CHAPTER 45

NEUROSCIENCE AND NEUROETHICS IN THE 21ST CENTURY

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Neuroethics: from futuristic to here-and-now

One might not know it to see the numerous chapters of this Handbook summarizing progress on a wide array of topics, but the field of neuroethics is very young. Most would date its inception to the year 2002, when conferences were held on the ethical implications of neuroscience at Penn and at Stanford-UCF and a few early papers appeared (Farah 2002; Illes and Raffin 2002; Moreno 2002; Roskies 2002). Initially neuroethics was a predominantly anticipatory field, focused on future developments in neuroscience and neurotechnology. In his introduction to the Stanford conference, "Neuroethics: Mapping the Field," William Safire explained the distinctiveness of neuroethics, compared to bioethics more generally, by explaining that neuroscience "deals with our consciousness, our sense of self…our personalities and behavior. And these are the characteristics that brain science *will soon be able* to change in significant ways" (quoted in Marcus 2002, p. 7, emphasis added).

Neuroethics has developed rapidly since then, driven in large part by developments in neuroscience. The anticipation and extrapolation that characterized its earliest years, which some skeptics dismissed as science fiction, has receded. In its place has grown a body of neuroethics research and analysis focusing on actual neuroscience and neurotechnology. What accounts for this change? Part of the shift reflects the deepening neuroscience expertise of many neuroethicists and the migration of neuroscientists to the field of neuroethics. This important trend has enabled neuroethicists to identify real developments to analyze, as opposed to in-principle possible developments. However, a more fundamental cause can be found in the rapidly evolving state of neuroscience itself.

An example of the new immediacy of formerly hypothetical neuroethical discussions concerns the ability of brain imaging to deliver useful psychological information about individuals. In an early paper I concluded that "mind reading is the stuff of science fiction, and the current capabilities of neuroscience fall far short of such a feat. Even a major leap in the signal-to-noise ratio of functional brain imaging would simply leave us with gigabytes of more accurate physiological data, whose psychological meaning would be obscure" (Farah 2002, p. 1126).

Although this statement is true, noise in the acquired images was not the next technical barrier to fall. Rather, breakthroughs in the statistical analyses of brain images, including aspects of images previously treated as noise, have taken us a major step closer to deriving useful information about mental content from functional brain images. Starting around 2003, statistical methods from the field of machine learning were applied to the analysis of brain images, revealing the unexpectedly rich information that could be derived from the fine-grained patterns of activation in unsmoothed functional brain images (e.g. Cox and Savoy 2003; Haynes and Reese 2006).

In addition, not all consequential applications of brain imaging require decoding activity on the scale of small ensembles of neurons. Thanks to our growing knowledge of the psychological roles of large-scale brain systems, many applications require only the measurement of brain activity within macroscopic regions. For example, activation of the brain's reward system can be used to estimate product desirability in marketing, and activation of executive control circuits can be used as an indicator of deception. As a result, brain imaging for marketing and lie detection are now commercially available services. Let us leave aside for the moment the question of whether these companies' systems actually perform as claimed. The mere fact that the technology exists, and is being used, illustrates the shift from hypothetical to real problems for neuroethics.

In this chapter I will review neuroethics from the standpoint of its growing real-world relevance. I will begin with an analysis of the history of neuroscience that suggests the reason for the emergence of neuroethics now, in the early 21st century. I will proceed to survey current applications of neuroscience to diverse real-world problems. Finally, I will conclude with a discussion of the ethical issues raised by these developments, and outline three general challenges for society in the age of neuroscience.

The history of neuroscience from 4000 BCE to 2000 CE

If we define neuroscience as the systematic study of nervous system structure and function, then its history stretches back at least as far as the 4th millennium BCE, when Ancient Sumerians documented the effects of the poppy plant on mood. Neuroscientist Eric Chudler has constructed a timeline of neuroscience history with over 500 milestones representing important discoveries about the nervous system (http://faculty.washington.edu/chudler/hist.html). Although it might seem absurd to propose any generalization about 6000 years of history, or 500 scientific discoveries, I believe that the following is true, almost without exception: For the first 6000 years of neuroscience, each advance has been of one of just two types.

The first type of advance in neuroscience encompasses advances in basic science. These are the advances in our ability to describe and explain the workings of the nervous system, including brain-based explanations of human behavior. The second type of advance in neuroscience encompasses medical applications. These are the advances in pathophysiology, diagnosis, and treatment in the clinical neurosciences, chiefly neurology and psychiatry. Like other medical advances, many of these arose by accident, and were only understood after further research. The initial discovery and development of neuropsychiatric drugs are a prime example of this: Drugs used as antihistamines or antihypertensives had unanticipated psychiatric effects, which were then studied, refined, and used to treat psychiatric illnesses (Barondes 2003). Other advances in applied neuroscience were not accidental, but resulted from the deliberate application of basic neuroscience to medical problems. An example of this type of advance is structural and functional neuroimaging, based on developments in neurophysiology, radiochemistry and magnetic resonance physics, and used widely in the clinic (Savoy 2001).

The age of *non-medical* applied neuroscience

However the past 6000 years' advances in applied neuroscience came about, by accident or by scientific design, they were almost invariably directed toward the understanding and treatment of medical conditions. Since the turn of the century, however, a third category of neuroscience advance has joined the first two categories of basic neuroscience and medical applications. We are suddenly seeing many advances in non-medical applications of neuroscience. No longer is neuroscience confined to the research laboratory or the medical clinic. It is now finding applications in the home, office, school, courtroom, marketplace, and battlefield.

The explosion of non-medical neuroscience applications at this point in history is a straightforward result of developments in basic neuroscience, specifically cognitive and affective neuroscience. These are the branches of neuroscience with the most obvious and direct relevance to human behavior, and which form the scientific basis of most of the non-medical applications to be discussed here. Around the turn of the century they finally came of age. We now have a theoretical framework, derived from the cognitive and computational psychology of the late 20th century, within which we can formulate working hypotheses about the neural systems underlying human cognition and affect. We also have a variety of empirical methods suited to testing those hypotheses, including the powerful new techniques of functional neuroimaging, which became widely available for this purpose in the last decade of the 20th century. Of course we do not now have a complete understanding of the neural bases of human thought and feeling—far from it. But we do have a body of knowledge, some agreed-upon next questions, and an armamentarium of methods to address those questions with.

As a result of the maturation of cognitive and affective neuroscience, we can now bring neuroscience to bear on solving problems in all those spheres of human life that depend on being able to understand, assess, predict, control, or improve human behavior. This includes the spheres of education, business, politics, law, entertainment, and warfare—none of which are medical applications. Indeed, neuroscience is already been applied in these spheres.

In the remainder of this chapter I will review examples of these applications, by individuals and by the state, and discuss some of the ethical issues raised by these applications.

Lifestyle neuroscience in the 21st century

Many of the new uses of neuroscience for non-medical purposes have found a place in the lives of private citizens, improving their lives at home, in school, and at the office. These applications of neuroscience, discussed in greater depth in other chapters within this volume, include the enhancement of individual psychological functioning, education, business, and a variety of other aspects of individual and community life.

Enhancement of mental function

The most familiar example of psychological enhancement by direct manipulation of brain function is the use of prescription stimulants by healthy individuals. Thanks to extensive media coverage, from "Desperate Housewives" to network news shows, the public has become aware that stimulants such as methylphenidate and amphetamine can be used to enhance concentration and productivity. Although the use of "speed" for non-medical purposes has a long history, almost as old as the synthetic stimulants themselves (Rasmussen 2008), its current use as a cognitive enhancement appears to be on the rise relative to recent years (Kroutil *et al.* 2006).

The segment of the population for which we have the best estimates of non-medical use of stimulants is the undergraduate student population on American college and university campuses. The results of a 2001 survey of over 10,000 such individuals showed that 7% had used a prescription stimulant non-medically, and this figure ranged as high as 20% on some campuses. This study was not designed to tell us why students were using the drugs. Studies of smaller and less representative samples of American college students have broached this subject and indicate that, for students who use methylphenidate and amphetamine non-medically, cognitive enhancement was the most common reason, although other "lifestyle" uses such as weight control were occasionally reported.

Anecdotal evidence, along with a variety of informal journalists' surveys, suggests that many students and professionals have added an array of different psychopharmaceuticals beyond the conventional stimulants to their work routines (Arrington 2008; Madrigal 2008; Maher 2008; Sahakian and Morein-Zamir 2007; Talbot 2009). These include newer compounds, originally intended for the treatment of neuropsychiatric disorders but already finding a role in the lives of normal healthy users.

Among the newer compounds that informal surveys suggest have already been taken up by healthy individuals for lifestyle reasons is modafinil. This drug was initially developed to reduce sleepiness in narcoleptic patients, but it also counteracts many of the cognitive symptoms of sleep deprivation in healthy normal users, allowing for more comfortable and productive "all-nighters" (Arrington 2008; Hart-Davis 2005; Madrigal 2008; Plotz 2003). Some research suggests that modafinil may also enhance aspects of cognition in healthy people who are not sleep-deprived (Turner *et al.* 2003). The ability to control when one gets sleepy, and perhaps even "work smarter" as well as work longer, has obvious lifestyle allure. Although healthy people comprise some of the market for this drug, how much of the market is not known. It is presumably limited by the expense of the drug, the need for a prescription and, last but not least, the unknown long-term effects of cheating one's body of sleep in this way.

In general, we know little about the lifestyle uses of cognitive enhancers outside the American college population. Do students generally leave their Adderall® behind on campus when they graduate and enter the world of work? Or do they carry this work habit over into their life at the office? We also know little about the prevalence and patterns of usage of other pharmaceuticals for cognitive enhancement, such as modafinil. Considering the likely public health implications of this phenomenon, as well as the potential impact on workplace hours, workforce competition and productivity, and the economy as a whole, the dearth of information is problematic.

Looking a bit farther out on the horizon, into the coming decades of the early 21st century, there are likely to be a number of new cognitive enhancers available. Several companies are developing drugs to manipulate learning and memory. Based on the research of Eric Kandel, Mark Bear, Gary Lynch, Tim Tully, and other molecular neurobiologists, molecules are being designed that will treat cognitive disorders and also enhance the memory abilities of normal people (Marshall 2004). If one projects the market for normal memory-enhancing drugs from sales of nutritional supplements sold for this purpose, it is clear that the economic motivation is huge to develop memory enhancing drugs to help normal people deal with their complex lives. Drugs to suppress unwanted memories are also the object of research and development (Singer 2009).

The enhancement of non-cognitive psychological processes is also a goal of corporations and the individuals who buy from them. Basic research has shown that trust and generosity can be manipulated neurochemically in humans through nasal administration of oxytocin (Fehr *et al.* 2005; Zak *et al.* 2007), an achievement with obvious potential for enhancing social and business interactions, not to mention forensic uses. A quick search online will turn up numerous companies selling oxytocin, although without evidence that the formulation being offered is effective.

Drugs with central nervous system targets can also be used to enhance sexuality. Testosterone patches and gels have been used to enhance libido in postmenopausal women (Fitzhenry and Sandberg 2005). A number of new drugs, including the serotonin agonist flibanserin, show promise for improving sexual function in otherwise healthy young women suffering from low libido, and are under review for this purpose with the US Food and Drug Administration (Fitzhenry and Sandberg 2005).

Pharmaceutical approaches to cognitive and affective enhancement have recently been joined by other technologies, including transcranial brain stimulation by magnetic fields (transcranial magnetic stimulation, TMS; e.g. Fecteau *et al.* 2007) or electric currents (transcranial direct current stimulation, tDCS), deep brain stimulation by implanted electrodes (Schiff and Fins 2007), stem cell grafts (Li *et al.* 2008), and gene knock-ins (Lehrer 2009). Most of these are too invasive or experimental to be considered for use by healthy humans, although the rapid pace of technological development makes this generalization a fragile one. In the past few years deep brain stimulation, for example, has been achieved non-invasively in animals using ultrasound (Tyler *et al.* 2008).

At present TMS and tDCS are the focus of active research programs on the manipulation of normal and abnormal brain function. In particular tDCS has earned the attention of researchers in recent years for its ability to enhance a variety of cognitive processes in healthy research subjects. Learning, working memory, decision-making and language have been enhanced under laboratory conditions using tDCS (e.g. Dockery *et al.* 2009; Floel *et al.* 2008; Fregni *et al.* 2006; Sparing *et al.* 2008). Unlike TMS, tDCS does not require expensive equipment, and online chatter indicates that people are experimenting with the method at home.

At present much brain enhancement in underground, with students illegally buying and selling stimulants in the college library and home hobbyists trying battery-powered tDCS. This may soon change, given the recent guidelines issued by the American Academy of Neurology's Ethics, Law and Humanities Committee (Larriviere *et al.* 2009). In a report entitled "Responding to requests from adult patients for neuroenhancements," they conclude that it is morally and legally permissible for physicians to prescribe brain enhancing medications to healthy individuals.

Neuroscience-based education

Education is an aspect of life that engages each of us growing up and, for most of us, again in adulthood as parents. For many years, stretching back well into the 20th century, educators sought guidance from neuroscience, especially the parts of neuroscience that address learning and development. Their hope was that neuroscience would inform the design of instructional systems based on knowledge of human brain function in general and would allow customization of instruction based on knowledge of individuals' brain function. Unfortunately, they were generally disappointed by a lack of relevant information in these areas of neuroscience. In 1997 John Bruer surveyed attempts to apply neuroscience to pedagogy and concluded that the relationship between neuroscience and educational practice was, in his words, "a bridge too far." It seemed a fair point. The understanding of long-term potentiation has little to say about the challenges of classroom learning, and critical periods for the development of stereopsis are no more than a metaphor for concepts of readiness to learn in school children.

Although it would be an exaggeration to say that Bruer's bridge now exists and supports heavy traffic, it is clearly under construction and has already enabled some transit between the two sides. Not surprisingly, the most common applications of neuroscience are found within education research—the kinds of research programs conducted in university departments of education—rather than in the instructional practices of classroom teachers. One would expect this to be the case, as new teaching methods ought to be subject to research before being implemented in the schools. Much of the progress in this area concerns reading, which is a difficult skill to teach, and which cognitive neuroscientists have learned a considerable amount about. An example of a research program with relevance to educational practice comes from the work of Fumiko Hoeft, John Gabrieli, and collaborators. They addressed the problem of evaluating when a child is ready to learn to read.

It has long been known that children become ready to learn to read at different ages, and assessing reading readiness is therefore an important task for kindergarten and first grade teachers. Traditionally, they have relied on tests of phonological processing, such as making rhymes and predicting what word you get by adding a hard "c" sound to the beginning of the word "at." Hoeft *et al.* (2007) scanned a sample of children and then looked to see which areas of functional activation, gray matter density, and white matter density are predictive of reading ability 1 year later. What they found is that the brain data is predictive and the traditional behavioral data is also predictive. More importantly, they found that if you take the traditional data into account, the brain imaging data can still further improve prediction of reading 1 year later, above and beyond what is possible with the traditional methods.

Children with reading difficulties are already being given computerized interventions produced by companies such as Scientific Learning (http://www.scilearn.com), which base their methods on general neuroscience principles such as the effects of timing and practice on neural plasticity.

The ratio of hope to proven benefits remains high in the area of education and the brain, but unlike the situation Bruer critiqued in the late 20th century, there is a growing body of research linking the study of brain function to educationally relevant aspects of human psychology. Reviews of recent neuroscience research on learning to read (e.g. Dehaene 2009), mathematical competence (e.g. De Smedt *et al.* 2010), and the socioeconomic achievement gap (e.g. Farah 2010) show that neuroscience can be fruitfully applied to education (see also Ansari and Coch 2006; Battro *et al.* 2008; Goswami 2006; Turner and Sahakian 2008).

Neuromarketing

Corporate strategies for advertising, positioning and pricing products are often informed by research on consumer psychology. The emotions and motivations of consumers are a particularly important focus for marketers, yet people are often unable to report accurately these aspects of their psychology. The prospect of directly "reading" the brain states of consumers is therefore of great interest to marketers. Compared to some psychological states, states of liking and wanting have a relatively straightforward relation to patterns of brain activity. Electroencephalography (EEG) and functional magnetic resonance imaging (fMRI) have therefore become widely used tools in market research, and in 2002 the term "neuromarketing" was coined to refer to this research (Lewis and Bridger 2005).

Published research in the field of neuromarketing is more focused on academic issues, such as the nature of the brain activity underlying consumer behavior and the accuracy of brain-behavior predictions, than it is on the real-world utility of neuromarketing for improving business. From the published research we have learned the ways in which packaging design, price, brand identity, spokesman celebrity and other marketing factors separate from the product itself affect neural responses to the product, and how accurately those neural responses predict purchasing decisions (for reviews see Hubert and Kenning 2008; Lee *et al.* 2006).

The success of neuromarketing as a business tool is harder to assess, but the list of companies paying for neuromarketing services suggests that many corporate decision-makers have faith in it. Forbes Magazine reported that this list includes Chevron, Disney, Ebay, Google, Hyundai, Microsoft, Pepsico, and Yahoo (Burkitt 2009).

The techniques of neuromarketing can also be used to study preferences for health behaviors (Langleben *et al.* 2009) and political candidates (Westen *et al.* 2006). The firm FKF Applied Research published advice to American presidential candidates for the 2008 election in

The New York Times Op Ed pages, based on their fMRI studies (Iacoboni *et al.* 2007). Their advice received widespread attention in the media and online (Aron *et al.* 2007; Farah 2007; see also Iacoboni 2008, Poldrack 2008). Less public attempts to understand voters' reactions to candidates based on measures of brain function have reportedly been carried out at the request of specific political campaigns (Linstrom 2008).

Other applications

Additional examples of new, non-medical applications of neuroscience that date from the turn of the century include entertainment, romance, and employment screening. To be sure, some of these examples involve products that have yet to demonstrate their effectiveness by objective criteria. But 15 years ago these applications did not exist whereas today they are beyond the prototype stage; they are products based on real neuroscience or neurotechnology, which have found at least a small initial market.

To start with the most light-hearted example, several companies offer EEG-based game controllers that allow video gamers to play with their brains instead of their hands (e.g. Emotiv, Mindball, Neurosky, OCZ). For example, the Neurosky "MindSet" headset uses a single electrode to detect EEG and enables owners to play specially designed games such as "The Adventures of NeuroBoy" by thought alone, as well as visualize their brain activity while they listen to music and measure their degree of attention or relaxation.

Several companies have developed ways to aid us in the search for love, focusing on the brain rather than the heart. Chemistry.com, which went live in 2006, characterizes potential mates according to various behavioral and morphological surrogates for neurotransmitter and neuroendocrine activity. For example, the degree of prenatal exposure to testosterone, which masculinizes brains, is estimated by the ratio of the lengths of the first and fourth fingers (pointer and ring fingers). This ratio has been found, empirically, to be related to prenatal testosterone exposure and later life behaviors.

The Amen Clinics, which offer SPECT scans for a variety of controversial diagnostic purposes (APACCAF 2005) have also begun to offer what they call "pre-screening of couples" (http://www.amenclinics.com). And for those who have found a date but want to confirm that this prospective partner is all that he or she claims to be, the company No Lie MRI offers fMRI-based lie detection for "dating risk reduction" and "trust issues in interpersonal relationships" (http://noliemri.com).

The same fMRI lie detection company offers brain-based employment screening. Their website states that brain imaging can "potentially substitute for drug screening, resume validation and security background checks" (http://noliemri.com). The Amen Clinics owner has proposed that presidential candidates be screened for psychological fitness to serve using brain imaging (Amen 2007).

In sum, the early 21st century has seen a proliferation of neuroscience products applied to everyday life. They vary in their maturity and effectiveness, and some will ultimately fail to deliver on their promises and succumb to market forces. However, this state of affairs represents a sea change from the preceding century. Before, applications of neuroscience were found almost exclusively in the biomedical realm. Now, a wide range of everyday human activities, from work to shopping, education to dating, and sleeping to voting, are being touched by neuroscience.

State uses of neuroscience in the 21st century

The novel *Brave New World* painted a frightening picture of life under a totalitarian regime that used a variety of biotechnologies to maintain its control (Huxley 1932). Among these biotechnologies, neurotechnology figured prominently. Children's brain development was chemically manipulated to create biologically distinct social castes, including those who would not object to their lives of servitude. Citizens of all castes were encouraged to dose themselves with the imaginary drug, Soma, to replace their doubts and worries with feelings of contentment and bliss. In this way psychopharmacology was used for social control, to short-circuit the motivation of the citizenry to take back control of their lives.

Of course, state use of neuroscience is not intrinsically negative. Whether it is dystopian or utopian in nature depends on the state and its goals. The recently completed UK Foresight project surveyed the neuroscience of human capital development and preservation with the goal of increasing the cognitive capacity and mental health of the population (Cooper *et al.* 2010). Such a program would arguably increase, rather than decrease, individual autonomy. However, interventions that affect our brain can affect our attitudes, decisions and behavior in ways that we may not be aware of or be able to resist. For this reason state uses of neuroscience merit special attention. They differ from the "lifestyle" applications of neuroscience just reviewed, which tend to be used by individuals voluntarily.

Criminal justice and the law

Neuroscience is potentially applicable to all of the same areas of criminal justice and the law to which psychology has already been applied. Within the criminal justice system, this includes a variety of sentencing options referred to as "therapeutic justice," where offenders are sent for anger management classes, parenting classes, treatment for drug dependence, and a variety of other forms of behaviorally-based psychotherapy.

In many states within the US, one particular form of brain-based therapeutic justice is already being practiced: sex offenders may be given long-acting forms of anti-androgen medications. This so-called "chemical castration" is effective through its effects on the brain. Other psychopharmacologic treatments with potential for therapeutic justice include serotonergic drugs such as selective serotonin reuptake inhibitors (SSRIs), which have been found effective for reducing repeat offending in sex offenders, as well as reducing impulsive violence (Briken and Kafka 2007; Walsh and Dinan 2001).

Defendants' personal, medical, and psychological history and diagnoses have long been introduced in court as mitigating factors at the sentencing phase of criminal trials. Increasingly information about defendants' brain function has also been introduced (Miller 2009; Morse 2006). In principle, neuroscience can also play a role in assessing dangerousness and risk of recitivism. Such information, to date based on behavioral history and psychological examination, is used in sentencing and parole decisions. Brain imaging studies of murderers have distinguished between groups who committed their crime impulsively and groups who proceeded in a more planful way, the latter being more likely to murder again (Raine *et al.* 1998).

Other possible legal applications of neuroscience extend beyond the criminal law, to such general considerations as jury selection and the evaluation of testimony. In connection with jury selection, lawyers and the courts seek to eliminate jurors with biases that could impair their ability to deliberate in an open-minded way. This task is challenging because jurors may not report, or even be aware of, their biases. FMRI has been shown to assess certain types of unconscious bias in cooperative subjects (e.g. Stanley *et al.* 2008, Fiske and Borgida 2008).

As mentioned in the introduction, and discussed in other parts of this volume (see Chapters 21, 38, and 40), fMRI has also been used to measure the likely truthfulness of testimony, although to date such methods have not been admitted as evidence in a court of law. A different type of brain-based lie detection, based on event-related potentials (ERPs) has been admitted as evidence in the US (Harrington v. State of Iowa), and in India. Indeed, in India the method has helped convict at least two defendants of murder (Aggarwal 2009).

Security applications: intelligence and military

As Canli and coauthors (2007) have pointed out, national security concerns have driven the development of many technologies, including neurotechnologies. Much of the success of both intelligence and military operations depends on personnel, and specifically on the psychological strength and dependability of personnel, which are functions of the brain.

Of course, information about security applications of neuroscience is often not accessible to the public. On the basis of available information, it has been surmised that brain imaging is likely to be among the methods being studied or used for interrogation (Marks 2007). Recent research in cognitive and social neuroscience on mechanisms of deception, inhibitory control and trust has obvious relevance to the development of methods to weaken an interrogee's ability to withhold information (Luber *et al.* 2009).

Personnel selection is critical for both intelligence and military operations, where loyalty and psychological resilience may be challenged under extreme conditions. Despite its many shortcomings, the polygraph has a long history of use in security screening (Committee to Review the Scientific Evidence on the Polygraph 2003). Might ERP or fMRI systems for lie detection, as imperfect as they are, be used instead of, or in addition to, the polygraph to provide a degree of evidence on truthfulness? Might brain imaging markers of vulnerability to anxiety or other disorders have a place in screening personnel for the stress of combat?

In addition to assessing or predicting the psychological traits of personnel, there is a strong military interest in enhancing personnel (Kautz *et al.* 2007). It is well established that war-fighting personnel use a variety of psychopharmacologic agents to increase concentration, decrease fatigue and counteract anxiety. Amphetamine has a long history in the military (Rasmussen 2008), joined more recently by modafinil (Caldwell and Caldwell 2005), and SSRI use is reported to be common among American troops in Iraq and Afghanistan (Thompson 2008). Other enhancements under development by the military are quite different from those shared with the civilian world. One example is the US Defense Advanced Research Projects Agency project known as "Luke's binoculars" (Northrum Grumman 2008). The device uses EEG signals to alert the wearer to his or her own unconscious perception of a relevant stimulus or event. This enhancement of visual attention is projected to be in use within a few years. Another example is a portable TMS device for delivering brain stimulation in the field (MUSC press release 2002; Nelson 2007). A final area of military applications of neuroscience consists of the development of non-lethal weapons (Gross 2010; Moreno 2006). Methods that render the enemy temporarily sleepy, confused, in pain, or terrified would all have their effects by selectively influencing brain function.

In sum, the early 21st century has seen a proliferation of individual and state uses of neuroscience. Pharmacologic manipulation of brain function for lifestyle reasons is already commonplace on campuses and in some workplaces. A number of new drugs and non-drug methods for enhancing everything from cognition to libido are on the market or in development. Brain imaging has been commercialized for applications ranging from lie detection to the assessment of romantic compatibility, and all of these methods for monitoring and manipulating the brain have found their way into government uses, from criminal justice to warfare.

Neuroethical challenges for the 21st century

How ought society to respond to the many new applications of neuroscience, which are beginning to influence human life at so many levels simultaneously? Simply avoiding or discouraging the application of neuroscience to non-medical problems would be neither feasible nor wise.

An across-the-board moratorium on non-medical applications of neuroscience would be unfeasible given that the genie is already out of the bottle; many of the relevant products exist and will continue to exist because of their medical applications (e.g. drugs, brain imaging). In addition, it would be unwise in that it would deprive us of the many benefits that these technologies offer. There is nothing inherently wrong with the application of neuroscience to any specific aspect of human life, and in many cases it is a means to indisputably good ends. Even state-imposed applications of neuroscience, which may conjure up the dystopian society of *Brave New World*, are not necessarily any more problematic than other ways in which the state exerts an influence on our lives. What matters, ethically, are the specifics of each case: How does it affect human health and well-being? Does it enhance or restrict freedom, enrich or diminish life's meaning, protect or undermine human dignity?

These questions are no different from the questions one would ask about any technology. In this regard neuroethics does not differ fundamentally from other branches of applied ethics. Some authors have accordingly questioned whether we need a new field, with a new name and its own journals and meetings and professional groups. They point out that most of the subject matter of neuroethics has precedents or analogous cases in bioethics more generally. This is true, and such precedents should of course be studied for the guidance they can offer.

Notwithstanding the progress we can make by piecemeal analogizing with earlier dilemmas in genetics, reproductive technologies, and other biomedical sciences, there is no precedent for the sudden and increasingly ubiquitous nature of neuroscience's influence on human life. Reproductive medicine and the molecular revolution in biology did not impact life outside the medical realm as neuroscience does, in business, education, law, warfare, and all the other areas of life discussed here. Among scientific and technological advances more generally—from the theory of natural selection to atomic physics—it is difficult to find any which intersect human life at so many points. The potential ubiquity of neurotechnology seems comparable only to that of information technology. Consider that in just a few decades IT has transformed work, education, individuals' social lives, and the global economy. For this reason, 21st century neuroscience warrants attention as a whole, and the emergence of neuroethics is a natural and useful response to the many inter-related changes being wrought by neuroscience.

In the sections that follow I will review some of the familiar and specific neuroethical issues, which have already been discussed in greater depth elsewhere (e.g. Farah 2005). I will then turn to three more general issues concerning the influence of neuroscience on society that emerge now with the proliferation of non-medical applications of neuroscience.

Familiar neuroethical issues: privacy, safety, fairness, freedom

Brain imaging is already able to deliver a degree of personal information about people without an individual even knowing what traits or states are being assessed (Farah *et al.* 2009). We therefore need to think about how and when to protect "brain privacy" (Committee on Science and Law 2005; Hyman 2004; Illes and Racine 2005; Kennedy 2004). The same privacy-related issues have arisen in connection with genotyping. Although the brain is a causal step closer to the behavioral endpoints of interest than are genes and may therefore ultimately be more psychologically revealing (Canli and Amin 2002; Farah *et al.* 2009; Hamer 2002), brain imaging and genotyping are similar in that both involve measures that can be taken for one stated purpose and used for a different one, either contemporaneously or later. We can therefore turn to the past two decades of bioethical work on privacy and genetics for helpful guidance (Illes and Racine 2005).

Safety is a concern that is crucial to the assessment of the ethical, legal, and social implications of any neurotechnology, be it psychopharmacology, brain stimulation or high-field MRI. As with privacy concerns, there are precedents that provide a framework for addressing safety-related concerns. Methodologies for assessing risk and for relating risk to benefit have already been developed and used for a wide variety of drugs and procedures within the clinical neurosciences and in other fields of medicine. This includes drugs and procedures intended purely for enhancement purposes. While there are important gaps in our knowledge of both the risks and benefits of many neurotechnologies, this is not from any special difficulty with obtaining this knowledge, but simply because the knowledge has yet to be sought.

The issue of fairness arises in neuroethics mainly in connection with brain enhancement. In competitive situations, from college admissions testing to chess championships, brain enhancements could confer unfair advantage. One might be willing to accept the fairness of an enhanced admission test score for an individual who intends to continue using brain enhancement, as that score truly reflects the level of ability the individual is likely to bring to his or her studies. However, if someone were to use a temporary enhancer to improve a test score and then stop enhancing, this would be undeniably unfair. Another way that neurotechnology can lead to unfairness is related to socioeconomic disparities. Brain enhancements have so far been more available to wealthier and better connected members of society. In a world where basic healthcare, education and personal safety cannot be guaranteed to all, it seems unlikely that brain enhancements will be equitably distributed.

Finally, while neurotechnology can be enabling (Lynch 2009), it can also limit individual freedom. State uses of neurotechnology feature the most blatant opportunities for coercion, but even individually chosen lifestyle applications of neuroscience can exert indirect pressure on people. Take, for the example, the situation that would occur when one worker in an office uses modafinil to extend his work hours on a regular basis and his colleague then feels pressure from the boss to be as productive (see Appel 2008, for a discussion of worker protections).

The problems of fairness and freedom raised by neurotechnologies have many precedents. For example, access to the latest information technology confers a competitive advantage on students and employees. With a personal computer, high-speed Internet access and a color printer, the quality, speed, and polish of a student's homework is improved, yet many students do not have access to this technology from their homes, a situation which is not fair. The diffusion of IT and its benefits can also reduce freedom. For example, once it became commonplace for workers to check email throughout the day and on weekends, we all became less free to work offline for long periods.

In the next three sections I will outline three new neuroethical challenges of a general nature. These are not associated with any particular application of neuroscience, but rather with the growing role of neuroscience in society as a whole.

New challenge #1: neuroliteracy for the neurocentury

Given its increasing influence on everyday life, the citizens of the 21st century will need at least a rudimentary grasp of neuroscience. Parents receiving educational recommendations based on their child's neuropsychological profile, workers looking to enhance work-related brain functions, judges presiding over trials involving brain imaging evidence on the truthfulness of testimony or the mental state of a defendant, and businesspersons considering an investment in neuromarketing are just some of the people whose personal or professional decisions should be informed by a basic understanding of neuroscience. Common misunderstandings about neuroscience, such as that brain differences are genetic and immutable, that neurotransmitter systems and psychological functions have a 1-to-1 relationship (enabling selective targeting of functions) or that brain images are more "objective" than behavioral measures, could contribute to poor decisions in the examples just mentioned.

Some professions have already taken steps to educate their practitioners about neuroscience. For example, educators can choose from a wide array of continuing education conferences, books, and journals, and even a graduate degree program on neuroscience and education (see, e.g. http://www.imbes.org/ and http://www.edupr.com/). Judges and attorneys also have access to workshops on neuroscience (see, e.g. http://www.gruterinstitute.org and http://www.aaas.org/spp/sfrl/projects/neuroscience/judicial.shtml). However, these professions are the exception.

If the trends discussed earlier in this chapter continue, neuroliteracy will be important for citizens in all walks of life, not just the professions. Yet neuroscience is barely represented in many school science curricula (see, e.g.http://www.collegeboard.com/prod_downloads/ap/students/biology/ap-cd-bio-0708.pdf). Much as environmental science and computer technology have entered the curriculum of most secondary schools over the past few decades, so neuroscience will need to be added in order to prepare students for life in the 21st century.

New challenge #2: ownership and control of neurotechnology

Who will control the applications to which neuroscience is put in the coming years? Who will determine which neurotechnologies are developed and which remain mere potential applications of neuroscience? For those neurotechnologies that are developed, who will determine who has access? And who will determine what users know about the technologies' effectiveness and safety? The answers depend in large part on who owns the technology. In turn, ownership of a technology depends in large part on who invested the money required to develop it.

Herein lays an important difference between medical applications of neuroscience and the non-medical applications that have been the focus of this chapter. Health-related research is supported by a diversity of funding sources from both the public and private sectors. The development of new neuropsychiatric drugs, for example, is supported by national funding agencies such as the National Institutes of Health (NIH) in the US, by private foundations with health-related missions, and by the pharmaceutical industry. The same mix of tax-payer, philanthropic and corporate investment has enabled the development of medical devices, from neural implants to new imaging modalities.

In contrast, once the pathway of developing a non-medical application of neuroscience diverges from clinical or basic neuroscience pathways of discovery and innovation, the cost is generally born by for-profit corporations. In the US, for example, NIH does not support research to develop methods for mainstream classroom education, the detection of deception or the enhancement of mental function in healthy normal individuals. Similarly, private foundations that support neuroscience generally focus on a disease entity. The National Science Foundation supports basic rather than applied neuroscience research. Therefore the task of shepherding non-clinical applications of neuroscience through the development process and into use falls mainly to business. The company Scientific Learning, rather than the US Office of Education Research and Improvement, is responsible for the development of Fast ForWord® and other computerized education programs. The company Cephos, rather than the National Institute of Justice, supported the largest study to date of fMRI-based lie detection (http://www.cephoscorp.com/about-us/index.php#about). This fact about the ownership of neurotechnology has important implications for which potential applications are and are not eventually developed, and for the availability of information about the products.

Concerning which non-medical applications of neuroscience are developed, the trend toward virtually exclusive private corporate funding implies that only the most profitable applications will be developed. While this is legitimate business practice, it will not necessarily give us the products that are the most beneficial to humanity. By analogy with morning television programming for young children, market forces give us the Mutant Ninja Turtle shows that children enjoy and advertisers pay for. In contrast, it is the Public Broadcasting System that gives us "Sesame Street," which the Education Resources Information Center finds beneficial to cognitive development and school readiness (1990) (http://www.eric.ed.gov).

Private ownership of neurotechnology also lessens incentive to evaluate the efficacy of popular products and communicate the evaluation results to users. Consider the case of Scientific Learning's flagship product, Fast ForWord®. This system has been in classrooms and clinics since the mid-1990s and has been used by an estimated 700,000 students worldwide. According to the company, "Based on more than 30 years of neuroscience and cognitive research, the Fast ForWord® family of products provides struggling readers with computer-delivered exercises that build the cognitive skills required to read and learn effectively." (http://www.scilearn.com/company/news/press-releases/20091009.php). In 2009 the Johns Hopkins University School of Education's Center for Data-Driven Reform in Education reviewed the evidence on the benefits of this product for struggling readers. They found little evidence available from appropriately designed studies. Furthermore, what evidence there was indicated that Fast ForWord® was of no value in improving the reading ability of struggling readers. Nevertheless, according to a recent press release, the company's third quarter revenue 2009 was $19-20 million (http://www.scilearn.com/company/news/press-releases/20091009.php), from sales to schools around the world. Lack of transparency and probable overclaim are also evident in the field of fMRI-based lie detection. For example, Cephos asserts that their method is 97% accurate (http://www.cephos.com), but the evidence for this claim in neither peer-reviewed nor published (S. Laken 2010, personal communication).

As the role of neurotechnology in society expands, we need a balance of public and private ownership to encourage the development of products whose social value is higher than their profit value, and to promote transparency concerning efficacy and, where relevant, safety. Public support, national and international, should be developed for non-medical applications of neuroscience.

New challenge #3: avoiding nihilism

A final neuroethical challenge for the 21st century will be to assimilate neuroscience's increasingly complete physical explanation of human behavior without lapsing into nihilism. If we are really no more than physical objects, albeit very complex objects containing powerful computational networks, then does it matter what becomes of any of us? Why should the fate of these objects containing human brains matter more than the fate of other natural or manmade objects? Why should we hold certain objects morally responsible for their actions and thus blame them rather than simply declaring them to be malfunctioning?

By showing how human behavior arises from mechanistic physical processes, neuroscience is eroding a fundamental distinction that underlies many of our moral intuitions: the distinction between persons and objects. Advances in basic science are revealing the necessary and sufficient neural processing underlying people's thoughts, feelings and personalities, the aspects of persons that seem to distinguish them from objects. Even the applications of neuroscience discussed earlier reinforce the view that we are physical objects. That is, to the extent that we increasingly manipulate our own and each others' brain functions in order to change abilities, moods and personality traits, we will be living with frequent reminders of the ultimately physical nature of our being.

The person–object distinction plays an important role in morality. First, we view persons as having agency and therefore generally hold them responsible for their actions. Although many people believe that, in principle, human behavior is the physical result of a causally determined chain of biophysical events, we tend to put that aside when making moral judgments. We do not say, "But he had no choice—the laws of physics made him do it!" However, as the neuroscience of decision-making and impulse control begins to offer a more detailed and specific account of the physical processes leading to irresponsible or criminal behavior, the amoral deterministic viewpoint will probably gain a stronger hold on our intuitions. Whereas the laws of physics are a little too abstract to displace the concept of personal responsibility in our minds, our moral judgments might well be moved by a demonstration of subtle damage to prefrontal inhibitory mechanisms wrought by, for example, past drug abuse or childhood neglect. This has already happened to an extent with the disease model of drug abuse (Leshner 1997). As a result largely of neuroscience research showing how addictive behavior arises from drug-induced changes in brain function (Rogers and Robbins 2001; Verdejo-García *et al.* 2004), addiction is now viewed as more of a medical problem than a failure of personal responsibility.

We also view persons as having a special moral value, as distinct from all other objects in the universe. Persons deserve protection from harm just because they are persons. Whereas we value objects for what they can do—a car because it transports us, a book because it contains information, a painting because it looks beautiful—the value of persons transcends their abilities, knowledge, or attractiveness. Persons have what Kant called "dignity," meaning a special kind of intrinsic value that trumps the value of any use to which they could be put (Kant 1996). This categorical distinction would be difficult to maintain if everything about persons arises from physical mechanisms. Similarly, progress in neuroscience challenges the belief in immaterial souls, common to many religions (Farah and Murphy 2009).

In sum, neuroscience is calling into question our age-old understanding of the human person, and with it much of the psychological basis for morality. Much as the natural sciences became the dominant way of understanding the world around us in the 18th century, so neuroscience may be responsible for changing our understanding of ourselves in the 21st. Such a transformation could reduce us to machines in each other's eyes, mere clockwork devoid of moral agency and moral value. Alternatively, it could help bring about a more understanding and humane society, as people's behavior is seen as part of the larger picture of causal forces surrounding them and acting through them.

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