pulses (i.e. a battery implanted under the skin in the person's body), 2) a coiled insulated wire, connected to 3) a few electrodes implanted in a target area (e.g. thalamus or globus pallidus). The device helps to regulate a number of neurological problems such as chronic pain, depression, Parkinson's disease or Tourette's syndrome. Apparently there does not seem to be an ethical problem here: patients' quality of life is greatly improved. The device, however, presents some risks; when the stimulations are not appropriately targeted and calibrated, they may cause psychiatric or neurological disorders, which, fortunately, are reversible after recalibration.

A second technical success was the epilepsy pacemaker stimulating the vagus nerve ("Vagus Nerve Stimulation", or VNS). A small electrical device implanted in the patient's body sends electrical impulses to the brain permanently (once every 5 minutes). The electrodes are used to analyze brain activity and identify an impending crisis. When a crisis is predictable, an implant inserted to this effect sends a stimulation to the cranial nerve, which is usually enough to prevent the crisis.

The next generation of invasive techniques is now underway: it is meant to hybridize artificial neural systems with assemblies of biological neurons. Hence a new research field, named "Biomimetic Microelectronics". Ted Berger,[3] from the Center for Neural Engineering at UCLA, first studied ways of providing cortical prostheses to individuals losing brain cells, such as Alzheimer patients. His work then turned to the development of a new generation of computers inspired by biology, with an eye on hybridizing them with neural systems. The technology crucially involved is that of VLSI (Very Large Scale Integration), in which integrated circuits combine thousands of transistor circuits into a single microprocessor (a first step to a brain nanorobotics). Silicon micro-circuits implanted in the hippocampus are thus expected to have a functional behavior similar to that of 10000 neurons. In a closely related line of research, Peter Fromhertz and his colleagues from the Max Planck Institute of Biochemistry have recently implemented *in vitro* a microprocessor connected with an excitatory chemical synapse; this device has been found to be able to transmit information to the natural neurons of a snake. From the scientific and technological prospective, these results are thought-provoking. It seems clear that

3 See Berger and Glanzman (eds.), 2005.

hybridization will help remedy cognitive deficits (such as traumatic amnesia or dementia), and also mitigate the normal effects of aging. More questionably, such research will also, inevitably, seek to expand mental skills beyond the limits of individual natural learning.[4] People will want to extend their memory, their reasoning abilities, regulate their affects at will. Implanted computers and improved nanotechnologies will allow the number of computations per second to be exponentially increased (Kurzweil, 2006). It will thus probably be possible, in a not too distant future, to shop for a cognitive enhancing device, as we go about choosing, today, the computer best adapted to our needs.

III - GENERAL DISCUSSION: COGNITIVE ENHANCEMENT, HUMAN NATURE, AND BIOETHICS

The present state of the art in the areas of sensory, motor and cognitive enhancement suggests that these will widely develop with progress in neuroinformatics and in nanotechnologies. The survey above of these trends allows us a glimpse at the advantages, risks, and ethical issues they involve. We now have two remaining questions to address. First, are these enhancement techniques in themselves prone to influence human evolution in the way that is feared by the bioconservatives, tolerated by the liberals and called for by the transhumanists? Second, (and based on how we address the first question), what are the main general ethical issues that they raise?

1) Does cognitive enhancement threaten our human nature?

Is wide application of such enhancing techniques likely to lead to the supplanting of humanity by post- or trans-humans? In order to address this question, one needs to look at the mechanisms on which enhancement depends. Let us first concentrate on non-invasive forms of sensory, motor and cognitive enhancement. Three types of conditions make such enhancement possible.

First, “neuroplasticity” must be present. This term refers to the brain’s ability to change its own organization, that is to say to change both its physiology and anatomy. There are, again, three ways in which neuroplasticity can be realized. The first is neurogenesis, i.e. the ongoing production of new neurons; this seems to be an exclusive property of certain structures, such as the hippocampus, the

[4] For a powerful transhumanist defense of hybrid entities, see Kurzweil, 2006.

olfactory bulb and the cerebellum. The second is the selective pruning of inactive cells. The third is the reorganization of synapses. These three types of mechanisms naturally enable the nervous system to adjust to the world, and especially to internalize appropriate forms of response.

The second precondition has to do with the existence of reliable, recurrent feedback. Feedback is the retroactive effect of the consequences of a command on the command itself. Learning a skill consists in identifying the various possible consequences of a command, and using them to predict action success, and to adjust the action to new contexts. Feedback plays a key role in making comparisons between the expected and observed results, and thus is a key to learning. All neurotechnology needs to rely on subjects' ability to identify appropriate feedbacks in order for them to expand or enhance their cognitive skills. As will be seen later, videogames can be developed for subjects giving them visual access to their brain states. Having such feedback enables agents to control, to some extent, the dynamics of these states and to learn how to attain new values of performance.

The third precondition has been discussed above: agents need to feel pleasure, and/or be motivated, in order to act. They cannot be sensorily or cognitively enhanced if they do not enjoy the learning activity that is involved: if such is the case, they will not attend to the relevant feedback. One cannot do just anything with a subject's brain: she must consent to learning, and engage in it willfully.

What is striking about these three preconditions, is that they are *constitutive of ordinary human cognition*. Neural plasticity and feedback explain the phenomenon of "technological scaffolding", which, for Andy Clark, make humans, from the start, "natural-born cyborgs" (Clark, 2003). Scaffolding refers to the dynamic coupling between feedback gained from tool use, and cognitive enhancement. Drawings, books, landmarks, maps, abacuses, are ancestors of our contemporary computers, and of the upcoming neurotechnologies. All these tools have enhanced our natural ability to remember, understand, and reason (not to mention the sensory enhancement derived from glasses, binoculars, telescopes, microscopes, and the motor enhancement derived from sporting gear and training etc.). As Clark observes, "we exist, as the thinking things we are, only thanks to a baffling dance of brains, bodies, and cultural and technological scaffolding" (2003, 11). Considering non-invasive techniques, it is justified to say that they do not threaten our human nature, because neuroplasticity, feedback (including brain-machine coupling), and motivation are three core dimensions in it.

Now the further question is whether this view can be generalized to invasive techniques (leaving aside, again, issues associated with genetic manipulation). Many thinkers, such as Francis Fukuyama, and Leon R. Kass, consider that invasive techniques violate the distinction between the living and the artificial. They *ipso facto* produce hybrid entities that no longer qualify as strictly human. Does not this conclusion, however, rely on a parochial view of our human nature? Given humans' propensity to externalize their mental capacities, as convincingly shown by Clark and Chalmers (1998), it is just a small step to insert these external means into their own body parts (arm, skull, trunk, etc.). There does not seem to be a radical difference between using an external i-phone and an implanted one, an external computer or one grafted onto our brains. Thus, there is no reason to think that hybrid technologies threaten our nature. They also qualify as an expression of our most "primitive human nature". (2003,168). They rely on our natural abilities to develop plasticity and integrate feedback from various sources to make more rational decisions. As a result, there is no reason to speak of post-human, or trans-human, evolution: all these forms are variations within human evolution, which from the origins has included the disposition to represent one's tools and manufactured environment as an extension of one's own mind and body.

Note, however, that even if one takes Clark's point, as I think we should, the ethical issues such as fairness, equality, dignity, and respect are still alive and kicking. Recognizing humans' ability to expand their control to new territories does not automatically justify the direction in which humanity will develop itself.

2) Enhancement techniques and bioethics

Let us first narrow the scope of the bioethically interesting issues. As we saw above, using sensory substitution, neuromotor supplementation and cognitive enhancement for the disabled is ethically uncontroversial. The purpose of such interventions is to offer patients the conditions to remedy their handicap. In this area, the only question is whether the amount of resources available should determine who can benefit from such techniques. Equality of access to enhancement or supplementation, might become, some day, a vocal social demand that the bioethicist does not need to settle as a matter of principle.

Ethical problems arise when these techniques are used, not to repair or supplement a function, but rather to add one as a matter of personal preference. A common worry that is voiced in the bioethics literature is that enhancement could be used in the pursuit of individual bodily and psychic perfection, which is illusory and dangerous.[5] The pursuit of perfection, in oneself or in one's offspring,

[5] Various religious motivations might fuel this worry, such as the fact that the man should not take himself to be his own creator, or that handicap and limitations are inherent to human condition, and should be endured as given by our own individual fates. They will not be discussed here.

expresses a “drive to mastery” that “misses and may even destroy an appreciation of the human powers and achievements” (Sandel, 2004).

However, one might respond to this argument that all the important technological steps taken by humans in the course of their history were also condemned for similar reasons. Is it not a mark of hubris to publish books that will survive their authors, to replace horses with steam engines, to fly over the Atlantic? Did not each step of progress lead us to disregard, regrettably, the previous human “powers and achievements”? An additional response by the liberal bioethicist John Harris is that it should be left to individuals to decide whether they should apply cognitively enhancing devices to themselves or to their children, as long as no harm results. A stronger ethical case for enhancement is made by Kurzweil, who argues that humans should enhance their cognitive capacities to address the survival issues (energy depletion, global warming, etc.) that the future has in store for humanity. While Kurzweil only considers enhancement in computing capacity, a case can be made for selecting areas of enhancement according to ethical considerations. For example, acquiring super-sensory abilities to conduct warfare or perpetrate criminal activities violates an elementary principle of fairness. Further, it promotes a cognitive arms-race that can only be detrimental to mankind. Developing superior attentional abilities, in contrast, works against violent behavior, and promotes efficient communicative abilities. A principle of scientific responsibility would argue for selecting the areas where cognitive and emotional enhancement would be fruitfully enhanced, while banning research in which enhancements are predictably conducive to violence, addiction, irrepressible consumerism, submission, and, in general, to behaviors that violate the agent’s dignity or autonomy.

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