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Neuroscience and Law: The Evidentiary Value of Brain Imaging

Noel Shafi
Teachers College, Columbia University

Neuroimaging evidence should be restricted in terms of admissibility in the courts, and should only be considered reliable under scientifically valid clinical methods. This topic will be approached in four stages: (1) a brief introduction to neuroscience and law, (2) a discussion of evidentiary laws in the American legal system, (3) a review of modern neuroimaging and the admissibility and applicability of neuroimaging evidence in the courtroom using actual cases, and 4) a closing argument, including interdisciplinary perspectives on neuroscience and law.

Neuroimaging has numerous legitimate legal applications, in addition to important clinical applications. Neuroimaging methods are primarily used to study brain and behavior relationships, which contribute to clinical and research disciplines such as radiology, psychiatry, neurology, and clinical neuropsychology (Bigler, 1991). However, there are numerous ways in which brain imaging can be interpreted and implicated in the court. In fact, neuroscience has been applied to many legal subfields, including, but not limited to: Intellectual Property Law, Tort Law, Consumer Law, Health Law, Employment Law, Constitutional Law, and Criminal Law (Tovino, 2007). Thus, brain scientists can use neuroimages to determine the cognitive, behavioral, and physiological traits of clinical patients and legal defendants.

The convergence between neuroscience and law is a recent phenomenon. In fact, "[t]he legal profession is at least two millennia older than the neurobiological profession, which is not much more than 150 years old at best, and in its current state of probing the mind of man and his subjective states is far younger than that" (Zeki & Goodenough, 2004, p. 1662). Nevertheless, developments in neuroscience have led to unprecedented changes in legal proceedings, whereby the brain has increasingly become a subject of legal inquiry. As neuroscience now has many implications within the legal realm, the "Neuro-Law" subfield has developed.

Admissibility of Scientific Evidence: Implications for Neuroscience

Admissibility of neuroimaging evidence is commonly based on the purpose of submission, rather than the imaging itself. There is a great deal of controversy regarding if and when neuroimaging should be used. Neuroimaging is not purely objective, but is "the product of a complex set of techniques, subjective decisions, technical choices, and informed interpretations" (Baskin, Edersheim, & Price, 2007, p. 249). Essentially, neuroimaging methods create a visual image of the brain and the imaging specialist interprets it. Various interpretations can be derived from brain imaging, including: the presence of structural abnormalities, functional deficits, personality traits based on physiological defects, and lie detection (Pettit, 2007, p. 321-323).

Brain images have physiological and behavioral correlates. Correlation of neuroimaging to behavior is presently very limited. A majority of the findings are still inconclusive, although many remain informative, and potentially useful. "With respect to understanding the brain and certain behaviors, the state of scientific knowledge is nascent, but promising. The more complex and specific the behavior examined, the more speculative the connection" (Baskin et al., 2007, p. 239). However, even the simplest behaviors involve highly sophisticated functions and interactions between multiple structures in the brain. The human brain is complex and, whether in the clinic or the courtroom, it should be analyzed and assessed by experts.

In a clinical setting, neurologists, neuropsychologists and other health care professionals use neuroimaging for medical purposes, in order to detect or diagnose neurological disorders or brain injuries. Technological advances and methodological improvements in neuroimaging techniques will continue to expand its use. Meanwhile, neuroimaging will be applied in the courtroom for purposes that extend beyond medicine.

In a courtroom setting, litigants use neuroimaging in civil litigation and criminal trials in order to affirm or deny claims of brain or spinal injury (Pettit, 2007, p.321-322). Some researchers assert that neuroimaging could be used to demonstrate the propensity for violence, the capacity to stand trial, as evidence of malingering, or to help establish or diminish the criminal responsibility of a defendant (Aharoni, Funk, Sinnott-Armstrong, & Gazzaniga, 2008). Recent research has also noted the use of brain imaging in detecting pain, but this method has not yet been scientifically validated for clinical use (Kupers & Kehlet, 2006).

Evidentiary rules have set parameters for the admissibility and reliability of scientific instruments, thereby limiting the application of neuroimaging. Yet, as Pettit (2007) states, "courts usually seem willing to consider brain-imaging evidence under the same standards that they apply to other scientific evidence" (p. 339). Legal history

Correspondence: Noel Shafi, noel.shafi@gmail.com

demonstrates that neuroimaging is most useful when it is applied with clinical methods. Ultimately, the rule of law and the current state of science determine the practicality of neuroimaging in the courtroom. The scientific reliability of neuroimaging evidence is an important part of legal admissibility.

The legal standard for admissibility of evidence depends on the court system. State and federal courts have their own standards but generally defer to federal rules. Federal rules are derived from previous court rulings, which established preliminary standards of admissibility. For example, *Daubert v. Merrell Dow Pharmaceuticals* (1993) and *Frye v. United States* (1923) are two pivotal cases that contributed to the federal standard for the admissibility of scientific evidence.

Gardland and Glimcher (2006) describe the Daubert standard – a legal criteria for evaluating the reliability of scientific testimony and evidence in the courtroom. This standard is derived from a civil suit, *Daubert v. Merrell Dow Pharmaceuticals*, whereby the Supreme Court established four general guidelines for the admission of scientific evidence.

In regard to the evidentiary law, the Daubert standard states that trial judges should carefully consider:

> …whether the theory or technique in question can be (and has been) tested, whether it has been subjected to peer review and publication, its known or potential error rate, and the existence and maintenance of standards controlling its operation, and whether it has attracted widespread acceptance within a relevant scientific community (p. 580).

Can neuroimaging evidence satisfy any of these criteria?

In *Daubert v. Merrell Dow Pharmaceuticals* (1993), the plaintiffs claimed that Bendectin, a prescription drug and antinauseant, caused them serious birth defects when their mothers consumed it during pregnancy. Experts for the plaintiff argued for medical causation, based on results from animal studies involving Bendectin and human studies involving similar drugs. Experts for the defendant argued that there was no evidence based on human studies indicating that the drug poses a risk for human birth defects. The defendants also cited the Frye (1923) case, arguing that expert testimony for the plaintiff was not based on the scientific method. The court ruled in favor of the defendant and concluded that the studies relating to Bendectin were inadmissible as evidence.

This case demonstrates that litigants and scientists equally recognize that scientific studies do not always establish causality, and that animal studies should not always be equated with human conditions. This case also demonstrates that expert testimony on scientific evidence can potentially influence the admissibility of evidence, or even the outcome of the case itself.

In *Frye v. United States* (1923), the defendant was charged with second-degree murder; in his defense, he requested a systolic blood pressure deception test, or lie detector test. The defendant believed that the test results would proclaim his innocence. The court excluded the test results because the testing device was not generally accepted in the scientific community. The court explained their decision as follows:

> Just when a scientific principle or discovery crosses the line between the experimental and demonstrable stages is difficult to define. Somewhere in this twilight zone the evidential force of the principle must be recognized, and while courts will go a long way in admitting expert testimony deduced from a well-recognized scientific principle or discovery, the thing from which the deduction is made must be sufficiently established to have gained general acceptance in the particular field in which it belongs (p. 1014).

This statement eventually became known as the “Frye standard” for the admissibility of scientific evidence.

Both the Daubert (1993) and Frye (1923) cases developed standards for the admissibility of scientific evidence. However, it was the Daubert standard that significantly contributed to the development of the federal standard, which was previously enacted. The Frye standard was generally used from the 1920’s to the 1980’s; the courts eventually shifted to the federal standard in the 1970’s and, in the 1990’s, Daubert (1993) ruled that Frye would no longer be the standard rule of admissibility of scientific evidence (Moriarty, 2008).

*Federal Rules of Evidence (FRE).*The current federal standard for evidence in the courtroom is known as The Federal Rules of Evidence (FRE). The FRE have provided a legal standard for the admissibility of evidence in United States federal courts since it was enacted in 1975 (Mosteller, 2006). Most U.S. state and federal jurisdictions refer to this standard. The FRE contains several rules relevant to the admissibility, presentation and application of scientific evidence in the courtroom. Generally, the judge decides whether the evidence is admissible, but only an expert witness can introduce and interpret the evidence (Moriarty, 2008).

Relevancy and expert testimony are two central concepts in the FRE that govern the admissibility of evidence. There are three rules of particular importance - two pertaining to relevancy, and one pertaining to expert testimony (FRE 401, FRE 702 and FRE 403 respectively). These rules are important because they help determine the admissibility of scientific evidence such as neuroimaging. They will be reviewed in order of mention.

Federal Rules of Evidence, FRE 401 (definition of “relevant evidence”). In regard to relevancy, FRE 401 (2008) states:

> *Relevant evidence* means evidence having any tendency to make the existence of any fact that is of consequence to the determination of the action more probable or less probable than it would be without the evidence.

Researchers are still debating the relevancy of neuroimaging to courtroom proceedings; however, the evidentiary value of neuroimaging is not only a matter of relevance to the case, but also, the sufficiency of the evidence itself. Husted and colleagues (2008) state that imaging studies "will not be relevant to every defense and, if utilized, should be only a component of the multi-faceted scientific data presented" (p. e15). Others disagree, stating that "neuroscience is insufficiently advanced to offer precise data that will be genuinely legally relevant" (Morse, 2006, p. 400).

Federal Rules of Evidence, FRE 702 (opinions and expert testimony). Whenever neuroscientific evidence requires specialized knowledge, there must be an expert witness to testify as to what the brain image means. Without the appropriate expertise, the evidence would be rendered inadmissible. FRE 702 (2008) states:

> If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education, may testify thereto in the form of an opinion or otherwise, if (1) the testimony is based upon sufficient facts or data, (2) the testimony is the product of reliable principles and methods, and (3) the witness has applied the principles and methods reliably to the facts of the case.

In summary, Rule 702 requires that testimony be factual, reliable, and applicable to the case. The previously mentioned factors will be evaluated in terms of how they apply to neuroimaging evidence. The following evaluation will only provide a general sense of the current medical-legal opinion on the admissibility of scientific evidence in the context of FRE.

Sufficient facts are necessary to prove certain aspects of the case. If the facts are insufficient, then they will not contribute to legal decision-making. For this reason, factuality can itself determine admissibility, despite the reliability of the evidence. For instance, "even if the science is good enough to pass muster for admission as expert scientific evidence under federal and state evidentiary rules, it may still be inadmissible because it will not be probative" (Morse, 2006, p. 400). So, it is not just a matter of whether neuroimaging is scientifically valid, but rather, whether or not it can provide enough information to establish important facts in the case.

Researchers Le and Hu (1997) explain that "[r]eliability concerns the extent to which a test, or any measuring procedure, yields the same results on repeated trials" (p. 160). Reliability is equally important in clinical neuroimaging as it is in evidentiary law. Aharoni and colleagues (2008) argue that "it is not clear when neuroscience findings should qualify as relevant, material, or competent, or reliable as defined by the rules of evidence" (p. 157). Whether such qualifications can be met really depends on the type of neuroimaging device being used, and the reason it is being employed. For instance, the Society of Nuclear Medicine Brain Imaging Council (1996) states that the "use of functional neuroimaging in forensic situations including criminal, personal injury, product liability, medical malpractice, worker's compensation and 'toxic torts,' remains especially controversial" (p. 1257).

The way neuroimaging methods are applied in legal cases is crucial. If applied unconventionally, brain scanning technology may undermine rather than contribute to justice. However, if the science is reliable, and provides relevant facts, litigants can introduce this evidence without compromising the integrity of their case. Therefore, the reliability of the method should be a prerequisite for its admissibility.

Generally, regardless of the type of case being tried, factuality, reliability, and applicability remain critical factors in the admissibility of scientific evidence under FRE 702.

Federal Rules of Evidence, FRE 403 (relevancy and its limits). Besides FRE 702, there are other federal rules that further stipulate what judges may allow in the courtroom. In fact, "[e]xpert testimony that survives scrutiny under FRE 702 might still be excluded under FRE 403" (Pettit, 2007, p. 327). FRE 403 (2008) provides stipulations that potentially exclude some evidence from the courtroom if the probative value is minimal. This rule specifies additional criteria for admissibility of evidence. FRE 403 (2008) states:

> Although relevant, evidence may be excluded if its probative value is substantially outweighed by the danger of unfair prejudice, confusion of the issues, or misleading the jury, or by considerations of undue delay, waste of time, or needless presentation of cumulative evidence.

In summary, Rule 403 specifies four criteria for admissible courtroom evidence (whether it is prejudicial, confusing, misleading or excessive). There are several arguments regarding how neuroimaging may or may not meet any of these criteria.

Prejudice and justice are inevitably intertwined in the field of law. Neuroscience can contribute to prejudice in the legal system in numerous ways. In criminal trials, rendering a verdict for the defendant simply based on a structural abnormality of the brain or a dysfunction of behavior oversimplifies the complexity of crime and creates undue prejudice. This may work for or against the defendant – the jury can relieve punishment for the crime if the defendant is believed to be insane or incompetent because of his anomaly, but the jury can also penalize the defendant because his brain disorder may indicate a propensity for criminal behavior. Therefore, brain abnormalities should not automatically diminish the responsibility of the defendant, nor should it substantiate guilt. Overall, neuroimaging evidence should be used in conjunction with other legal or scientific evidence. Thus, prejudice is likely to enter the courtroom depending on the way the evidence is presented and how it is applied.

Neuroimaging technology is also potentially confusing for the jury. The expert witness must be able to simplify the information being presented, and accurately summarize relevant findings on the brain. Brain evidence is especially difficult to present without confusion because "society has not yet reached a consensus as to whether, as a matter of morality or legality, neurological explanations should lead to exculpation" (Baskin et al. 2007, p. 268). However, one legal expert believes that neuroimaging can revitalize the search for truth in the courtroom. Feigenson (2006) states that the "courtroom display of such images should not only greatly assist triers of fact in understanding the fMRI expert testimony [or any other type of neuroimaging device] but also disabuse them of the tendency to view the data representations naively and hence uncritically" (p. 251). Thus, it is arguable that neuroimaging could enlighten the jury, rather than confuse them.

Baskin and colleagues (2007) argue that neuroimaging can mislead or bias the jury. In fact, "data from fMRI, SPECT, and PET scans can be referenced and presented in dazzling multimedia displays that may inflate the scientific credibility of the information presented" (p. 268). Defendants with insanity pleas can further complicate judicial decisions. One study examined the effect of neurological evidence on legal decision-making. Gurley and Marcus (2008) presented a group of 396 participants with hypothetical case summaries of defendants in criminal trials. The participants were asked to provide a verdict of guilty or not guilty by reason of insanity. This study found that participants were more likely to render a verdict of not guilty by reason of insanity when the hypothetical defendant had psychological or neurological problems, which were demonstrated by psychiatric or neuroimaging techniques. These results seem to demonstrate the favorability of brain-based evidence in the courtroom, and how it can bias the jury and the outcome of the verdict (Gurley & Marcus, 2008). To counteract this bias, Baskin and colleagues (2007) suggest that medical witnesses interpret neuroimages with reservation, and be more speculative and less definitive in presenting their testimony in court.

Neuroimaging does not seem to present a problem of undue delay as other forms of scientific evidence might. Whether neuroimaging in the court is a "waste of time" or a "needless presentation of cumulative evidence" depends on the ability of brain imaging specialists to contribute new facts to the case; considering the history of neuro-law cases, it seems that brain scans can do just that.

Structural and Functional Neuroimaging I: Clinical and Courtroom Applications

Modern neuroimaging techniques such as magnetic resonance imaging (MRI), computerized tomography (CT), single photon emission computed tomography (SPECT), positron emission tomography (PET), and functional magnetic resonance imaging (fMRI), will be reviewed in terms of their clinical and legal applications. SPECT, fMRI, and PET are functional brain scanning technologies, while MRI and CT are structural scanning technologies. The former is concerned with physiological functions, whereas the latter is concerned with physiological features. Neuroimaging techniques create a visual image of different structures or functions in the brain (see Figures 1-2 for a basic review of brain anatomy). Each neuroimaging modality is based on distinct methods of operation, and has varying degrees of scientific validity and reliability. The question is whether or not the neuroimaging methods in the clinic have evidentiary value in the court.

Figure 1. Displaying the cortical surface of the brain. Adopted from Fallon (2006).

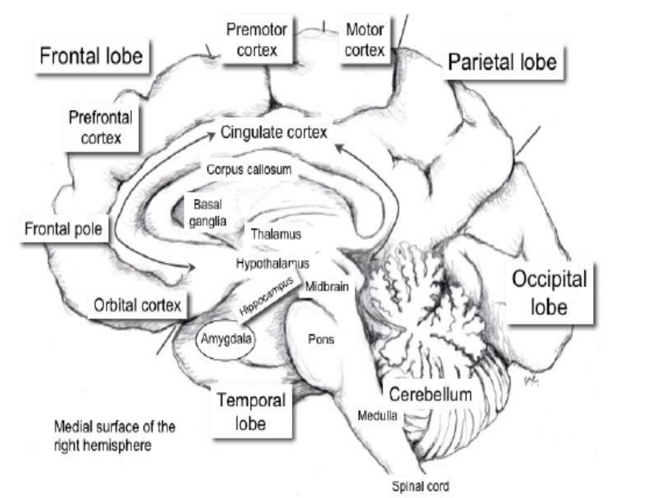
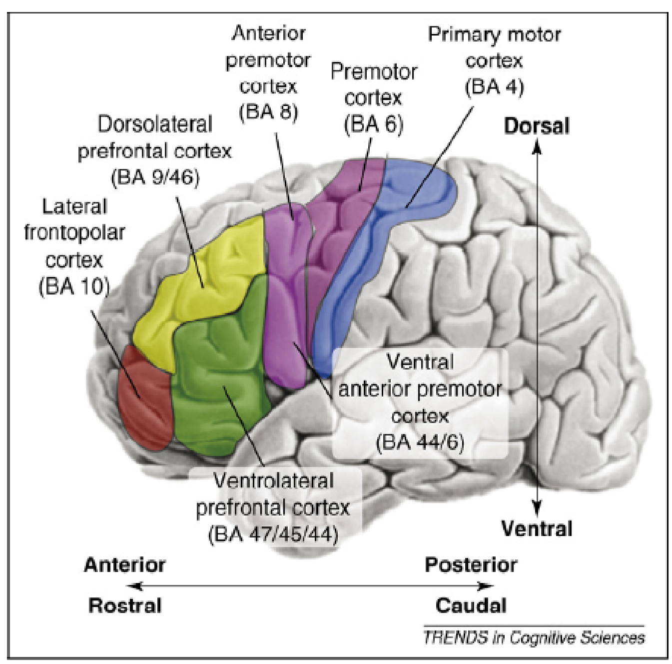


Figure 2. Anterior, posterior, ventral and dorsal views of the brain. Adopted from Badre (2008).



Lawyers and scientists typically consider the capabilities and limitations of neuroimaging techniques before making any conclusions about a patient, client, plaintiff, or defendant. The following segment of this paper will review several examples of how law has interacted with neuroimaging in recent legal history. The author will first begin by analyzing the scientific reliability and legal applicability of structural neuroimaging, such as MRI and CT, and functional neuroimaging, such as PET, SPECT and fMRI. Several legal cases involving each neuroimaging modality will be reviewed, followed by a brief discussion on the admissibility and reliability of neuroimaging evidence submitted in court.

Magnetic Resonance Imaging (MRI). Magnetic resonance imaging (MRI) is a structural brain imaging technique focusing on the structure of the brain. MRI is a noninvasive procedure, unlike PET and SPECT. MRI displays visual images of the brain by "using a powerful magnet to obtain its images" (Baskin et al., 2007, p. 248). The authors describe MRI scans as a static visualization of the brain. MRI has numerous capabilities. MRI has high spatial resolution and is scientifically established as a reliable measurement of brain injury (Mettingr, Rodiger, De Keyser, & van der Naalt., 2007). Specifically, "structural MRIs can often detect acutely diffuse axonal injury,[2] small hemorrhages,[3] edema,[4] or contusions[5] that characterize TBI" or Traumatic Brain Injury (Baskin et al. 2007, p. 254). Also, "MRI produces images superior to CT scans, both in its ability to differentiate gray from white matter and its clear visualization of brain structures" (Moriarty, 2008, p. 31). Furthermore, "the great advantage of MRI is the absence of radiation, which is important for the assessment of the young and in benign conditions" (Rankin, 2008, p. 239). Some researchers consider MRI an effective tool and an admissible form of evidence for postmortem evaluations of traumatized brains (Harris, 1991). Overall, MRI is designed to detect or diagnose physiological abnormalities of the brain.

However, MRI also has limitations. MRI scans are unable to accurately predict age or gender (Baskin et al., 2007). Moreover, Ewers and colleagues (2006) state that "[v]ariability in MRI-based measurement between clinical sites may potentially influence the accuracy of biological measures and thus compromise applicability of MRI-based diagnostic criteria across sites" (p. 1051). Differences in clinical standards do exist, and that there is a subjective element in MRI analysis in the clinic, and consequently, in the court.

The following case exemplifies the evidentiary value of MRI in diagnosing head injuries. In *State of Delaware v. Vandemark* (2004), the defendant filed a motion, or a request to the court, to "bar testimony about shaken baby impact syndrome or inflicted head trauma" (p. 1). The defendant was "charged with assault by abuse involving a child" (p. 1) approximately sixteen months old at the time the injury was thought to occur. The child was hospitalized and underwent neuroimaging soon after the injury. A CT scan detected a small subdural hematoma[6] with a "mass effect on the left side" of the child's brain (p. 1). A MRI was also performed, and found "an extensive subacute left-sided subdural hematoma" throughout the left hemisphere (p. 2). The court recognized the greater sensitivity of MRI over CT, in that it was able to better display the extent of the hematoma in the brain. Medical experts in this case agreed that the head injuries sustained by the child were "consistent with…Inflicted Head Trauma" and that the injuries were "not accidental" (p. 2). One physician testified that the shaking of a child or blunt force inflicted on the child, or both, causes injuries; this notion is generally accepted in the relevant scientific community, namely, pediatrics (p. 4).

MRI and CT scans substantiated the evidence supporting head injury, and coincided with expert testimony regarding the diagnosis of shaken baby impact syndrome. The court concluded that the testimony was relevant and reliable, and would therefore, be admitted into evidence in the subsequent trial. The motion by the defendant to exclude evidence on inflicted head trauma was denied (p. 17-18). In this case, MRI and CT evidence was both admissible and reliable.

As demonstrated in the previous case, MRI and CT can provide proof of injury, but may not always provide sufficient evidence for medical causation. The following case highlights the problem of making causal inferences from neuroimaging. In *Siharath, Rider and Rider v. Sandoz Pharmaceuticals Corporation* (2001), the plaintiffs sought "compensatory and punitive damages" alleging that Parlodel, a drug manufactured by the defendant, caused seizures[7] and stroke[8] (p. 1349). The defendant filed a motion to exclude evidence insinuating medical causation. Plaintiff Siharath took the prescription for several days, and soon after, experienced "three seizures and a subarachnoid hemorrhagic stroke" (p. 1349). The plaintiff's physician was unable to establish a cause or provide a diagnosis. The second Plaintiff, Ms. Rider, experienced involuntary movements in her right leg. She later underwent a CT scan, which indicated that she had "an acute intracranial hemorrhagic stroke," and a MRI scan, which also confirmed that she had suffered "a left parietal hemorrhage" (p. 1350). The experts for the

[2] Axonal injuries are characterized by lesions in the white matter of the brain.
[3] Hemorrhages are instances of internal or external bleeding.
[4] Edema is an accumulation of fluid in bodily tissue or cavities causing swelling to occur.
[5] Cerebral contusions are bruises in brain tissue caused by injury.

[6] A hematoma is defined as a collection of blood in bodily tissue or organs usually caused by hemorrhaging; a subdural hematoma is a mass of blood accumulating within the dura mater, and is caused by head injury.
[7] Seizures are characterized by abnormal neural activity accompanied by changes in sensation and behavior.
[8] Strokes are defined as a sudden loss of brain function caused by changes in blood supply to the brain, usually causing changes in movement, vision or speech.

plaintiffs provided testimony that relied on case reports, partly because there was a lack of epidemiological studies on Parlodel. The expert witness for the plaintiff, an expert on adverse drug reactions, argued that Parlodel causes strokes. The defendant argued that case reports do not satisfy the scientific method.

The court finally agreed with the defendant, although the MRI and CT evidence confirmed the injuries in the plaintiffs' brains. Despite the fact that the MRI and CT scans indicated separate incidents of stroke in two plaintiffs with the same prescription, it does not establish a causal relationship between the drug and the results of the brain scan. The court ruled in favor of the defendant, who filed for "summary judgment on issues of medical causation" (*Siharath*, 2001, p. 1374). In this case, MRI and CT evidence was admissible, but unreliable.

The following case is an example of how neuroimaging evidence can be used, in conjunction with neuropsychological evidence, to establish a link between brain injury and intellectual capacity. This case demonstrates that brain scan evidence can coincide with or support the basis of other scientific evidence in the courtroom. In *United States v. Sandoval-Mendoza* (2006), the defendant appealed his conviction for conspiracy to sell methamphetamine, arguing that he was influenced by government agents to commit the crime, and that the presence of a brain tumor can explain his susceptibility to influence. One defense witness, a psychologist, testified that the defendant had an unusually large pituitary tumor, which caused irreversible brain damage. The court acknowledged that pituitary tumors may affect thyroid production, causing mood disorder, and damage to the frontal, temporal and thalamic regions, which may cause problems in "memory, decision-making, judgment, mental flexibility, and overall intellectual capacity" (p. 653).

Another defense witness, a neurologist, testified that the MRI showed that Sandoval-Mendoza had a tumor which shrank after treatment. Afterwards, the frontal lobe herniated into the empty space previously occupied by the tumor; the tumor then caused atrophy in the left temporal lobe and further damage in other areas.

The court recognized that this kind of damage to the brain affects judgment, memory, and emotional memory. Both witnesses agreed that such brain damage causes disinhibition, but does not necessary increase "susceptibility to inducement to commit crimes" (p. 653). Prosecution witnesses, also consisting of neurologists and neuropsychologists, testified that although the MRI showed a pituitary tumor, the connection between cognition and behavior remains questionable, and that the tumor should not be attributed to disinhibition (p. 653-654).

The court also recognized that although expert testimonies on both sides were contradictory, they were not potentially confusing and that "the jury was capable of weighing the conflicting medical expert opinion testimony against the rest of the evidence presented and determining whether or not predisposition existed" (p. 656). In this case, MRI evidence was admissible, although its reliability is disputable.

Computerized Tomography (CT)

Computerized tomography (CT) is a structural imaging technique and x-ray technology used to visualize internal organs, including the brain. CT is also a noninvasive technology that revolutionized diagnostic neurology (Khoshbin & Khoshbin, 2007, p. 179). CT "produces an excellent combination of both high spatial and temporal resolution" (Rankin, 2008, p. 239). CT is also a valid clinical method of assessing head trauma (Metting et al., 2007, p. 699). Moreover, Moriarty (2008) states that CT and MRI scans are typically presented in U.S. courts as evidence for brain trauma or neurological disease; he argues that there "is general agreement and substantial proof of reliability that CT scans and MRI technology can detect brain injury, damage or atrophy[9]" (p. 40-41). According to Metting and colleagues (2007), "CT is one of the first developed and most commonly applied imaging techniques in the acute phase of head injury" (p. 699) and "the overall sensitivity of CT to abnormalities in acute head trauma is 63-75%" (p. 700). However, the implication that such injuries have on mental capacity remains unknown.

In some cases, CT scans are being admitted as evidence in the courtroom for purposes it was not designed. Although brain scans may have important implications on the mental capacity or sanity of an individual, it is minimally capable of defining the former, and is currently incapable of proving the latter. The following cases demonstrate that CT evidence can be used or misused accordingly. The first case is a court case involving CT evidence supporting the insanity defense. The second case involves CT evidence establishing mental capacity.

In *United States v. Hinckley* (1982), the defendant was tried for his attempt to assassinate President Ronald Reagan. The defense presented an insanity defense, which they based, in part, on CT scan evidence. The expert witness, a psychiatrist, argued for the defense and testified that the CT scan showed atrophy in the brain. The psychiatrist then argued that atrophy is associated with schizophrenia. A radiologist was also consulted and testified that the scans showed brain abnormalities, but did not have any causal implications on the behavior or sanity for the defendant. Nevertheless, the jury found Hinckley not guilty by reason of insanity. It is likely that CT evidence had an effect on the verdict (Khoshbin & Khoshbin, 2007, p. 184), by diminishing the responsibility of the defendant and supporting his insanity defense. Such an inference from neuroimaging is not based on scientific evidence. This is one example of how brain scans can be used in a way it was not intended. Neuroimaging is not capable of proving insanity. Although the images coincided with the psychiatric

[9] Atrophy is a physiological process characterized by cell death, causing a progressive decline in tissue.

assessment, it was unable to substantiate it. In this case, CT evidence was admissible, but seemingly unreliable.

In *re Estate of* Meyer (2001), the plaintiffs sued because they were unrightfully denied benefits from Meyer's trust. The plaintiffs argued that Meyer was not mentally capable of creating the trust and was possibly manipulated by his lawyer. Moriarty (2008) noted that the court allowed the plaintiffs to introduce CT scans of Meyer which indicated various abnormalities including "brain atrophy, vascular dementia[10] and focal brain changes" (p. 41), which supported the claim that Meyer lacked the capacity to create the trust. As mentioned earlier, CT scans have the ability to localize damage in the brain. However, the association between atrophy, dementia, and CT evidence is questionable. Both early and recent reports have questioned the reliability of CT in measuring cognitive decline (Bird, 1982; van Straaten, Scheltens, & Barkhof, 2004). According to the court, neuroimaging provided substantial proof to explain Meyer's mental state, or lack thereof. In this case, CT evidence was admissible, but reliability is debatable.

As shown in some of the previous cases, structural imaging in the courtroom is relatively reliable. Functioning imaging is also applicable in legal cases.

Single Photon Emission Computerized Tomography (SPECT)

Single photon emission computerized tomography (SPECT) is a functional imaging technique that measures metabolic activity and cerebral processes in various structures. Scientists can use functional imaging to study the neurochemistry of the brain and develop a cognitive profile based on an increase or decrease in blood flow (Baskin et al., 2007, p. 250). SPECT has a wide variety of clinical applications. SPECT imaging studies have generated data on psychiatric and neurological disorders, like dementia, epilepsy, schizophrenia, and depression, but with mixed results (Bonne, Krausz, & Lerer, 1992).

SPECT also has several disadvantages. Granacher (2008) notes the clinical and legal limitations, stating that "the reliability of SPECT…when applied forensically to MTBI [Mild Traumatic Brain Injury] or TBI cases, will not meet all Daubert criteria" (p. 326), and that "general acceptance of the theory and technique within the relevant scientific community…has not been achieved" (p. 327). Metting and colleagues (2007) note the technological limitations, stating that SPECT has low spatial resolution, limited availability, and is not routinely used as a clinical tool for assessing head injury. At the present time, there is no scientific consensus on the validity of SPECT. Furthermore, "[r]eliable analysis of SPECT date remains a major challenge" (Bonne et al., 1992, p. 298).

[10] Vascular dementia is a common neuropsychiatric disorder characterized by cognitive decline and impairment, producing focal effects in the brain.

In previous cases, it was demonstrated that the causality of brain injury can not be easily established. In the following case, it seems equally difficult to establish causation between brain injury and post-injury symptoms. In *Lanter v. Kentucky State Police* (2005), the appellant sought "workers' compensation benefits due to a head injury" (p. 45) sustained during a police training incident. Lanter had previously received partial disability benefits. However, the appellant wanted total disability benefits and requested several brain scans to determine the extent of his injury. In order to receive total benefits, the claimant must demonstrate that his work-related brain injury caused continuous emotional, neurological, and behavioral symptoms. Several brain scans of different types were admitted as evidence. The medical experts performed MRI, EEG[11] and SPECT scans. One expert diagnosed the appellant with a cerebral contusion and post-concussive syndrome (*Lanter*, 2005).

Another expert performed and analyzed additional SPECT scans, which "revealed functional defects in the right parietal and left occipital lobes of the claimant's brain" (p. 48). However, these results did not indicate that the injury caused his behavioral symptoms. The claim for disability benefits was denied, in part, because the medical experts for the plaintiff did not establish causation between injury and affect. SPECT evidence in this case was admissible, but unreliable.

Other cases have also admitted SPECT imaging as evidence for brain injury claims. For example, in *Boyd v. Bell* (2005), the appellant, a former athlete, sustained head injuries during sports activity. The appellant (Boyd) requested SPECT scanning to determine the cause and extent of his organic brain injury in order to apply for additional disability benefits. The radiologists appointed to the case confirmed the head injuries, but noted that the exact cause was uncertain. Subsequently, the court ruled against the appellant, denying his claim for disability benefits, partly because there was no way to prove that his current physiological abnormalities were due to head injuries he sustained in the past. SPECT evidence in this case was once again admissible, but unreliable.

The following case shows that although SPECT imaging is unlikely to establish causation, it can be used to demonstrate incompetence. In *United States v. Kasim* (2008), the defendant, a pediatrician, was accused of conducting fraudulent insurance practices. The defendant filed for a competency evaluation in 2008. His defense team found that, in 2003, "Kasim was diagnosed with anoxic encephalopathy caused by an acute myocardial infarction," as well as sleep apnea during hospitalization (p 8). The EEG produced abnormal results the following day. Days later, EEG and MRI results performed on Kasim were normal. Numerous

[11] The electroencephalogram (EEG) is a functional technique used to assess "cerebral maturation, for determining a patient's physiological (awakening and sleep) and pathological (comas) level of wakefulness and in epileptology" (Praline et al., 2007, p. 2149).

medical expert witnesses were consulted for further scanning. A SPECT was later performed, indicating a reduction in blood flow in the temporal and frontal lobes. The frontal and temporal lobes are associated with executive functioning and memory, respectively. The defendant exhibited deficits in both areas of cognition during neurological and psychological testing. One medical witness diagnosed Kasim with frontal lobe dementia, based on the SPECT results.

Although at least one physician disagreed with the diagnostic validity of SPECT in cases of dementia, or the extent of reduced blood flow in the frontal region, almost all agreed that the defendant exhibited cognitive deficits. Despite the discrepancies in the neuroimaging results from SPECT, EEG, and MRI, several medical witnesses testified that normal results from EEG and MRI scans do not necessarily imply normal brain functioning. The court considered SPECT as an objective test of cognitive abilities. Also, the court found that "Kasim's demeanor during various medical evaluations portrayed poor judgment, an inability to concentrate, and an inability to understand the charges at hand" (p. 46). The court concluded that the defendant was incompetent to stand trial. Neuroimaging evidence contributed to the outcome of the case, which was in favor of the defendant. SPECT evidence in this case was admissible and reliable.

Positive Emission Tomography (PET)

Positive emission tomography (PET) is a functional imaging technique that measures metabolic processes, including "blood flow, blood volume, and metabolism" (Baskin et al., 2007, p. 248). It is a relatively invasive procedure that requires an injection of radioactive elements (or tracer molecules) into the circulatory system, which eventually interact with other molecules to produce measurable changes in activity. Essentially, PET scans "use radioactivity to map differences in metabolic activity in areas of the brain" (Pettit, 2007, p. 320). They can also be used to "measure reduced tissue perfusion" (Baskin et al. 2007, p. 250), a characteristic of neurodegenerative disease, where a decrease in blood volume is observed in specific tissue. According to Metting et al. (2007), "PET studies generally show cerebral dysfunction beyond the structural abnormalities demonstrated by CT and MRI" (p. 703); however, PET has low spatial resolution and is not routinely used for assessing mild or moderate traumatic brain injuries. Although PET is more sensitive than SPECT, it is inferior in terms of specificity (Ebmeier, Donaghey, & Dougall, 2005). PET also has additional limitations in methodology.

The Society of Nuclear Medicine Brain Imaging Council (1996) explains methodological issues with structural neuroimaging. The council names seven sources of interpretive error in using SPECT and PET: (1) "Differences in patient behavioral conditions during acquisition"; (2) "Processing and display variations"; (3) "Nonstandardized definitions of normal and abnormal"; (4) "Availability of scanner-specific or archived normative databases"; (5) "Nonuniform use of quantitative analyses in conjunction with descriptive readings"; (6) "Availability of few published standards defining the criteria for disease pattern identification"; and a (7) "Lack of published determinations of sensitivity and specificity for scans to indentify specific diseases and syndromes before their routine clinical use" (p. 1257). The clinical limitations of SPECT and PET should be acknowledged in the courtroom. Interpretative errors in neuroimaging could certainly compromise expert testimony. For this reason, and others, the courts have increasingly "rejected the use of scans when performed for less than well-established clinical indications" (p. 1257).

Yet, despite the skepticism on introducing neuroimaging to litigation, many courts are accepting brain scans as reliable evidence. For instance, PET and SPECT have relatively high rates of admissibility. In fact, Feigenson (2006) states that "PET and/or SPECT evidence has been admitted in more than four-fifths (73 of 89, 82.0%) of cases in which it has either been admitted or excluded" (p. 237). Feigenson (2006) also states that there have been over 130 court opinions involving PET and SPECT evidence in U.S. federal and state courts. The rate of admissibility for PET and SPECT does not substantiate reliability, however.

In the following case, unreliable evidence was admitted for the defendant, to confirm his claim of incompetence due to Alzheimer's disease. In *United States v. Gigante* (1997), the defendant was being prosecuted by the federal government for several counts of murder and other serious charges. The defendant requested a PET brain scan to confirm Alzheimer's disease (AD) and demonstrate incompetency.[12] According to the court opinion, the expert witness for the defense found that the "defendant was suffering from organic brain dysfunction, possibly due to Alzheimer's disease or multi-infarct dementia" (p. 147). The witness was unable to determine the cause, but concluded that the defendant was incompetent to stand trial.

The prosecution team, however, found evidence that such abnormalities can be attributed to drug use (p. 147). The court noted that Gigante was taking medication at the time. This case exemplifies that neurological deficit does not imply psychological dysfunction, especially considering the confounding variables in the neuroimaging results. Also, the defendant exhibited brain abnormalities which may or may not have existed during the commitment of the crime. The evidence probably undermined, rather than supported, the defendant's case.[13] In this case, PET evidence was admissible, but unreliable.

[12] There is one fundamental problem with the defense in this case. In regard to a PET-based diagnosis of Alzheimer's dementia, "there are postmortem criteria...but *in vivo* histological findings are rarely feasible" and "guidelines have generally not supported the routine use of functional imaging in the diagnostic evaluation of dementia" (Ebmeier et al., 2005, p. 49).

[13] This case was also reviewed elsewhere (Pettit, 2007, p. 335-336).

Sometimes neuroimaging is excluded as evidence because it is being used for reasons that are not clinically valid, such as diagnosing injuries that lack clinical criteria in PET studies. In *McCormack v. Capital Electric Construction Company* (2005), the plaintiff, a carpenter, filed for negligence after being electrocuted during work. The plaintiff attempted to introduce PET brain scans to confirm his injuries and gain compensation. Experts testified that the scans showed abnormal brain activity. However, the defendant argued that the PET "scans were inadmissible…as an unreliable method of diagnosing electric shock injuries" (p. 399). The court ruled in favor of the plaintiff, not because of PET, but because of the alternative scientific evidence presented, including neuropsychological and medical evaluations. Although the PET scan of the plaintiff provided the court with important information relating to the case, it was not sufficient to substantiate his claim. PET evidence in this case was admissible, but unreliable.

In yet another legal case, the reliability of PET evidence depends on the availability of control groups in clinical studies; these studies are used to validate neuroimaging methods. In *Penney v. Praxair, Inc.* (1997), the plaintiff sustained a motor vehicle accident, and sought awards for brain damage. Experts for the plaintiff testified that PET scans detected brain abnormalities, which indicated that Penney had sustained traumatic brain injuries. However, the court found that the plaintiff "did not prove its results were not affected by his age and his medications" (p. 330). PET results are believed to be compromised by age, medical history or medications. The reliability of PET results also depends on the control groups used in PET studies. In this case, the plaintiff's age did not match the controls used for PET experiments at the time. Nevertheless, the court ruled in favor of the plaintiff, awarding damages to the plaintiff "for past and future medical expenses related to injuries he allegedly sustained" (p. 330). Furthermore, according to the court, the admissibility of scientific evidence does not strictly depend on general acceptance in the scientific community, but the relevance and reliability of the method employed (*Daubert*, 1993). In this case, PET evidence was inadmissible and unreliable.

Functional Magnetic Resonance Imaging (fMRI)

Functional magnetic resonance imaging (fMRI) is a brain scanning technology that measures "localized brain activity by determining blood flow and oxygen utilization in portions of the brain" (Applebaum, 2007, p. 461). Aharoni et al. (2008) states that, "in general, abnormal activation could manifest as hypoactivation, hyperactivation, positive or negative activation, or some erratic pattern" (p. 152). Baskin et al. (2007) notes fMRI and other forms of functional imaging are "most advantageous for studying neurochemistry" (p. 248). Also, fMRI is "widely used for imaging the neural correlates of psychological processes and how these brain processes change with learning, development and neuropsychiatric disorder" (Aron, Gluck, & Poldrack, 2006, p. 1000).

The introduction of fMRI advanced the study and science of the brain, and is considered to be technologically superior to PET and SPECT (Khoshbin & Khoshbin, 2007). However, fMRI has numerous limitations. The interpretation of brain activity patterns remains a question of debate among neuroscientists. Neuroimaging studies examine cognitive functions associated with specific brain patterns of neural activity. However, there is no indication that any particular pattern is necessary for any specific behavior (Desmond & Chen, 2002). Several confounded variables, such as head movement and anatomical differences, also undermine the interpretation of fMRI results (Desmond & Chen, 2002). Also, another limitation in fMRI is its "meager temporal resolution" (Aharoni, 2008, p. 158).

Feigenson (2006) describes six additional reliability issues noted with fMRI usage: (1) fMRI scans provide relative measures of brain activity, not absolute measures; (2) fMRI data in neuroimaging studies are not always based on a same level of significance (e.g. $p < .05$); (3) fMRI data usually represents group averages of brain activity, and results may not apply to individuals; (4) anatomical variability compromises the accuracy of structural localization; (5) there are several confounded variables that may effect physiology, neurochemistry or cognition (e.g. drugs and toxins); and (6) generalizing the results from fMRI is difficult considering the lack of uniformity in the experimental methods used for neuroimaging studies[14] (p. 240-241).

Feigenson (2006) also refers to one brain researcher, who states that "[t]here is no single-subject reliability" in fMRI findings (Robinson, 2004, p. 716). Furthermore, fMRI also has several limitations in regard to diagnosis of injury. Granacher (2008) states that "[t]he evidentiary usefulness of functional neuroimaging to provide mild TBI in a court of law lacks a sufficient scientific database and lacks sufficient scientific standards" (p. 327). Nevertheless, fMRI is a "non-invasive technique," which "does not require exposure to ionizing radiation" and creates anatomically precise images of the brain, while assessing the neural correlates of cognition and behavior (Metting et al., 2007, p. 705).

Researchers speculate that fMRI is likely to be the future of truth (or lie) detection in legal proceedings, and is superior to the polygraph[15] in accuracy and reliability (Kittay, 2007). Applebaum (2007) explains that lie detection with fMRI is based on the assumption that lying activates

[14] Some argue that the development of science sometimes depends on diverse modifications of its methods. A universal method is potentially detrimental especially if the method retains weaknesses that would otherwise be corrected in an alternative scientific approach to research methodology (Chalmers, 1999, p. 161-162).
[15] A polygraph is an instrument used to record physiological data and changes in the sympathetic nervous system. The examiner records the responses and determines whether the examinee is lying based on bodily reactions.

brain areas associated with executive functioning. Higher cognitive processes would be necessary to suppress a truthful response and plan for deceit. Defendants being scanned by authorities would exhibit abnormally high levels of brain activity in frontal areas when lying to investigators. This is one way in which fMRI would be considered useful.

However, Appelbaum (2007) names seven limitations that exist with fMRI lie detection: (1) There is no scientific consensus on the neural basis of deception; (2) fMRI studies use group norms to define activation levels in test participants, but these norms may not apply to individuals; (3) fMRI studies of lie detection are fairly recent and lack substantial data; (4) false-positive and false-negative rates are not currently available, so an accuracy assessment is not possible; (5) external validity is yet to be established – laboratory use and findings may differ from, or may not apply to, courtroom use; (6) there are confounded variables like attention and emotion that would potentially affect the results of fMRI lie-detection; and (7) even if a physiological basis for lying and deception is defined, a measurement would have to be devised to differentiate between absolute truth and partial truth, or absolute lies and partial lies (p. 461).

In theory, fMRI is a potential psychological profiling tool. Arrigo (2007) states that fMRI can be used for "interrogating suspects of criminal wrongdoing or extracting information from actual violations of the law" (p. 462). In this regard, fMRI is inadequate, and such a method of use raises important questions concerning humanitarian ethics and constitutional law.[16] Arrigo (2007) contends that fMRI "represents a form of coercion" and a violation of privacy rights (p. 463-466).[17] With further research and development, it is only a matter of time before fMRI lie detection is introduced in the courts to pick up where the polygraph left off. Arrigo (2007) speculates that interactions between criminal justice and neuroscience will set a legal foundation for biological laws to determine the criminal culpability of the defendant (p. 474).

As of yet, "there are no cases to date admitting fMRI evidence as proof of deception or truth-telling" (Moriarty, 2008, p. 46). Furthermore, as one legal expert notes, "it is not clear…how courts will react to a scientifically valid lie detector" (Bellin, 2008, p. 711). Mosteller (2006) asserts that "if there were a truly accurate lie detection technology, over time it would have a substantial impact both on how criminal cases are handled before trial and on how they are tried" (p. 539). Truth or lie detection with neuroimaging is still a process in development, and a subject of intense interest in neuroscience and law (Mosteller, 2006). There have been few cases involving fMRI evidence, and like with any other neuroimaging technique, "there may be real concerns about the reliability and relevance of fMRI based expert testimony" in legal proceedings (Feigenson, 2006, p. 251).

The following case is concerned with the relationship between violence and cognition, rather than information extraction or lie detection. In *Entertainment Software Association [ESA] v. Blagojevich* (2005), the plaintiff sued the state (represented by the defendant, Blagojevich, Governor of the state of Illinois) and attempted to enjoin, or forbid, the enforcement of a state law designed to prohibit the promotion of violent or explicit video games to minors without parental consent. The state wanted to regulate the distribution of games because they believed exposure to violent media causes a lack of behavioral inhibition in minors.

The defendant used an fMRI study (Kronenberger et al., 2005) to justify anti-video game legislation. The defendant referred to this study as evidence demonstrating that exposure to violent media has a negative effect on child behavior and brain function. Using fMRI, the Kronenberger et al. (2005) study found reduced frontal lobe activity in subjects with disruptive behavior disorder in comparison to controls; a relationship between violent media exposure and changes in brain functioning was also found in both experimental subjects and controls. The plaintiff consulted Dr. H.C. Nusbaum, a cognitive psychologist and expert witness, who challenged the testimony of Dr. W.G. Kronenberger in court.

In his review of the *ESA v. Blagojevich* (2005) case, Feigenson highlights some weaknesses which Dr. H.C. Nusbaum noted from Dr. W.G. Kronenberger's testimony and fMRI study (Feigenson, 2006). First, the experimental design was fundamentally flawed: participants only simulated video-game playing while being scanned, so alternations in brain wave activity can not be associated with the actual playing of violent games but only a mere simulation. Second, reduced frontal activity does not necessarily indicate susceptibility to violent or aggressive behavior, because other regions of the brain are also involved in aggression. Kronenberger testified that reduced activity in the frontal lobe indicates lack of impulse control. Nusbaum disagreed, and testified that the frontal lobe has various functions; a reduction in frontal activity can be attributed to other mental and physical processes besides exposure to violent media. Thus, a causal relationship between negative behavior and altered brain activity can not be drawn.

The court found that the Kronenberger et al. (2005) study was invalid, and could not support the defendant's

[16] Suggested readings are The Fourth and Fifth Amendments of the United States Constitution which further elaborate on the legal implications of privacy and testimony that relate to fMRI in the courtroom (Pettit, 2007).

[17] Arrigo (2007, p. 464-466) applies anti-modernist and sociological theories of French philosopher, Michel Foucault, to explain the diametric struggle between social authority and individual privacy. The implication for neuroimaging is that it contributes to the former, while undermining the latter. In this context, science is not a tool for justice, but merely a biosocial commodity of power and enforcement, used by legal and psychiatric authorities to deconstruct and normalize the individual. From this perspective, neuroimaging represents the most pervasive force against humanity, exerting itself onto one of the most intimate parts of the human experience: thoughts.

claim that violent media exposure causes negative behavior, thereby ruling in favor of the Plaintiff's motion to enjoin the law prohibiting the sale of violent games to minors (*ESA v. Blagojevich*, 2005). Further developments in functional imaging techniques are necessary before implementing this technology in a legal context. In this case, fMRI evidence was admissible, but unreliable.

In summary of the previous cases, it seems that neuroimaging methods have a limited degree of admissibility and reliability in the court, despite their extensive use in the clinic. The applicability of structural and functional neuroimaging depends on the type of case being presented. From the examples provided, MRI is able to confirm head injury (e.g. *State of Delaware v. Vandemark*, 2004), but is unable to establish causation between injury and stroke (e.g. *Siharath v. Sandoz Pharms. Corp.*, 2001) or to determine susceptibility to criminal behavior (e.g. *United States v. Sandoval-Mendoza*, 2006); CT is certainly capable of defining mental capacity to some extent (e.g. *In re Estate of Meyer*, 2001), but unable to prove insanity, although surprisingly influential in at least one case (e.g. *United States v. Hinckley*, 1982); SPECT can help determine competency to stand trial (e.g. *United States v. Kasim*, 2008), but is unable to establish causation between injury and affect (e.g., *Lanter v. Kentucky State Police*, 2005), or the exact cause of organic brain problems (e.g. *Boyd v. Bell*, 2005); PET can detect traumatic brain injuries or brain abnormalities (e.g. *Penney v. Praxair*, Inc., 1997), but is unable to diagnose neurodegenerative diseases like Alzheimer's (e.g. *United States v. Gigante*, 1997) or electric shock injuries (e.g. *McCormack v. Capital Electric*, 2005)**;** and finally, fMRI is unable to establish a connection between exposure to violence and aggressive behavior (e.g., *ESA v. Blagojevich*, 2005), but is quite possibly the future of lie detection technology.

Structural and Functional Neuroimaging II: A Comparison of Methods

Structural and functional neuroimaging have significantly contributed to legal decision-making, providing key information about anatomy and behavior in neurolaw cases. However, there are considerable limitations to the applicability of neuroimaging methods; controversy remains as to whether such techniques are being used according to their capability. Researchers maintain that brain scans are only capable of providing anatomical, rather than behavioral information. "At the present time, imaging technology reveals the anatomical structure of and blood flow patterns in the brain but cannot directly provide information about behavior" (Illes et al., 2009, p. 108). Moreover, in U.S. courts, behavioral inferences from neuroimages are likely to be excluded as evidence (Moriarty, 2008).

Nevertheless, neuroimaging modalities are used in a variety of legal contexts (Moriarty, 2008). Structural imaging, like MRI and CT scans, have been used in the courts as proof of physical or mental illness (e.g., *In re Care and Protection of Sharlene*, 2006; *In re estate of Meyer*, 2001; *State of Nebraska v. Kuehn*, 2007; Moriarty, 2008, p. 40-41); functional imaging, like PET and SPECT scans, has been used in civil cases (e.g., *Blodgett-McDeavitt v. University of Nebraska*, 2004; *Green v. K-Mart Corp.*, 2004; *Lanter v. Kentucky State Police*, 2005), criminal cases (e.g., *People v. Goldstein*, 2004; *People v. Williams*, 2004; *State of Washington v. Marshall*, 2001; *United States v. Mezvinsky*, 2002) and in the penalty phase of capital cases (e.g., *Hoskins v. State of Florida*, 1999; *State of Tennessee v. Reid*, 2006).

Regardless of why the evidence is being submitted, litigants should carefully consider the reliability of neuroimaging prior to admission. As one researcher notes, "[h]istorically, neurological data have been given great evidentiary weight, often before the scientific basis warranted this degree of confidence" (Baskin et al. 2007, p. 258). Therefore, the evidentiary value of neuroimaging should be equally weighed in the scales of law and science to determine admissibility. Structural imaging seems to be more admissible and reliable than the functional type, because it has been used and tested for a greater period of time. However, this should not negate the potential of functional imaging. Although structural imaging has a more extensive history in the legal system, functional imaging will certainly compete with its technological predecessor, both in terms of applicability and accuracy. While some emphasize the reliability of structural imaging (Pettit, 2007), others emphasize the potential of functional imaging (Mobbs et al., 2007). Generally, U.S. courts have questioned the reliability of PET, SPECT and fMRI in contrast with MRI and CT, but researchers will continue to refine both structural and functional techniques for clinical and legal use.

Conclusion: Interdisciplinary Perspectives on Neuroscience and Law

The evidentiary value of neuroimaging evidence depends on the validity of its use and its relevance to the case. Brain imaging is more applicable in some court cases than others. In conclusion, it seems that neuroimaging evidence is generally admissible, but usually unreliable when it lacks a scientifically valid method. Clinical applications in neuroimaging are more likely to be admitted and deemed reliable as evidence. Yet, the admissibility of unreliable evidence is a reality that compromises legal integrity and scientific credibility. There is still medical-legal debate on the extent to which neuroimaging and law should interact. Most scientists and lawyers believe that neuroimaging can provide important details regarding the brain in both clinical and courtroom settings, but, there is no legal or scientific consensus on which neuroimaging technology should be admissible or reliable – this will remain an open question for some time.

The evidentiary value of neuroimaging depends on its scientific reliability and legal admissibility. Technology will increase the former, and consequently, improve the latter. With all likelihood, science will continue to advance, whereas law will continue to adapt. Both neuroscientists and lawyers should maintain their current dialogue on the legal implications of neuroscience and law. The integration of both fields does not necessarily imply a compromise in either: "Developments in neuroscience may well have substantial impact on how the law views people and behavior, but the legal system should be able to assimilate and use even revolutionary science [such as neuroimaging] without upending its own fundamental structure" (Garland, 2004, p. 5).

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Author Note

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