Neuroethics: The Ethical, Legal, and Societal Impact of Neuroscience

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Abstract

Advances in cognitive, affective, and social neuroscience raise a host of new questions concerning the ways in which neuroscience can and should be used. These advances also challenge our intuitions about the nature of humans as moral and spiritual beings. Neuroethics is the new field that grapples with these issues. The present article surveys a number of applications of neuroscience to such diverse arenas as marketing, criminal justice, the military, and worker productivity. The ethical, legal, and societal effects of these applications are discussed. Less practical, but perhaps ultimately more consequential, is the impact of neuroscience on our worldview and our understanding of the human person.

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WHY NEUROETHICS, WHY NOW?

The word "neuroethics" entered the vocabulary of academic neuroscientists and bioethicists at the beginning of the twenty-first century. It was coined by William Safire, a scholar of word history and meaning (for 30 years he wrote the *New York Times* column "On Language") who also stayed abreast of developments in neuroscience as chairman of the Dana Foundation. From its first mention in a 2001 Safire column, "neuroethics" has come to refer to a broad range of ethical, legal, and social issues raised by progress in neuroscience. To understand the emergence of neuroethics as a field, meriting a name of its own, we must consider some recent scientific history.

For much of the latter twentieth century, genetics was viewed as the science most likely to challenge our ethical, legal, and social practices and assumptions (e.g., Silver 1997). Findings from twin studies and other behavioral genetics methods demonstrated the substantial role of genes in most aspects of human psychology, and the development of molecular genetics promised to reveal the mechanisms by which personality, intelligence, psychiatric vulnerabilities, and other traits developed, as well as to open the door to targeted interventions (e.g., Parens 2004). By the turn of the century, however, it had become clear that psychological traits bore only the weakest relationships with individual genes and that the genetics of human psychology involve extremely complex patterns of interaction among genes and between genes and environment, limiting the ease with which theories could be constructed and also the effectiveness with which interventions to change behavior could be achieved (e.g., Van Gestel & Van Broeckhoven 2003).

Contemporaneous with the lowering of expectations for genetics, neuroscience was undergoing rapid development into the areas of cognition, emotion, and social processes, thanks in large part to the advent of functional neuroimaging. Like genetics, neuroscience deals with the biological essence of persons,

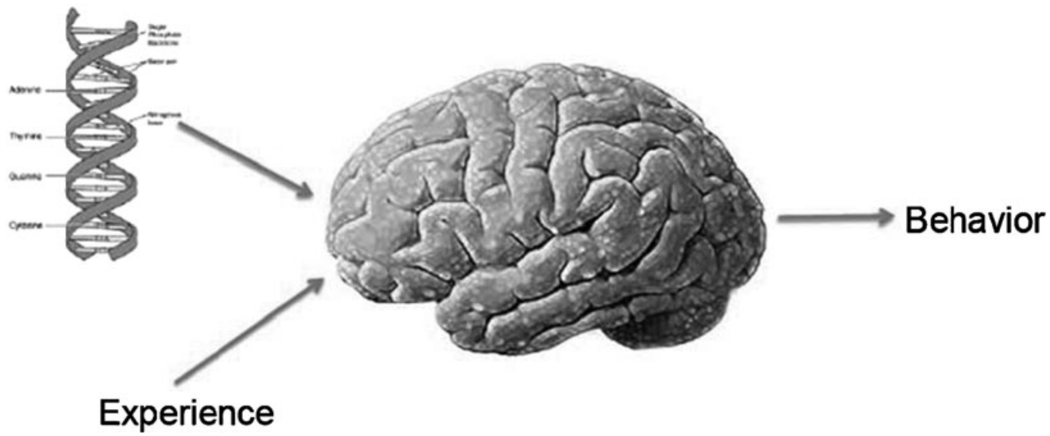

Figure 1

Schematic illustration of the relations between genes, experience, the brain, and behavior.

including their minds and behaviors. However, as represented in **Figure 1**, neuroscience encompasses the totality of genetic influences on behavior combined with environmental influences. Also apparent in **Figure 1**, the brain is one causal step closer to behavior than to genes or features of the environment. These considerations suggest that neuroscience may turn out to be far more successful than genetics in explaining, predicting, and changing human behavior. Indeed, so far neuroscience has been living up to this promise. For example, whereas single genes account, typically, for 2% to 4% of the variance in personality traits (Van Gestel & Van Broeckhoven 2003), brain imaging studies typically capture an order of magnitude more variance (Farah et al. 2009).

As a result of these developments in cognitive, affective, and social neuroscience, neuroscience can now be brought to bear in many different spheres of human life, beyond the traditional application area for biological science, medicine. Any endeavor that depends on being able to understand, assess, predict, control, or improve human behavior is, in principle, a potential application area for neuroscience. This includes diverse sectors of society, for example, education, business, politics, law, entertainment, and warfare. The goal of this article is to review the current and near-term role of neuroscience in our lives and evaluate its likely impact on individuals and society.

What Can We Do? What Should We Do?

The next two sections of the article address the issues that emerge from neuroscience-based technologies, in other words, relatively pragmatic issues concerning how the fruits of social neuroscience can and should be applied. These include ethical, legal, and social challenges raised by newfound abilities to image the brain and thereby obtain information about mental states and personal traits, as well as by our growing ability to intervene in individuals' brain function to alter these states and traits. These first two sections in effect begin with the question, "What can we do with neuroscience?" and go on to analyze the ethical question that follows, "Should we do it?"

What Do We Know? How Should We View Ourselves?

The final section addresses neuroethical issues that emerge from the impact of social neuroscience on our understanding of human beings. In this section it is the knowledge per se, not its technological applications, that is the focus

MRI: magnetic resonance imaging

Incidental finding: abnormality that is unintentionally discovered in the process of laboratory testing

PET: positron emission tomography

of the review. This section includes the ways in which our evolving understanding of the human person challenges our long-held beliefs about morality and spirituality. The questions of this section are, in effect, "What do we know about the neural bases of the human mind?" and "How does this knowledge change the way we view ourselves, as moral and spiritual beings?"

NEUROETHICS OF BRAIN IMAGING

Ethical Issues, Familiar and New

Developments in brain imaging have engendered a large literature in neuroethics. Some of this literature is concerned with issues for which we can find helpful precedents in clinical bioethics. For example, now that magnetic resonance imaging (MRI) of healthy normal subjects is a widespread research method, we face the issue of what to do when anatomical abnormalities or signs of disease are revealed in the course of scanning. Do researchers have a duty to search scans for such abnormalities? If they are not qualified to screen for abnormalities themselves, must they show them to someone who is? Should subjects be allowed to opt out of being informed of such findings in advance of the scan? There is currently no universally accepted procedure for dealing with incidental findings from research scans (Illes et al. 2004). Of course, the ethical issues raised by incidental findings from brain scans are not fundamentally different from those that would be raised by imaging other organ systems or by genetic testing. Although important work remains to be done on this topic, the issues are not particularly unique to the brain.

Another important neuroethical issue with close analogies in clinical bioethics is predictive and diagnostic imaging for progressive diseases that lack effective treatments, such as Alzheimer's disease (Karlawish 2011). Such scans are intended for research aimed at understanding the pathophysiology of neurodegenerative disease and the development of treatments for use in the presymptomatic phase. However, these scans could be used for other reasons by the "worried well" of the baby boomer generation or their worried employers or insurers. In such cases, the benefits of foreknowledge, for example the greater opportunity to plan, must be weighed against the psychological burden of this knowledge and its potential impact on employability or insurability. As with the problem of incidental findings, the ethical, legal, and societal dimensions of this problem are largely familiar from clinical bioethics outside of brain imaging, particularly in the area of genetic testing.

In other cases, brain imaging raises new ethical, legal, and social issues that stem directly from the special relationship between brain and mind. The ability of brain imaging to deliver information about our psyches—about who we are and what we might be thinking or feeling while in the scanner—opens up a range of ethical challenges with few, if any, direct precedents. These relatively new neuroethical issues provide the focus for the remainder of this section.

Imaging the Mind

Since Michael Posner and Marcus Raichle first adapted positron emission tomography (PET) scanning to the study of cognitive processes in the 1980s, brain imaging revolutionized the study of psychology and neuroscience and led eventually to the scientific capabilities that today present ethical, legal, and social challenges as well as benefits.

The first phase of this process was the harnessing of functional brain imaging for the study of human psychology, which required the ability to isolate the brain activity associated with specific component mental processes from the totality of brain activity evoked by the numerous processes engaged when people perform psychological tasks. To do this, the pattern of brain activity associated with performing one task was subtracted from the pattern of brain activity associated with another task, hypothesized to require all the same component processes as the first along with one additional process (see, e.g., Posner & Raichle 1994). By the assumptions of the subtraction method, the difference image resulting from the subtraction of two images would depict the brain activity associated with that single additional process. The subtraction method and later elaborations and variations, such as conjunction and disjunction and parametric and habituation methods, allowed imaging to isolate individual psychological processes. Instead of presenting us with the superposition of all processes involved in performing a task, for example solving mental rotation problems, these methods enabled researchers to disentangle the component processes, for example perceiving the 3-D form of the mental rotation stimulus, the process of mentally rotating that stimulus, and the process of responding. These advances enabled the rapid growth of cognitive neuroscience in the 1990s.

Although the methods just described were initially applied to the study of cognition (e.g., language, memory, visual perception), by the mid-1990s researchers had begun to use them for the study of emotion (see, e.g., Phan et al. 2002 for a review of early work in this area). Soon thereafter the field of social neuroscience was born, and the more complex emotions and cognitions involved in interpersonal processes became subjects of study in functional neuroimaging (see, e.g., Lieberman 2007 for a review). During the same period, functional neuroimaging methods developed further to include better statistical solutions to the false-positive activations in whole-brain analyses and methods for studying functional connectivity (Aguirre 2010), both of which helped to realize the potential of functional imaging to illuminate the functioning of the brain as a whole system, and were joined by new methods for studying structure, including voxel-based morphometry and diffusion tensor imaging (Le Bihan 2001, Mechelli et al. 2005).

As a result of continued methodological development of imaging, and especially its growing use for the study of affective and social processes, by the turn of the century neuroimaging had entered the public's awareness. Pictures showing the brain bases of deeply personal aspects of ourselves—fear, joy, love—made striking news. Brain imaging seemed to show that our highest human virtues and worst human vices were localizable functions of the brain, revealed as colored hot spots on anatomically detailed grayscale images. Even the scientifically sophisticated among us had to admit to the occasional feeling of wonder or awe when viewing such evidence. As is discussed in the final section of this review, by demonstrating the existence of physical correlates of our most important human qualities and experiences, neuroimaging has contributed to a fundamental change in how we think of ourselves and our fellow persons.

Imaging Individual Minds and Mental States

One more type of methodological development was needed in order for brain imaging to become a tool that poses practical ethical, legal, and social challenges. This was the development of methods for disaggregating imaging data by subject and by mental event. In the early decades of functional brain imaging research, inferences were made about groups of subjects with the goal of generalizing about typical normal brains or about brains that are typical of a group of interest (e.g., males or females, depressed or nondepressed people). For such analyses, variation between subjects within the group was treated as a form of measurement error. Similarly, imaging experiments generally involved a small number of conditions, for example a baseline condition and one or two experimental conditions, with many trials per condition. The trials were treated as repeated measures of the condition of interest and not analyzed for the sake of making inferences about the individual events themselves. This changed around the turn of the century, with different groups of researchers focusing on the problem of analyzing the results of single trials and on the study of individual differences in brain activity.

Voxel-based morphometry: MRI method of assessing the size and shape of a brain by comparing it, voxel by voxel, to reference brain

Diffusion tensor imaging: MRI method using degree of anisotropy of water diffusion to assess the integrity of white matter tracts in the brain

Implicit Association Test: a reaction-time test developed in social psychology to assess the degree to which different concepts are associated in someone's mind

fMRI: functional MRI

If cognitive neuroimaging was the achievement of the 1980s and social-affective neuroimaging was the achievement of the 1990s, then the imaging of individual people and individual mental states was the achievements of the next decade, the 2000s. This enabled imaging to deliver information with pragmatic ethical, legal, and societal implications, such as correlates of the social and affective traits of individuals. Examples of research on individual differences include many examples with the potential to be developed as tools for screening or assessment. Such uses could benefit individuals and society or introduce new harms. Consider the following findings, all of which are the results of basic research, not attempts at measurement.

Personality traits such as neuroticism, extraversion, conscientiousness, and empathy, which have been the mainstays of self-report studies of individual differences in personality, have become active topics of brain imaging research (Hamann & Canli 2004). In addition, many traits that fall outside the realm of traditional personality psychology, such as attitudes and propensity to violence, have also been found to have neural correlates measurable by brain imaging. For example, an early and influential study by Phelps and collaborators found that white subjects' amygdala activation correlates with the degree of unconscious negative evaluation of black faces (Phelps et al. 2000). Specifically, the discrepancy between amygdala activation to black and white faces correlated with the magnitude of unconscious bias against blacks measured in the Implicit Association Test (Greenwald et al. 1998). Coccaro et al. (2007) showed subjects with and without a history of impulsive aggression photos of faces displaying different emotions while measuring neural responses to these photos with functional MRI (fMRI). In addition to finding overall differences between aggressive and nonaggressive subjects in their response to the sight of an angry face, including greater activation of the amygdala and less activation of the presumably regulatory orbitofrontal cortex, they also found a correlation between amygdala activation and aggression. The more aggressive one's behavior, measured over one's lifetime, the higher the activation of the left amygdala to angry faces. Turning to a more desirable trait, altruistic cooperation, Rilling et al. (2002) scanned subjects while they played an iterated Prisoner's Dilemma game and assessed the relationship between the tendency to prolong mutually cooperative play and the activation of reward-related brain areas by such cooperation. They found a correlation between cooperative behavior in the scanner and the activation it evoked in the ventral striatum, an area associated with the enjoyment of rewards from money to chocolate (Delgado 2007). In these studies just cited the correlations are moderate in size, between 0.5 and 0.7, and this accords well with the majority of appropriately analyzed fMRI studies of individual differences in social and affective traits (e.g., Vul et al. 2009).

Nonmedical Applications of Brain Imaging

Given the moderately strong relationships that exist between some psychological traits and imaging measures, could imaging be used as a method for assessing personality or ability? My colleagues and I addressed this issue in secondary analyses of data published prior to 2007, taking into account both the prediction error attributable to the less-than-perfect correlations and the prediction error attributable to the less-than-perfect estimates of the correlations themselves (Farah et al. 2009). We concluded that by scanning a new subject in a typical imaging paradigm from this literature, one could gain a modest degree of information about an individual. For example, if the best prediction from a person's brain activity is to a very high or low value of a psychological trait, one could conclude that the person is in fact unlikely to be low or high, respectively, on that trait. Such minimal predictive power would not be a practical use. However, among the studies we reviewed, some were more predictive. Assuming that imaging protocols with different tasks and different regions of interest provide nonredundant information about traits, more precise prediction may be possible by combining paradigms for the purpose of trait measurement.

Whereas brain imaging is not being used to assess psychological traits for practical purposes, it is being used to assess psychological states. One state that researchers have attempted to read from brain activation is lying. Early studies of deception were aimed at the basic science goal of characterizing the differences in brain activation between lying and truth-telling (e.g., Langleben et al. 2002) and showed that the anterior cingulate cortex as well as regions of prefrontal and parietal cortex were more active during lies (for reviews, see Bles & Haynes 2008, Christ et al. 2009). Some of the more recent research on deception with fMRI has been aimed explicitly at the reverse inference of determining the truthfulness of individual statements on the basis of brain activation. Two companies currently offer fMRI lie detection services: Cephos (**http://www.cephoscorp.com/**) and No Lie MRI (**http://www.noliemri.com/**). Among the purposes for which they advertise their services are vindication "if your word, reputation or freedom is in dispute," reduction of "risk in dating," and as a substitute for drug screening, resume validation and security background checks in employment screening. Both companies have scanned defendants in legal cases, but as of this writing neither has succeeded in having its results admitted as evidence in court. In the 2010 case of *United States v. Semrau*, the Cephos method was the subject of a hearing to determine whether it met the criteria for admissibility set out in *Daubert v. Merrell Dow Pharmaceuticals*. The court determined that it did not satisfy the Daubert requirements because its accuracy outside of artificial laboratory tasks had not been examined. In this connection it is worth noting that an electroencephalography (EEG)-based method for detecting deception has been used for several years in Indian courts (Aggarwal 2009).

Neuromarketing is another example of the use of brain imaging to assess mental states for a practical purpose. The emotions and motivations of consumers are crucial for many marketing decisions, from brand identity to pricing, but consumers are notoriously poor at reporting these aspects of their own psychology. The prospect of directly "reading" consumers' brain states is therefore of great interest to marketers. In addition, brain imaging is relatively well suited to this type of reverse inference. Compared with some psychological states, states of liking and wanting have a relatively straightforward relation to patterns of brain activity. EEG and fMRI have therefore become widely used tools in market research.

Reverse inference: inferring a psychological state from brain data rather than starting with a known psychological state and discovering its neural correlate

EEG: electroencephalography

Published research in the field of neuromarketing has illuminated the ways in which packaging design, price, brand identity, spokesperson celebrity, and other marketing factors that are separate from the product itself affect neural responses to the product and how accurately those neural responses predict purchasing decisions (for reviews, see Hubert & Kenning 2008, Lee et al. 2007). The success of neuromarketing as a business tool is harder to assess, but the list of companies paying for neuromarketing 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 are not limited to selling products and services. They have also been 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, based on their fMRI studies, to American presidential candidates for the 2008 election in the Op Ed pages of the *New York Times* (Iacoboni 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 on the basis of measures of brain function have reportedly been carried out at the request of specific political campaigns (Lindstrom 2008).

Ethical, Legal, and Societal Issues in Brain Imaging

Concerns about the ethics of brain imaging fall into two general categories, which can roughly be described as the "damned if you do and damned if you don't" categories. To the extent that brain imaging can actually deliver useful information about a person's mental states or traits, the issue of privacy is important. To the extent that it cannot, but people believe that it can, the issue of public misunderstanding is important.

Brain Privacy

A number of writers have commented on the potential threat to privacy posed by functional neuroimaging (e.g., Comm. Sci. Law, Assoc. Bar City N.Y. 2005; Hyman 2004). On the face of things, brain imaging poses a novel challenge to privacy in that it can in principle deliver information about thoughts, attitudes, beliefs, and traits even when someone offers no behavioral responses.

More concretely, and perhaps more importantly, imaging-based psychological investigations lend themselves to stealth uses in ways that more conventional paper-and-pencil or other low-tech methods do not. Both structural and functional brain images can be obtained with consent for one purpose but later analyzed for other purposes. Furthermore, in many studies the stimuli and instructions do not reveal the nature of the psychological information being sought. For example, in two of the studies cited previously, unconscious racial attitudes and impulsive aggression were both correlated with brain activity evoked by simply viewing pictures of faces (Coccaro et al. 2007, Phelps et al. 2000). Hence, in principle it seems possible to obtain information about racial attitudes and aggressive tendencies without subjects' knowledge or consent by misleading them into thinking the study concerns face perception.

Overpersuasiveness of Brain Images

At present, the problem of public misunderstanding of neuroimaging is a more immediate challenge than is the problem of mental privacy. A number of authors have suggested that laypersons may attribute greater objectivity and certainty to brain images than to other types of information about the human mind (Dumit 2004, McCabe & Castel 2007, Racine et al. 2005, Roskies 2008). This may contribute to the premature commercialization of brain imaging for various real-world applications.

Tovino (2007) outlines a range of possible regulatory responses to nonmedical neuroimaging, aimed primarily at protecting consumers and citizens from overhyped and underperforming methods. She is rightly cautious about strict or blanket restrictions. Not all premature or unvalidated applications of neuroimaging pose serious danger, and entrepreneurs should have some motivation to develop new solutions to societal problems using brain imaging. Different application areas call for different levels of regulatory protection. For example, lie detection for vetting potential dates (an advertised application) should not have to meet the same standards of evidence as for national security-related interrogations. It has even been argued that brain-based lie detection need not meet the same standards of accuracy expected of scientific evidence to be appropriate legal evidence (Schauer 2010).

From a global perspective, it seems unlikely that regulation of neuroimaging applications will be uniform. Thus, efforts to discourage imaging-based approaches to problems with potentially significant economic or security relevance have an element of unilateral disarmament. Although the risks of premature adoption of these methods, to individuals and society, are substantial, overly restrictive policies can also be counterproductive. Neither the unrealistic science fiction scenarios of mind reading nor the irresponsible hawking of unvalidated methods are reasons to discourage the development and validation of neuroimaging approaches to lie detection, employment or security screening, business, and education.

NEUROETHICS OF BRAIN ENHANCEMENT

Ethical Issues, Familiar and New

As used in the neuroethics literature, "brain enhancement" refers to interventions that make normal, healthy brains better, in contrast with treatments for unhealthy or dysfunctional brains. People have been chemically enhancing their brains for millennia, far longer than they have been treating brain disorders. Coffee, tea, coca leaves, and alcohol are among the familiar substances used to alter brain chemistry for improved cognition or mood. Yet with the advent of biological psychiatry, drugs developed for the purpose of treating neuropsychiatric disease can now be used by healthy people for enhancement, greatly increasing the variety and potency of methods for adjusting our brain states chemically. In addition, nonpharmacologic means of altering brain function, for example by magnetically stimulating specific brain regions to achieve specific psychological effects, are now poised to make the same transition from clinical to lifestyle use. These developments raise a host of new questions concerning personal improvement in the age of psychopharmaceuticals and neurotechnology.

One important set of issues concerns the tangled relationships connecting the pharmaceutical industry, university research, regulatory oversight, and physician education, especially in the United States (Lo & Field 2009). These problems are not unique to psychopharmacology, although they weigh especially heavily there for at least two reasons. One is the chronic nature of many neuropsychiatric conditions. Drugs that must be taken for decades by each individual patient are subject to especially powerful profit motives. Another is the problematic state of psychiatric nosology and the associated shortcomings of current diagnostic criteria. In the absence of valid diagnostic tests, it is difficult to draw the line between sick and borderline or borderline and well. Treatment of milder cases, like treatment for longer periods, increases sales. Thus the corporate profit motive plays a role in the expanding use of psychopharmacology by the relatively healthy. However, this can be viewed as a special case of a more general trend toward developing and marketing of medications for chronic conditions and for treating less severe forms of those conditions, a trend that is also evident in medical approaches to high blood pressure, high cholesterol, and diabetes.

The safety of brain enhancement is another topic of relevance to neuroethics. Most people find it reasonable to hold enhancements to a higher standard of safety than treatments. In terms of risk:benefit ratio, this is because we assume that treatments have greater benefits than enhancements; the value of returning someone to health is greater than the value of making a healthy person even better off. Yet little is known about the long-term safety of using neuropsychiatric medications or neurotechnology for enhancement. Indeed, relatively little is known about the long-term effects, both efficacy and safety, of many neuropsychiatric treatments, and evidence concerning their effects on normal healthy subjects is generally confined to early, short-term clinical trials (Hackshaw 2009). The safety of enhancement has recently attracted attention in the neuroethics literature, and deservedly so. Of particular concern have been the risks associated with prescription stimulants, including heart attack, psychosis, and addiction (Chatterjee 2009, Volkow & Swanson 2008). Of course, the question of how to weigh safety against potential benefits and methods for assessing safety are essentially the same, whether one is considering cognitive enhancement or cosmetic surgery.

In the remainder of this section we explore the more distinctive neuroethical issues associated with the enhancement of cognitive and social-affective brain functions. By manipulating our intellects, personalities, and moods, are we distorting our own nature? Or are we expressing that very nature, as a species driven to innovate and improve our world and ourselves?

How will the growing trend toward brain enhancement affect us, as individuals and as a society?

ADHD: attention deficit hyperactivity disorder

SSRI: selective serotonin reuptake inhibitor

Cosmetic psychopharmacology: the use of psychiatric medications to enhance mood or personality

Cognitive Enhancement

Amphetamine has a long history of nonmedical use (Rasmussen 2008), and the past decade saw a distinct rise in its use as a study aid on college campuses in the form of Adderall, a mixture of amphetamine salts intended primarily for the treatment of attention deficit hyperactivity disorder (ADHD). The cognitive neuroscience literature is mixed concerning the effectiveness of stimulants as cognitive enhancers for normal healthy subjects, with some studies finding improvements in learning and executive function and some finding null results or even occasionally impairment for subsets of subjects (Smith & Farah 2011). Nevertheless, many college students are at least occasional users. The results of a 2001 survey of more than 10,000 American college and university students showed that 7% had used a prescription stimulant such as Adderall nonmedically, and this figure ranged as high as 20% on some campuses (McCabe et al. 2005). Smaller and less scientific samples have produced estimates as high as 50% in more recent years (DeSantis et al. 2009). A number of studies reviewed by Smith & Farah (2011) indicate that academic performance enhancement was the most common reason students use these drugs, although other "lifestyle" uses such as weight control were occasionally reported.

Anecdotal evidence and informal journalists' surveys suggest that some professionals, as well as students, have added amphetamine and other stimulants to their work routines (Arrington 2008, Madrigal 2008, Maher 2008, Sahakian & Morein-Zamir 2007, Talbot 2009). Among the newer compounds mentioned in such surveys 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 allure.

Looking to the next decade or two, a number of new cognitive enhancers are likely to be available. Several companies are developing drugs to manipulate learning and memory. Spearheaded by scientists such as Eric Kandel, Mark Bear, Gary Lynch, Tim Tully, and other molecular neurobiologists, these companies are developing drugs designed to treat cognitive disorders and also to 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).

Social-Affective Enhancement

Neuroscientists have succeeded in manipulating normal levels of mood, personality, empathy, trust, aggression, and so forth, although little of this work has been translated into clinical or enhancement use. The modern age of social-affective enhancement began with the introduction of selective serotonin reuptake inhibitors (SSRIs) such as Prozac in the 1980s. These drugs offered much-needed new treatment options for patients suffering from depression and anxiety disorders and had wider societal effects as well. Peter Kramer (1997) foretold many of the current dilemmas concerning the manipulation of mood, personality, and identity in his book *Listening to Prozac*, coining the term "cosmetic psychopharmacology."

Any discussion of brain enhancement must address the question of where to draw the line between enhancement and treatment. For cognitive enhancement, the question is usually framed in terms of diagnostic boundaries between everyday distractibility and ADHD, or between normal cognitive aging and dementia. In the case of SSRIs for social-emotional enhancement, the question is more complex, partly because there are so many different therapeutic uses of SSRIs—including depression, premenstrual dysphoria, general anxiety, social anxiety, obsessive-compulsive disorder—and partly because the relevant diagnostic boundaries appear to have shifted because of the SSRIs themselves. In the case of depression, antidepressant medications before Prozac had more troublesome side effects and were therefore reserved for patients with major depression. The greater tolerability of SSRIs, combined with the pharmaceutical industry's energetic marketing to patients and doctors, has led to a larger number of less-ill patients using these drugs and to a revision of diagnostic categories (Healy 2004). As the division between pathology and health moves to include more people on the pathological side of the line, uses of medication that would originally have been considered enhancement become therapy.

Antidepressants are now the most widely used class of drugs in the United States, with an estimated 10% of the population having received a prescription for them in the year 2005 (Olfson & Marcus 2009). In light of this, recent findings that SSRIs alter personality take on broad societal significance. A recent study in depressed patients found that the SSRI paroxetine affects personality above and beyond its effect on depression (Tang 2009). The most pronounced effect on personality was on the trait of neuroticism, the tendency to experience negative emotions. Studies that have examined the effects of SSRIs in nondepressed subjects have found that their main effect appears to be the diminution of negative affect or neuroticism (Knutson et al. 1998). For example, Knutson and colleagues (1998) administered paroxetine or placebo for four weeks and assessed the effects of the drug on personality and social behavior. The drug reduced negative affect, particularly hostility, and increased affiliative behaviors. For example, subjects on the drug spoke fewer commands and instead made more suggestions to their partners in a problem-solving exercise. Among the subjects who received the drug, plasma levels correlated with changes in negative affect and social behavior.

In subjects selected for criminal behavior rather than psychiatric diagnosis or lack thereof, SSRIs have demonstrated potential for another socially relevant use: promotion of prosocial and law-abiding behavior. Impulsive violence is associated with abnormalities in seratonergic systems, and SSRIs reliably decrease aggression in individuals prone to violence (Berman et al. 2009, Walsh & Dinan 2001). SSRIs have been found to decrease repeat offending in sex offenders and are used for this purpose, along with hormonal treatments to decrease sex drive (Bourget & Bradford 2008).

Love, romance, and sexuality in healthy normal people constitute another realm for brain enhancements. Drugs that affect these aspects of life through central nervous system mechanisms have not achieved the success of, for example, Viagra, but more limited successes have been reported. The drug known as ecstasy (MDMA) increases feelings of closeness and interpersonal connection and can be used to enhance relationships, although serious risks accompany its use (Sessa 2007). Hormone supplementation has been used by low-testosterone men and postmenopausal women to increase libido. A number of new drugs are being explored for improving sexual function in young women suffering from low libido (Fitzhenry & Sandberg 2005).

In recent years a wealth of new findings has emerged on the role of the hormones oxytocin and vasopressin in trust, altruism, and bonding (Donaldson & Young 2008). Intravenous or inhaled doses of these hormones have been shown to alter the same range of behaviors. Oxytocin has been shown to engender more trusting and generous strategies in economic games (Kosfeld et al. 2005, Zak et al. 2007) and to interfere with normal responses to betrayal in such games (Baumgartner et al. 2008). This research has obvious potential for translation

TMS: transcranial magnetic stimulation

tDCS: transcranial direct current stimulation

rTMS: repetitive TMS

into a number of applied domains. It provides a proof of concept for altering the interpersonal relationships between spouses, parents and children, and business associates. It could also be used in diplomatic, forensic, and security contexts. The practical difficulties of administering oxytocin are being overcome by the development of oral drugs that target oxytocin receptors in the brain (Ring et al. 2010).

Nonpharmacological Enhancement

A very different set of technologies influences brain function with electronics. The two least invasive, and thus most promising for brain enhancement, are transcranial magnetic stimulation (TMS) and transcranial direct current stimulation (tDCS). The physics of these methods is simple, although their physiological effects are another matter. Both methods have transient and more lasting effects, and the latter have been found to include enhanced psychological functions in normal volunteers.

With TMS, a magnetic field penetrates the head and induces current flow that, among its physiological effects, triggers action potentials in targeted neurons. Repetitive TMS (rTMS) involves pulsing the magnetic field, which can increase or decrease cortical excitability, depending on the frequency of stimulation. In contrast, tDCS puts the head in a simple circuit by applying two electrodes, anode and cathodes, to the outside of the head with a weak power source between them. The currents resulting from tDCS are of lower amperage and are thought to modulate the resting membrane potentials of neurons rather than cause action potentials. Cortex near the anode, where current enters the brain, is rendered temporarily more excitable, whereas cathodal stimulation renders the cortex less excitable. At present the development of rTMS and tDCS protocols is based partly on general rules of thumb concerning stimulation parameters (duration, intensity, and location for rTMS frequency and for tDCS polarity) but remains largely trial and error.

Hamilton and colleagues (2011) have reviewed the prospects of noninvasive brain stimulation for psychological enhancement of normal, healthy subjects. They cite research that has demonstrated enhancement of learning and memory, including language learning, complex problem solving, and mood.

Ethical, Legal, and Societal Issues in Brain Enhancement

Individuals, organizations, and societies have a multitude of interests that can be served by influencing people's behavior, for example making people (self or other) smarter, happier, more generous, or more law-abiding. Our growing ability to influence normal healthy brain function is being harnessed for many of these purposes, and this raises an array of ethical, legal, and social issues almost as diverse as the reasons for brain enhancement.

Voluntary Physician-Assisted Enhancement

Let us begin with the ethically simplest situation, voluntary enhancement with medical supervision. Here there is no coercion and health risks are minimized. What is the ethical and legal status of such a scenario, and how might it impact society beyond the individual patient and physician?

Concerning the physician's role, the main ethical issue is whether physicians should promote the well being of their patients beyond healing illness and alleviating suffering. Although other medical specialties now include "lifestyle" services such as cosmetic surgery and cosmetic dermatology, those treating the brain have only begun to grapple with this expansion of their role. Clinicians report widely varying attitudes toward providing their patients with brain enhancement (Banjo et al. 2010). However, at least one professional body has examined the ethical issues and concluded that the practice is not intrinsically problematic. In a report entitled "Responding to requests from adult patients for neuroenhancements," the American Academy of Neurology's Ethics, Law and Humanities Committee recently advised that it is morally and legally permissible for physicians to prescribe brain-enhancing medications to healthy individuals (Larriviere et al. 2009).

What ethical considerations apply to the individual who is choosing to enhance his or her brain? These depend in part on the psychological traits being enhanced. For example, issues of competition, fairness, and freedom arise mainly in connection with cognitive enhancement, as mental ability is a positional good as well as having value in its own right. That is, the benefits of cognitive enhancement come in part from being smarter than the competition, as well as from the inherent desirability of improved cognition. By increasing the competitive advantage of some, cognitive enhancement influences others. In contrast, social-affective enhancements have relatively less-direct effects on people other than the user of the enhancement, so the externalities are relatively weaker. Instead, the value of authenticity and human feeling are the main issues that arise.

Ethical, Legal, and Societal Implications of Cognitive Enhancement

The two main issues that arise with cognitive enhancement are fairness and freedom. Cognitive enhancement has been characterized as unfair in the same way that doping in sports is unfair. Although there are similarities, the analogy is imperfect for at least two reasons. First, there are reasons to enhance cognition that have nothing to do with competition, for example improved understanding and increased productivity, whereas performance enhancement in sports is primarily for the purpose of competition. Individuals who do not engage in competition of any kind could still have reason to enhance their cognition.

Second, even in competitive situations the purpose of the competition is typically different for athletic and cognitive competitions. For athletics, the goal is ostensibly to find out who is the best athlete without performance enhancement because of the value given to athletic talent, training, and effort. For cognitive competitions, in contrast, we are generally interested in predicting future performance. Aptitude tests, such as the Scholastic Assessment Test and the Medical College Admission Test, are designed to assess capacity for success in college or medical school. Licensing exams are intended to discriminate between those who will and will not practice their trade or profession competently. Even quizzes and exams in school are essentially means of assessing how much knowledge and understanding the student is likely to carry forward out of the course.

If someone routinely uses cognitive enhancement and plans to continue doing so, then using cognitive enhancement during a test would provide a representative estimate of his future capabilities. From this perspective, enhanced test taking is not unfair unless the test taker plans not to use cognitive enhancement in the future.

Cognitive enhancement can also be unfair to individuals or groups who do not have access to it. The drugs now used for this purpose are more available to the wealthier members of society, and this seems likely to be true for future drugs as well as devices. Cognitive enhancement therefore has the potential to exacerbate socioeconomic disparities within and between countries.

Finally, although cognitive enhancement can be enabling, it can also limit individual freedom. This could take the form of direct coercion by employers or schools. For example, it is in an employer's interest to have workers with enhanced attention or the ability to work through the night periodically. It is in a school's interest to have students who score well on tests and follow classroom instructions easily. Indeed, in some school districts the proportion of students on pediatrician-prescribed stimulant medication is higher than the prevalence of ADHD, suggesting that enhancement is taking place (Diller 1996). Possibly in response to schools' conflict of interest, the U.S. government has enacted a federal law preventing schools from requiring treatment for ADHD.

Unfortunately, it is more difficult to legislate against indirect coercion, which will naturally emerge as enhancement becomes more common. Once a single employee wows the boss with the productivity made possible by medication-enabled all-nighters, that boss will want to encourage others to do the same. Workers may get the message that those who do not regularly pull high-productivity all-nighters are likely to be replaced with workers who do. As more young learners are able to surpass expectations for classroom behavior and academic performance, schools may raise their expectations, and students with average abilities may find themselves performing below par if they do not engage in enhancement.

The U.S. Air Force is explicit in providing pilots with a choice concerning enhancement that is indirectly coercive: They are told that they may choose whether or not to use stimulant medication on long flights, but if they choose not to, they may be found unfit for duty (Borin 2003). Any profession for which work must be performed under conditions of distraction, sleep deprivation, or stress, especially those for which the safety of others is at stake, could become subject to such a choice.

Ethical, Legal, and Societal Implications of Social-Affective Enhancement

The problems reviewed above in connection with cognitive enhancement concerned relatively pragmatic considerations of market forces, productivity, and the protection of workplace freedoms. Although some of the same issues arise in connection with social-affective enhancement, as cheerful and outgoing individuals may be more successful in some work contexts, they are not the most obvious or pressing ones. Rather, concerns about enhancing our emotional and social lives tend to be more philosophical in nature, focusing on the value of authenticity in our feelings about ourselves, our relationships, and our world.

The enhancement of mood and personality using SSRIs has been criticized for distorting our perspective on ourselves and our lives. Although few experts would discourage a depressed person from using antidepressant medication, some see serious problems with the use of such medications for minor mood disturbances or gloomy temperaments. Fukuyama (2002) has worried that SSRIs inappropriately raise the self-esteem of the user, thus undermining an important source of motivation in our lives. He asks if Caesar and Napoleon would have created their empires had they been able to raise their self-esteem simply by popping a pill (Fukuyama 2002, p. 46). Elliott et al. (e.g., 2004) has raised another danger of chemically induced contentment. Perhaps the angst or alienation we feel about our lives is an important signal that can prompt us to seek a more meaningful life if it is not medicated away with an SSRI.

These critiques rest on psychological assumptions that, although plausible, are not necessarily true. Does low self-esteem motivate people to achieve greatness, or does it more often discourage people from trying to realize their goals? Perhaps there were other leaders and military strategists as visionary as Caesar and Napoleon, or even more so, who never built their empires because they did not have sufficient faith in themselves. More generally, does raised self-esteem lead to more or less self-efficacy? As for the assumptions underlying Elliott's critique, it is plausible that an increased sense of well-being might rob us of the incentive to seek more meaningful activities and relationships or to work toward a better world, yet it might also enable us to imagine better possibilities and to have the energy and optimism to pursue them.

The ethical, legal, and social implications of brain enhancement to alter interpersonal relationships are somewhat hypothetical. On the one hand, basic research shows that oxytocin, as well as related hormones such as vasopressin, can alter our feelings and behavior toward others. On the other hand, the effects of these hormones on human behavior have only begun to be investigated, and their effects in different genders, individuals, and circumstances, in combination with one another and with other hormones, requires more systematic study before they form the basis of useful brain enhancements. In addition, the difficulty of intranasal administration limits current usefulness. This will change if drugs are developed that can cross the blood-brain barrier to target oxytocin receptors.

In the meantime, there may be some special circumstances under which intranasal administration is feasible. Anecdotal evidence suggests that some psychiatrists use oxytocin in couples therapy (L. Young, personal communication). Given the effectiveness of personal rapport and trust in obtaining information during interrogation, intranasal oxytocin could be used in law enforcement and national security contexts (Moreno 2006). In view of this, Dando (2009) has called for inclusion of oxytocin as a chemical weapon in international law concerning war, for example, the Geneva Convention. With better delivery methods or new drugs, surreptitious manipulation of the oxytocin system could be a profitable, if unethical, business strategy. By increasing trust, generosity, and forgiveness in one's opponents, one could influence the outcomes of financial, political, or other negotiations.

The ethical issues raised by relationship enhancement are complex. Whereas drugging an unsuspecting business associate for financial advantage seems clearly wrong, what if we could obtain socially valuable information from an unwilling informant without causing physical or psychological pain? What about encouraging a successful resolution of difficult negotiations by enhancing feelings of bonding and brotherhood in both parties? With both parties' informed consent?

Some commentators emphasize the ethical similarity of relationship enhancement by neurochemical means and by other means (Savulescu & Sandberg 2008). From a purely consequentialist point of view, sufficiently high benefits to society should tip the moral balance in favor of oxytocinizing interrogees or all parties in a political conflict, even without their consent. Yet most of us sense a troubling violation of personhood in these scenarios. It is not just the assault on autonomy inherent in influencing people without their knowledge; it is the co-opting of our highest moral emotions for instrumental purposes. After all, part of what makes these emotions so precious, to individuals and society, is precisely that they guide us away from selfishness. They shift us from the pursuit of our own selfish ends to consideration for the well being of others. The prospect of someone harnessing these emotions for their own ends is therefore especially repugnant.

Consequentialist: an approach to ethics whereby the rightness or wrongness of an action depends solely on the value of its consequences

Similarly, involuntary enhancement of criminal offenders to improve their personality, mood, and self-control (with SSRIs) or to promote trust and empathy for others (oxytocin) presents us with another set of tradeoffs between potentially desirable outcomes and troubling infringement of personhood. If these treatments can enable offenders to live outside of prison and can protect society against crime, then the "benefit" side of the equation is substantial. However, state-imposed psychopharmacology poses a relatively new kind of limitation on offenders' autonomy and privacy. In contrast to the restrictions on autonomy and privacy imposed by incarceration, which mainly concern physical restrictions, brain interventions would restrict offenders' abilities to think, feel, and react as they normally would.

THE NEUROSCIENCE WORLDVIEW

Neuroscience does not merely give us new tools to be used to the benefit or detriment of humanity; it gives us a new way of thinking about humanity. The idea that human behavior can be understood in terms of physical mechanisms runs counter to deeply ingrained intuitions. Whereas we naturally think in terms of physical causality to understand the behavior of most objects and systems in the world—why a bicycle is easier to pedal uphill in low gear, why a plant grows in the sun or withers in the shade, why a printer jams—when it comes to human behavior we think about people's intentions and reasons. There is evidence that even infants understand human behavior in terms of intentions and reasons rather than physical causes (Woodward 2009).

Neuroscience provides an alternative perspective, from which human behavior can also be understood as the result of physical causes. Even for people who do not follow the latest trends in science or spend time thinking about the nature of humanity, the applications of neuroscience reviewed in the previous two sections will provide many reminders that our minds are, at root, physical mechanisms. By making people part of the clockwork universe, neuroscience challenges many assumptions about morality and personhood. Three challenges are reviewed here.

Moral Agency and Responsibility

The idea that all of our behavior, moral and immoral, is physically caused by brain processes throws a monkey wrench into our intuitive reasoning about moral responsibility. We think of ourselves as moral agents when we act intentionally, with free will. Thus, I am morally responsible for knocking down the old lady if I pushed her, on purpose, to get her out of my way, but not if I stumbled or was myself pushed and thereby pushed her because of the physics of my body and its interactions with other parts of the scene. Far more could be said about the notion of free will and its relation to responsibility (e.g., see Morse 2005), but for present purposes the important point is that we are intuitively disinclined to hold someone responsible for an action they performed when the action is physically caused.

Of course, many people believe in the abstract that human behavior is physically determined. However, we tend to put aside such abstractions 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 personality, 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 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 & Robbins 2001, Verdejo-García et al. 2004), addiction is now viewed as more of a medical problem than a failure of personal responsibility.

Presumably because specific neuroscience accounts of behavior are more compelling than generalizations about physical determinism, neuroimaging evidence is increasingly presented by the defense during the sentencing phase of criminal trials (Hughes 2010). A study examining the influence of neuroscientific evidence in the guilt phase found that when it is included, judges and juries are more inclined to find defendants not guilty by reason of insanity (Gurley & Marcus 2008). Outside the courtroom, people tend to judge the behavior of others less harshly when it is explained in light of physiological rather than psychological processes (Monterosso et al. 2005). This is as true for serious moral transgressions, such as killing, as for behaviors that are merely socially undesirable, such as overeating. The decreased moral stigma surrounding drug addiction is undoubtedly due in part to our emerging view of addiction as a brain disease.

What about our own actions? Might an awareness of the neural causes of behavior influence our own behavior? Perhaps so, according to a study by Vohs & Schooler (2008). They asked subjects to read a passage on the incompatibility of free will and neuroscience from Francis Crick's (1995) book, *The Astonishing Hypothesis: The Scientific Search for the Soul*. This included the statement, "'You', your joys and your sorrows, your memories and your ambitions, your sense of personal identity and free will, are in fact no more than the behavior of a vast assembly of nerve cells and their associated molecules." The researchers found that these people were then more likely to cheat on a computerized test than those who had read an unrelated passage.

Will neuroscience change our laws, ethics, and mores? The growing use of brain scans in courtrooms, societal precedents such as the destigmatization of addiction, and studies such as those described above seem to say the answer is yes.

Religion and the Nature of Persons

Most religions endorse a two- or three-part view of the person: body and mind or soul, or body, soul, and spirit. This accords well with most people's intuitions, according to which there is some essence of a person that is more than just the matter that we can see and touch. Yet as neuroscience advances, all aspects of a person are increasingly understood to be the functioning of a material system. This first became clear in the realms of perception and motor control, where mechanistic models of these processes have been under development for decades. Of course, such models do not seriously threaten the multipart view of the person: You can still believe in what Arthur Koestler called "the ghost in the machine" and simply conclude that color vision and gait are features of the machine rather than the ghost.

However, as neuroscience begins to reveal the mechanisms of personality, love, morality, and spirituality, the idea of a ghost in the machine becomes strained. Brain imaging indicates that all of these traits have physical correlates in brain function. Furthermore, pharmacologic influences on these traits, as well as the effects of localized stimulation or damage, demonstrate that the brain processes in question are not mere correlates but are the physical bases of these central aspects of our human personhood. If these aspects of the person are all features of the machine, why have a ghost at all?

By raising questions like this, it seems likely that neuroscience will pose a far more fundamental challenge than evolutionary biology to many religions. After all, the genesis myth of the Old Testament is taken as literal truth by a relatively small number of fundamentalist Christians. In contrast, belief in an immaterial mind or soul is common to most of the world's religions.

Finding Meaning in a Material World

Just as we have traditionally viewed persons as different from other objects because of their capacity for moral agency, we have also viewed them as having a special moral value, as distinct from all other kinds of objects. 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 between persons and other things is difficult to maintain if everything about persons arises from physical mechanisms (Farah & Heberlein 2007). 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 man-made objects? The physicist Steven Weinberg (1993) has written, "The more the universe seems comprehensible, the more it seems pointless." This seems an even more acute problem in neuroscience than in physics.

In sum, neuroscience is calling into question our age-old understanding of the human person. Much as the natural sciences became the dominant way of understanding the world around us in the eighteenth century, so neuroscience may be responsible for changing our understanding of ourselves in the twenty-first century. 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 society that is more understanding and humane as people's behavior is seen as part of the larger picture of causal forces surrounding them and acting through them.

SUMMARY POINTS

1. Like genetics, neuroscience concerns the biological essence of who we are; in comparison to genetics, neuroscience has advanced rapidly since the year 2000 and offers an array of feasible methods for predicting and controlling human behavior.
2. The newfound ability of neuroscience to explain and influence human behavior has made it relevant to many new areas of application outside the traditional biomedical realm, including education, business, and criminal justice.
3. Brain imaging has advanced to the point where it can provide reliable information about the mental traits and states of individuals in at least some circumscribed contexts.
4. The ethical, legal, and social challenge posed by progress in brain imaging is to use information from imaging judiciously, protecting privacy while resisting exaggerated claims based on the scientific aura and appeal of brain images.
5. Neurotechnologies including drugs and noninvasive brain stimulation can be used to enhance normal brain function.
6. Brain enhancement raises a host of ethical, legal, and social issues related to safety, freedom, fairness, and personal authenticity.
7. Neuroscience supports a physicalist view of the human person, according to which our thoughts, feelings, and actions all result from physical mechanisms. This view cannot easily be reconciled with traditional notions of moral responsibility, spirituality, and meaning.

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