HUMAN ENHANCEMENT?

Ethical Reflections on Emerging Nanobio-technologies

Report on an Expert Working Group
on Converging Technologies
for Human Functional Enhancement

NanoBio-RAISE EC FP6 Science and Society Co-ordination Action

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NanoBio-RAISE

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Summary

A multi-disciplinary working group of experts in science, medicine, ethics and social sciences has examined the ethical and societal implications of converging technologies which might enable the functional enhancement of the human body beyond medical purposes, responding to a 2004 EC expert group report, which called for the study of potential challenges to societal values. The present study examined the nature of enhancement and the implications of three examples of near term developments - brain chips, chemical stimulants for cognitive performance, and electrode stimulation of the brain.

Enhancement poses many philosophical and conceptual problems. For example, can we know what it is to enhance ourselves without an agreed external frame of reference for what it is to be human? Would some functional ‘enhancements’ prove not be improvements in a wider perspective? Tensions were noted between functional and holistic understandings of humanness, between external and internal changes, and progressive and radical alterations. Whereas an initial methodological distinction was made between changes primarily related to medicine and those seen as personal preference, study was made of substantial ‘grey areas’ of ambiguity and overlap. Each case study considered the potential impact of the envisaged technology on basic ethical principles and consequences, social impacts, justice and risk.

The claim that enhancement technologies are an ‘inevitable’ trajectory was not accepted. Assessment of technical feasibility is a pre-requisite to ethical reflection. Thus, silicon chips can be interfaced with neurons and medical prosthesis of sensory organs or motor function might create new human capacities such as near-infrared ‘vision’. But current successes may reflect how smart our brain is at processing rather than great technological strides. A full, two-way integration of artificial information processing systems and 20 billion neurons in the brain remains remote not only in scale, but even in concept.

Pharmacological cognition enhancement raises practical and ethical problems. Ambiguity already exists between treatment and enhancement in the use of neurostimulants for attention deficit in children. Drugs which enable performance with little sleep pose questions of lessened autonomy or inducing dependency in the normal performance of tasks. A brief review of chemical enhancements in sport showed that, where these are not forbidden by regulation, some sports have diverged into an elite professional tier and an unenhanced ordinary level. This would raise concerns if mirrored in wider society. The competitive use of stimulants, for example to gain a marginal advantage in exams, could induce a ratchetting effect. Peer pressure and the desire not to fall behind could lead students to feel forced to use stimulants against their basic values. Once generally adopted, the advantage would cease, but no one would dare *not* to use them, for fear of falling behind the new norm. The capacity of enhancement technologies to stimulate intended or unintended social engineering would pose serious ethical problems for many of the group.

The side effects of deep brain electrode stimulation for treating severe Parkinson’s disease might be used to induce mood change or address eating habits. We asked whether it is less than fully human to create technical sensations remote from the normal context in which we experience them? Serious risks, taken in an extreme medical context, are also difficult to justify for milder situations or for enhancement.

The study did not identify any strong societal benefits from these technologies that would warrant public funding for envisoned enhancements. There needs to be an effective system for governmental and societal oversight of any application for human enhancement purposes of techniques which had been developed and justified only in medical contexts. Moreover, on current knowledge, each case examined had social dimensions which took them beyond matters of individual choice. We therefore strongly urge that the social issues of enhancement technologies are given further study, especially on who controls developments, what are important values to uphold with far-reaching technologies, and on issues of risk and social justice. Public awareness remains low. Many claims made for enhancement are exaggerated, but the potential for radical and disruptive change means that people should have the opportunity to become literate about enhancement technologies. The aim should be to develop the critical tools by which societies will need to assess whichever of these technologies do eventually come close to fruition.

2. Aim of the Study

It is important that the areas selected by the European Commission for research in nanobiotechnology do not raise deep conflicts because of the violation of ethical and social standards, risking rejection by societies. Perhaps the most sensitive emerging issue is the potential for human functional enhancement, arising from the convergence at the nano-scale of bio- and information technologies, and the materials and cognitive sciences. A 2004 EC expert group report '*Converging Technologies – Shaping the Future of European Societies*' identified the need to examine social and ethical issues if significant modifications or enhancements of the human body and its systems became possible, beyond what might be seen as medical purposes. [2]

As part of the NanoBio-Raise programme in ethics and communication in nanobiotechnology, a multi-disciplinary expert working group was formed to help explore these potential questions. The group brought together eight specialists in relevant areas of scientific and medical research and technologies, ethics and the social sciences for a series of seven meetings over a period of a year in various venues. This included a notable visit to the University Hospital at Grenoble to see a clinical operation of electrode stimulation of the brain to treat a patient suffering from advanced Parkinson's disease.

It was agreed at the outset to ground the study by examining specific cases which were of more immediate relevance, rather than focus on the more speculative notions. We chose three areas of scientific development which have implications for enhancement or which might reasonably be considered feasible for use in human enhancement in the medium term, and might therefore illustrate future directions. These were connecting between neural cells and computer chips; electrode stimulation of the brain; and the use of chemical stimulants to enhance performance. Additionally we considered enhancement in sports as a special context where use occurs and is highly controversial. To what extent might this arena hold insights in relation to any wider cultural use of enhancements?

With each case, our first aim was to attempt a realistic appraisal, from the expertise of the group, of what is feasible in these technologies, and what is unlikely. Then we considered what ethical issues these interventions would pose, and identified what might be benefits, risks or other drawbacks. Although we did not study the more radical claims and aspirations of human enhancement, the context set by some of these claims, together with their political and moral presuppositions, formed an important backdrop to our discussions. So we begin by stepping back for a moment and asking what is meant by human enhancement. We describe some of its features and look at some of the broader ethical and social questions, before turning to the individual cases in sections 4-7. Then, in our concluding reflections to this short study, we have identified some common themes, noted particular issues with each of the cases, and we make recommendations, including important areas that will require more in depth examination.

3. What do we mean by Human Enhancement?

a). Features of Enhancement

In many respects this is the key question. What are enhancement technologies and what do they do? Some have asked if it is even logically coherent for the human species to claim it knows what it means to enhance itself, without any agreed external standpoint of reference against to judge what a true enhancement might be. Given that some believe they do know, we considered what are the important factors in a putative enhancement. These dimensions can be understood in terms of four distinctions or tensions, namely :
i). enhancement as a change of state or a change of degree,
ii). permanent or reversible enhancements,
iii). external or internal enhancement technologies,
iv). enhancement as opposed to therapy.

At a basic functional level we might say it is using technology to increase physiological attributes that could not be achieved naturally, or possibly even to create entirely novel human capabilities. This might be a sense we do not possess like ultrasound or near infrared vision. The implication is that such interventions and the creation of novel capabilities are different from existing human activities like eating, education or the use of tools. This suggests a first dimension by which to distinguish enhancements. It highlights a tension between a change of degree, based on what we already are, and a change of state to something qualitatively different. Both Khushf and Nordmann point out that the former has an element of assumed continuity from existing science and technology, whereas the latter implies a discontinuity – some kind of step change. Some claimants see a seamless robe from one to the other. People have always tried to enhance themselves in many different ways in order to become better, it is argued, so why not use new techniques? Such claims need to be scrutinised further.

George Khushf distinguishes between "stage one", and "stage two" or radical enhancements. He thus describes a step change in the creation of novel human capabilities where radical enhancements challenge our ethical response.[3] Alfred Nordmann speaks of a step change with respect to technology.[4] Until now, our technologies have produced more or less invasive, more or less reversible enhancement effects upon human bodies. When we use binoculars, for example, we can see further with than the limitations of our normal eyesight. Technology is an ingenious way by which human beings with biological limits can get more out of the world, and adapt it to human needs. Current visions of enhancement technologies, however, aim to remove or push back the very human limits themselves. Hitherto, we have made enhancements by devising creative technical means to supplement our biologically given means. The radical vision is seek to transform and transcend the human beings themselves, rather than adapt the world to human needs. It is claimed (although highly disputed), that it would make humans less dependent on the world "out there" since they have greater powers "in here." In its radical form, this is a vision of a step change which involves a different conception both of technologies, and of the human being, and thus of the relationship between the two.

Incremental Enhancements	Radical Enhancements
…represent a change of *degree* in the expansion of human power or in the development of technology	…envision a change of *state* regarding human capabilities or the purpose of technology
…involve technologies which are *external* to the body and which add to it	…integrate technology with biology *within* our bodies

…can be either reversible or irreversible	…introduce *permanent* and irreversible change
…generally assume a distinction between interventions that arise from therapeutic contexts and those that serve enhancement purposes	… are dedicated to refashioning human beings and as such go beyond therapeutic interests; some would deny any inherent distinction

A second dimension in the definition of enhancement technologies is the notion of making changes that become internal to the body, just as one might internalise a tool. Brain electrode stimulation and brain chips both have something of this idea. More radically, one could imagine ocular modifications to replace spectacles, or that aspiring rock climbers could opt for having treatments that create gecko-like structures in human skin to bind to a cliff face, thereby 'internalising' sticky-soled boots.

A third dimension concerns the question of whether a change is permanent or reversible. Some enhancement technologies produce transient effects that are achieved only as long as one, for example, takes a chemical stimulant like Ritalin. But permanent or irreversible changes could be envisaged genetically, or (more likely) at a cellular level, or by way of a permanent implant.

The fourth tension is very contentious. Can a valid distinction be made between therapeutic changes to humans for medical purposes, and changes that are introduced as enhancements for reasons of personal preference which are not connected to any recognised medical condition? The group members expressed differences of view regarding the usefulness of the distinction between therapy and enhancement.

According to the doctrines of transhumanism, the distinction between therapy and enhancement is already part of the problem. Restricting therapy to restoring and conserving "normal function" holds back humans from our destiny, which is to use our technological skills to exceed our biological limitations. Disability or bodily disfunctions that we would class as illness are just social constructs, which are relativised by the project to improve all aspects of the human body beyond present norms. In this sense, the question is not so much illness measured against current distributions of normality, but that our very baseline should be considered 'puny' by comparison with what we could be as a species, which is taken as a new normative concept of the human race.

Set against those assumptions is a common sense notion that there is a difference between doing something because someone is ill, to make then 'better', and taking a healthy person and 'improving' them. Compassion and the desire to address human suffering provide a strong ethical justification for the former. The same is not immediately true of the latter. In various places an ethical distinction is made between interventions which would be justified under particular medical circumstances but would otherwise not be. Thus the European Convention on Human Rights and Biomedicine allows sex selection to avoid a gender linked genetic disease but not just for personal preference.[5] Some of the group believe that the broad categories of medical change and enhancement - and what is justified in those different circumstances - are valid as a first approximation, and should not be merely abandoned. To think otherwise would be to buy into a set of assumptions which many would not hold.

The challenge is how to address the 'grey' areas where it is far from obvious where one would draw a line of distinction, such as human height. The uptake of fluoride ions from water into the hydroxyl-apatite structures of teeth produces significant resistance to decay. Vaccinations introduce protective antibodies into the human system. These are enhancements to give the body new resistances to stresses and threats, but are they classed as medical interventions, albeit anticipative rather than reactive? It is in examining such questions that the desirability or otherwise of enhancement technologies may be identified.

While we do not expect to settle once and for all the question of how to define enhancements, it is important to explore the various dimensions of the term. Some like Harris and Caplan argue that *all* technologies are enhancement technologies, [6] [7] but, as we noted above, the claims made about by many advocates of enhancement are that something radically different lies ahead. The working group sought to take this claim seriously, while at the same time, not simply leaping into some remote imagined future, regardless of all likelihood. Indeed, the very presumption of an 'inevitable' technical progression from where we are now to such futures has seriously distorted discussion of ethics in new science and technologies. As has been noted in other contexts, the claim of the 'inevitability' of a technology is a dangerous one for two reasons. One is that we are led to weigh up developments that are not inevitable but would become so if everyone believed them to be. The second is that we are led to focus on the ethical and societal consequences of improbabilities or things that are simply incredible. We sought to steer a middle-course by looking at various recent developments, trying to identify underlying aspirations and ethically significant ideas. We explore some of these briefly below.

b). Is there a Human Nature?

At one level this is to ask the obvious. Yes, in so far as we do in practice distinguish ourselves from, say, animals or machines. I do not think I am a dog or a windmill. Even if we may be hard pressed to define it, we have something in mind when we do so. But in the face of the technological possibilities we discuss in the case studies, where do machines end and people begin? Similarly, one may argue that humans have evolved,[8] as distinct from other animals, with capacities which make us both apart *from* nature - and able to shape it to our designs - and yet also a part *of* nature - in what we share with the rest of the natural world, and, crucially in these days, in our interdependence with it for our own flourishing. As a species we fit a specific but wide evolutionary niche, which means we can do certain things, but not others, like flying. Can we use technology to populate other niches, or can we take capacities from other niches and add them to our own, in order to extend our powers beyond our current human limits?

The conventional assumption of technology, as adapting the world to human needs, does not presume a purely technical view of the human being itself. However, if one considers technologies to refashion and optimise human beings, this presupposes a view of humans in terms of performance parameters, and that are therefore amenable to technical improvement. On this latter view, we may ask to what extent and in what sense would such enhancements be improvements. When looked at as a whole, rather than in terms of specific functions, would we still be better off with the body and brain we have, more or less?

Are there features about being human that remain broadly consistent, despite all the diversity within human beings, cultures and environments, and all the changes that have occurred throughout our history? If so what are there normative characteristics which we identify about being human, and which to change would diminish our humanity? Fascinating as such theological and philosophical questions are, they lie beyond the scope of this study. Some perspectives hold to a distinct sense that there is such a thing as human nature, based on the insights of a particular value system. Others take a reductionist view that sees all life forms as a dynamic continuum in which we happen to be in one node in our evolutionary era. Observing the lack of evidence for evolutionary change within the species, the transhumanist makes a unique distinction about human nature that we alone have the capacity to take our evolution into our own hands. But, if there is no human nature, then it is hard to see how we could know what 'better' would mean, because there is no putative external reference point against which to compare and say, 'Yes that truly would be an enhancement', or 'No, that would not be'.

c). Aspirational and Religious Factors

At the individual level, people will have different images of what they would like to be, compared with what they are. For some, life is already so rich they would not wish to change it with enhancements; they are content with using well what they have got. But humans can also aspire to 'better themselves'. Is technological enhancement any different, then? Would such aspirations be satisfiable by some enhancement technique or technical fix? It is a commonplace observation that wealth, power and fame appear not to deliver the satisfaction that one might expect them to. Is enhancing ourselves to commit to a permanent treadmill of unfulfillable aspirations, where exactly the same questions about inadequacy would be asked at some point in the future, but just at a different level? Perhaps we should develop an ethic of learning to wish well, that would be wisdom. Some would argue that to be truly human is to work well within our current limitations.

To the extent that the desire for enhancement is driven by dissatisfaction, or by the perception that there is something wrong with us, the question has an important theological dimension. All the religions of the world agree that humanity is not what it is supposed to be, but differ in their interpretation of what it is and thus about what is the solution. Transhumanism is seen by some to represent a secularized version, offering an entirely human 'salvation' in our own self-improvement. This teleological vision serves as a unifying aspiration and drive for the practical projects of enhancement. There is an implicit notion of technologically mediated and inevitable progress, allied to an unbounded optimism about human potential now within reach, if we were once allowed to realise it. For example, the empirical phenomenon of Moore's 'Law' is widely cited as the yardstick for technological progress. Originally this was an observed exponential trend in the amount of information that could be put on a computer chip, over a particular recent historical timeframe, which was used in projections of the expansion in computing power. Although it has no grounding in any physical formula, it is widely claimed by transhumanists as an exemplar, or even guarantee, of the pace of future technological advance over a wide range of unrelated technological fields. This extrapolation seems to be a matter of aspiration rather than of science.

There is a potential conflict with several major religions, which might see functional enhancement, at best, as missing the point of what needs changing about ourselves, or, at worst, as founding a Babel-like project as an alternative but, in their view, ultimately illusory secular way of human 'salvation'. This is because the things that many religions regard as basically wrong with humans - our moral, relational and spiritual failings – would remain unchanged. Humans would continue to expresses those same failings but through ever more sophisticated and technologically ingenious means. According to this perspective, the effects of enhancement might just be, as C.S. Lewis once said of education without due attention to values, "to make man a more clever devil." [9]

In his extensive study of the field, Erik Parens of the Hastings Institute sees an irreconcilable distinction between those who see human life as gift, and who regard the body as something we should let be, and those who use a framework of technological progress and are creatively free to experiment with body and mind, and see what happens.[10] This would not rule out intermediate views, since one might feel that there are things which can be changed legitimately without necessarily embracing an agenda of unending radical human transformation. Some

Christian reflection, for example, while maintaining that whereas humans are a gift from God ‘made in God’s image’, might yet allow creativity under God to make changes, but always within the context of what it sees as God-given values which would define limits on what may be done.

Setting such questions more broadly in our plural societies, are there aspects of our humanity against which we can agree for our cultures, would be improved, unaffected or violated by any particular plan of functional enhancement? Alternatively is this purely a matter of individual choice in which society plays no role other than in policing harm to others?

d). Enhancement and the Societal Dimension

Some of the most important issues raised by the concept of individual human functional enhancement are its social impacts. Many of the examples which are discussed focus on the individual. But how do we balance the rights and duties of the individual, and his/her flourishing, with the wider flourishing of the society to which they belong, and the role of that society in a global context? In this wider context, who decides what is regarded as ‘better’, or what ranks an enhancement? More generally, how do our plural societies handle the widely different normative assumptions about being human?

A major argument made against human enhancement is that it is inherently socially divisive. Unless some utopian future society could be realised, the strong likelihood is that a few might be greatly advantaged but the majority would not have access. Who would be the losers as well as the winners in any development? If the potential for individual human enhancement is indeed as far reaching as the claims which its proponents make, this is an extremely serious problem. Being realistic, there seems little hope of the greatly trumpeted benefits being available to all but a very few rich or otherwise fortunate people. To dismiss this concern on the grounds that new technologies have always been economically or socially divisive would seem a wholly inadequate response to the realities.

A second question relates to what values are driving the research and development of converging technologies in the different spheres, academic, industrial and military. To what extent are these the values of an elite which are not shared with the population at large?[11] Military and commercial dimensions may be especially problematic for some, because the driving values of these contexts might diminish other important value considerations. Eurobarometer surveys report that most European citizens are not aware of much that is being researched in this area?[12] The gap between citizens and the innovators was one of the underlying problems with the crisis in agricultural biotechnology. One of the aims of the NanoBio-Raise programme is to help to bridge this gap, both ways.

A report on public engagement activities on nanotechnologies in the UK notes that people are aware that nanotechnologies have positive potential, and also some of the risks, but that they would like to have more say in what is being developed on their behalf.[13] This has been examined further in the public engagement activities in Work Package 3 of NanoBio-Raise. In the Democs card games on nanobiotechnology which have been played to date, a majority of participants in the expressed concerns about human enhancement, but a few expressed enthusiasm for it. Similar issues were expressed in the Convergence Seminars run in four countries. If this pattern is reflected more broadly, it indicates an important need for social oversight of enhancement technologies in Europe.

There are also familiar range of general social issues of technology including accountability and control. Who controls what is done, and how far should both academic and commercial sector be subject to public ethical scrutiny for what it funds? There need to be procedures and regulations to govern the risks. How precautionary should these be over uncertainties and ‘unknown unknowns’? What would constitute adequate knowledge to proceed in any given case? If things go wrong with enhancements, whose responsibility is it?

One must also consider the ethics of foregoing potential benefits. Harris cites a moral duty to enhance if we have it within our power to do so.[14] One difficulty is predicting whether an enhancement would actually be socially beneficial. The social impact of information and communication technologies has proved notoriously difficult to foresight. Science fiction has explored some of the deep seated fears of what might happen if enhancement technologies became as invasive and pervasive as might occur. Would it lead to more conformity or more diversity? How far would social pressure force the issue on people who would have chosen to avoid something but now feel they would risk being ‘left behind’?

In this overview, we have mapped some of the main topography of the profound, controversial and far reaching ethical and social issues in the field of human enhancement. We have identified some of the key issues raised. In this relatively short study, it was not our purpose to analyse these in great detail in the abstract. Rather we examined how these issues related to concrete examples in our case studies of technical developments, to which we now turn.

4. Case study 1 - Brain Chips [15]

Discussions on a paper by Richard Jones

a). Introduction

There can be few more potent ideas in futurology and science fiction than that of the so-called brain chip**.** The concept is to seek to create devices which make some kind of a direct interface between the biological information processing systems of the brain and nervous system and the artificial and rather different types of information processing systems of microprocessors and silicon electronics. It is an idea that underlies science fiction notions of "jacking in" to cyberspace, or uploading one's brain, but it also provides hope to the severely disabled that lost functions and senses might be restored. It is one of the central notions in the idea of human enhancement. Perhaps through a brain chip one might increase ones cognitive power in some way, or have direct access to massive banks of data. Because of the potency of the idea, even the crudest scientific developments tend to be reported in the most breathless terms. Stripping away some of the wishful thinking, what are the real prospects for this kind of technology?

The basic operations of the nervous system are quite well understood, even if the way the complexities of higher level information processing work remain obscure, and the problem of consciousness is a truly deep mystery. The basic units of the nervous system are the highly specialised, excitable cells called neurons. Information is carried long distances by the propagation of pulses of voltage along long extensions of the cell called axons, and transferred between different neurons at junctions called synapses. Although the pulses carrying information are electrical in character, they are very different from the electrical signals carried in wires or through semiconductor devices. They arise from the fact that the contents of the cell are kept out of equilibrium with their surroundings by pumps which selectively transport charged ions across the cell membrane, resulting in a voltage across the membrane. This voltage can be relaxed when channels in the membrane, which are triggered by changes in voltage, open up. The information carrying impulse is actually a shock wave of reduced membrane potential, enabled by transport of ions through the membrane.

Four types of interaction can be envisaged.
1. Interfacing out of the brain: getting biological information out from a living system, for example reading brain information and using it to control a limb.
2. Interfacing into the brain: sending information from outside into a living system, as in a cochlear implant
3. Loop of information: sending information out from a biological system to a semi-conductor processor and then back into a biological system.
4. Using biological information processing to supplement silicon-based processing, speculations about a neural computer, a vat of brain cells as an emotional co-processor to one's laptop.

b). Interfacing out of the brain

To find out what is going on inside a neuron, one needs to be able to measure the electrochemical potential across the membrane. Classically, this is done by inserting an electrochemical electrode into the interior of the nerve cell. The original work, carried out by Hodgkin, Huxley and others in the 1950's, used squid neurons, because they are particularly large and easy to handle. In principle one could obtain a read-out of the state of a human brain by measuring the potential at a representative series of points in each of its neurons. Current technology has managed to miniaturise electrodes and pack them in quite dense arrays, allowing the simultaneous study of many neurons. Ted Berger's group at the University of Southern California has an array of 64 electrodes with 28 µm diameter, separated by 50 µm.[16] These electrodes can both read the state of the neuron and stimulate it.

This kind of electrode array forms the basis of brain interfaces that are close to clinical trials, for example the BrainGate project which aims to restore some functionality for a limited, group of severely motor-impaired individuals.[17] This uses a sensor that is implanted on the motor cortex of the brain and a device that analyzes brain signals. It relies on the fact that brain signals are generated even though they are not sent to the arms, hands and legs. The signals are interpreted and translated into cursor movements, to control a computer with thought, as the gateway to a range of self-directed activities. These activities may extend beyond typical computer functions to include the control of objects such as a telephone, television or lights Another application is a neural prosthesis which aims to recover some of the loss of memory following brain damage by replacing biological cognitive functions by silicon-based processing. Neural activity in the hippocampus is fed to a chip which delivers back to the rest of the brain for prosthesis by-passing damaged tissue.

The ingenuity of such achievements needs however to be put in context. There are around 20 billion neurons to be studied in a human brain. The method is thus still essentially a blunt instrument, like jamming a tent peg into a cell. Such applications work basically because the brain is clever enough to sort out the signals even from these relatively crude systems. In the context of the enhancement debate, this is perhaps indicative of the superiority of the biological over the technological.

c). Interfacing into the brain

In a rather different class from these direct, but invasive probes of nervous system activity at the single neutron level, there are some powerful, but indirect measures of brain activity, such as functional magnetic resonance imaging (MRI) or positron emission tomography (PET). These don't directly measure the electrical activity of neurons, either individually or in groups; instead they rely on the fact that thinking is hard work (literally) and locally raises the rate of metabolism. Functional MRI and PET allow one to localise nervous activity to within a few cubic millimeters. This is revealing, in terms of identifying which parts of the brain are involved in which kind of mental activity, but, again, the technological potential of this should not be exaggerated. There are concerns that this will be used to detect and interpret behaviour far more definitively than it is in fact capable of doing. It remains an indirect method and which is a long way away from the goal of unpicking the brain's activity at the level of neurons. Mapping out in a non-invasive way the activity of a living brain at the level of single neurons still looks a long way off.

The group of Rodolfo Llinas at the New York University School of Medicine makes an ambitious proposal,[18] pointing out that if one could detect neural activity using probes within the capillaries that supply oxygen and nutrients to the brain's neurons, one would be able to reach right into the brain with minimal disturbance. They have demonstrated the principle *in vitro* by inserting a 0.6 µm platinum electrode into one of the capillaries which supply the neurons in the spinal cord. Their proposal is to further miniaturise the probe using 200 nm diameter polymer nanowires. They also suggest they could make the probe steerable, using electrically stimulated shape changes. "We are developing a steerable form of the conducting polymer nanowires. This would allow us to steer the nanowire-probe selectively into desired blood vessels, thus creating the first true steerable nano-endoscope.” Even one steerable nano-endoscope is still a long way from sampling a significant fraction of the 25 km of capillaries that service the brain.

d). Information Loops between Brain and Computer

A different approach does probe activity at the single neuron level, but does not feature the invasive procedure of inserting an electrode into the nerve itself. These are the neuron-silicon transistors developed in particular by Peter Fromherz at the Max Planck Institute for Biochemistry. These really are nerve chips. There is a direct interface between neurons and silicon microelectronics of the sort that can be highly miniaturised and integrated. Not invasive or banging in a peg, but looking from the outside. It is not clear what is actually doing the coupling.

The central ingredient of this approach is a field effect transistor (FET) which is gated (controlled) by the excitation of a nerve cell in contact with it. In other words, the amount of current passed between the source and drain contacts of the transistor strongly depends on the voltage state of the membrane which is in proximity to the insulating gate dielectric layer. This provides a read-out of the state of a neuron. Input to the neurons can also be made by capacitors, which can be made on the same chip. The basic idea was established 10 years ago.[19] The strength of this approach is that it is entirely compatible with the powerful methods of miniaturisation and integration of CMOS planar electronics. In more recent work, an individual mammalian cell can be probed,[20] and an integrated circuit with 16384 probes, capable of probing a neural network with a resolution of 7.8 µm has been built.[21]

Fromherz’s group have demonstrated two types of hybrid silicon/neuron circuits.[22] One circuit is a prototype for a neural prosthesis. An input from a neuron is read by the silicon electronics, which does some information processing and then outputs a signal to another neuron. Another, inverse, circuit is a prototype of a neural memory on a chip. In this case, there is an input from a silicon chip to a neuron, which is connected to a second neuron by a synapse, and this second neuron sends its output signal back to a silicon chip. This allows one to combine silicon electronics with the basic mechanism of neural memory. This relies on at the fact that the strength of the connection between two neurons at the synapse can be modified by the type of signals the synapse has transmitted in the past. These systems give a means of finding out more about how individual neurons work, and creating a simple memory device. Among the practical problems are that it seems difficult to extend from the laboratory bench to a living system, that it is restricted to two dimensions, and that the spatial resolution is still quite large.

Pushing down to smaller sizes is the province of nanotechnology. Charles Lieber at Harvard has taken adapted the basic idea of the neuron gated field effect transistor, using FETs made from silicon nanowires. This method permits the excitation and detection of signals from a single neuron with a resolution of 200 nm.[23] This is enough to follow the progress of a nerve impulse along an axon. This gives a picture of what is going on inside a living neuron with unprecedented resolution, and indicates potential future directions in understanding neuron activity. As with Fromherz’s systems, this is restricted to two dimensions. Everything has been done in vitro with cultured neurons, which need a culture medium to promote the effect, in order to get the chemistry right for the silicon chip. Again, it is very hard to see how this would be done *in vivo*.

e). How Feasible are 'Brain Chips'?

Thus, in some senses, the brain chip is already with us, but there is a continuum of complexity and sophistication of such devices. Fromherz cautiously writes: "Of course, visionary dreams of bioelectronic neurocomputers and microelectronic neuroprostheses are unavoidable and exciting. However, they should not obscure the numerous practical problems." We are still a long way from science fiction visions like downloading the brain to a computer. It is clearly possible to create an interface between the brain and the external world, and this has in some form been realised. Hybrid structures which combine the information processing capabilities of silicon electronics and nerve cells cultured outside the body are very close. But a full, two-way integration of the brain and artificial information processing systems remains a long way off. This may not be a problem only of scale but of the concept itself, as we shall discuss later.

A general application in the body of the concept of neural prosthesis is also far away, but two areas have more immediate prospects, in motor function and in sensory organs. The work which can enable tetraplegic patients to direct a computer indicates the possibility interfacing with motor function in the brain. Such interventions are not without danger, however. In general, highly invasive research to test such devices is only possible when driven by the desperate need of the patient in question. Under such circumstances, neurosurgeons may do things which would otherwise be illegal, but they have often proceed empirically, not able to rely on well established science (see Case Study 4).

The other current application is in sensory organs. Cochlear implants are already quite widely used. These are micro-devices implanted in the brain which mimic the brain function of hearing. Only a very limited visual sensation has been demonstrated with retinal implants, where a digital camera worn on the user's body transmits an image as electrical signals and beams them to the electrode array implanted on the back of the retina. It gives some global perception, but there are currently biocompatibility problems. The CTECS report of the EC expert group on converging technologies cites this as a notable example of potential enhancement, where the recording device need not be restricted to the visible region of the spectrum.[24] 'Sight' could be given for example in the near infrared region, which could be of great value for night driving, it is claimed, saving many lives. On the other hand, it might be more practicable simply to use external night vision cameras in the car. This highlights a general principle to ask about both more radical enhancements. Why would you need to hard wire such a device into the brain?

f). Ethical Issues of Brain Chips

This latter case illustrates two general questions about human enhancement technologies identified in the previous section. What is the driver behind the technology, and what is medical and what is an enhancement? In this case, have the scientists made have a clever invention for which they are looking for a use? Or have they found an optimum solution to an already identified problem?

An invention may be regarded as justified in the context of medicine or disability. But someone sees possibilities to use the same method to enhance the well and able-bodied, or for use in warfare, or some quite different purpose. The extension of human vision beyond the range we call 'visible' would not be classed as a medical intervention, on the grounds that it is not a capacity like ordinary sight, which most people have and use but which some have lost or never had. No one has ever had this capacity. This particular example is unusual in that the enhancement is not only for my personal benefit in having a function I never had before. It also has a claimed social benefit, if it did make a positive difference to my safety in night driving. But would I simply drive faster at night, relying on the technology, and still run the much same level of risk to myself and others? Another general question which this raises is whether in fact an enhancement proves beneficial. What is presented through certain lenses of argument as an enhancement, when viewed prospectively, may not always prove to be such a good idea once I actually have it and see the fuller picture of its implications.

Another issue is the defence of human choice. Some might argue that, if it could be shown that there was no prospect of significant *harm* in an enhancement, the burden of proof should lie on those who would argue to prohibit its use. In enhancement technologies an assumed overriding principle is my personal autonomy to choose what risks to take, as against a societal decision of what enhancement technologies should proceed, and which not. There is a case to be made both ways. A key question about enhancement technologies would be to establish guidelines or criteria about what would constitute the sort of technology over which societal approval is a prerequisite over and above personal choice.

f). Risk Issues with Brain Chips

The arguments made above presuppose that risk questions about brain implants could be answered satisfactorily, especially in relation to long term consequences not envisaged by the inventors. Risks may arise in some use of nanotechnologies. There is a new micro device undergoing clinical trials for motor disfunction in the eye, in which the definition is enhanced by nano-scale surface modifications depositing carbon nano-particles. It is not clear what the toxicological risks are. Carbon nanoparticles can pass very quickly into neurons. Techniques to test these would be needed. Nanoscale coatings on surgical implants may give enhanced biocompatibility, but one would need to assess the risk that abrasion in long term use might eventually release nanoparticles into the brain.

In the case of implants, reversibility and controllability are important factors. If something went wrong, could the device be got out of my body, or could it perhaps merely be deactivated? How long could an implanted chip or device remain safely in place and would it eventually have to be removed because it would become less effective or wear out? How good would be its biocompatibility long term; would the body eventually start to reject it? In a medical context where the justification had been a serious condition like blindness or paraplegia, such risks may be embraced as part of what is entailed in getting the sensory or motor function restored. In the context of enhancement, the risk-benefit where the comparison is with normal function rather than correcting something that has gone wrong, the risks would need to be very low.

g). Brain Chips, Analogies and Aspirations

The grand vision of brain chips as the precursors of greatly enhanced human cognitive ability and radical brain-machine interfaces needs also to be put in context. Some poor analogies have been made between biology and electronic engineering. The choice of metaphor and language may reveal implicit value claims which the person is making through the analogy. The analogy of the brain as a computer frames one’s thinking in a certain way and can be somewhat misleading. For example, the assertion by some transhumanists that the brain is wet, inefficient, and with not very many neurons, is challenged by others. The claims that laptop computers already have more computing power than insects and will soon exceed that of humans, need unpacking. Simply comparing numbers of neurons and transistors gives a false picture.

Biological information processing is much better than silicon-based at some functions like self-consciousness. In biological systems, the basic unit of processing is molecular. (Bacteria for instance perform all their information processing with molecules). Nerve cells generate shock waves of ions, a pulse of voltage, moves down an axon, by an imbalance of the number of ions inside the axon and the number outside it. This is very different from electrons moving along a wire or in a semi-conductor. If connectivity is taken into account, the brain is very much more complex, connections in the nervous system are made to 200 other logic gates, not merely three in CMOS. The brain operates as a network of electrical-chemical interactions from external impulses. If activity is not maintained of a network "path" it will cease to be available. Some consider that to progress with computing should start with the brain, instead of improving the brain with the model of the comparatively crude model of the computer.

5. Case Study 2 – Psychostimulants and Cognition Enhancement [25]

Discussions on a paper by Elfriede Walcher-Andris

a). Methylphenidate and ADHD

Our second case is about chemical enhancement. It is an area where some enhancement is already happening, using what one might call ‘old’ nanotechnology, namely chemistry. But it addresses issues which will be equally relevant to the trajectories to cellular interventions and targeted molecules through ‘new’ nanotechnology. Pharmacological Cognition Enhancement (PCE) aims at an improvement of cognitive activity and performance in healthy people, achieved by appropriate drugs that are otherwise used to treat mental disorders. One example is the use of Methylphenidate, a derivative of amphetamine. It is the active ingredient of Ritalin and related pharmaceutical products, which are prescribed as neurostimulants in the treatment of Attention-Deficit-Hyperactivity-Disorder (ADHD). These compounds are also now being used by young people to assist their performance in exams.[26] There was a large increase in the prescription of Methylphenidate to treat ADHD in Europe and USA in the 1990s. This can reach up to 20% of the boys in schools in some US states.[27] This increase goes far beyond the incidence of the disease in a small number of children from a very early age.

This increase has led to much debate on both the means of diagnosis of the condition and use of the drug. By no means all children now being diagnosed as ADHD have displayed the problematic behaviour from birth. Styles of behaviour may be interpreted differently in different parts of the world. In France a year of tests is required; in the USA, much less. Some children's behaviour improves with the treatment. Temporary Methylphenidate medication could be appropriate to break a downward spiral in a child, to allow a period to enable less invasive treatment which is not dependent upon long term dependence on the drug. But some authors claim that erroneous treatment in children may be as high as 95%.[28]

Treatment		
Healthy Person Normal Function	**Grey Zone** Classification depending on **perception** **estimation** **interests**	**Ill Person** Pathological Function
Enhancement		**Therapy**

Fig.1: Between enhancement and therapy there is a grey zone which can be broad especially in psychiatric disorders

ADHD highlights the difficulty of drawing a clear line between treatment and enhancement. On the one side, patients are treated when they are ill. A physician will observe a recognised set of symptoms and/or biological markers which call for treatment, and prescribes accordingly. At the other end of the scale, a person may wish to receive the same intervention to enhance his / her life in some way. For psychiatric diseases which present as spectrum disorders, reliable biological markers are often not available, and diagnosis then depends much more on interpretation, where social, historical and cultural values play a greater role. A transition between the two poles of healthy and ill leaves a grey zone between them, and accordingly between treatment and enhancement. In consequence, the influence of normative values and decisions is of increasing importance.

Treatment of ADHD with neurostimulants raises a series of questions. The first lies in the medicalisation of social and educational problems. Secondly, if children are given a stimulant treatment ostensibly because they exhibit ADHD symptoms, this can be regarded as a "hidden enhancement". For example, a child may be feeling under stress at the school, and 'treated' with the drug, but primarily in order to cope better at meeting the standards at the school. Thirdly, there is now increasing, probably underestimated, 'off label' use of stimulants for performance enhancement by students and other young people who try to boost their cognitive performance with stimulants. Many try to be diagnosed with ADHD, in order to use the drug and gain other advantages for exam conditions. Others buy stimulants like Methylphenidate or Modafinil (benzhydryl-sulphinyl-acetamide) via the internet. [29]

Many of the cognitive functions which are fundamental to everyday procedures such as alertness, attention, planning, problem-solving and adapting behaviour, can be influenced by these stimulants in many, if not all people in laboratory tests. Experience with amphetamines in sport has produced less desirable effects, including euphoria, reduction of critical faculty, enhanced readiness to take risks, enhanced aggressiveness, raised threshold of fatigue, which might even become risky, and stereotypy.[30] Such effects are dose dependent, but it indicates some tendencies of effect. The long term effects of use in everyday life are unclear. It would be a formidable challenge to investigate the long term effects that these drugs have on cognition, and the extent to which changes in laboratory measures of functioning will translate into improvements in everyday performance. [31] Modafinil was said to have no side effects but warnings were recently issued that it can cause life-threatening skin and other hypersensitivity reactions.[32]

b). Risks and Impacts

Several areas of concern can be identified, including long term learning ability, confidence, dependence and diminished autonomy. The impact of repeated stimulant use on the developing brain of children and young persons also cannot be predicted so far.[33] For example, the development of cognitive strategies may be affected if drugs change the conditions under which learning takes place. The child may also not trust herself to succeed in a given task without the drug, or may fail to learn self-control because the drug imposes control.

Does long term stimulant use interfere with the learning process and the motivation to learn? The learning process is understood to induce a rewarding signal, associated with dopamine levels, that supports the reorganisation in the brain and the future motivation to learn at the same time. If stimulants cause an increase in the dopamine level before the user has done any learning, this could be a disturbing factor rather than a benefit. Would such means of enhancement be consistent with the general aims of a comprehensive education and development of personality?

The human brain is not a ready-to-use product. To a certain degree its development after birth follows a well defined programme, but to a certain degree it depends on how it is used.[34] Higher executive functions like memorizing,[35] or self-control depend on cognitive strategies that have to be learned. The capability to anticipate desires together with the acquisition of self control strategies is regarded as a precondition for an elevated level of autonomy.[36] The acquisition of cognitive strategies depends on appropriate interaction with emotionally attached persons and others. This is part of the complex socialisation process by which cultural values and techniques are transferred from one generation to the next. A widespread use of stimulants in the context of education and learning would certainly change interactions and hence socialisation of children and young people.

c). Wider Uses of Cognitive Enhancement

The drug Modafinil appears to have similar effects to Methylphenidate. Those who have taken it are able to remain awake for a number of days without suffering from sleep deficit. The drug has been used for many years in military contexts and has led to significant questions, discussed below. There are also drugs (e.g. Donazepil) that can improve memory which are helpful in treatments for such illnesses as Alzheimer's disease. However, these are not seen as helpful for healthy people because by no means all our memories are ones we would like to recall. It is normal to "keep" bad past experiences deep in your memory.

Amphetamines can have the desired effect, but may also reduce critical functions, increasing the possibility of taking greater risks. Rats influenced by stimulants still go for the greater rewards even if the obstacle is bigger; the inference being that stimulants can change how we evaluate risk, in ways that may not always be appropriate. Indeed, some commentators consider that with such drugs, even Modafinil, there is an increase in the tendency to take unnecessary risks. Clearly there situations where rapid action is important but if we enhance our speed of decision making in general, we might be diminishing proper space we need for evaluation and for moral reflection.

Laboratory tests suggest that drugs which change one’s state too quickly disturb normal reflex and adjustment. Stimulants in this range also have poor side-effects such as hallucination, euphoria, reduced optical capacity and greater aggressiveness. Thus a degree of enhancement may perhaps be achieved, but accompanied by a variety of harms. In another context, 11 monkeys were treated with Amphetamine and observed for three and a half years.[37] Dendritic complexity was reduced significantly and resulted in schizophrenia-like pathology and cognitive disfunction. The conclusion seems to be that our current level of understanding of the biological mechanisms of the brain is such that intervening chemically in our brain without due need is not justifiable.

d). Ethical Issues : Autonomy

An informed adult should be in a position to make autonomous decisions. There should be independence of action, within the limits of the social and physical environment, and an absence of coercion. Important aspects of a personal rational capacity with inner autonomy involve a variety of factors. These include self-identity, self-worth, self-awareness, strategies for self-control towards long term goals, standards of truth, clarity to correct observed views and ability to change if beliefs or facts change. Such qualities are usually distinguished from addictive behavior, strong habits or impulsive actions. As people age they tend to lose features of this capacity. A cognition enhancing drug might be a repair for the elderly to restore a level once reached normally but now lost.

Questions of diminished control were raised by the case against two US military pilots who mistakenly bombed Canadian troops in Afghanistan. The pilots were using dextroamphetamine, as a standard issue to help them stay alert on long missions. According to some expert witnesses, the use of the drug may have contributed to reacting too quickly in making a quick conclusion to release a bomb on what he took erroneously to be evidence of enemy fire but was an allied training exercise.[38] Charges were eventually dropped but the significance of this case is that the claim was being made in court that the use of the drug leads to a significant loss of responsibility for a people's actions and, to that extent, their autonomy also.

If the ability to act autonomously and responsibly is regarded as a fundamental human trait, any technique like cognition enhancement has to be questioned as to whether or not it affects human autonomy, both in specific decisions and as a capacity. An autonomous decision would certainly be a minimum prerequisite for a legitimate cognition enhancement. This involves agency, independence and rationality. Agency involves awareness of oneself as having desires and intentions and acting on them. Independence means an absence of coercion and manipulation, but is always moderated the limitations of one's physical and social environment. For rational decision making one has to have standards of truth and evidence, the ability to construct and evaluate alternative decisions and the ability to change decisions if beliefs or values change.

In contrast, if drug intake is the reason for a change in decision, to what extent is the person surrendering a degree of autonomy? An action that someone would not perform under normal conditions might be done under stimulant condition. The action is accomplished faster, because extra neuronal loops of thinking are suppressed. This means that the basis of decisions is changed as a consequence of a change in transmitter balance, which is not caused by perception or reason.

A strong argument in favour of enhancement is the right of autonomous individuals to decide on their own what is good for them. But this applies much less in young children, the very old, or people whose consciousness is impaired in some way. In ADHD it is thus the parents who decide by proxy for their children, and it is sometimes unclear whose aims are pursued. As observed above, social pressure can also greatly alter one's ability to make one's own decision. Peer pressure among adolescents and competitiveness to achieve at school suggest that the use of Ritalin for exams may not be straightforwardly autonomous. If one becomes dependence on substances in order to keep up high level cognitive functioning in order to be 'good enough', this affects self-esteem and confidence to be able to cope with present and future challenges.

f). Ethical Issues : Social Ratchetting and Values

The ratchetting effect of such an enhancement, driven by competitivity, may lead people to do what goes against their values. A young person may feel 'forced' to take Ritalin to be able to get a good grade in an exam, knowing all her friends are doing it. She may feel that if she does not take it, her performance relative to her friends will be lower. She may perhaps fear that she will not now get one of the few places to college which she would normally have expected to get. Even students who normally would not experiment with drugs like marijuana now seriously struggle with questions about whether to use 'smart drugs'. In such a scenario the availability of a performance enhancing drug has 'upped the ante'.

There is a general principle here which points to a deep injustice. If there are drivers in the social context through which a few people would use the enhancement and gain an advantage, whether real or perceived, this could then precipitate a rapid, even panic, uptake against most people's better judgement. The enhancement would become normalised through the back door, as it were. Ironically, it would cease to be an advantage, if everyone in the competitive situation now used it. The value of such an enhancement is not in the enhancement itself, but in having it before someone else does. But the enhancement would have become part of the social context, but now essentially useless, yet no one would now dare *not* to use it, for fear of falling behind the norm.

g). Addiction and Control

Modafinil is taken by some people to be able to work without sleep with no apparent side-effects, earning time, which is seen as a very precious commodity. Modafinil is unusual in having no known physiological side-effects. It seems to effect only one centre whereas amphetamines and Prozac affect many targets in the brain. However, does one lose the remedial effect of sleep? If this is selected as an occasional strategy there may be little harm, however, can one become addicted to this prize of additional time? There is a degree of loss of control, which could impact on others also. Again the social context may put pressure on me. If I want to buy a house I may not merely work overtime, I might take a drug that would enable me to work all night, because, in my terms 'I need the money'.

Against this some argue that the main issue is about moderate and controlled uses of an enhancement. People are capable of choosing when to use an enhancing technology and under what circumstances. They would be able to recognise where there might be a risk of adverse consequences, or perhaps discover it is not so beneficial after all. It is possible to maintain a sense of self-discipline. A counter example was anecdotal experience with colleagues who use Modafinil regularly, where the distinction of chronic and transitory use was no longer the case. They started using transitorily but soon moved to what was now chronic use. It became 'normal' and so becomes a kind of dependence in their lifestyle. Ironically, could becoming dependent upon cognitive drugs lose something of our inner autonomy that is a key factor in seeking enhancements?

h). Cognitive Enhancement Drugs : Summary

We have explored a number of risks, impacts and ethical considerations. The value of neurostimulants in treating ADHD is acknowledged, but with considerable ambiguity as to where treatment and enhancement begin and end. Their widespread use does not seem to cohere well with aims of all round education and development of personality. We have identified problems about their wider use of neurostimulants as enhancements. While gaining abilities to perform in exams or work with less sleep, they may also interfere with the capacity of autonomy and lead to states of dependence in normal performance of tasks. We have identified a serious ethical problem with stimulants in a social context where peer pressure and competition lead people to use them when they would otherwise not have wished to do so. Khushf argues that the pressure for such competitive enhancement could grow such that, just as in some sports, drugs will become considered essential in order to keep up in education and business.[39] The long term consequences of neurostimulant use for enhancement are so far unknown, but the many open questions and problems which could be associated suggests that pharmacological cognition enhancement is both practically and morally problematic.

6. Case Study 3 - Human Enhancement and Sport

Discussions on a paper by Andy Miah

a). Enhancement in Sports Governance

We examined the case of human enhancement in sport not so much because of the detail of the converging technologies themselves, as for the fact that this is a specialised social domain in at least some of which enhancement is already a live practical, ethical and regulatory issue.

Sports medicine is recognised as an integral part of the development of sport. Whereas medicine implies something restorative, sports medicine is also involved with the process of improvement. It addresses performance and the recovery processes, seeking to speed this up. Medical commissions are concerned about the level of injury and take a paternal interest because they take the view that athletes are in general risk takers.

Since the early 1900s, sports governing bodies have developed guidelines for the use of human enhancement technologies. Typically, this has taken the form of an interest to avoid the 'abuse' of medical substances and procedures, though the sports community is also particularly keen to ensure a 'level playing field' in competition. In 1967, this process gained across-sport relevance when the International Olympic Committee initiated its Medical Commission, whose task was to address the problem of doping in sport. The current international standard for doping technologies is the World Anti-Doping Code, which indicates that two of three conditions must be met in order for a technology to be banned from sport. These are being harmful to health, performance enhancing and against the 'spirit of sport'. It is widely recognised that determining whether these conditions are satisfied requires some form of discursive process.

One question is whether the sports which currently ban certain chemicals can ever be even-handed in administering a ban, especially when science is usually one step ahead all the time. Precautionary legislation was introduced in 2003 on genetic interventions ("gene doping"), defined as "the non-therapeutic use of cells, genes, genetic elements, or of the modulation of gene expression, having the capacity to improve athletic performance." A related set of questions arises in the context of genotyping of children for their athletic capacity. How far true genetic engineering for performance is feasible and how far it would be detectable are both open questions. But some kinds of enhancement cannot be detected, would this not render an anti-doping policy ineffective and inconsequential?

b). Forms of Enhancement in Sport

Such discussions do not cover all forms of performance enhancement. In general they exclude improvements to equipment such as tennis racquets and pole vaulting poles. The relevant specific sports federation will consult its own guidelines on technical specifications to determine whether the innovation is acceptable. In many sports technology has long been already a constitutive element. Much of this is expensive and clearly enables an advantage to the richer countries where such technology is affordable. This includes monitoring devices and altitude simulation chambers which enable elite athletes in some countries to benefit from high technology training methods. Here is a difference between external tools and internalised enhancements. Drug enhancement may receive high media coverage but it is not the only area where science is used to provide an advantage which may not be fair. Some argue that a closer connection between such equipment enhancements and doping technologies is desirable.[40] [41]

There are also surgical enhancements. The treatment of injuries sustained by athletes is a similar area where post-operatively they are able to compete once more having been "fixed up" by the top doctors. Tommy John (US Baseball) had surgery on his arm after which he was able to pitch faster / harder. Is this artificial enhancement of a naturally occurring selective advantage? Top US footballers have long distance precision 20-15 vision. The leading golfer Tiger Woods had laser eye treatment to achieve the same effect, quite legally within the sport. Taking this a little further again, is the example of a paralympic athlete who has had prosthetic legs fitted that allow him to run at speeds that are beginning to challenge those who are fully fit. The International Olympic Committee has ruled that he cannot compete against the able-bodied athletes.

c). Ethical Issues in Sports Enhancement

The way of dealing with various sport technologies in sports has not been particularly systematic. Various scholars have attempted to develop a conceptual, ethical framework for distinguishing between different kinds of technologies. For instance, one might make an ethical distinction between *isolated* and *systemic* interventions, the latter of which might be perceived to have some greater bearing on the stability of biological systems. Another issue is to establish what features are seen as constitutive of the sport in question, what exactly constitutes excellence in it, and what is the role of technology.

Sports are games played within certain agreed rules, to which anyone wishing to participate has to consent. Thus Maradona’s famous handling of the ball in order to score a vital World Cup goal would be seen as cheating according to the rules of soccer. Rules may be changed by agreement, but then everyone must play within the confines of the new rules. Another important principle is the notion of fairness for anyone to be able to play without disadvantage. All sports have to have ways of handling the tension between the desire to win or to maximize one’s personal performance, and the notion of fair play. Performance enhancing drugs have been seen by the governing authorities of many sports as something that would be considered an unfair advantage and thus to be eliminated as far as possible.

Some, however, criticise the basis for such a ban, the politics surrounding it, and the inconsistencies it leaves. They point out that, the playing field is not level because of other many barriers such as poverty and finances, cultural issues, infrastructure, investment, availability of advanced equipment, climate, altitude and educational systems. Why, it is argued, select one area for sanctions and not the others? This could be an argument for better regulation rather than deregulation, however.

Another ethical concern about doping in sport reveals a worry about the ‘dehumanisation’ of sport.[42] This is a sense that technology is reducing the athlete’s role in performance and, in so doing, diminishes the value of competition. The athlete is seen as a product of a scientific or technological process, somehow automated in performance. This was typified in one of the Rocky films, where a doped athlete is presented as a cold, machine-like, performance body, in contrast to the ‘natural’, virtuous hero of the film. Miah has argued that the ‘dehumanisation’ thesis about sport and technological progress is not accurate, but is a historical consequent of disenchantment with grand, technological progress. Others suggest that the value judgement is about *inappropriate* use of technology. At the elite level of tiny margins between the finalists in an Olympic sprint final, if what makes the difference between winning or coming second is taking a better performance enhancer, this would no be a supreme contest between of the finest of *human* athletic ability. Would it be *de facto* about who has the smartest pharmaceutical company?

The question is therefore whether drug enhanced performance is all part and parcel of an Olympic sprint - as it would be part of for example US major league professional baseball- or is something alien to it? This relates to a deeper question of the integrity and character of sports. There is a tension between what might be described as traditional versus a technological character for sports. In the Oscar winning film *Chariots of Fire*, the trainer of the sprinter Harold Abrahams says, “We’ve an old saying in my game. You can’t put in what God’s left out.” He finds the crucial extra yard for his athlete for victory at the Olympic Games by correcting his stride length, but not by adding something ‘missing’.

In 2004, Miah’s book *Genetically Modified Athletes* proposed that sport should soon enter a transition phase where the dominant model of anti-doping is brought into question as a result of changes to technology policy outside of sport.[43] Could it now be argued that if an athlete has natural levels of a substance well below that of the "average" performer, he or she should be allowed to normalise the level – putting in what God left out - by taking drugs? Some indeed argue for removing any ban on drug use and allowing a ‘free-for-all’. This is indeed the case for US baseball where the sport has separated into two classes – elite professional where to reach and stay at the top requires performance enhancing drugs, and amateur unenhanced leagues.

Is sheer performance now the primary criterion, by whatever means, or is it natural ability the yardstick with only certain types of activity allowed to enhance it? If sports enhancement prefigures what might be done more generally in the culture, we see in these two scenarios possible futures.

7. Case Study 4 : Electrode Stimulation of the Brain

Discussions on a paper by Francois Berger

a). The Technique of Brain Electrical Stimulation

Brain implants are a major opportunity to treat neurological illness. Normal brain function is based on the association of neuro-anatomical synapses which linking electrical and chemical communication. With the immense complexity of these networks we have a correspondingly low understanding of the global brain function which is a major basis of human status. Brain diseases have a major socio-economical impact, especially in developed countries with increasingly ageing populations. Example of the resulting pathology include neurodegenerative diseases such as Alzheimer’s or Parkinson’s diseases, and brain tumours. The therapy of brain disease is difficult partly because of the low accessibility of the brain, and partly because of the high functionality of most brain locations. Systemic therapy using drugs has many side effects, because it is not able so far to achieve local, functional targeting. Brain dysfunction is often located to specific neuronal network, which is very difficult to target from the periphery. Despite its invasiveness, local targeting provided by a brain implant can provide better efficacy compared with systemic drug therapies. Moreover, brain devices may deliver a functional and reversible effect which dramatically increases their safety.

Functional neurosurgery was mainly demonstrated by the work of Alim Louis Benabid. In 1987, he was trying to destroy a particular nucleus in the brain, which at that time was seen as a therapy for persistent tremors. He observed that high frequency electrical stimulation induced an effect similar to the intended lesion. Moreover, he found that the direct effects of the probe were reversible. While the probe was turned-on the patient experiences changed in his/her ability to control the impaired motor function, but as soon as the probe was turned off the, patient's condition returned to what it had been. The function of the probe is manageable externally, and can be stopped at any time.

Classical psychiatric surgery required making lesions and was irreversible. High frequency electrostimulation was thus able to have the same effect, by a reversible inhibition of, in this case, an over-expressed brain function, at the specific location targeted by the electrodes. This use of neurostimulation for psychiatric diseases clearly demonstrated that superior brain function can be modulated by implants. The trials initiated in the psychiatric field were in patients with incurable fatal diseases. The concept has since been shown to be highly efficient in essential and Parkinson’s disease tremor with the target of VIM, and extended to the sub-thalamic nucleus. In this location not only tremors, but akinesia can be treated with high efficacy. Long term efficacy and safety has now been demonstrated, continuing in the longest patients for up to 20 years.

There may be a long term change in the brain which is not reversible, conferring a kind of neuro-protection. This is very controversial. While the French researchers do not place too much trust in this finding, some US labs are following it up with a commercial company which wishes to push the technology, looking for a patent. The clinical reality is often not how people would imagine that research like electrode stimulation is done. A neurosurgeon is often working well ahead of the basic scientific understanding. Neuro-coagulation was being used in 1990s in conditions resistant to other treatments. Benabit found a clinical effect that electrical hyperactivity in the sub-thalamic nucleus can be neutralised by high frequency neural stimulation, without lesions. But he did not know the mechanism of how it worked. The surgeon may make a rapid progress at a clinical level and something works. It’s seen as a miracle! But then the team has to go back to basic science and technology to try and understand what had been achieved.

b). Extensions of Electrode Stimulation of the Brain

A number of technical developments can improve the specificity and effectiveness of the basic methods. Thus, it may become possible to implant silicon chips on the stylus to obtain a local fingerprint or to modify the surface in order to detect or modify proteins. Electrode stimulation could be integrated with micro-fluidics or electrophysiological monitoring on the electrode. Research is expected to decrease the size of the existing micro-scale devices. Carbons nanotubes coated on the electrodes should increase biocompatibility and physiological integration at the electrical level. Magnetic nano-beads could be injected intravenously to target and highlight a specific area of the brain when an external magnetic field is applied. This concept could provide a direction for the next "nano-electrodes".

The concept of electrode stimulation has now been extended to other targets in the brain, which could provide cures for previously incurable neurological illnesses, such as dystonia or epilepsy. More recently therapeutic efficacy was also observed in major depression and obsessive compulsive disorders resistant to chemical therapy. There is also a potential application for feeding disorders, mild depression, or even aggression. From a technical point of view, this gradual progression from tremor to wider motor efficiency, to dystonia, then to new applications for compulsive disorders and depression, is entirely logical. But it shifts into some very different areas ethical concern, and ultimately poses a question if this should be extended into non-medical applications?

c). Risks of Electrode Stimulation of the Brain

The risks associated with this form of treatment arise from the need to enter the brain through the patient's skull. The targeted sites are located deep within the brain. The problems of locating the correct site at this level of precision are obvious. A patient may suffer from damage to the brain on entry, through manipulation of the probe, as well as in the management of the probe via adjustments in voltage. A small proportion of cases lead to serious bleeding or clotting. Since this may lead to death or permanent physical handicap, these cases usually require open brain surgery.

There are clearly substantial unknowns here. Can we make adequate judgements about such risks on the basis of what we know today? The Royal Society/Royal Academy of Engineering report identified some types of nanoparticles requiring further study before they can be used more generally. It is clear that risks of any particles proposed for use in conjunction with brain stimulation would need to be examined in each particular context. Some papers show that nanoparticles of some materials can pass the blood brain barrier to target neurons. Could this itself be a possible source of neuro-degeneration? There would need reasonable assurance that these kinds of interventions would not be likely to cause adverse health consequences, medium-to-long term, which we would find difficult to reverse. We need to keep an open mind whether existing regulatory frameworks which extrapolate from existing categories, would be sufficient if at the nanoscale there are phenomena whose toxicity were not a simple continuity from micro- and macro-scales.

d). Information, Consent, Privacy and Identity

There are important information and privacy issues. The stimulation technique entails brain activity to be monitored externally, usually with fixed settings determined by the doctor. The assurance of privacy protection is clearly crucial. In a medical context there are existing protocols for patient confidentiality, backed also by the code of ethics which bind the medical professions to a common set of basic norms. If enhancements were used, no such safety net would exist either in protocols or codes of ethics. The protection from abuse of the basic information coming from a new and powerful access to brain function would raise many problems. The problem of legal responsibility of a human being harbouring implanted devices will need to be addressed.

To add a physical artefact which can pass a barrier in our person could be seen as highly invasive. There could be a sense of matter out of place, something where it should not be. In this sense implants might be seen to invade our sense of authenticity or integrity, perhaps especially where brain function was involved. Are electrode implants always foreign or do they become part of you? We might accept this for a life-threatening medical intervention but would we do this for, say, a sensual pleasure or to lose weight?

There can also be psychological side-effects, for example in terms of mood change, which are an artefact of the technique. In addition, experience has shown that there can be profound effects in the response of the patient to going from being seriously ill, unable to move properly, being medicalised and dependent, to being ‘normal’ and now independent. This can lead to depression, and tragically has even led to suicide in some rare cases.

There is therefore an important question about the patient’s sense of identity and self-perception. The dramatic effect of the treatment to an extent changes their personal biography. Who was the original person, and who is now the person that results from the intervention? This poses an additional problem to the already difficult issue of how a psychiatric patient and/or family members can give meaningful consent. Who is the self who consents in a situation where the patient cannot envisage what they will become? This re-contextualisation of a life has led to a recognition of the need for especial psychological counselling of the prospective patient.

e). Brain Control and Public Perception

A two-dimensional 5 x 5 electrode implant has now been developed which can be controlled by an external device. This was portrayed in the French media as a means of being ‘taken over’ by someone else. This was misleading because there are no tools of this type at present which have the ability to persuade people against their will. No one knows the neurophysiology of convincing people, as yet. But we have tools to invade the brain already in ways which would now be seen as unacceptable, and some societies have used techniques to brainwash victims. More broadly, people can and do seek to manipulate others in human relations. So there is a plausibility to the suggestion that this is a technology which could potentially by-pass my ability to resist. It is possible to imagine some future technologies which might enable, say, supermarkets to tinker with the in-store environment to encourage customers to buy particular products. This plausibility could be a major factor in the public fears, since they know societies are not always able to avoid misuses and that misuse is difficult to avoid absolutely. Citizens have evidence-based data from the past that sends warning messages about what might be done with powerful invasive cognitive techniques.

f). Should we Ban non-Medical use of Brain Implants?

There is already an ambivalence in the above medical applications, in so far as one of the effects accompanying electrode stimulation can be a degree of mood change. At present, the level of electrode current is pre-set by the doctor. It is fixed, based on the optimum effect that was established for the patient during the lengthy operating procedure. It is possible to imagine electrodes in future with variable settings, which the patient could perhaps choose, in order to change their mood according to personal preference. This is a grey zone where the effect goes beyond the original therapeutic intention, and which could lead to a different doctor-patient relationship.

As observed above it has also proved possible to extend electrode stimulation to treat serious and unusual compulsive disorders. This might be extended to broader eating disorders, for example, or to deliberate mood change. A set of checks and balances needs to be established to address non-therapeutic situations, and also what constitutes a normal condition and what is deemed to fall outside it. For example would we treat children who have eating disorders just like all other members of their peer group? At what point do we intervene and withdraw them for specialised treatment?

The research and treatments are extremely expensive. In France, the ability to pay is not the criterion for treatment, but what is affordable for health care budgets? This raises several questions. How do we define the "special cases" suitable for treatment? Should it be based on degree of illness, economic factors, or other criteria? There is a general question of the extent to which extreme interventions of this nature are justified against pressing health issues for the poor, whether in third-world countries or our own cities. Therapeutic criteria may not be the only information upon which treatments are developed. Should obesity treatment be seen as a medical or social/personal problem? In general if it was not an abnormal pathology, the condition was not met and medical treatment would not be offered.

What is a valuable enhancement? This caused us to consider what things we already to that we believe will improve our lot in some way. Some examples at random are taking up rock climbing or sky-diving, riding a magnificent motor bike, embarking on an Open University course late in life, or learning to paint. Such things may bring about lasting changes, for instance in overcoming fear, or a sense of worth at a difficult achievement, finding an expression for artistic creativity. But they remain externalities as such, and the enhancement is indirect. The same applies to coffee and other chemical stimulants. Is there justification for use in what would not be termed pathological behaviour? A technique like electrode stimulation might be clear in addressing an intractable tremor in Parkinson's disease. Should this use also be available in an enhancement context? And, if so, to whom? For a competitive archer a 'normal' tremor might make the difference between winning and losing. Would this simply be unfair, if the same was not available to an unsponsored athlete or in a poorer country, or if it entailed a risk which other competitors were not prepared to take? Should brain stimulation be mandatory for certain military situations, like fighter pilots who require exceptional steadiness of nerve?

The type of direct stimulation of the brain seems to be of a different order, being direct stimulation of a brain centre, and being an effect created without an associated context. Electrode stimulation slightly to one side of the site for tremor control has been shown sometimes to induce laughter or feelings of deep depression in some Parkinson's patients. The fact that this simply occurs - without a joke or some event or situation to bring it on - de-contextualises the normal experience of, say, laughter. Suppose it were possible to have an array of electrodes implanted in my brain and then to type a laughter number into my mobile phone to achieve the effect. This would abstract humour to becoming a sensation which we want to have when we feel like it. Would this actually be an enhancement, compared with picking up a book and reading a funny story? From anything other than a purely reductionist functional view, something seems to be missing compared with whatever it was about the story that struck as funny. To remove sensation from the normal human context in which we experience it would seem less than fully human.

Finally, there are issues of researchers of funding, public profile and overclaiming. How does a scientist describe the research prospectus in an area like electrode stimulation of the brain? It may sound scary to the lay person, but it also has recognisable benefits if you can envisage the Parkinson's tremor of your elderly relative being cured. Applications beyond this are more problematic. In reality, the pioneering unit at Grenoble only addresses two diseases, and it does so in serious, limited, clinical trial situations. But the attraction of funders may be the more speculative 'science fiction' aspects of how the research might one day be used. In reality the researcher needs much more basic funding which is not so attractive for the funder. There is a problem if the scientists become locked into the claims they feel they have to make. The danger is that this could eventually rebound and end up with the work under threat, because too much had to be claimed in order to get the funding.

8. Concluding Reflections

We have examined a range of applications of technological convergence which might lead to human enhancement techniques becoming available in general social use. A few are already feasible or close to feasibility, but most remain future prospects. Some of these are micro-scale some truly nano, but the point at issue is to examine the context of technical enhancement rather than restrict ourselves to what is currently less than 100 nanometres. In the context of this European NanoBio-Raise project, we have also tried to restrict ourselves to the more immediate, rather than radical change. In doing so we have identified a number of issues which would apply also to more radical interventions, were these to become possible.

The group exhibited a range of views and backgrounds. Some of us are enthusiastic about these potential applications, others are more sceptical or very concerned. We have tried to portray the different sides of arguments where we disagreed. The result is more critical than it is positive, but this reflects the balance of what the members of this particular group have had to say.

We have examined briefly the many philosophical and conceptual problems with dealing with the idea of human enhancement. What conditions does society need to establish to manage these sorts of examples, or to prohibit, and if so, in which ways? Amongst the questions to be asked about either the application or the research leading to it are:

- Should it be considered inherently wrong?
- Are overwhelmingly negative consequences a likely outcome?
- Would arouse concerns of injustice, for example if it is only for a very few rich people?

Amongst other things, we asked whether we actually know what an enhancement is and whether in the long run people might conclude that some of the applications presented as enhancements in prospect would not to have improved us, all things considered. The jury has hardly gathered yet in assessing that question. We also noted a general problem about beneficial claims for enhancements, arising out of the way humans may use improvements in practice. With near IR-enhanced night vision, for example, would I actually be a safer driver or would I use the enhancement to drive faster instead?

The choice of metaphor and language to describe the enhancement landscape may reveal implicit value claims or assumptions based on the beliefs of the writer, which the person is making through the analogy. For example, the concept of the human brain as a kind of computer whose capacity we can shortly expect to exceed may simply be misleading. Ingenious devices have been demonstrated which interface silicon chips with neurons in various ways. The fact that these work may be more a testimony to how smart our brain is at processing than great strides we have made towards making brain chips or interfacing signals out of the brain. Many of the devices constructed under laboratory conditions would be hard to realise in vivo. The enhancement potential of such IT-based developments has to be compared with linkages among 20 billion neurons and the three dimensional, dynamic complexity of the living brain.

We have found considerable ambiguity in the use of neurostimulants to treat ADHD syndrome, as to where treatment and enhancement begin and end. We note that their widespread use does not seem to cohere well with aims of all round education and development of personality. The long term consequences of neurostimulant use for enhancement are so far unknown, but we identified many open questions and problems which suggest that pharmacological cognition enhancement is both practically and morally problematic. While gaining abilities to perform in exams or work with less sleep, they may also interfere with the capacity of autonomy and lead to states of dependence in normal performance of tasks.

In many sports, chemical enhancements are seen as antipathetic to the nature of excellence that the sport celebrates, or to the fairness of the competition. While some argue that this regulation is anomalous when many other sources of unfairness exist, some of us thought it pointed to a need to more consistent regulation rather than necessarily to deregulation. We noted that, in some sports where chemical enhancements are not forbidden by regulation, two cultures had emerged. There was an elite professional, enhanced tier of competition, and a much broader, run of the mill, unenhanced level. Stimulants and enhancement seemed almost a pre-requisite of going from the latter to the former. Many of us thought this was a disturbing development, if sport indeed prefigures the role that enhancement technologies might play in wider society.

A general and serious ethical problem arises in the context of cognitive enhancement for exam performance. This is the potential ratchetting effect of introducing stimulants for a marginal advantage, which raises the stakes in a competitive context. Peer pressure and the desire not to fall behind lead people to use stimulants when they might otherwise not have wished to do so. People might feel ‘forced’ to do actions against their basic values by competitive social pressure. Once generally adopted it would then cease to be of any advantage, yet no one would now dare *not* to use it, for fear of falling behind the new norm. Khushf argues that the pressure for such competitive enhancement could grow such that, just as in some sports, drugs will become considered essential in order to keep up in education and business.[44] The capacity of enhancement technology for stimulating intended or unintended social engineering and a ‘race to the bottom’ would pose severe ethical problems for many of us.

There is already an ambivalence in medical applications, in so far as one of the effects accompanying electrode stimulation can be a degree of mood change. As observed above it has also proved possible to extend electrode stimulation to treat serious and unusual compulsive disorders. The invasive and risky nature of the technology is a disincentive. Risks which might be justified in a serious medical context would be difficult to justify if the aim was enhancement. We considered the scenario of using an array of electrodes implanted in my brain to stimulate sensations like laughter in the absence of a joke. Would this actually be an enhancement, compared with reading a funny story in a book? To remove sensation from the normal human context in which we experience it could seem less than fully human.

But even if an enhancement was not valuable, should people be allowed to have it nonetheless? To what extent would such technologies be my purely personal choice? One view is that I should allowed to use whatever technology that I define as beneficial to me out of my personal context, provided it is not harmful to others. But this presumes that it is available and that I can afford it, and that I merely operate as an autonomous individual. None of these may strictly apply. What is the role of societal oversight and regulation and on which technologies? All of the cases would certainly seem, at this point in time, to go beyond matters of individual choice, because so little is known.

The idea that we have a range of things to select from is superficially very appealing, but it is not so simple. What is on offer is open to all the forces that would underlie what was stacked on shelves of a metaphorical enhancement supermarket. In practice, who would be owning and supplying the service, and, before that, who would be choosing what enhancements were developed and commercialised? As we observed at the beginning, a crucial issue is the need to know the values against which the ‘products’ have been developed, and to have submitted these to social ethical scrutiny, health and safety, and if necessary regulation.

We have identified substantial questions about diminished autonomy and the potential of enhancement technologies for social divisiveness or social injustice. These concerns were also widely expressed among participants in the Democs public participation game exercise in Work Package 3. These could be 'show stoppers' for some areas of enhancement if use became more generally possible.

Human beings exhibit a range of unusual or eccentric behaviour. Some of this might seem very odd to most people, raise a smile or simply puzzlement, but we accept a lot of this as part of being human. We would not normally prohibit it without some sense that it violated some basic value about ourselves or nature, or was likely to lead to harm to someone else or the person themselves. How far do enhancements act as a technological fulfilment of personal eccentricities in general, and in particular as the realisation of something we read in a science fiction book and rather fancied doing, if we ever could? How far should society act as gate keeper to new technologies which could enable people to extend their eccentricities technologically?

The problem of a potential modification of the status of the human body will clearly have to be discussed at a societal level. It is not clear when and how to address such very upstream issues, when it is so uncertain what would be feasible. Khushf argues that we are on the verge of the most radical technological changes in people and that we should be examining now the issues surrounding this radical potential.[45] Others are sceptical of how feasible and realistic a lot of the claims really are. We have considered whether the trajectory is as inevitable as is claimed, unless of course we chose to act as though it were, and thereby made it so.

In the UK upstream engagement has become a topic of much debate. There is much to commend it, and we think this should now begin in enhancement technologies. But how should it be done is not straightforward. As with nanotechnologies in general, it runs problems of unfamiliarity, where people do not yet understanding the issues, and of fears of technical complexity, at least as seen from the layperson's standpoint, which make people lack confidence to engage, or not see the relevance of doing so. There is also the inherent problem of the inaccuracy of technical foresighting, perhaps especially in converging technologies. The risk is that in examining and raising issues in advance people become alarmed about some things that may never happen and missing things that will. The risk of not doing so, is that people do not have the opportunity to become literate about these areas of technology, and so begin to develop the critical tools by which societies will need to assess whichever of these technologies do eventually come close to fruition.

In general one would not wish to stop innovation or therapeutic trials. But it may be that in some particularly sensitive areas a moratorium is needed, as there was for early genetic modification of micro-organisms, to allow for the investigation of physical, environmental and social impacts, side-effects and unintended consequences. The ultimate aim would be to establish societally which areas should go ahead and which should not. But this is a process we have hardly begun. Our experience in other fields is that the gap between the world of research and societal reflection on novel science is one which takes a long time to bridge. We would caution against undue haste in coming to closure on many of these questions. It will take a long time before anything like a societal discourse has taken place on such far reaching issues, or before scientifically literate Parliaments are in a position to debate and pronounce on these, as representatives of the democratic process. But some day they will need to.

9. Recommendations

1. We urge that in the consideration of potential technologies for human enhancement that feasibility is considered as a pre-requisite to ethical and societal reflections.

2. We have not identified a strong societal benefit from these technologies that would warrant public funding for the envisoned enhancements.

3. There needs to be effective government/societal oversight with some system of accountability, entailing checks and balances or regulation, with regard to any adaptation for human enhancement of techniques developed and justified in a medical and other contexts.

4. We strongly urge consideration of the social issues of enhancement technologies. Major concerns are expressed about the potential of enhancement technologies for social divisiveness or injustice. These include who or what controls what is done; how far both academic and commercial sector should be subject to public ethical scrutiny for what it funds; who and what regulates its safety; how precautionary should we be over uncertainties and 'unknown unknowns'; what would be adequate knowledge to proceed in any given case; who are the losers as well as the winners in any given development; and how do our plural societies handle the different normative assumptions about being human.

5. Guidelines or criteria should be established about what would constitute the sort of enhancement technology for which societal approval is a prerequisite, over and above personal choice.

6. There needs to be a wider societal discussion about the potential role of cognitive enhancement using drugs. We wish to avoid seeing in fields like education, job skills and business the phenomenon observed in some sports of an essentially runaway development for the sake of competitive advantage, which results merely in changing the playing field to a different level, and which locks the competitors in to the technologies. People should have the opportunity to become literate about these areas of technology, and so begin to develop the critical tools by which societies will need to assess whichever of these technologies do eventually come close to fruition.

Appendix 1 : Members of the Working Group

Professor Francois Berger: Professor and Physician in Cellular Biology and Oncology at Joseph Fourrier University, Grenoble, France.

Dr Donald Bruce: Managing Director, Edinethics Ltd, Edinburgh, Scotland, UK; (until July 2007, the Director of the Society, Religion and Technology Project of the Church of Scotland, Edinburgh).

Professor Richard Jones: Professor of Physics, University of Sheffield, and Special Advisor on Nanotechnology, Engineering and Physical Sciences Research Council, UK.

Dr Andy Miah: Reader in New Media & Bioethics, School of Media, Language & Music University of Paisley, Ayr Campus, Scotland, UK.

Professor Alfred Nordmann:, Professor of Philosophy, Institut für Philosophie, Technische Universität Darmstadt, Germany.

Dr Ottilia Saxl:, Chief Executive, The Institute of Nanotechnology, Stirling, Scotland, UK.

Elfriede Walcher-Andris: Interdisciplinary Centre for Ethics in Science and Humanities, Universität Tübingen, Germany.

Professor Brian Wynne: Professor of Science Studies, University of Lancaster and Associate Director, ESRC Centre for Economic and Social Aspects of Genomics, Lancaster, UK.

Appendix 2 : Meetings and Activities of the Working Group

Seven meetings of the working group were held as follows.

1. Carberry Tower, Edinburgh, 24 November 2006 : Introduction, Facilitated Brainstorming on the nature of human enhancement; the scientific state-of-the-art; the current political and deliberative contexts in Europe, USA and globally; major ethical and social issues; **Agreeing a Work Programme**

David Bennett (NanoBio-Raise steering group), Donald Bruce, Richard Jones, Alfred Nordmann, Ottilia Saxl, plus Ann Bruce (facilitator), Susanne Sleenhof (NanoBio-Raise administrator) and Alan Whitson (SRT Project administrator)

2. Edinburgh, 29 January 2007 : First Case Study on Electrode Stimulation of the Brain presented by Francois Berger, followed by discussion of its implications for enhancement

Donald Bruce, Francois Berger, Andy Miah, Elfriede Walcher-Andris, Brian Wynne, Alan Whitson

3. University of Sheffield, 7 March 2007 : Second Case Study on Brain Chips presented by Richard Jones and discussion of implications

Donald Bruce, Francois Berger, Richard Jones, Andy Miah, Ottilia Saxl, Elfriede Walcher-Andris

4. University Hospital Grenoble, 3-4 April 2007 : Attendance at an Electrode Stimulation Surgical Operation by Professor Benabit and his team; **Visit to Research Laboratory** hosted by Francois Berger; Meeting with senior nanotechnology researchers from CEA Grenoble ; discussion of implications

Donald Bruce, Francois Berger, Andy Miah, Elfriede Walcher-Andris

5. Edinburgh, 25 May 2007 : Third Case Study on Psychostimulants and Cognition Enhancement presented by Elfriede Walcher-Andris**; Fourth Case Study on Sports Enhancement** presented by Andy Miah; followed by discussion of implications

Donald Bruce, Francois Berger, Andy Miah, Elfriede Walcher-Andris, Alan Whitson

6. Köln, 8 June 2007 : Discussion of US developments and ethical perspectives on enhancement with Professor George Khushf(Center for Bioethics and Medical Humanities, University of South Carolina, NanoBio-Raise steering group)

Donald Bruce, George Khushf, Alfred Nordmann, Elfriede Walcher-Andris

7. Edinburgh, 29 October 2007 : Discussion and re-drafting of Report

Donald Bruce, Alfred Nordmann, Elfriede Walcher-Andris

Appendix 3 : Role of the Working Group identified in NanoBio-Raise

It is of great importance for the social validity and economic value of nanobiotechnology research sponsored by the European Commission that the areas selected do not raise deep conflicts because of violation of ethical and social standards and thereby risk of rejection by societies. One such area which can already be identified is the potential for the modification and enhancement of the human body and its systems, for both medical and non-medical/lifestyle purposes. This issue was especially identified for further ethical consideration in the recent EC expert group report '*Converging Technologies – Shaping the Future of European Societies*'[27]
To help explore the potential questions a multi-disciplinary expert working group will be formed which brings together, on the one hand, experts from the relevant areas of scientific research, industry and regulation relating to nanobiotechnology and enhancement, and, on the other, specialists in ethics, social sciences, media and public attitudes. The objective is to hold 6-8 meetings with 8-10 participants. The format will follow the long-established methodology of the Society, Religion and Technology Project, which has successfully conducted working groups for issues such as GM crops and animals and cloning. Such groups have proved immensely valuable in elucidating and exploring issues in a non-aligned context, and establishing long term relationships between the scientific and humanities communities. The group will meet regularly over a 12 month period, drawing on the expertise of the members and the constituencies and networks to which they belong. It will identify both current and future issues, explore different value perspectives, disciplinary insights and societal contexts.

The expert group meetings will be closely related to the horizon scanning workshops (WP 2) and further co-ordination activities. The more in-depth cross-disciplinary examination of a particular subject will also provide an example of how expert bodies can address other issues arising from nanobiotechnology, in institutional or international contexts. It will engage scientific practitioners with the ethical and social implications of their research and inform ethical and social science experts in what is and is not realistic in the science. This methodology is also able to go into more depth and rigour than is possible with short workshops or focus groups and is complementary to direct dialogue with lay publics. It avoids some of the difficulties of public participation (such as representativeness, difficulties in achieving informed discussion without unduly influencing the framing of the issues, and high costs). Each member of the group brings their own networks into the wider discussion. Each person is also a 'lay' person outside their own expertise.

Synergies with other Work Packages and Programmes

Donald Bruce and Francois Berger attended joint horizon scanning workshops of NanoBio-Raise Work Package 2 with the Nano2Life FP6 European Network of Excellence on the Human-machine Interface in Münster, Germany 9-10 January 2006 and on Theranostics in Münster, May 2007. The insights of these workshops fed into the working group's work together with many informal one-to-one discussions with other experts in the field during the course of the project. The emerging insights from the working group fed in turn into the development of the Democs card game on nanobiotechnology in Work Package 3, in lectures given at the two NanoBio-Raise Oxford courses in March and September 2007 in Work Package 4. Donald Bruce and Francois Berger also served on the Ethical, Legal and Social Aspects Board of Nano2Life, with which there was much cross-fertilisation of ideas. Useful discussions were had with the members of the FP6 CONTECS, DEEPEN and ENHANCE programmes.

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