The Law's Use of Brain Evidence

Jay D. Aronson

Department of History, Carnegie Mellon University, Pittsburgh, Pennsylvania 15213; email: aronson@andrew.cmu.edu

Annu. Rev. Law Soc. Sci. 2010. 6:93–108

First published online as a Review in Advance on June 7, 2010

The *Annual Review of Law and Social Science* is online at lawsocsci.annualreviews.org

This article's doi:
10.1146/annurev-lawsocsci-102209-152948

1550-3585/10/1201-0093$20.00

Key Words

neuroscience, brain images, admissibility, criminal responsibility, deception detection, national security

Abstract

This review examines how advances in neuroscience are affecting civil law, criminal law, and law enforcement. Brain imaging techniques have already been used to detect brain injury, assess pain, and determine mental state and capacity for rational thought. There is also much excitement about using neuroimaging to detect lies and deception in legal and national security contexts. Despite claims of neuroimaging's revolutionary nature, numerous questions should be answered about their validity and reliability before they become widely adopted. Neuroscientists still do not fully understand the link between brain activity and behavior or memory formation. Important legal and ethical questions remain unresolved, particularly around the potential effect on juries and judges of colorful, but scientifically unproven, brain images. Finally, the very impetus behind the use of neuroscience in the legal system—to avoid the subjectivity and uncertainty of more traditional methods for assessing thought and behavior—may be misguided.

INTRODUCTION

Interest in the implications of advances in neuroscience for law has surged in the past decade. Conferences have been held, special issues of journals have been produced, mass media outlets have reported on developments in our understanding of the brain with increasing frequency, and the academic literature on the topic has exploded. Some commentators have even pointed to the development of the new fields of neurolaw and neuroethics (much to the consternation of many academics and practitioners). Almost all branches of law that are faced with questions of mental state, competency, rationality, pain and suffering, and responsibility have been implicated in this trend—the criminal justice system has been particularly affected.

For most of recorded legal history, it has been impossible for the legal system to directly interrogate the inner workings of the mind in order to determine whether a defendant met the minimum standards of intentionality and rational thought to be held responsible for a crime. As such, it has largely looked to proxies for mental state, particularly behavior and psychological or psychiatric assessments of rationality and mental capacity. Furthermore, claims that the defendant did not mean to commit a crime (perhaps because he had an epileptic fit or a loss of consciousness while driving), was unable to understand the gravity of the act (because of a mental illness or disability), or simply could not control his or her actions (because of a pathological mental state or insanity) have depended upon psychological analysis and expert opinion that could potentially be gamed or manipulated by the prosecution and the defense. The shortcomings of such psychological expert testimony are well known (Kulynych 1997), and empirical evidence suggests that jurors are skeptical of expert testimony alleging that the defendant is, or was temporarily, insane (Perlin 2009b).

Recent advances in neuroscience, however, have made it possible for the first time to examine the human organ known to be the seat of consciousness, thought, decision making, memory, behavior, and even personality. Although this science is still in its infancy, the potential of brain imaging has led many commentators to claim that neuroscience will fundamentally change the law and our legal system. Optimists suggest that we will one day be able to determine mental states, assess memories, detect lies, and assess claims of injury-induced pain with unprecedented accuracy and efficiency. Many argue that once we understand the biological basis of behavior, and particularly the problematic but widespread belief in free will, our attitude toward criminal justice will shift from punishment to prevention and rehabilitation (Greely 2008, Greene & Cohen 2004, Sapolsky 2004). Although the application of neuroscience in legal contexts is, of course, fraught with ethical and constitutional concerns, these commentators suggest that its benefits will outweigh any potential negative aspects.

Other commentators, however, are less excited by advances in neuroscience. In the context of the criminal justice system, they remind us that "brains don't commit crimes, people do" (Morse 2006, p. 397) and that, no matter what the physical or physiological cause of a particular behavior, the brain is an incredibly complex organ that requires an intricate set of interactions among neurons to function properly. We simply do not yet have the technology or the understanding to link the brain structure and activity to behavior in any legally meaningful way (Aronson 2007, Brown & Murphy 2010, Erickson 2010, Morse 2006, Pustilinik 2009). Still others worry that the powerful images produced by neuroscience might seduce the jury into making an unwarranted assessment of a defendant's mental capacity. A subset of these neuroskeptics also suggest that the fact that a behavior might have a biological or physiological cause does not change the role of the legal system—to punish wrongdoers and to protect society (Erickson 2010; Morse 2004, 2006; Roskies 2006). These concerns are also present in the civil law context, along with others that are discussed below.

This review proceeds in the following sections: (*a*) a brief overview of the techniques and methods most commonly used to examine the brain; (*b*) a description of current and potential uses for these techniques in legal contexts, as well as potential admissibility issues; (*c*) an examination of some of the most important issues and questions that remain unresolved at this intersection of law and science; and (*d*) conclusions.

TECHNIQUES

Jones et al. (2009) provide a very useful overview of the most commonly used brain imaging techniques. They begin with X-ray and computed tomography (CT) scans, both of which involve passing radiation through the body onto a photographic film, producing an image of the body's interior structures based on differing tissue density. CT differs from X-ray scanning in that multiple images are taken from various angles and the images are made into a composite 3-D image via computer. Both provide static images of the body at a particular moment in time.

Positron emission scanning (PET) enables the examination of brain function over time. By measuring how, where, and in what concentration radioactive tracers injected into the bloodstream are accumulated in different tissues, the activity of the brain can be measured over time. This is particularly informative when a person is performing specific tasks while in the imaging device. PET, however, has limited application because of the need for radioactivity.

Electroencephalography (EEG) overcomes this ethical and health challenge because it is noninvasive, requiring only the attachment of sensors to the scalp. EEG measures electrical activity in different parts of the brain while specific stimuli are being administered. One of the most interesting and controversial applications of EEG is P300 detection, which relies on the detection of a specific electrical signal from the brain 300 milliseconds after being exposed to familiar stimuli (Meegan 2008). A related technique, MERMER, relies on the detection of multiple signals 300–800 milliseconds after exposure. The potential legal value of these techniques is that guilt, innocence, or involvement in a terrorist plot could be determined by the presence or absence of a response to a particular stimulus—whether it is the murder weapon, a letter, clothing, or a name—tightly linked to the crime or plot under investigation, even if the test subject is not compliant (Applebaum 2007, Meegan 2008).

Magnetic resonance imaging (MRI) does not require radioactivity. Instead, it works by using a large magnet to alter the alignment of hydrogen atoms within the body and then detecting the signal the atoms give off when they return to their initial state. Because different types of tissues respond differently to this procedure, very fine levels of anatomical detail can be produced by good MRI scanners. This technique enables examination with less (but not no) concern for potential detrimental health effects (Kulynych 2007). One of the outcomes of the relative safety of MRI has been the long-term study of human brain development from infancy to adulthood. By taking scans of study participants at regular intervals between birth and adulthood, researchers have pieced together a time-lapse view of how the brain develops over this period. A surprising finding is that certain parts of the brain (particularly those involved in higher-order thinking, decision making, and emotion) continue to develop well into adulthood (see Aronson 2007 for a review of these studies and their implications).

More recently, neuroscientists have developed MRI-based methods for detecting real-time changes in blood flow in subjects who are asked to perform specific tasks or are exposed to specific stimuli. In functional MRI (fMRI), changes in blood flow are taken to indicate brain activity (because active tissue requires oxygenation) and can at least conceivably be used to localize specific actions and responses to particular parts of the brain in time and space. As Jones et al. (2009) and many others note, however, it is important to be modest in interpreting the results of fMRI as they are not as straightforward as they may appear when converted into colorful images and movies for public consumption (see Dumit 2004 and Joyce 2005 for an

PET: positron emission scanning

EEG: electroencephalography

MRI: magnetic resonance imaging

fMRI: function magnetic resonance imaging excellent discussion of the public representation of neuroimages).

NEUROSCIENCE IN THE LEGAL SYSTEM—ADMISSIBILITY AND USES

This section briefly reviews the kinds of cases in which neuroscientific evidence has been introduced, paying attention to admissibility concerns where appropriate. Readers wanting a thorough overview of the most important published legal cases involving neuroscience should consult Snead (2009) and also look for updates from the evolving MacArthur Foundation Law and Neurosciences Project's Criminal Law Neuroscience Evidence Case Database (**http://www.lawneuro.org/Neuro-Evidence-Survey.aspx**).

Civil Law

In civil law, neuroimaging evidence has been admitted for various purposes, including determining the extent to which violent video games affect the brains and behavior of young children (*Entertainment Software Assn. v. Blagojevich* 2005) and competency to enter into contracts (*Korenek v. Korenek* 2008) (Snead 2009). PET and PET-related techniques have been used to show damage to the brain in numerous product liability, workers' compensation, and personal injury cases, which are succinctly reviewed by Snead (2009). Brain evidence has also been admitted to support claims that vaccines have caused neurological damage [see, e.g., *Moberly v. Sec'y of Health & Human Services* (2005) and Snead (2009) for description of similar cases].

In the civil context, Tovino (2007a, 2008, 2009) has explored the role that structural and functional MRI is playing in the effort by various stakeholders to secure benefits (e.g., health insurance coverage and social security eligibility) for common mental health conditions and to officially recognize gender-specific mental health conditions like premenstrual syndrome and postpartum depression. Whereas similar claims were once couched in seemingly more subjective diagnoses of mental, mood, or nervous disorders (which lacked a definitive organic or physical cause), now stakeholders buttress their claims with colorful images and movies of brain activity in affected individuals. Although many of these claims are indeed based on at least minimally reasonable science, Tovino (2007b) is concerned about the normative argument that often accompanies such claims, namely that all brain differences are worthy of special legal protection and ought to be covered by all insurance plans as a matter of law. Is it fair, for instance, for a particular condition that has a known physical correlate in the brain to be more worthy of coverage and protection than a similarly disabling condition that does not?

Kolber (2007) focuses on the potential role of neuroscience in pain detection for product liability, medical malpractice, personal injury, and workers' compensation cases. He notes that pain is interesting in that it is a subjective experience that has, until now, remained primarily in the private realm (i.e., only the individual can definitively know when he or she is in pain), despite the very public implications of liability judgments in cases in the courtroom. Kolber argues from a normative privacy point of view that we ought not to be forced to reveal information about what we are feeling. But he notes that neuroscientific inquiry into pain will not raise the same kinds of ethical and privacy red flags as inquiries into other subjective experiences (such as sexual arousal or racial bias), primarily because we do not typically use pain to render judgments about another's character, nor does pain reveal much about our innermost thoughts. Further, in the legal context, we are already expected to provide proof of pain in order to be compensated for it.

Criminal Law

Brain imaging techniques are increasingly being used in the context of assessment of the mental state and capacity at trial or during sentencing (Aharoni et al. 2008). In most cases, neurological evidence is used to demonstrate some sort of pathology in the brain that might explain antisocial or criminal behavior. This trend began in the late 1970s and captivated the public's attention during the 1981 trial of John Hinckley for his attempted assassination of President Ronald Reagan. Hinckley was ruled insane based partly on admitted CT scans showing signs of abnormal brain atrophy (*United States v. Hinckley* 1981). Two other notable cases are *People v. Weinstein* (1992) and *United States v. Gigante* (1997). In *Weinstein*, the defense convinced the judge to admit CT scans showing a large cyst in the frontal lobe of the defendant, who was on trial for strangling his wife and then throwing her out a window. The defense argued that Weinstein could not be held responsible for his crime because of a mental defect. Upon admission, the prosecutor plea-bargained the case down to manslaughter (Rosen 2007). In *Gigante*, the reputed leader of the Genovese crime organization sought to introduce CT scans that a psychiatrist said demonstrated organic brain dysfunction related to Alzheimer's Disease or dementia, which would make him incompetent to stand trial for various mafia-related criminal offenses. Ultimately, the judge in the case rejected this evidence, stating that there was no baseline data for the defendant to compare the scans against and that the use of CT scans to determine competence to stand trial was not developed enough to be introduced into a court of law.

One area where neuroscience may have a major impact during the guilt phase of criminal trials is in cases involving the insanity defense (Aharoni et al. 2008), enabling legal fact finders to overcome the seeming limitations of opinion testimony from character witnesses, psychologists, and psychiatrists. If so, Perlin (2009a) wonders whether an inherent inequality will emerge in which wealthy defendants can use the services of neuroscientists but indigent ones cannot. Perlin suggests that, ultimately, even the seductive power of brain imaging will not change the minds of jurors, who start from the assumption that almost all people can recognize the difference between right and wrong and have the capacity to control their actions. Bennett (2009), on the other hand, suggests that neuroscience may also lead to a rethinking of the mental incompetence defense—which has changed little in the past 160 years—because, for instance, of new understandings of the neurological differences between self-control and the inability to resist impulses. He also notes that new neuroscience suggests that failure to restrain one's behavior can increasingly be related to damage or disease in particular regions of the brain.

In addition to introduction during the guilt phase of the trial, brain images showing damaged or diseased brains are increasingly being introduced by the defense as mitigating evidence of diminished culpability during sentencing. In most of these cases, adult defendants use brain images as physical proof of a cognitive deficiency or mental incapacity caused by gross pathology in regions of the brain responsible for decision making, emotion, and impulse control (Snead 2007, 2009).

Going beyond single trials, Snead (2007) argues that the cognitive neuroscience community is engaged in a two-prong project to bring about an end to capital punishment. In the short-term, these scientists are testifying as mitigation experts for defendants, arguing that criminal behavior is determined by the brain and not subject to complete control by offenders. This diminished culpability, of course, creates a situation in which the death penalty becomes cruel and unusual punishment. In the long-term, Snead argues, "these same experts (and their like-minded colleagues) hope to appeal to the recent findings of their discipline to embarrass, discredit, and ultimately overthrow retributive justice as a principle of punishment. Taken as a whole, these short- and long-term efforts are ultimately meant to usher in a more compassionate and humane regime for capital defendants" (Snead 2007, p. 1265). For Snead (2007) and Barth (2007), however, such efforts are misguided and risk the creation of a death penalty regime that is even more flawed than the one we have now. They worry that brain evidence may be used to demonstrate a future dangerousness that mandates permanent incarceration for offenders with clearly damaged or disordered brains. Thus, the goals of the criminal justice system could shift from meting out punishment based on past actions to protecting society by locking people up based on crimes that could be, but have not yet been, committed.

In a subset of these cases involving adolescent offenders, the defense community has sought to narrow the legal category of full culpability by constructing a model of a normal, mature adult brain that is capable of supporting the functions of a "reasonable person" and contrasting that model with one of a teenager's brain (Aronson 2007, Caulum 2007, Johnson et al. 2009, Maroney 2009). In the U.S. Supreme Court case *Roper v. Simmons* (2005), the defense sought to have both anatomical and cognitive normalcy and pathology defined by age rather than by some diagnosable medical disorder or mental state. The essence of this argument is that, as a population, juveniles' brain structure and function have not yet matured to the level found in a normal population of adults. Therefore, they cannot be held to the same degree of responsibility. Some juvenile justice advocates have even argued that brain imaging results should invalidate the old "reasonable person" standard for offenders under the age of 18 (Baer 2005). Instead, a new standard of the "reasonable adolescent" (Baer 2005) should be created based on the scientific and sociological understanding of teen brain anatomy and behavior (see Aronson 2007 for a comprehensive review of this topic).

Lie and Deception Detection for Courts, Law Enforcement, and National Security

The newest frontier in the law's use of neuroscience is deception detection. Keckler (2006) distinguishes three types of deception: feigned ignorance, in which the subject denies knowledge of something that he or she actually knows about; the classic lie, in which the subject offers incorrect information in response to a query; and finally, the more complicated case of the subject misleading the questioner without actually lying or denying knowledge of anything. So the theory goes, each of these forms of deception can be correlated to specific patterns of neural activation based on their deviance from nondeceptive thought and communication.

Meegan (2008) presents the characteristics that a neuroscientific test for memory would have to have for it to be useful in a forensic/legal context: There must be memory specificity (i.e., what the investigator cares about is prior knowledge of the murder weapon, not kitchen knives in general); memory recall must be automatic so that countermeasures cannot be used; the crime-related memory must have been properly encoded at the time of the crime (and not later or poorly, particularly if the item being shown to the perpetrator, such as the shirt worn by the victim or an item found at the crime scene, was not a significant part of the crime in his or her view); and the memory effect must remain measurable for a long time (i.e., it must have longevity). Further, the offender has to be more than just familiar with anything involved in deception detection—it has to be specific to the crime and known only to the perpetrator. Thus, the technique would not work in highly publicized cases. Problems with any of these requirements could lead to false negatives or false positives.

Keckler (2006) notes that a neuroscientific form of deception detection would be fundamentally different from the polygraph (or lie detector), which is no longer accepted as evidence in American courts (although it is still widely used for employment and national security purposes by the U.S. government). Specifically, rather than measuring signs or symptoms that a person is lying, neuroimaging seeks to understand the process by which lies, deceptions, and misleading statements are produced in the brain—i.e., what parts of the brain are required to do something other than tell the truth as well as what parts of the brain are activated when the test subject is presented with information or objects with which he or she is familiar or unfamiliar. Porter & ten Brinke (2009) note that preliminary evidence suggests that deceptive knowledge is associated with increased prefrontal, parietal, and anterior cingulate cortex activation. These hypotheses, however, are based on a limited number of studies, so more work needs to be done before most scientists are willing to accept neuroscience-based deception detection as ready for use in the legal system (Greely & Illes 2007, Keckler 2006, Porter & ten Brinke 2009, Spence et al. 2004, Spence 2008). This caution has not stopped two companies (No Lie MRI and Cephos) from offering fMRI-based lie detection to the public, however (see Greely & Illes 2007 for an excellent review of this trend), and the U.S. military is engaged in research involving the technology (Moriarty 2008, 2009; Moreno 2009; Porter & ten Brinke 2009).

Keckler (2006) is hopeful that neuroscientists will one day be able to detect the first form of deception—feigned ignorance—but he is less sure about other forms of deception. Deception, of course, is most likely an evolutionary response to social life as humans (Langleben 2008), and the ability to deceive may be such a part of our social decision-making skills that "it is simply not possible to distinguish it from the ordinary way in which we communicate where we 'modulate' what we say, how we say it, and what we do not say, in order to convey the desired impression" (Keckler 2006, p. 539).

Brain Fingerprinting

EEG-based memory detection, sometimes referred to as "brain fingerprinting," is currently the most common test for the classic lie (Taylor 2006). Neuroscientific memory detection made international headlines recently in an Indian murder case in Maharashtra in which a P300-based EEG system called a Brain Electrical Oscillations Signature Test was used by investigators to show that the defendant, a young woman who was on trial for killing her fiancé by arsenic poisoning, possessed knowledge of the crime that only the murderer would know (the "guilty knowledge test"). According to an account of the case in *The New York Times* (Giridharadas 2008), investigators read aloud their version of events to the defendant using the first person ("I bought arsenic"; "I met [the victim] at McDonald's") and also presented her with neutral statements, like "The sky is blue," in order to give the lie detection software non–memory related brain responses for comparison. According to scientists who interpreted the results of the test, the regions of her brain associated with memories were very active during the crime-related questions, but not during the neutral ones. The judge in the case found the test persuasive, arguing that it not only provided definitive evidence of guilty knowledge, but also corroborated other testimony and evidence presented at trial (Giridharadas 2008). Just a few months later, though, echoing concerns from the international neuroscience community, an expert scientific committee led by the head of the Indian National Institute of Mental Health and Neuro Sciences concluded that the technique lacked scientific foundation and should be "discontinued as an investigative tool and as evidence in court" (Raghava 2008).

To date, there is only one published case involving memory detection in the United States, *Harrington v. State* (2003). In this case, Terry Harrington filed a request for postconviction relief from his 1978 conviction for first degree murder. Among the new evidence introduced was Brain Fingerprinting®, a patented technique offered by a private company called Brain Fingerprinting Laboratories, as evidence that he did not possess guilty knowledge of the crime. Although the district court judge admitted this evidence into the record, he declined to grant Harrington a new trial. On appeal, the Supreme Court of Iowa reversed the lower court decision, thus granting him a new trial, but it explicitly declined to consider the Brain Fingerprinting evidence (Snead 2009).

Numerous commentators in addition to the Indian expert panel have voiced concern about the state of the science of memory detection (Greely & Illes 2007, Meegan 2008, Moriarty 2009, Wolpe et al. 2005). Wolpe et al. (2005) point out that the proprietary nature of the Brain Fingerprinting technique means that it has not been subjected to adequate peer review.

Meegan (2008) notes that the technique has not been validated yet and has not been tested under conditions of poor encoding and long periods of time between the crime and the test. The time gap was 23 years in *Harrington* and 1 day in published accounts of the technique (Meegan 2008, p. 17). More than anything, this creates the potential for false negatives. Meegan also notes that we are left with two fundamental problems of memory that no technology can fix: absentmindedness and transience (i.e., forgetting). Iacona (2008), on the other hand, takes issue with the claim that P300-based tests lack validity. He argues that they accurately measure whether a particular memory is stored in the brain (i.e., whether the person possesses "guilty knowledge"). Obviously, this does not imply guilt or innocence, but it does provide evidence that should be taken into account by the jury at trial.

That said, most commentators agree that neuroscience-based deception detection techniques are currently not ready for use in the legal system or for national security purposes. Moriarty (2009) goes so far as to argue for an informal moratorium on admission of deception detection evidence until (*a*) scientists and their critics reach consensus on validity, reliability, reproducibility, accuracy, and error rates; (*b*) potential confounding problems with current studies are resolved; and (*c*) a serious dialogue has taken place about whether the legal system really wants or needs this kind of evidence given other methods of assessing credibility and due process/fair trial norms. Greely & Illes (2007) propose that when this day comes, a regulatory process akin to that used by the FDA for new drugs and biologics ought to be applied to neuroscience-based lie detection. They argue that traditional admissibility tests are not sufficient in this case because of the complexity of the technology and the legal and human stakes involved.

Marks (2007) examines lie detection from another angle, the context of national security and the fight against terrorism, which is being actively pursued and funded by the U.S. government (including the FBI and CIA). He is concerned that rather than making torture and abusive interrogation less common (as many claim it will), "neuroimaging may become a means of selecting detainees for such treatment" (Marks 2007, p. 486). In addition, the trust that interrogators may develop in the technology may make them even more likely to engage in wanton mistreatment.

Admissibility Concerns

Admissibility issues for all neuroimaging techniques and uses are based on concerns about the validity and reliability of this relatively new science, as well as on the lack of scientific knowledge about the relationship between behavior and the brain. Readers interested in a more complete review of these topics should consult Aggarwal (2009), Aronson (2007), Brown & Murphy (2010), Khoshbin & Khoshbin (2007), Merikangas (2008), Moriarty (2008), Pettit (2007), Shafi (2009), Spence (2008), Spence et al. (2004), Tancredi & Brodie (2007), and Wolpe et al. (2005). Some of the most pressing concerns include the facts that

- We possess limited understanding of the physical link between brain activity and behavior;
- We do not fully understand how brains interact with environmental, cultural, social, economic, and other forces to produce behavior;
- The extent to which higher-order brain functions can be localized in particular sites of the brain remains unclear;
- Most studies have been done on compliant test subjects (often college students) who are performing simple binary tasks (answer yes/no; deceive/be honest) under circumstances very different from those in which crimes and terrorist plots are planned and committed. These experiments lack risk, situational urgency, and emotional intensity (i.e., "ecological validity");
- Cost, availability of volunteers, ethical issues, and practical problems make it

difficult to generate statistically significant results in many studies;

- There is a lack of understanding about the threshold of brain development required to make functionally adult decisions;
- There is a tremendous amount of neural variation within human populations, so it is difficult to define exactly what is "normal";
- Researchers have been unable to reliably reproduce results over time and across different laboratories;
- There is a lack of understanding of how countermeasures by test subjects affect test results.

Aside from concerns about the scientific validity of the technique, many commentators have expressed reservations about the potentially prejudicial effect of brain images on judges and juries. Moreno (2009) worries that, in the absence of a sound understanding of neuroimaging technology, judges responsible for gatekeeping will rely on their own experiences or those of their family members with MRI in a medical context (where brain imaging techniques are used in a more limited and better characterized way) to determine the admissibility of neuroscientific evidence in the legal context. Brown & Murphy (2010, p. 101) argue that "the mere presentation of brain images can make a bad argument appear more sensible." Mobbs et al. (2007, p. 699) have described the prejudicial dimension of brain imaging as the "Christmas Tree Phenomenon," which can produce "explanatory neurophilia" (Trout 2008, p. 281). Weisberg et al. (2008, p. 470) report the results of survey experiments suggesting that "explanations of psychological phenomena seem to generate more public interest when they contain neuroscientific information. Even irrelevant neuroscience information in an explanation of a psychological phenomenon may interfere with people's abilities to critically consider the underlying logic of this explanation." Brown & Murphy (2010) worry that traditional cross-examination may not be able to compensate for the prejudicial effects of brain imaging because of the potential that the damage is done once the image is seen by fact finders.

Neuroscience and Legal Decision Making

Several scholars are focusing attention on the psychology of the punisher rather than of the defendant or offender. Pustilinik (2009), for instance, argues that neuroscience may one day give us insight into issues such as racial and ethnic bias and other socially oriented thought processes that affect legal decision making. According to Goodenough (2001, 2004) and Goodenough & Prehn (2004), to truly understand the legal notion of responsibility, we need to understand the extent to which the punisher believes the punishment he or she inflicts will have an impact on the behavior of the transgressor. If the answer is yes, then the punisher has license to punish as he or she sees fit; if not, the situation becomes more complex. This equation, which depends on a utilitarian rather than a retributivist perspective, requires the punisher to determine whether the transgressor is mentally competent or not. Goodenough (2001) argues that neuroscience might help us understand what is going on in the brain when we engage in legal reasoning and moral thought. This may prove to be important because the law is based on a particular understanding of how people make decisions. He also suggests that we may one day be able to understand the extent to which subconscious thought processes overrule established legal code in the process of meting out justice (Goodenough 2001).

Salerno & Bottoms (2009) explore the effects of emotionally laden evidence, such as crime-scene photos, victim impact statements, or details of the defendants personal life, on jury decision making. Based on neuroimaging results, they argue that the presence of such evidence causes a decrease in "effortful cognitive processing" and an increase in emotional response after exposure to such evidence. They further argue that this result explains why juries tend to be more punitive when exposed to emotional evidence, and it also ought to spur more research on how emotional evidence effects jury outcome in actual criminal cases.

Knabb et al. (2009) review regions of the brain implicated in moral reasoning. They also seek to advance a theoretical model, the event-feature emotion complex (EFEC), for understanding criminal behavior from a neuroscientific point of view. EFEC takes into account three major components of decision making: factual knowledge; knowledge about what an appropriate response would be to a given situation in a particular social context; and information gathered from semantic and nonverbal social cues such as facial expressions and gestures as well as the "central motive state" of the actor. Thus, the EFEC begins from the assumption that "moral cognitive phenomena emerge from both content-dependent and context-independent representations in cortical as well as limbic networks" (Knabb et al. 2009, p. 225). Knabb et al. suggest that EFEC might one day be used to better understand legal decisions by providing insight into the minds of both criminals and legal fact finders. It also provides a framework for understanding how specific brain abnormalities and defects affect the decision-making process.

UNRESOLVED ISSUES AND QUESTIONS

Is Neuroscience Phrenology Redux?

Several scholars link the search for the neurobiological roots of criminality to past experiences with Lombrosian biological criminology, psychointerventions including lobotomy and electrode implantation, and phrenology (see, e.g., Greely 2008, Khoshbin & Khoshbin 2007, Pustilinik 2009, Tovino 2007c). In Pustilinik's (2009, p. 183) words, "criminal law and neuroscience have been engaged in an ill-fated and sometimes tragic love affair for over two hundred years." She argues that the relationship between neuroscience and criminal law is based upon three fundamental premises: first, that the brain is the correct level at which we ought to understand criminal behavior; second, that unlawful behavior can be causally linked to dysfunctions in particular areas of the brain; and third, that people who commit violent crimes are biologically different from those who do not, in that they possess some form of brain disease or disorder (i.e., the criminal is a biological "other") (Pustilinik 2009, pp. 183, 188). She notes that "in each era, it starts with bold promises and a belief in the genuine mutual compatibility of the two fields, but ends in disappointment and even tragedy. With every resurgence in this mutual infatuation, lawmakers and scientists swear that they will not make the same mistakes this time—principally because this time, science has finally matured" (Pustilinik 2009, p. 185; see, e.g., Garland & Frankel 2006).

The Effect of Neuroscience on Criminal Jurisprudence

Many commentators have sought to analyze how much the law will have to adjust or change in response to developments in neuroscience. Redding (2006, p. 53) calls for a "neurojurisprudence" that is in sync with current understandings of the "role of brain dysfunction in impulsive criminal behavior." He argues that "brain-disordered defendants" have a fundamental right to provide evidence that they should not be held accountable for the crimes they commit. Gazzaniga (2008) argues that it is the brain, and not the mind, where decisions are made. He explains that "a decision can be predicted several seconds before the subject consciously decides. If it is simply the brain, working up from its unconscious neural elements, that causes a person to act (even before he or she is aware of making a decision), how can we hold any person liable for his or her mental decisions?" (Gazzaniga 2008, p. 413). In his view, this notion has significant implications for legal understandings of culpability. "To hold someone responsible for his or her actions," he writes, "one must find a 'there' there. Is a little guy pulling the levers in your head producing a free-floating you? Modern neuroscience, of course, tells us the answer is 'no'" (Gazzaniga 2008, p. 413).

For psychologists Joshua Greene and Jonathan Cohen, new discoveries from cognitive neuroscience about the biological mechanisms "responsible for behavior" will undermine some of our current "common-sense, libertarian assumptions about individual free will and the retributivist point of view that depends on it" (Greene & Cohen 2004, p. 1776). As a result, new knowledge from neuroscience may lead to a criminal justice system focused more on rehabilitation than on punishment. Greene & Cohen (2004, p. 1784) state, "Free will as we ordinarily understand it is an illusion generated by our cognitive architecture. Retributivist notions of criminal responsibility ultimately depend on this illusion, and, if we are lucky, they will give way to consequentialist ones, thus radically transforming our approach to criminal justice. At this time, the law deals firmly but mercifully with individuals whose behavior is obviously the product of forces that are ultimately beyond their control. Some day, the law may treat all convicted criminals this way. That is, humanely." Greely (2008) comes to a similar conclusion, arguing that neuroscience will lead to a more therapeutic, rather than punitive, legal system.

Erickson (2010) disagrees. Like Snead (2007), he argues that enthusiasm and rhetoric about the implications of neuroscience in the law hides a desire to end distributive punishment and replace it with a prediction model guided by the behavioral sciences. Erickson (2010, p. 34) asserts that proponents of this view believe that "crime itself is a mental illness and not behavior of lawless citizens." Therefore, criminal justice policy should be handled by scientists rather than judges, lawyers, and politicians. But Erickson finds these claims highly problematic, primarily because he does not accept the reductionist claim that all behavior and mental decision making can be explained by the physical and chemical activity of specific regions of the brain (see Jones et al. 2009). He notes that "behavior and brains influence each other; brains are dynamic and constantly in flux; and behavior is the outcome of a range of responses to stimuli. Brain activity is a global phenomenon, not merely a localized one within compartments of the brain, even for simple behaviors" (Erickson 2010, p. 32).

For Morse (2006), whatever the cause of behaviors within the brain, individuals must ultimately take responsibility for their actions and be punished for their unlawful or antisocial behaviors (assuming of course that they are capable of understanding that their actions were wrong and that they performed them intentionally—or failed to perform their duties if the issue is negligence). Just because the actions begin in the brain does not mean that the person whose head contains that brain should be off the hook when they do something that has been deemed by society to be illegal.

Ultimately, Erickson (2010) argues, we should not give up the criminal justice system to scientists, their brain scans, or their predictive models of future dangerousness. Rather, we should rely on lawyers and the adversarial system to mete out justice as we have for hundreds of years. Most of us are not prisoners of the simplistic impulses of our brain—we are capable of an incredibly rich variety of moral thought, and as a normal part of our mental process, we human beings constantly mediate between seemingly irreconcilable impulses and choose to behave in ways that are neither criminal nor antisocial. Humans are agents, and law, not science, is equipped to evaluate their behavior based on generations of thought and deliberations about what constitutes proper conduct and what the punishment for violations from this code ought to be.

Morse (2006) comes to the same conclusion but from a different perspective: the notion that the criteria for criminal responsibility are fundamentally normative. The legal system is tasked in our society with deciding what rationality means and how much is required for responsibility. Just because neuroscience shows that there are demonstrable differences in the brains of particular people or groups does not mean that the law must then treat them in a radically different or new way. He writes, "If the person meets the behavioral criteria for responsibility, the person should be held responsible, whatever the brain evidence may indicate, such as the presence of an abnormality. If the person does not meet the behavioral criteria, the person should be held not responsible, however normal the brain may look. Brains are not held responsible. Acting people are" (Morse 2006, p. 405).

A Neurosurveillance Society? Neuroscience and Self-Incrimination

The ethical and constitutional dimensions of lie and deception detection have been a topic of much debate (Fox 2009, Greely & Illes 2007, Halliburton 2009, Pardo 2006, Stoller & Wolpe 2007). Questions that have been posed by scholars and others concerned about civil liberties include: To what extent are efforts to examine neural activity in the brain violations of privacy? Should the chemical and physical events taking place in the brain be considered communicative testimony or physical evidence? If they are testimony, is it possible for them to be considered self-incriminating? If they are evidence, are law enforcement officials required to get a search warrant or court order to compel testing if consent is not freely given by a suspect or defendant?

At the most fundamental level, Fox (2009) argues, people have a moral and constitutional right against the state appropriating thoughts from their brains without their consent (i.e., the right for one's brain to remain silent). He calls this notion "mental consent." Thus, assuming that it will one day be possible to do so, the state cannot constitutionally extract a person's thoughts without explicit consent "or [make] use of her compelled thoughts to lay criminal blame upon her" (Fox 2009, p. 763). In Fox's view, brain imaging is fundamentally different from all other forms of evidence proffered in court because state officials can conceivably obtain information directly from a person's brain, "in a way that affords her no opportunity to control the transmission of that information" (Fox 2009, p. 764). This is a direct violation of the Fifth Amendment right to remain silent upon questioning by authorities. This suggests that a defendant may opt for deception detection testing in order to exculpate himself, but he cannot be compelled to do so by the state against his wishes.

Fox further argues that the American legal system's recognition of a distinction between testimonial evidence and physical evidence rests on a flawed understanding of mind/body dualism. The seminal case in the testimony/physical evidence dualism is *Schmerber v. California* (1966), which involved a man who ran his car into a tree after drinking at a local bowling alley. While he was being treated for his injuries at a nearby hospital, police arrived, arrested him, and asked him to consent to a blood test to measure his blood alcohol content. He refused, but the arresting officer demanded that his doctor take the sample anyway. This sample showed that he was indeed intoxicated, and he was convicted of driving under the influence despite the fact that he refused to willingly provide a sample of his blood. The case eventually reached the Supreme Court, where Schmerber argued that the blood test violated his rights against self-incrimination. In a 5–4 ruling, the Court dismissed his claim, stating that although Schmerber's blood did indeed testify to his intoxication, it did not reveal anything whatsoever about the interior mental life that the Fifth Amendment was enacted to protect. According to the Court, the right to silence was limited to evidence that was actively testimonial in nature (i.e., involving mental action and a choice of whether or not to communicate certain information), not passively or physically testimonial.

Forensic neuroscience is new in that it is ultimately physical evidence that has the potential to reveal information and knowledge that a suspect might ordinarily withhold during interrogation. Thus, investigators can conceivably use the body to gain access to the mind, thus negating the physical/testimonial distinction that has been at the heart of Fifth Amendment jurisprudence for more than 40 years. At the end of the day, though, what we really care about is an individual's control over his or her thoughts and mental life, and this is what ought to be explicitly protected (Fox 2009, Stoller & Wolpe 2007).

Pardo (2006) has a different perspective. He argues that brain imaging is not testimony per se. Rather, it is, like photographs, handwriting analyses, eyewitness testimony, or DNA evidence, ultimately opinion evidence. Although potentially prejudicial, all opinion evidence should be evaluated by jurors and judges to determine its credibility. Because jurors do this all the time with evidence ranging from lineups to DNA profiles, Pardo is confident that they can do so with neuroscientific evidence. From a constitutional point of view, he argues that we have a reasonable expectation of privacy with respect to our internal functioning, including that of our brain, so the Fourth Amendment holds for brain imaging. Thus, the potential danger in neuroscience-based lie detection methods is not self-incrimination, but rather unreasonable search and seizure. Thus, in Pardo's view, brain scans can be forcibly compelled only with probable cause and a legally obtained warrant or by subpoena (Pardo 2006).

A third view is expressed by Stoller & Wolpe (2007), who argue that neurotechnological lie detection methods raise fundamental problems that can be resolved only with changes in the law. Although they do not give concrete suggestions for policy and legal changes, they suggest that the Fourth and Fifth Amendments and existing laws are simply not enough. On a different note, Seaman (2008, 2009) worries that a very accurate lie detection technique might supplant the role of the jury, which would be potentially very bad for justice because juries have the right to nullify what ought to be a clear conviction by law if they disagree with that law (by acquitting)—a good example is a Northern jury's refusal to convict someone for harboring slaves under the Fugitive Slave Act. One final concern, which is discussed by Aggarwal (2009), Aronson (2007), and others, is that functional neuroimaging might strip individuals of agency in a way that could be detrimental in the future (such as by declaring that juveniles are incapable of making certain kinds of personal decisions based on neuroscientific evidence of brains that are not as highly developed as those of adults).

CONCLUSION

There are many unresolved questions regarding the role that neuroscience may ultimately play in the legal system. None of the issues is settled, and more basic research and validation work needs to be done on almost all applications of the technology for legal purposes. Yet part of the allure of neuroscience is that it seems to a nonspecialist to be immune from many of the perceived shortcomings of methods that have traditionally been used to determine mental state, assess the capacity for rational thought, and determine the extent to which a suspect, witness, or defendant is being truthful. But the one conclusion we can make with great certainty is that the state of the science is far from mature enough to replace these traditional legal and forensic methods anytime soon.

And even if the science does develop to the point that it is considered accurate and reliable for use in the legal system, many scholars make compelling arguments about why we might resist the temptation to use technology to adjudicate truth versus falsity, rationality versus insanity, and even guilt versus innocence. As Baskin et al. (2007, p. 264) argue, "there is no illness, injury, or anatomical locus to correlate with the most reliable risk factors for criminal behavior (youth, gender, socioeconomic status, and previous violent acts)." And further, even if we can one day make the link between brain activity and behavior, society will still need to decide whether this neurological evidence is grounds for exculpation or increased surveillance and control of the individual. What we can be sure of is that science is no escape for the uncertainty of the legal system and human judgment. As phrenology and the frontal lobotomy remind us, today's state of the art can very easily become tomorrow's pseudoscience. And science, at least at its best, is defined by effort to identify, discuss, and try to manage uncertainty at every stage of the process. This, of course, is a familiar task for anyone who has ever set foot in the courtroom.

DISCLOSURE STATEMENT

The author is not aware of any affiliations, memberships, funding, or financial holdings that might be perceived as affecting the objectivity of this review.

LITERATURE CITED

Aggarwal NK. 2009. Neuroimaging, culture, and forensic psychiatry. *J. Am. Acad. Psychiatry* 37(2):239–44

Aharoni E, Funk C, Sinnott-Armstrong W, Gazzaniga M. 2008. Can neurological evidence help courts assess criminal responsibility? Lessons from law and neuroscience. *Ann. NY Acad. Sci.* 1124:145–60

Applebaum PS. 2007. The new lie detectors: neuroscience, deception, and the courts. *Psychiatr. Serv.* 58(4):460–62

Aronson JD. 2007. Brain imaging, culpability, and the juvenile death penalty. *Psychol. Public Policy Law* 13:115–42

Baer S. 2005. *Roper v. Simmons*: How will this case change practice in the courtroom? Presented at Teleconference, Am. Bar Assoc. Cent. Contin. Legal Ed., June 22

Barth AS. 2007. A double-edged sword: the role of neuroimaging in federal capital sentencing. *Am. J. Law Med.* 33:501–22

Baskin JH, Edersheim JG, Price BH. 2007. Is a picture worth a thousand words? Neuroimaging in the courtroom. *Am. J. Law Med.* 33:239–69

Bennett M. 2009. Criminal law as it pertains to 'mentally incompetent defendants': a McNaughton rule in the light of cognitive neuroscience. *Aust. N.Z. J. Psychiatry* 43(4):289–99

Brown TR, Murphy ER. 2010. Through a scanner darkly: functional neuroimaging as evidence of a criminal defendant's past mental states. *Stanford Law Rev.* 62:1119–208

Caulum MS. 2007. Post adolescent brain development: a disconnect between neuroscience, emerging adults, and the corrections system. *Wis. Law Rev.* 2007:729–58

Dumit J. 2004. *Picturing Personhood: Brain Scans and Biomedical Identity*. Princeton, NJ: Princeton Univ. Press

Entertainment Software Assn. v. Blagojevich, 404 F.Supp.2d 1051 (N.D.Ill. 2005)

Erickson SK. 2010. Blaming the brain. *Minn. J. Law Sci. Technol.* 11(1):27–77

Fox D. 2009. The right to silence as protecting mental control. *Akron Law Rev.* 42:763–801

Garland B, Frankel MF. 2006. Considering convergence: a policy dialogue about behavioral genetics, neuroscience, and law. *Law Contemp. Probl.* 69:101–13

Gazzaniga MS. 2008. The law and neuroscience. *Neuron* 60(3):412–15

Giridharadas A. 2008. India's novel use of brain scans in courts is debated. *NY Times*, Sept. 15, p. A10

Goodenough OR. 2001. Mapping cortical areas associated with legal reasoning and moral intuition. *Jurimetrics* 41:429–42

Goodenough OR. 2004. Responsibility and punishment: Whose mind? A response. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* 359(1451):1805–9

Goodenough OR, Prehn K. 2004. A neuroscientific approach to normative judgment in law and justice. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* 359(1451):1709–26

Greely HT. 2008. Neuroscience and criminal justice: not responsibility but treatment. *Kans. Law Rev.* 56:1103–38

Greely HT, Illes J. 2007. Neuroscience-based lie detection: the urgent need for regulation. *Am. J. Law Med.* 33:377–421

Greene J, Cohen J. 2004. For the law, neuroscience changes nothing and everything. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* 359(1451):1775–85

Halliburton C. 2009. How privacy killed *Katz*: a tale of cognitive freedom and the property of personhood as Fourth Amendment norm. *Akron Law Rev.* 42:804–84

Harrington v. State, 659 N.W.2d 509 (Iowa 2003)

Iacona WG. 2008. The forensic application of 'brain fingerprinting': why scientists should encourage the use of P300 memory detection methods. *Am. J. Bioeth.* 8(1):30–32

Johnson SB, Blum RW, Giedd JN. 2009. Adolescent maturity and the brain: the promise and pitfalls of neuroscience research in adolescent health policy. *J. Adolesc. Health* 45(3):216–21

Jones OD, Buckholtz JW, Schall JD, Marois R. 2009. Brain imaging for legal thinkers: a guide for the perplexed. *Stanford Technol. Law Rev.* 5:1–48

Joyce K. 2005. Appealing images: magnetic resonance imaging and the construction of authoritative knowledge. *Soc. Stud. Sci.* 35(3):437–62

Keckler CNW. 2006. Cross-examining the brain: a legal analysis of neural imaging for credibility impeachment. *Hastings Law J.* 57:509–56

Khoshbin LS, Khoshbin S. 2007. Imaging the mind, minding the image: an historical introduction to brain imaging and the law. *Am. J. Law Med.* 33:171–92

Knabb JJ, Welsh RK, Ziebell JG, Reimer KS. 2009. Neuroscience, moral reasoning, and the law. *Behav. Sci. Law* 27(2):219–36

Kolber AJ. 2007. Pain detection and the privacy of subjective experience. *Am. J. Law Med.* 33:433–56

Korenek v. Korenek, 2008 WL 2894906 (Tex. App., 2008)

Kulynych J. 1997. Psychiatric neuroimaging evidence: a high-tech crystal ball? *Stanford Law Rev.* 49:1249–70

Kulynych J. 2007. The regulation of MR neuroimaging research: disentangling the Gordian knot. *Am. J. Law Med.* 33:295–317

Langleben DD. 2008. Detection of deception with fMRI: Are we there yet? *Leg. Criminol. Psych.* 13(1):1–9

Marks JH. 2007. Interrogational neuroimaging in counterterrorism: a "no-brainer" or a human rights hazard? *Am. J. Law Med.* 33:483–500

Maroney TA. 2009. The false promise of adolescent brain science in juvenile justice. *Notre Dame Law Rev.* 85(1):89–176

Meegan DV. 2008. Neuroimaging techniques for memory detection: scientific, ethical, and legal issues. *Am. J. Bioeth.* 8(1):9–20

Merikangas JR. 2008. Commentary: functional MRI lie detection. *J. Am. Acad. Psychiatry Law* 36:499–501

Mobbs D, Lau HC, Jones OD, Frith CD. 2007. Law, responsibility, and the brain. *PLoS Biol.* 5(4):e103

Moberly ex. rel. Moberly v. Sec'y of Health & Human Services, No. 98-0910V, 2005 WL 1793416 (Fed.Cl. 2005)

Moreno JA. 2009. The future of neuroimaged lie detection and the law. *Akron Law Rev.* 42:722–37

Moriarty JC. 2008. Flickering admissibility: neuroimaging evidence in the U.S. courts. *Behav. Sci. Law* 26(1):29–49

Moriarty JC. 2009. Visions of deception: neuroimages and the search for truth. *Akron Law Rev.* 42:739–61

Morse SJ. 2004. New neuroscience, old problems. In *Neuroscience and the Law: Brain, Mind and the Scales of Justice*, ed. B Garland, pp. 157–98. New York: Dana

Morse SJ. 2006. Brain overclaim syndrome and criminal responsibility: a diagnostic note. *Ohio State J. Crim. Law* 3:397–412

Pardo MS. 2006. Neuroscience evidence, legal culture, and criminal procedure. *Am. J. Crim. Law* 33:301–37

People v. Weinstein, 591 N.Y.S.2d 715 (N.Y. Sup. 1992)

Perlin ML. 2009a. "And I see through your brain": access to experts, competency to consent, and the impact of antipsychotic medications in neuroimaging cases in the criminal trial process. *Stanford Technol. Law Rev.* 4:1–13

Perlin ML. 2009b. "And his brain has been mismanaged with great skill": How will jurors respond to neuroimage testimony in insanity defense cases? *Akron Law Rev.* 42:885–916

Pettit M Jr. 2007. fMRI and BF meet FRE: brain imaging and the federal rules of evidence. *Am. J. Law Med.* 33:319–40

Porter S, ten Brinke L. 2009. The truth about lies: What works in detecting high-stakes deception? *Leg. Criminol. Psychol.* 15:57–75

Pustilinik AC. 2009. Violence on the brain: a critique of neuroscience in criminal law. *Wake Forest Law Rev.* 44:183–237

Raghava M. 2008. Stop using brain mapping for investigation and as evidence. *The Hindu*, Sept. 6, p. 1

Redding RE. 2006. The brain-disordered defendant: neuroscience and legal insanity in the twenty-first century. *Am. Univ. Law Rev.* 56(1):51–127

Roper v. Simmons, 543 U.S. 551 (2005)

Rosen J. 2007. The brain on the stand. *NY Times Mag.*, March 11, p. 48

Roskies A. 2006. Neuroscientific challenges to free will and responsibility. *Trends Cogn. Sci.* 10(9):419–23

Salerno JM, Bottoms BL. 2009. Emotional evidence and jurors' judgments: the promise of neuroscience for informing psychology and law. *Behav. Sci. Law* 27(2):273–96

Sapolsky RM. 2004. The frontal cortex and the criminal justice system. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* 359(1451):1787–96

Schmerber v. California, 384 U.S. 757 (1966)

Seaman J. 2009. Black boxes: fMRI lie detection and the role of the jury. *Akron Law Rev.* 49:931–39

Seaman JA. 2008. The 2008 Randolph W. Thrower Symposium: Legal science: an interdisciplinary examination of the use and misuse of science in the law: article and essay: black boxes. *Emory Law J.* 58:427–88

Shafi N. 2009. Neuroscience and law: the evidentiary value of brain imaging. *Grad. Stud. J. Psychol.* 11:27–39

Snead OC. 2007. Neuroimaging and the 'complexity' of capital punishment. *NYU Law Rev.* 82:1265–339

Snead OC. 2009. *Neuroimaging and the courts: standards and illustrative case index*. Prepared for Am. Bar Assoc. Annu. Meet., Chicago, July 29–Aug. 2

Spence SA. 2008. Playing devil's advocate: the case against fMRI lie detection. *Leg. Criminol. Psychol.* 13:11–25

Spence SA, Hunter MD, Farrow TF, Green RD, Leung DH, et al. 2004. A cognitive neurobiological account of deception: evidence from functional neuroimaging. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* 359(1451):1755–62

Stoller SE, Wolpe PR. 2007. Emerging neurotechnologies for lie detection and the Fifth Amendment. *Am. J. Law Med.* 33:359–75

Tancredi LR, Brodie JD. 2007. The brain and behavior: limitations in the legal use of functional magnetic resonance imaging. *Am. J. Law Med.* 33:271–94

Taylor E. 2006. A new wave of police interrogation? "Brain fingerprinting," the constitutional privilege against self-incrimination, and hearsay jurisprudence. *Univ. Ill. J. Law Technol. Policy* 2006(2):101–24

Tovino SA. 2007a. Functional neuroimaging and the law: trends and directions for future scholarship. *Am. J. Bioeth.* 7(9):44–56

Tovino SA. 2007b. Functional neuroimaging information: a case for neuro exceptionalism? *FSU Law Rev.* 34:415–89

Tovino SA. 2007c. Imaging body structure and mapping brain function: a historical approach. *Am. J. Law Med.* 33:193–228

Tovino SA. 2008. The impact of neuroscience on health law. *Neuroethics* 1(2):101–17

Tovino SA. 2009. Remarks: neuroscience, gender, and the law. *Akron Law Rev.* 42:941–53

Trout JD. 2008. Seduction without cause: uncovering explanatory neurophilia. *Trends Cogn. Sci.* 12(8):281–82

United States v. Gigante, 982 F.Supp. 140 (S.D.N.Y. 1997)

United States v. Hinckley, 525 F.Supp. 1324 (D.D.C. 1981)

Weisberg DS, Keil FC, Goodstein J, Rawson E, Gray JR. 2008. The seductive allure of neuroscience explanations. *J. Cogn. Neurosci.* 20(3):470–77

Wolpe PR, Foster KR, Langleben DD. 2005. Emerging neurotechnologies for lie-detection: promises and perils. *Am. J. Bioeth.* 5(2):39–49

Annual Review of Law and Social Science

Volume 6, 2010

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