Brain Injury Litigation Update

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John A Sundahl, Discovery in Traumatic Brain Injury Cases 27 Wyoming Lawyer 16 (October, 2004)[1]

Claims of traumatic brain injury create unique problems for both plaintiff and defense attorneys. The purpose of this article is to identify various discovery techniques to assist in obtaining the necessary information to evaluate such claims.

Compilation of Information

The nature of the written discovery for claims of traumatic brain injury is far reaching and generally not time limited. Attorneys must obtain information regarding pre- and post-accident functioning. A critical aspect of discovery is a thorough search of medical records, psychiatric/psychological/counseling records, test sources and academic records. This discovery may assist in showing behavioral and psychological features that explain the plaintiff's then-current symptoms. The categories of records to request include the following:

1. School records, including IQ testing, grades, counseling and learning disability issues;

2. Medical records since childhood;

3. Records of any counseling or psychological treatment;

4. Information concerning the family history (to determine whether there are familial explanations for the symptoms);

5. Information concerning contact sports;

6. Information on prior accidents, car accidents, workers' compensation claims, and history of being knocked unconscious;

7. Personnel file from places of employment both before and after the accident, including the names of all supervisors, aptitude testing, performance evaluations, and records of discipline;

8. Military records; and

9. X-ray, CT, MRI, brain scan, or other diagnostic or radiographic studies.

Plaintiffs often undergo neuropsychological testing in support of expert testimony. It is crucial to obtain all raw test information, the actual tests used (including the form employed and the particular edition), test questions, scoring, and the actual test answers (as opposed to a summary or total scores). If the raw test results were adjusted according to age or education, obtain those adjustments

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and the reasons for them. Identify the norms (i.e. standards for what is “normal”) that were used, the test protocol (to determine how the testing is to be administered), and identify all validity scales or internal measures used to evaluate the straight-forwardness or cooperation of the plaintiff.

The raw test scores, as adjusted, are compared with normative data to determine whether the plaintiff scores within the published norms. Do not accept the neuropsychologist's claim that the test result is within the range of normal, borderline or abnormal, without being able to evaluate whether the conclusions of the test administrator are accurate. Unfortunately, tests are sometimes scored incorrectly and, may be read as abnormal when, in truth, they are within the normal range. It is important to obtain the documents that reflect normative metrics, percentiles and standard deviations for each test. Also, be aware that multiple norms may be available for the same test, and classification of the results as normal or abnormal may rest on a biased decision on which norms to use.

Obtain all intake information and patient questionnaires that were completed either by an interview with the plaintiff, or by the plaintiff himself. Obtain the hand written notes of the test administrators and the neuropsychologist. These notes will often provide insight into their approach and the history of the claimed injury. Obtain all billing records and diagnostic codes. Obtain the resumes for the neuropsychologist and any person who performed the tests on the plaintiff. Neuropsychologists often use computerized scoring profiles for tests such as MMPI - 2. Your discovery should request any computerized ***17** profiles or scoring. Finally, obtain a copy of the entire file that relates to the plaintiff, including any reports to the plaintiff's attorney, the results of the neuropsychologist's interview, the raw notes of the neuropsychologist or other test administrator, and the administrative instructions for the tests administered, the actual test booklets used and notes from interview sessions.

Upon receipt of the foregoing information, it is imperative to retain the services of a consultant to help you understand what you have been provided. In addition, the lawyer must carefully review all raw data.

Testing Results and Interpretation

Unfortunately for both plaintiff and defendant, it is rare to have pre-accident baseline neuropsychological testing. As a result, neuropsychologists use other evidence of pre-accident functioning as a surrogate. For example, neuropsychologists frequently conduct IQ testing and compare the post-accident testing with the scores previously received. The neuropsychologists then draw conclusions about whether there has been a decline in intelligence functioning.

Interpretation of neuropsychological tests can be and often is highly subjective. Almost all “normal” individuals will test in the abnormal range on at least some neuropsychological tests. Neuropsychological testing overlaps. A person might test in the borderline or impaired range on one test, but may test within the range of normal on another test that measures the same functions. It is

important to understand the purpose and scope of each of the tests administered in order to develop this relationship.

Assuming the neuropsychological tests were properly scored and the plaintiff's functioning is determined to be below the range of pre-accident functioning, an additional consideration remains. Neuropsychological testing, at best, measures a snap-shot in time that can be heavily influenced by what is happening in the plaintiff's life when the tests are administered. To the extent that neuropsychological testing is able to distinguish abnormal results from normal results, determining the cause of the cognitive impairment or when it occurred is often speculative. Attorneys should explore all possible causes, including depression, anxiety, alcoholism, drug use, a history of psychological disorder, physical illness, stress, fatigue, or lack of effort, all of which can lower test scores.

Potential Discovery Disputes

Neuropsychologists occasionally object to producing the raw test data arguing that the tests, test materials, and test results are barred from discovery. They sometimes argue that the data may only be delivered to a trained professional, to prevent being misinterpreted by an unqualified lawyer. They will claim that neuropsychologists are barred by their code of ethics from delivering such information to lawyers. Most neuropsychologists recognize however, that the raw test information adds validity to their conclusions regarding demonstrated cognitive impairment, and will voluntarily deliver the requested materials. The plaintiff clearly has the right to that information, and has waived his/her claims of any privilege with the filing of the lawsuit. *Wardell v. McMillan*, 844 P.2d 1052, at 1065-66 (Wyo. 1992). It may be necessary to obtain a court order for the production of the materials. Courts generally require disclosure of records that are pertinent to the claims of mental or cognitive impairment that was allegedly caused by an accident, and view with skepticism claims by neuropsychologists that only they are capable of using and interpreting the data. Pursuant to Rule 26, raw test materials and data are clearly relevant to the issue of plaintiff's level of functioning and claims of traumatic brain injury. In *State of Missouri ex rel Svejda v. Circuit Court*, 88 S.W.3rd 531 (Mo. App. 2002), the court rejected the claim that production of raw neurological test data would violate the ethical principles of psychologists, and that the ethical rules allow a psychologist to disclose raw data only to persons qualified to use and interpret the data. The psychologist offered to provide the data to any qualified expert named by the defendant. After noting that the psychologist - patient privilege afforded in Missouri was waived by placing her mental condition at issue, the court stated:

We do not find any exception to any Missouri's broad discovery rules that permits a psychologist to interpose his profession's ethical principles to bar otherwise legitimate discovery. On the contrary, Rule 56.01(b)(1) plainly says that a party 'may obtain discovery regarding *any* matter, not privileged, which is relevant to the subject matter involved in the pending action ...' (emphasis supplied). A psychologist such as Dr. Cowan should not be able to unilaterally interpret his professional rules and then decide that they bar discovery under this state's legal system. While we acknowledge and

appreciate the ethical principles governing Dr. Cowan's work, those principles must yield to Missouri's legal rules governing discovery of evidence.

Litigants run substantial risks if a neuropsychologist refuses to disclose all relevant data and materials. In *Anduszewski v. Cantello*, 247 A.D.2d 876, 668 N.Y.S.2d 297 (A.D.N.Y. 1998), the court ordered production of the treating psychologist's complete files, including tests administered to plaintiff, along with tests books, instruction, manuals, raw test data, questions, answers, profiles and means of scoring the test. Plaintiff produced some but not all requested materials. The court precluded the psychologists from testifying and precluded the plaintiff from using their files at trial, noting on page 298:

> The fact that plaintiff's doctors were uncooperative in producing reports does not relieve plaintiff of her burden of providing defendant with the documentation necessary to prepare a defense ***.

See also *Drago v. Tishman Construction Corp.*, 777 N.Y.S.2d 889, 893 (N.Y. 2004).

Conclusion

Detailed discovery of all matters that effect the level of functioning, both before and after an accident, are of utmost importance in order to properly evaluate the propriety of brain injury claims. Unfortunately, there are no shortcuts to proper preparation of this very complicated subject matter.

Footnotes

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Bruce H. Stern, Rethink Cross-Exams in Traumatic Brain Injury Cases 48 Trial 16 (April, 2012)[2]

***17** Mild traumatic brain injuries don't have telltale signs, which is why the defense is likely to call a medical expert to testify that there is no objective evidence to support your client's injury. Don't try to discredit this witness; instead, get that expert to prove your case for you. Here's how.

IF you've ever represented a client with a mild traumatic brain injury, you know what it's like at trial to have to sit patiently while the defense leads its medical expert witness through his or her testimony, selectively presenting your client's history. The expert may emphasize the lack of a direct blow to your client's head, no loss of consciousness, and post-injury medical test results within normal ranges--basically arguing that there is no objective evidence to support your client's

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subjective complaints. You want to scream when he or she testifies that even if your client did sustain a minor concussion, everyone recovers within six to eight weeks.

Then the judge turns to you and says, “Your witness, counsel.” The urge is to jump up and attack--to eviscerate opposing counsel's medical expert.

But consider another approach: Make the defense's medical expert witness your own. It seems counterintuitive to one of the purposes of cross-examination, which is to discredit the testimony of the opposing counsel's witness, but by not putting the witness on the defensive, he or she may prove your case for you.

Trial lawyer Carl Bettinger cautions that in cross-examination, “You need not ‘destroy’ every witness by discrediting everything one says or showing that each expert is a hired gun.”[1] Trial consultant David Ball says, “Most often the defense case pushes your harms case out of the spotlight. Don't let it. Keep the jurors thinking about harm at every opportunity.”[2] Using this advice ***18** as a springboard, the following lines of questioning will get the defense's medical expert to bolster your client's case during cross-examination.

But this cross-examination does not start when the trial judge turns to you and says, “Your witness.” It starts when you are preparing for trial. You must familiarize yourself with the scientific literature on traumatic brain injury, including peer-reviewed journals such as the *Journal of Head Trauma Rehabilitation*, *Brain Injury*, and the *Archives of Clinical Neuropsychology*.[3]

Investigate which aspects of traumatic brain injuries are not open to interpretation. When medical experts are on the stand, they are inclined to provide their medical opinions. Instead, you'll want to get them to acknowledge facts. It's unlikely for experts to disagree with you when asked to acknowledge the objective scientific evidence. However, solicit their medical opinions and you'll find very little agreement.

On the Stand

Start with obtaining concessions from opposing counsel's medical expert that help undermine the defense's theme but, more important, debunk any myths about traumatic brain injuries.[4] For example, ask the witness:

• Would you agree that a person could sustain a brain injury--for example, in a car crash--even if that person does not strike his or her head? Perhaps simply due to the stop-and-go forces that occur in a rear-end collision?

• Does a person have to lose consciousness to sustain a brain injury?

• Can you rule out or reject the diagnosis of traumatic brain injury simply because a person did not lose consciousness?

• Does a normal neurological examination rule out the diagnosis of traumatic brain injury? That is, can a person with a traumatic brain injury still have normal results from a neurological examination?

• Do you agree that MRI and CT scans are often normal when performed on a patient who has suffered a mild traumatic brain injury?

• Is it true that MRI and CT scans are often not sensitive enough to detect brain damage?

• Is it true that the reason a doctor orders an MRI or CT scan is to look for a brain bleed?

• Isn't it true that emergency department physicians often fail to diagnose traumatic brain injury even when the patient has sustained such an injury?[5]

• A person who has sustained a traumatic brain injury may experience the symptoms for a long time, correct?

• Is it true that some people with traumatic brain injuries never fully recover?

Define the Injury

Using an accepted definition of mild traumatic brain injury will force the defense's medical expert to acknowledge that your client sustained this type of injury. One of the most widely accepted definitions, developed by the American Congress of Rehabilitation Medicine, states: "[P]atients with mild traumatic brain injury can exhibit persistent emotional, cognitive, behavioral, and physical symptoms, alone or in combination, which may produce a functional disability."[6]

First, get the defense's medical expert to agree that this definition is widely accepted and relied on by experts in the field to diagnose mild traumatic brain injury. And get him or her to agree to the definition itself. Then connect each of your client's symptoms to the definition. Symptoms fall under one of the following categories.

• ***Physical symptoms*** (nausea, vomiting, dizziness, headache, blurred vision, sleep disturbance, quickness to fatigue, lethargy, or other sensory loss) that cannot be attributed to other causes.

• ***Cognitive deficits*** (involving attention, concentration, perception, memory, speech/language, or executive functions) that cannot be completely accounted for by emotional state or other causes.

• ***Behavioral changes*** or alterations in the degree of emotional responsiveness (irritability, quickness to anger, disinhibition, or emotional lability) that cannot be accounted for by a psychological reaction to physical or emotional stress or other causes.

***19** This is a lot of information for jurors to grasp, so a visual aid may help them understand the concepts. I create an enlarged chart that lists each symptom under these three categories. Then, I go

through the chart with the defense's expert, checking off each of my client's symptoms to demonstrate that he or she meets the definition.[7]

Get the defense's expert to acknowledge that your client experienced these symptoms following the injury and to acknowledge how these symptoms affect your client's activities of daily living. For example, ask him or her:

• My client has complained of problems of attention and concentration since the injury and underwent neuropsychological testing. The results demonstrated problems with attention and concentration. Is neuropsychological testing objective?

• Problems with attention and concentration are cognitive deficits consistent with mild traumatic brain injury, correct?

• Would you agree that the symptoms that my client has complained about meet the criteria in this scientifically accepted definition?
• Would you agree that people with mild traumatic brain injury who have physical, cognitive, and behavioral symptoms experience problems in activities of daily living?

• Can they also experience problems at work?

Establish a Baseline

Even when you can get opposing counsel's medical expert to acknowledge that your client has trouble with activities of daily living, you still need to tie your client's problems to the specific trauma that is the basis of the lawsuit. The defense will try to attribute your client's problems to some prior injury or illness even if unable to specifically identify it. Use lay witnesses, such as family and longtime friends or coworkers, to counter this defense. Their testimony will go a long way in refuting the defense's allegations that your client's symptoms, impairments, or disabilities pre-dated the traumatic incident.

To establish a patient's overall level of functioning in activities of daily living, psychiatrists use a tool called the Global Assessment of Functioning (GAF) Scale.[8] It identifies the patient's functioning on a scale of 0 to 100. Patients with a rating from 91 to 100 are “superior functioning”; essentially, they are without symptoms. A rating of 41 to 50 is for symptoms that lead to antisocial behavior or social dysfunction. Patients who score at the bottom of the scale, such as between 1 and 10, pose a threat to themselves or others, cannot maintain their personal hygiene, or are suicidal. These patients are mostly dysfunctional on a daily basis and in need of immediate help.

Although the GAF Scale is for evaluating a patient's level of functioning at the time of administration, a psychiatrist can also use it to evaluate your client's functioning prior to the injury. Establishing a normal pre-injury baseline can help defeat the defense's prior injury or preexisting illness defense.

Ask the expert if he or she assessed your client's level of functioning using the GAF Scale. The answer is likely to be “no,” but if he or she answers “yes,” ask for your client's score. Also ask if he or she assessed your client's level of functioning within a day or week of the injury so that a pre-injury baseline can be established.

If the defense's medical expert did not do assessment, make him or her do it on the stand. Say to him or her:

• Let's determine that baseline now. Do you have any evidence that my client was having any problems at home or work?

• In preparing your report, did you interview any of my client's family, friends, or any of the people who work with him or her?

• Were you provided with the names and statements of my client's family, friends, or people who work with him or her?

• Did any of those statements suggest that my client was experiencing any problems?

• Returning to the chart that defines mild traumatic brain injury, was there any evidence that my client was experiencing any of these problems before the crash?

• Would you agree that my client's level of functioning shortly before this crash would put him or her in the 90-100 range, which is normal to superior?

Your client's case isn't weakened if he or she has a preexisting psychiatric condition, such as a history of depression or anxiety, or drug abuse or dependence. People with a history of psychiatric conditions are at higher risk for poorer outcomes following mild traumatic brain injury,[9] which can explain why your client did not fully recover.

If your client has a history of a psychiatric condition, ask the defense's medical ***20** expert the following questions:

• You testified that my client fully recovered from any injury that he or she might have sustained. Is that based on population statistics that 85 to 90 percent of people with mild traumatic brain injuries fully recover within the first 6 months?

• Were you provided with my client's medical records?

• Does my client have a history of a psychiatric condition?

• Would you agree that people who have a history of depression or anxiety, for example, have worse outcomes following an injury?

• Is a history of depression a risk factor for a poor outcome following a traumatic brain injury?

• Would a person such as my client, who has a history of a psychiatric condition, be expected to have a worse outcome than someone with no history?

• Could my client's history explain why he or she did not fully recover?

The defense will likely try to undermine your client's mild traumatic brain injury case by calling to the stand a medical expert witness who can obfuscate the facts. Cross-examination enables you to use the defense's own expert to tell your client's story. It is an opportunity to debunk the myths of mild traumatic brain injury, to establish a pre-injury baseline, and to demonstrate that your client's symptoms meet the definition of traumatic brain injury. While the natural inclination may be to attack, think again. Don't let a golden opportunity to enhance your client's damages through cross-examination go to waste.

MORE ON TRAUMATIC BRAIN INJURY

Visit the Web pages below for additional information.

AAJ SECTION

Motor Vehicle Collision, Highway, and Premises Liability

www.justice.org/sections

AAJ LITIGATION GROUP

Traumatic Brain Injury

www.justice.org/litgroups

LITIGATION PACKET

“Traumatic Brain Injury”

www.justice.org/exchange

AAJ EDUCATION PROGRAM

“Specialized Track: Traumatic Brain Injury Litigation” (Convention track # 402-P07)

Footnotes

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1 Carl Bettinger, *Twelve Heroes, One Voice: Guiding Jurors to Courageous Verdicts* 128 (Tr. Guides 2011).

2 David Ball, *David Ball on Damages: The Essential Update: A Plaintiff's Attorney's Guide for Personal Injury and Wrongful Death Cases*, 189 (2d ed., Natl. Inst. Tr. Advoc. 2005).

3 *See also* Brain Trauma Found, www.braintrauma.org; Ctrs. for Disease Control & Prevention. *Injury Prevention and Control: Traumatic Brain Injury*, www.cdc.gov/traumnticbraininjury; Natl. Insts. of Health, Natl. Inst. of Neurological Disorders & Stroke, *NINDS Traumatic Brain Injury Information Page*, www.ninds.nih.gov/disorders/tbi/tbi.htm.

4 Ten common myths are: mild traumatic brain injury is not serious; loss of consciousness is necessary to sustain a traumatic brain injury; one must strike one's head to suffer a traumatic brain injury; negative MRIs, CT scans and electroencephalograms rule out brain injury; the effects of traumatic brain injury are immediate; neuropsychological testing is subjective; cognitive impairments on neuropsychological testing must fit a predictable pattern; children with traumatic brain injury all get better; mild traumatic brain injury is not permanent; and mild traumatic brain injury is not disabling. Bruce H. Stern & Jeffrey Brown, *Litigating Brain Injuries*, ch. 2 (AAJ Press 2011).

5 Janet M. Powell et al., Accuracy *of Mild Traumatic Brain Injury Diagnosis*, 89 Archives Physical Med: & Rehab. 1550 (Aug. 2008). The study found that emergency department physicians missed the diagnosis of brain injury in 56 percent of cases.

6 Mild Traumatic Brain Injury Committee of the Head Injury Interdisciplinary Special Interest Group of the American Congress of Rehabilitation Medicine, *Definition of Mild Traumatic Brain Injury*, 8 J. Head Trauma Rehab. 86. 87 (1993); *see also* David K. Menon et al., *Position Statement: Definition of Traumatic Brain Injury*, 91 Archives Physical Med. & Rehab. 16.17 (Nov. 2010).

7 *See also* Ctrs. for Disease Control & Prevention, *Facts About Concussion and Brain Injury: Where To Get Help* 1-2, 4-7, www.cdc.gov/concussion/pdf/Facts_about_Concussion_TBI-a.pdf; *Heads Up: Facts for Physicians About Mild Traumatic Brain Injury (MTBI)*, www.cdc.gov/Ncipc/pub-res/tbi_toolkit/physicians/mtbi/mtbi.pdf.

8 *Diagnostic and Statistical Manual of Mental Disorders* 34 (4th ed. text rev., Am. Psychiatric Assn. 2000).

9 *See* George Mooney & John Speed, *The Association Between Mild Traumatic Brain Injury and Psychiatric Conditions*, 15 Brain Injury 865 (Jan. 2001); Jeffrey M. Rogers & Christina A. Read, *Psychiatric Comorbidity Following Traumatic Brain Injury*, 21 Brain Injury 1321 (2007).

Samuel D. Hodge and Shilpa Kadoo, A Heads-Up on Traumatic Brain Injury in Sports 17 Journal of Health Care Law and Police 155 (2014)[3]

"You are supposed to be tough. You are supposed to play through pain. You are not supposed to cry. We are taught that early on in the game as kids. . . . It's like the gladiator. People want to see the big hits. They wind up on Sports Center. And as a player, you don't want to admit you are injured."[1]

-Eric Dickerson

Hall of Fame Running Back

I. Introduction

Football took away the ability of young Zackery Lystedt to live a normal life, but he continues to change the face of sports.[2] During a game, he received a severe blow to the head and fell to the ground in pain.[3] After a brief respite, Zackery returned to the contest and received a second hit to his cranium causing a brain ***156** hemorrhage.[4] He was "in and out" of a coma for several months and physicians questioned whether he would survive.[5]

Zackery's story did not end with this tragic event but became the motivation for a change in the way head injuries involving student athletes are managed.[6] At the time, this thirteen-year-old lived in Washington but that state had no laws pertaining to concussions.[7] There was a lack of awareness about the consequences and risks associated with "return to play" following this form of traumatic brain injury.[8] Because of the determination of a number of people impressed with Zackery's plight, Washington became the first state to enact the Lystedt Law.[9] This model legislation requires mandatory education for athletes, parents, and coaches concerning the dangers associated with blows to the head.[10] If an athlete is suspected of having a concussion, that individual may not resume play until a licensed health care professional clears the athlete to return.[11]

Because of Zackery's case,[12] and the highly publicized suits by former professional football players against the National Football League (NFL),[13] the public has gained a much better appreciation of the health issues associated with brain injuries, including the greater propensity for cognitive slowing, increased ***157** propensity for re-injury, early onset of Alzheimer's disease, second impact

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3 Copyright (c) 2014 by Samuel D. Hodge, Jr. & Shilpa Kadoo.

syndrome, and chronic traumatic encephalopathy.[14] This awareness has also prompted state legislatures as well as governing sports organizations to establish rules and policy changes focused on the increased safety of athletes, along with standardized medical care.[15]

II. Traumatic Brain Injuries and Concussions Defined

A traumatic brain injury (TBI) does not have a single agreed upon definition. Nevertheless, it is a major health problem in the United States, resulting from trauma to the head from such things as a blow or a jolt.[16] It can also be caused by a penetrating head wound that interferes with brain function.[17] As noted in Bennett v. Richmond,[18] a TBI happens in the course of a closed head injury, and its severity can vary from mild to severe.[19] According to the National Collegiate Athletic Association's (NCAA's) Sports Medicine Handbook, a mild TBI involves "a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces."[20] On the other hand, a severe head injury is one in which person has lost consciousness for at least for six hours, or the individual suffers post-traumatic amnesia for twenty-four hours or more.[21]

A related form of brain trauma is a concussion.[22] This term was defined in Pham v. Wal-Mart Stores, Inc. as a mild traumatic brain injury, which usually occurs after a blow to the head.[23] A concussion has also been labeled an altered ***158** disturbance of brain function resulting from trauma.[24] As these varying definitions point out, physicians and sports medicine researchers do not agree on one exact definition of this condition.[25] Nevertheless, the experts agree that a concussion is an injury to the brain,[26] and this type of insult can result from any form of recreational activity, sports or trauma.[27] Therefore, sports enthusiasts, parents, and coaches need to become familiar with the symptoms of this form of brain injury and how to proceed if such trauma happens.[28]

Concussions are often referred to as mild TBIs.[29] It is important to note, however, that concussions may be considered mild TBIs, but not all mild TBIs are concussions.[30] These types of brain injuries are usually self-limited in length.[31] The American Academy of Neurology labeled this form of injury as a "trauma-induced alteration in mental status that may or may not involve loss of consciousness."[32] On the other hand, the American Medical Society for Sports Medicine explains a concussion as "a subset of mild traumatic brain injury (MTBI) which is generally self-limited and at the less-severe end of the brain injury spectrum."[33]

Anatomically, the brain is a soft structure that has the consistency of gelatin, and a TBI takes place when some form of energy is transmitted to this delicate structure.[34] This energy can be caused by diverse factors, from a whiplash-type injury to a cranium-fractured skull.[35] The outcome of the insult is a mixture of metabolic, ionic, and functional changes resulting in an axonal injury.[36] Symptoms ***159** of a concussion include loss of consciousness, headache, dizziness and vertigo, lack of awareness, nausea, vomiting, mental dysfunction, sleep deprivation, and tinnitus.[37]

Both TBIs and concussions have the potential to have long-term neuropathological, neurological, and neurobehavioral consequences.[38] Yet concussions are transient in nature, typically emphasized

as having more of a functional rather than structural impact.[39] Loss of consciousness may or may not be present,[40] a structural injury may occur whether a loss of consciousness takes place at the time of insult.[41]

III. An Overview of the Problem

Sports play a large role in society.[42] Statistically, approximately 30 million children and young adults engage in some type of structured sports events annually.[43] In just this population alone, more than 3.5 million sport-related injuries occur annually.[44] Historically, concussions have not been given the attention that they deserve by the sports and medical community.[45] Generally, ***160** sports enthusiasts who incur a mild concussion return to the game in short order as though nothing had happened.[46] After all, it is a common mantra shared by many athletes that they should push themselves beyond their normal endurances.[47] This includes playing with a variety of injuries.[48] Additionally, athletes have an innate desire to help their team win, which often takes precedence over their individual safety.[49] This causes athletes to underreport medical problems which may cause them to miss time from the game.[50] There may also be other reasons to excel in sports, such as scholarship opportunities or being drafted by the professionals.[51] Even some parents may be adverse to pulling their son or daughter from the event because of a desire for them to perform well.[52] Furthermore, physicians cannot attribute a specific number of incidents prior to the onset of permanent brain damage.[53]

A. Concussions

Concussions are a concern in contact sports, particularly in football and hockey,[54] because once an individual is cleared to play, the athletes return to an environment in which a head injury is likely to reoccur.[55] In fact, position and style of play seem to have a bearing on the chances of sustaining a concussion.[56] Concussions typically occur as the result of "player-to-player" contact.[57] Therefore, sports in which collisions are a regular part of the game will result in a higher percentage of athlete concussions.[58] For instance, the positions in ***161** professional football that have higher numbers of concussion include running backs, defensive backs, quarterbacks, and wide receivers.[59] In fact, a player in one of these positions has three times the risk of suffering concussions than a "lineman".[60] It is no wonder that college and professional football are discouraging runbacks on kickoffs since these athletes have four times the risk of sustaining concussions as athletes involved in a running or passing play.[61] Linebackers and running backs in high school are the most frequent players to suffer concussions at that level of competition.[62] There is also misconception that soccer is "safe" to play but these athletes suffer concussions as the result of player-to- player contact;[63] however, studies show that head injuries occur with some frequency in those sports in which the head is used as part of the game, such as in soccer.[64] It is difficult to implement safeguards to protect the head in this sport, such as requiring the wearing of head gear, because heading is an integral part of the game.[65] In fact, one study reported that that at least 60% of those playing soccer on the collegiate level developed symptoms compatible with a concussion during a season.[66] These statistics vividly demonstrate that head injuries in soccer are more common than most imagined.[67] An investigation performed by the U.S. Consumer Product Safety Commission reveals that 40% of concussions in

soccer result from head-to-player contact;[68] 12.6% are caused by the soccer ball striking the cranium;[69] 10.3% result from the player's head contacting the goal post, ground, or wall;[70]and 37% are not specified.[71]

The effects of concussions are revealed through neuropsychological tests, which measure concentration, problem solving, memory, visual-spatial, counting, ***162** and language skills.[72] Common results of concussions include deterioration of planning and memory, functions which are controlled by the brain's frontal and temporal lobes.[73] In addition, difficulty with memory of new material, attention, information processing speed, and integrative tasks contributing to executive function have also been shown to occur.[74] Studies show that soccer players who regularly head the ball experience more concussions, and are more likely to exhibit impaired performance on neuropsychological tests.[75] It is not surprising that those who sustain repeated concussions in football also report worse performances on neuropsychological testing than players with either a lone concussion or no concussion at all.[76]

Most concussions will become asymptomatic as long as the person is allowed the proper time to rest.[77] Players who return to sports prematurely following a concussion, however, are at an increased risk of developing permanent brain damage;[78] this risk is even greater in children because their brains are still developing.[79] This vulnerability is attributed to the difference in blood volume, blood-brain barrier, the brain's water content, amount of myelination, cerebral metabolic rate of glucose, and other metabolic factors.[80] A child's brain may also have less cognitive reserves than the adult brain.[81] This may explain the proven increase in time required to recovery from concussion seen in younger athletes.[82] Catastrophic consequences are more probable in younger athletes and are believed to be linked to the physiologic differences between younger and older brains.[83]

B. Second Impact Syndrome

While a single, isolated concussion will not typically cause death, repeated TBIs may cause cumulative damage to the brain, resulting in severely harmful effects.[84] For example, repeated concussions raise the probability that second ***163** impact syndrome,[85] a potentially fatal condition,[86] will occur.[87] As noted in Parker v. South Broadway Athletic Club,[88] this syndrome is demonstrated by a swift swelling of the brain.[89] After the initial concussion, brain cells that are not irreversibly destroyed remain vulnerable.[90] A second hit to the head while an athlete is still recovering from a prior concussion could lead to a fatal herniation of the brain.[91]

Returning to athletics too soon after sustaining second impact syndrome places the person at risk of permanent disability and even death.[92] Unfortunately, sideline personnel are not usually able to diagnose this injury during the event, thereby complicating the problem.[93] The only way to identify it is through magnetic resonance imaging (MRI) or computed tomography (CT) scans of the brain, yet these techniques may not even catch the subtle pathology associated with concussions.[94]

C. Chronic Traumatic Encephalopathy

Another harmful effect of repeated concussions and brain trauma is chronic traumatic encephalopathy (CTE).[95] This condition is closely associated with athletes who play contact sports such as boxing,[96] football, wrestling, and hockey.[97] ***164** CTE is a progressive neuro-degeneration clinically associated with memory disturbances, behavioral and personality changes, Alzheimer's disease, Parkinson's disease, and speech and gait abnormalities.[98] It eventually leads to dementia.[99] It is also characterized by numerous pathological conditions, including brain atrophy.[100] Further, CTE develops well before clinical manifestation of its symptoms.[101]

IV. Statistics

The scope of the problem with TBIs is far-reaching. According to the Centers for Disease Control and Prevention (CDC), more than 300,000 sports and recreation-related TBIs occur each year in the United States.[102] In fact, it is believed that at least 3.8 million concussions occur annually in this country during sports activities.[103] Unfortunately, 50% of these concussions go unreported.[104] Concussions in scholastic sports are also on the rise, after an eleven-year study ascertained that the number of concussions in scholastic sports increased 16.5% since 1997.[105]

This issue is one of great concern, particularly because it involves the brain, which is incapable of regeneration.[106] Brain injuries are also one of the leading causes of death in athletes and a source of catastrophic injury.[107]

V. Athletes' Stories

Numerous athletes are negatively affected by the lack of proper concussion management. One such person is Merril Hoge, a six-foot-two-inch tall, two hundred thirty-pound professional football player and current sports announcer.[108] This rugged athlete suffered a concussion during a preseason game while playing ***165** for the Chicago Bears.[109] He described the experience as feeling like an "earthquake . . . I got hit from at least three directions. I had a hard time getting up, but I stayed in for two more plays and walked to the sideline. I played the next week, even though I had trouble remembering plays."[110] Six weeks later, Hoge sustained another concussion during a game.[111] Ten days later, his symptoms remained unabated and he complained of headaches, dizziness, the inability to stay awake, and his memory was impaired.[112] In addition, he had trouble with his short-term memory, including remembering what he was speaking of from one minute to the next.[113] Later that year, Hoge retired from the NFL at the age of twenty-nine.[114]

Mike Webster, an all-pro center for the Pittsburgh Steelers and member of the NFL Hall of Fame, died at the age of fifty from a heart attack[115] Following the end of his football career, his life took an unfortunate turn, and he became unemployed because of his inability to complete the duties of his job.[116] Following his death, an autopsy confirmed the presence of CTE, most likely the result of repeated blows to his head during his football career.[117]

Terry Long, another former Pittsburgh Steelers player, committed suicide at forty-five years old.[118] Long displayed similar symptoms to those displayed by Mr. Webster, including depression and erratic behavior.[119] CTE was discovered at autopsy, a by-product of his football career and repeated blows to the head.[120]

These examples are not isolated. In 2005, the University of North Carolina's Center for the Study of Retired Athletes surveyed thousands of former NFL players on their experiences with concussions.[121] The survey determined that the players' risk of suffering from neurological illnesses such as Alzheimer's disease, depression, and cognitive impairment was proportionate to the number of concussions they suffered.[122] Players who suffered three concussions in their lifetime had more than three times the rate of clinically diagnosed depression and ***166** five times the rate of mild cognitive impairment, a precursor to Alzheimer's disease.[123]

VI. Post-Concussion Testing and Return to Play Guidelines

Recognition and management of concussions is a topic of much controversy.[124] Recent data suggested a trend of increased annual concussion rates over the past decade.[125] While the reason for this increase is unknown, much emphasis is placed on concussion education and awareness for players, coaches, physicians, and medical trainers.[126] Awareness, and an emphasis of the importance of following concussion guidelines, may play a key role in making a difference in the impact that concussions have had on the brain and person. A lack of awareness of the impact of concussions, however, may be the cause of athletes returning to play sooner than they should. For example, Troy Aikman, a former quarterback for the Dallas Cowboys, sustained eight detected concussions in his professional career.[127] Aikman's performance on the field declined, causing many to blame the concussions.[128] Though Aikman was treated by medical professionals, he was assured that the concussions would have no long-term effects, so he continued to play.[129] Theoretically, had Aikman been informed of the long-term effects of concussions, he may have chosen to take some time off to rest or perhaps even retire in order to prevent any future damage.

A. Concussion Guidelines

It is difficult to standardize the treatment of sports-related concussions because at least sixteen different concussion guidelines exist.[130] The guiding principle of the rules is that any athlete who remains symptom-free for seven days and fails to demonstrate any residual neurologic deficits may be allowed to return to athletics.[131]

***167** 1. American Academy of Neurology and Brain Injury Association Guidelines
The American Academy of Neurology (AAN) and the Brain Injury Association announced guidelines for concussion management in 1997.[132] The guidelines attempt to use neuroscience to create a model for concussion management,[133] and are based on a grading scale system that determines the severity of the concussion.[134] A “Grade 1” concussion is defined as one that is transient in nature, without any loss of consciousness, and where symptoms abate in under fifteen minutes.[135] This form of injury is hard to diagnose because the person does not lose consciousness

and has only temporary confusion.[136] In order to treat Grade 1 concussions, the AAN recommends removing the person from athletic participation, providing an immediate examination with follow-up care spaced out in five-minute intervals, and permitting a return to play only if post-concussive symptoms clear up within fifteen minutes.[137] If the athlete suffers a second Grade 1 concussion in the same game, he or she may not return to the event that day.[138]

A "Grade 2" concussion is transient confusion with no loss of consciousness and symptoms that last longer than fifteen minutes.[139] If the symptoms of a Grade 2 concussion last longer than one hour, medical observation is required.[140] A "Grade 3" concussion is any loss of consciousness, whether brief or prolonged.[141] This type of concussion is the most serious and the AAN guidelines recommend extensive treatment.[142]

In March of 2013, the AAN updated its sports management concussion guidelines. Among the most important recommendations made is that any athlete suspected of suffering a concussion must be immediately removed from play.[143] Additionally, the athlete must not return to play until assessed by a licensed health ***168** care professional trained in concussions.[144] When the athlete does return to the sport, he or she must return to play slowly and only after all acute symptoms are gone.[145] High school athletes and young children who sustain concussions must be followed closely, because it takes their brains much longer to recover than college athletes.[146]

2. The American Medical Society for Sports Medicine

In January 2013, the American Medical Society for Sports Medicine (AMSSM) published a position statement to provide a best practices summary for physicians who evaluate and manage sports concussions.[147] The AMSSM took the position that any athlete believed to have sustained a concussion should be removed from the game and examined by a licensed health care provider trained in the evaluation and management of concussion.[148] The initial assessment should be governed by a symptom checklist, cognitive evaluation, including questions pertaining to orientation, past and immediate memory, new learning, and concentration, balance tests, and an additional neurologic physical examination.[149] The AMSSM expresses the view that standardized sideline tests offer an important guide for the examination.[150] The reliability of these tests among different populations, however, is for the most part indeterminate.[151] Their usefulness is also not completely identified.[152] Difficulty with balance, for example, may be diagnostic for a concussion but is not a very sensitive symptom as it relates to the ability to correctly identify those with this form of brain trauma.[153] Balance testing can differ from standard baseline tests because of such simple things as the type of shoes being worn, artificial turf versus natural grass, and the use braces or tape.[154]

As a basic rule, there should be no return to play for any athlete on the same day that the concussion is diagnosed.[155] In fact, these athletes must be closely monitored to make sure that there is not a diminishing of his or her physical or mental condition.[156] In fact, concussion symptoms should be resolved before the player is allowed to return to exercise and this should be followed by a measured, ***169** increase in sports related activities.[157] If the symptoms resurface with this gradual return to

play, the athlete must be rested.[158] Therefore, a return to practice following a concussion should only take place following the appropriate medical clearance.[159]

3. The Cantu Guidelines

The Cantu guidelines, created in 1986, are based on the study and experience of Dr. Robert C. Cantu, MD.[160] These guidelines focus on repeated concussions in an athlete and are designed to prevent second impact syndrome.[161] They support the proposition that a return to play decision should only be made by a qualified physician, but there may be some divergence from the doctor's recommendation based upon individual circumstances.[162]

The Cantu guidelines also have a grading scale system to determine the severity of a concussion.[163] An "asymptomatic" concussion is one in which there are no headaches, dizziness, memory loss or inability to concentrate.[164] Cantu describes a "Grade 1" concussion as one in which the patient sustains no loss of consciousness and amnesia that last less than thirty minutes.[165] A "Grade 2" concussion involves loss of consciousness of less than five minutes and post-traumatic amnesia greater than thirty minutes.[166] A concussion classified as "Grade 3" requires amnesia of more than twenty-four hours or a loss of consciousness greater than five minutes.[167]

4. Colorado Guidelines

The Colorado Medical Society Guidelines (Colorado Guidelines) were established in 1991 as the result of the deaths of several high school football players who sustained severe brain injuries.[168] These guidelines are quite rigorous and require emergency transport and close follow-up care for those who are unconscious for any length of time.[169] The Colorado Guidelines also create a three-***170** tier grading system,[170] with a "Grade 1" concussion involving symptoms that resolve within thirty minutes with no signs of no amnesia or loss of consciousness.[171] Those who sustain a concussion labeled "Grade 1" may go back to a sports-related activity only if their symptoms clear up after twenty minutes.[172] A "Grade 2" concussion encompasses those injures in which confusion is present but there is no amnesia or loss of consciousness.[173] If, however, the person suffers two "Grade 2" concussions, he or she must remain inactive for at least a month.[174] Finally, a "Grade 3" concussion requires a complete loss of consciousness.[175]

5. Baseline Testing

Baseline testing, which involves a series of questions, is now standard protocol in many sports.[176] This protocol requires a doctor or trainer to check the "athlete's orientation, memory, vision, attention span, language, mental flexibility, and coordination."[177] The general protocol is for the athlete to undergo a benchmark study at the start of the season in order to establish a baseline, and then follow-up studies are conducted after a concussion is sustained.[178]

In 1995, the NFL first utilized a variation of this baseline testing technique, which involved testing players at established times both before and after a suspected concussion.[179] This assessment, which

became protocol in 2012,[180] involves asking an injured player the following three questions: (1) "Where are we?" (2) "Who did we play in the last game?" and (3) "What is the date today?"[181] In addition, a baseline test done during physicals at the start of the preseason is utilized for comparison.[182] Both tools are used by all NFL teams after a pilot program was successfully implemented by a few teams.[183] By using such an assessment tool, results of a baseline test and a post-injury test are able to be ***171** compared side-by-side.[184] The desired result is that this type of comparisons "will speed diagnosis and assist doctors and trainers in recognizing when a player should be removed from a game."[185] The goal of the NFL is to eventually have independent neurologists present at a game to help team doctors in diagnosing and properly treating players.[186] The players union is pushing for independent doctors with an expertise in concussions who will have an almost exclusive authority in detecting concussions and administering tests.[187] This will allow them to focus exclusively on individuals who have a concussion, unlike team doctors who may be busy tending to multiple players.[188]

The post-injury test takes only six to eight minutes to administer and is comparable to baseline testing.[189] This type of test is desired because it provides a comparison of the two protocols, which may show a decline in cognitive function.[190] By way of comparison, both tests contain a player's concussion history section in addition to a twenty-four-symptom checklist.[191] Athletes are then asked to self-assess themselves in categories such as sleeping problems, dizziness, confusion, and irritability.[192] Neck pain and reaction of pupils to light are recorded,[193] and balancing and concentration tests are administered.[194]

The marked difference contained in the post-injury test is that it includes a series of five questions, known as Maddocks questions, designed to test the orientation of the player.[195] Such questions include: Where are we?; What quarter is it right now?; Who scored last in the practice or game?; and Did we win the last game?[196]

6. Pre-Participation Qualification Process

Pre-participation qualifications are also used for standardized concussion treatment.[197] Under this process, a physician decides whether an athlete is healthy ***172** enough to compete in athletics.[198] One area that is assessed in this process is the medical history of an athlete, which includes inquiry into any past episodes of loss of consciousness.[199] Pre-participation qualification attempts to recognize medical issues that prevent participation in sports and develop treatment and rehabilitation plans to advise the player of which sports are suitable for participation.[200]

7. Ineffectiveness of the Guidelines

While these guidelines attempt to serve as a method in which to better manage and treat athletes' concussions, they are still not perfect. First of all, there are no standardized grades and testing for concussions.[201] As a result, concussions are handled in different manners based on the guideline system which is utilized.[202] The guidelines also lack agreement on the specific time in which an

athlete may return to play, further increasing the disparity in the method of handling concussions.[203] Also, the guidelines fail to consider individual variability in the presentation of concussion symptoms.[204] In addition, the guidelines rely on the reporting of the injured athlete, who may or may not be fully aware of his symptoms.[205] A uniform management system for concussions would better serve the needs of athletes.[206]

While these tests are helpful in diagnosing concussions, they are not perfect tools and may not always detect all problems prior to a player's return to play.[207] For example, New York Jets running back Shonn Greene was hit in the head while playing in an NFL football game[208] and was consequently removed from the field after walking unsteadily.[209] He was able to pass the NFL baseline tests and returned to the game.[210] In addition, NFL quarterback Alex Smith was hit in the head, resulting in blurred vision.[211] Though he remained in the game for several plays after passing the NFL baseline tests, he was later found to have had a ***173** concussion.[212] These examples demonstrate that while these tests are useful in detecting concussions, they should not be considered as conclusive evidence.[213]

VII. Additional Efforts

A. International Conference in Zurich

Every four years since 2001, the International Conference, consisting of representatives from various organizations including the NFL, the NHL, and FIFA, is held to find a consensus on the best way to manage and prevent concussions in sports.[214] One topic of discussion in 2012 was that of symptoms and signs of an acute concussion.[215] It was determined that this diagnosis involves the assessment of a range of areas, including cognitive, somatic, and emotional clinical symptoms, physical signs such as loss of consciousness and amnesia, behavioral changes such as irritability, cognitive impairment including slow reactions times, and sleep disturbances.[216] If any of these symptoms are present, it was determined that a concussion should be suspected and that appropriate steps must be taken.[217]

It was also determined that if a player shows any signs of a concussion, the athlete should be removed from play and be evaluated by a physician or other licensed healthcare professional.[218] Once immediate first aid issues are addressed, sideline assessment tools should be utilized to assess the concussive injury.[219] All athletes should undergo a clinical neurological assessment, which includes an evaluation of their cognitive function,[220] and should not be left alone following the concussive trauma.[221] The Conference also agreed that a player who is thought to have a concussion must not be permitted to return to any athletic endeavor on the day of injury.[222] Following a concussion, athletes allowed to return to play on the same day may demonstrate neuropsychological deficits post-injury that may not be ***174** evident on the sidelines and are more likely to have a delayed onset of symptoms.[223]

In order to assist in a diagnosis or exclusion of an injury, it was stated that conventional structural neuroimaging contributes little to concussion evaluation.[224] Nevertheless, this methodology should

be used if a structural lesion such as a skull fracture exists.[225] In addition, imaging modalities like functional MRIs (fMRIs)[226] show patterns that correlate with concussions symptoms, their severity and prognosis for recovery, and may offer further understanding into the pathophysiological process.[227] Magnetic resonance spectroscopy (MRS)[228] and positron emission tomography (PET),[229] however, should not be performed unless done for research purposes, as these tests are still considered investigational for brain trauma.[230]

B. The CDC's "Heads Up" Campaign

The CDC developed the "Heads Up" campaign to prevent and control TBIs in sports and increase awareness about the dangers of concussions for young athletes.[231] It also made numerous resources available to the public to assist in this ***175** goal, such as guidelines to properly identify the signs of concussions.[232] This includes a set of rules for high school coaches to follow.[233] For instance, the following rules apply when a coach suspects an athlete has suffered a concussion: (1) remove the athlete from the game; (2) have the athlete examined by a physician; (3) notify the parents of the athlete about the brain injury and provide information about concussion; and (4) do not allow the athlete to participate in any sport activities on the day of the injury and until a physician allows the athlete to return to sports.[234]

The National Federation of State High School Associations adopted the CDC's approach to concussion recognition and management and established guidelines stating that coaches must be aware of the symptoms and behaviors that signal a possible concussion.[235] Furthermore, if an athlete is thought to have a concussion, that student must be removed from play immediately.[236] No athlete should return to play or practice on the same day that he or she sustains a concussion.[237] While the CDC guidelines are not mandatory, they serve as a model standard of care for high school coaches.[238]

The CDC also provides a free online training course for healthcare professionals.[239] This course includes rules for concussion assessment and management of athletes who are suspected to have sustained a concussion.[240] Prior to approval of return to play, the individual must be asymptomatic and returned to pre-concussion baseline status.[241]

***176 C. The AMSSM's Statement**

The AMSSM recently published a Position Statement for Concussions in Sports[242] with the purpose of "provid[ing] a best practices summary to assist physicians with the evaluation and management of sports concussion."[243] In addition, it was written in order to establish areas that may need additional research.[244] The AMSSM Position Statement is useful in that it provides guidance on the recommended assessment for sports-related concession. First, it identifies a number of risk factors associated with sports-related concussions[245] such as a history of concussions or migraines, being female or young, having a learning disorder, or an attention deficit disorder.[246] It further explains that

sports concussions are best managed by qualified physicians who are familiar with the patient and have experience relating to the assessment of concussions.[247] In assessing a person for a concussion, a number of steps should be used including a symptom checklist, cognitive testing for memory, balance, learning, and concentration, and other neurologic procedures.[248] Imaging modalities should also be employed to assess cerebral bleeding.[249] Those players found to have concussion like symptoms should not be allowed to return to play that day and must be followed to make sure that there is not a decline in physical or mental status.[250]

The AMSSM Position Statement also expresses "concern that head impact exposure and recurrent concussions contribute to long-term neurological issues" such as CTE.[251] Because of the possibility of recurrent concussions, the AMSSM Position Statement identifies the importance of improving the diagnosis of concussions, their management, and prevention.[252] The AMSSM also addressed the need for additional research to assess diagnostic tools, develop the proper role for neuropsychological testing, and to improve the identification process for those at risk for developing long-term problems.[253] Evolving technologies for the diagnosis of concussion may also offer a fresh understanding on how to evaluate and manage concussions in sports.[254]

*177 VIII. Concussion Litigation

Various cases have been litigated as a result of individuals suffering from sports-related concussions.[255] The cases range from suits against coaches to claims against sports organizations.[256] For example, Merril Hoge, whose story was previously discussed,[257] sued the Chicago Bears' athletic trainer for not warning him about the signs and symptoms of his concussion and the risks of returning to play while still symptomatic.[258] Because he was unaware of this information, Hoge claimed that he was denied the chance to recover from his brain injury[259] and sought damages as the result of his premature retirement from professional football as well as his loss of earning power.[260] He claimed that as a result of his multiple concussions, he suffers from permanent damage such as headaches, light sensitivity, anger-management issues, and problems with concentration and memory.[261] Furthermore, Hoge alleged that he was "unable to fully attend to his ordinary duties for nearly a year . . . and continues to suffer from certain post-concussion signs and symptoms."[262] Hoge also demanded pain and suffering damages as well as money for a permanent disability.[263] In the end, the jury found in favor of Hoge and awarded him $1.45 million for the two years of his contract that the Bears did not honor, along with an additional $100,000 for pain and suffering.[264]

Suits by professional football players relating to concussions are not always successful.[265] For instance, Atkins v. Bert Bell/Pete Rozelle NFL Players Retirement Plan involved a former football player who sued to gain more lucrative disability benefits as the result of a claimed brain injury.[266] The NFL Players Retirement Plan offers monthly assistance to qualified former professional football players known as "Football Degenerative" or "Inactive" total and permanent disability ***178** benefits.[267] Football Degenerative allowances are available if the disability is the result of "football activities."[268] A player may obtain "Inactive" benefits if his disability "arises from other than League football activities."[269] Atkins asserted he could not work because of pain, headaches, and difficulties in dealing with people.[270] A doctor appointed by the NFL Players Retirement Plan concluded that

Atkins suffered from illiteracy and borderline mental abilities, which were not related to Atkins's prior football activities.[271] He further concluded that Atkins suffered from depression, which could not be determined to be the result of football, and pain which was the result of football.[272] On the other hand, the expert called by Atkins testified that the plaintiff was experiencing severe post-concussion syndrome and was "probably beyond that into early traumatic encephalopathy."[273] The court ruled in favor of the NFL Players Retirement Plan, holding that the former player only qualified for "Inactive" disability benefits instead of the more lucrative "Football Degenerative" benefits.[274] This decision was sustained on appeal.[275]

In Cerny v. Cedar Bluffs Junior/Senior Public School, a high school football player attempted to recover money for a head injury allegedly sustained as the result of the negligence of his coaches who permitted him to return to the football game, and to participate in practice a few days later.[276] When he came out of the game following the initial head injury, Cerny told the coaches that he felt dizzy, disoriented, and extremely weak.[277] He was also observed to have shortness of breath.[278] When the coaches later observed him, Cerny appeared to be completely normal.[279] The plaintiff showed no signs of a brain injury such as disorientation, abnormal speech, or headaches.[280] His coaches also observed that his color looked good, his eyes looked clear, and his speech was normal.[281] As a result, he was allowed to re-enter the game.[282] Even though this case exhibited a similarity to that of Hoge's case due to a failure to warn and because both players were allowed to return to play without a recovery period, the court in Cerny found in favor of the ***179** school.[283] The court determined that the appropriate duty of a coach regarding the diagnosis of a brain injury was that of "a reasonably prudent person holding a state teaching certificate with a coaching endorsement."[284] In this instance, the evidence supported the court's conclusion that the coaches' conduct in evaluating Cerny and allowing him to return to play were actions that would have been taken by a reasonable state-endorsed football coach in a similar position.[285]

In Shriber v. The Care Station, a high school football player sued a physician at an urgent care facility.[286] The plaintiff alleged that he suffered a head injury during practice.[287] The doctor believed that the student merely suffered from dehydration and therefore advised him not to engage in athletics as long as he had a headache.[288] On the other hand, Shriber maintained that the doctor was negligent in failing to discover that he had sustained a concussion and for not informing him to stay away from contact sports for five to seven days.[289] The jury found in favor of the player and awarded him $7.5 million.[290]

Sports-related TBI litigation also occurs in a products liability setting.[291] These matters often deal with the liability of a football helmet manufacturer to those who sustain a brain injury while playing football.[292] In Lister v. Bill Kelley Athletic, a high school football player was tackled during a game, resulting in a head impact and a fracture of his cervical spine.[293] Even though the player was paralyzed, the Illinois appellate court held that the inherent danger of football precluded a duty by the helmet manufacturer to warn a user of a possible head injury.[294] Similarly, in Rawlings Sporting Goods Co. v. Daniels, a high school football player brought suit against a helmet manufacturer after his helmet caved in when he collided with another player during practice, resulting in a massive brain injury.[295] The court found the manufacturer grossly negligent and held that the manufacturer

should have provided a warning that the helmet would not protect against concussions and subdural hematomas.[296] The court stated that "where it is ***180** foreseeable that a consumer will rely on the product, thus exposing himself to a risk he might have avoided had he known of the limitations, there is a duty to warn."[297]

Litigation also occurs as a result of concussions sustained from actions that were not part of a game, such as during practice.[298] In People of the State of New York v. Schacker, an action was brought against a hockey player who struck an opponent on the back of the neck with his hockey stick after the play was over.[299] The player suffered a concussion and memory loss as the result of the insult.[300] The court dismissed the action, holding that "the normal conduct in a hockey game can not be the standard for criminal activity under the Penal Law, nor can the Penal Law be imposed on a hockey game without running afoul of the policy encouraging athletic competition."[301]

Concussion litigation is also brought in the context of insurance disputes.[302] For instance, Boston Mutual Insurance Co. v. New York Islanders Hockey Club, L.P. involved Brett Lindros, whose hockey career was cut short by repeated concussions.[303] The facts demonstrated that the Islanders contracted with Boston Mutual Insurance Company for coverage, but failed to explain that the player had suffered three concussions within the year prior to becoming a member of the hockey franchise.[304] The court found in favor of the defendant, holding that the Islanders "intended to deceive the underwriters and that the misstatements had the effect of increasing the insurers' risk of loss."[305]

Athletes also sue the governing bodies of sport organizations. For instance, in Serrell v. Connetquot Central High School District of Islip, the plaintiff claimed that he suffered a serious injury as the result of a series of head injuries incurred while playing football at high school.[306] The plaintiff instituted suit against the State Public High School Athletic Organization (Athletic Organization), whose primary task was to arrange sporting events for academic institutions.[307] The student claimed that the defendant failed to implement rules pertaining to head injuries and return to play protocols and these omissions were the cause of his injuries.[308] The court found in favor of the Athletic Organization because no ***181** factual issue was presented that the defendant's omission was the cause of the student's injuries.[309] Rather, it was the responsibility of the school districts, the individual schools and medical experts to implement rules concerning concussions and return to play guidelines.[310] Furthermore, the court found that as an administrative body, the defendant's primary purpose was to arrange sporting events, and it did not have sufficient employees or expertise to create mandates dealing with concussions and related issues.[311]

Since it is well established that "coaches and instructors have a duty not to increase the risks inherent in sports participation,"[312] athletes are also suing their coaches. Whether a coach has a duty to limit participation of an injured player to avoid exasperating an injury largely deals with the foreseeability of further injury.[313] In Zemke v. Arreola, a high school football player sued his coach for injuries sustained as the result of playing with a concussion.[314] The player, however, did not appear to have a head injury and did not inform his coach or medical personnel.[315] Instead, he merely complained of a finger injury.[316] The player returned to the game and sustained a right subdural hematoma.[317]

This case was dismissed because the evidence failed to establish that the coaching staff took any actions that increased the player's risk of a foreseeable injury.[318] Furthermore, it was established that a player who does not notify the coach of an injury may be contributorily negligent thereby barring or proportionally reducing any recovery to which the person is entitled.[319]

In Yatsko v. Berezwick, the plaintiff was a starter on her high school basketball team.[320] During a game, she leapt for a rebound and her head struck ***182** another player.[321] She consequently developed a headache and problems with her vision.[322] When the game was over, Yatsko told a coach that she had struck her head, and was having symptoms.[323] The coach escorted the player to her mother telling her that the plaintiff had been "bumped around in the game,"[324] but the coach did not urge the player to talk to the trainer because she was afraid that the trainer would remove the athlete from the game.[325] The team had a game the following day, at which point the student informed the coaches that she had sustained a concussion,[326] and still exhibited symptoms of a concussion during warm-ups.[327] The coaches dealt with the problem by setting up a signal for the athlete to use when she had to remove herself from the game.[328] The coaches further encouraged her to continue to play, noting that she was their tallest player.[329] The plaintiff maintained that these actions were the "legal and moral equivalent of pressuring, goading and coercing the Plaintiff . . . to play the game after a serious head injury."[330] The student instituted suit claiming that the coaches' conduct violated her due process rights.[331] The court dismissed the claim, stating that it "could not find a constitutional violation in conduct by a state actor that, as alleged, rises only to the level of negligence."[332]

Cases involving sports-related injuries, but absent concussions, are instructive in ascertaining liability-producing conduct for the management of a sport injury by a coach. Jarreau v. Orleans Parish School Board, involves a high school running back who injured his wrist.[333] There was some evidence that the wrist injury may have been exacerbated in subsequent athletic endeavors, but the coaches continued to allow the student to practice and play in games.[334] When the season was over, the athlete's request for a referral to a sports medicine doctor was denied.[335] While the court stated that a coaching staff may not be expected to diagnosis the extent of an athlete's injury, they should refer any player who continues to have medical problems to a physician.[336] In finding the defendant liable, the court noted this ***183** obligation is clear as the result of relationship between a coach and athlete.[337] Therefore, a coaching staff has an affirmative duty to send a student for medical care in the face of persistent medical complaints.[338] A coach may also incur liability for failing to notify the parents when an athlete is injured, for not summoning a rescue squad so that a player can obtain the proper medical care[339] or when the coach allows an injured athlete to participate in sports before the player receives the proper medical clearance.[340] Liability can also attach when the coach mandates that a student athlete play in the game while injured.[341]

IX. Federal and State Statutes

Attempts to enact remedial legislation on the federal level have been unsuccessful.[342] In May 2013, however, a bill was introduced in Congress to protect children from sports-related traumatic brain

injuries and to eliminate misinformation about the safety of equipment by manufacturers.[343] This proposed law, entitled the Youth Sports Concussion Act of 2013, would also require safety standards for helmets and other protective gear, in addition to reducing the number of deceptive safety claims by manufactures.[344] As one of the bill's sponsors noted: "We want our children to be active and participate in sports, but we must take every precaution to protect them from traumatic head injuries."[345]

On the state level, laws relating to TBIs in sports have been more widely adopted. Washington was the first to pass remedial legislation on the topic in May ***184** 2009.[346] This law sets guidelines and standards to help recognize concussions and protect young athletes from further injury by returning to play too soon.[347] As a result of the lobbying efforts by the NFL and the passage of the Lystedt Law,[348] most other states have enacted concussion legislation.[349]

As of 2014, all fifty states, along with Washington, D.C., have enacted legislation addressing concussions with most of them being modeled after the Washington law.[350] Many states include the three basic tenets of the Lystedt Law: (1) the requirement of education for athletes, parents, and coaches about the dangers of concussion, (2) the requirement that if an athlete is suspected of having a concussion, he must be removed from the game or practice and may not return to play, and (3) the mandate that a licensed health care professional must also clear the athlete to return to play in the following days or weeks.[351] Beyond these three tenets, a number of jurisdictions require coaches to receive training, particularly guidance specific to concussions.[352] Many jurisdictions also require that such training be conducted on a regular basis.[353] Others mandate that a statewide group develop policies and standards for youth concussion awareness to be used by the state's school districts.[354]

***185** Nevertheless, there are many discrepancies between these laws.[355] For example, only a small minority of jurisdictions require that states review and update their youth concussion information outreach programs on a regular basis.[356] In addition, few states focus on ensuring that incentives to report concussions are provided.[357] This is because few states lack liability clauses that impose penalties on coaches who fail to comply with the legislative provisions.[358] Without enforcement mechanisms, there is little incentive for compliance with such laws.[359]

X. Conclusion

Traumatic brain injuries are matters of great concern.[360] It is a problem that permeates the sports world among all athletes: whether young or mature athletes and amateur or professional.[361] While efforts are being made to address this ***186** problem, athletes, coaches, officials, and parents all must be educated about signs, symptoms, and dangers of these types of injuries.[362] They must also be aware of the appropriate methods of evaluation and treatment.[363] Effort must also be put forth to ensure that standardized systems of approaching concussions are present.[364] While most states have passed laws addressing these issues, few states impose penalties on coaches who fail to comply with reporting requirements, therefore weakening the efficacy of the legislation.[365]

Footnotes

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1 Quotes from Players and Experts As Told to Me, Head Impacts on Youth Football, Stone Phillips Reports, http:// www.stonephillipsreports.com/2012/01/quotes-from-players-and-experts/ (last visited Feb. 28, 2014).

2 Alex Marvez, Lystedt Lays Down Law on Concussions, Fox Sports, http://msn.foxsports.com/nfl/story/zack-lystedt-bring-awareness-nfl-concussion-issue-lystedt-law-052012 (last updated May 22, 2012, 1:07 AM).

3 Id.

4 Id.

5 Joe Frollo, Three Years Later, Lystedt Law Protects Young Athletes in 34 States and D.C., USA Football (May 10, 2012; 9:36am), http://usafootball.com/news/featured-articles/three-years-later-lystedt-law-protects-young-athletes-34-states-and-dc. Marvez, supra note 2 (explaining how physicians told Lystedt's parents that Lystedt may not survive).

6 Marvez, supra note 2.

7 See id. (demonstrating that Washington state passed this legislation in 2010, four years after Lystedt's injury).

8 See Zackery Lystedt Law, Wash. Rev. Code § 28A.600.190 (2010) (describing how student athletes were prematurely allowed to return to play following possible concussions).

9 Marvez, supra note 2.

10 See § 28A.600.190(2) (2010).

11 Id. § 28A.600.190(4).

12 See Marvez, supra note 2 (describing Zackery's ongoing efforts to publicly share the details of his experience to create greater awareness and advocate for concussion safety legislation).

13 See Paul D. Anderson Consulting, LLC, The Lawsuits Continue, NFL Concussion Litigation (Nov. 12, 2013), http://nflconcussionlitigation.com/? p=1270 (describing how more than 30% of all former NFL players have filed some form of concussion-related lawsuit against the NFL, and speculating that this number could rise as high as 50%). A suit has now been filed against the National Hockey League over a concussion and some say this litigation may be the impetus to ban fighting in the sport. Paul D. Anderson Consulting, LLC, NHL Concussion Litigation - The Boogaard Family Strikes First, NFL Concussion Litigation (May 13, 2013), http://nflconcussionlitigation.com/?p=1446. About 4,100 plaintiffs in 222 consolidated lawsuits filed by former NFL players are pending in federal district court in Philadelphia. Albert Breer, Concussion Lawsuit: State of Things Entering Tuesday's Hearing, Nat'l Football League, http://www.nfl.com/news/story/0ap1000000158376/article/concussion-lawsuit-state-of-things-entering-tuesdays-hearing (last updated Apr. 9, 2013, 11:50 AM). This litigation is not a class-action lawsuit, but the cases have been consolidated to streamline the claims, so that all pre-trial motions can be taken care of more efficiently. A tentative multi-million dollar settlement was reached but rejected by the presiding judge. Id.

14 See, e.g., State v. McKague, 246 P.3d 558, 575 (Wash. Ct. App. 2011) (demonstrating increased public awareness of brain injuries through warning labels, increased media coverage, and legislation preventing young athletes from obtaining medical clearance before returning to play after a suspected concussion), aff'd, 262 P.3d 1225 (Wash. 2011).

15 See Christopher S. Sahler & Brian D. Greenwald, Traumatic Brain Injury in Sports: A Review, Rehabilitation Res. and Prac. 1, 7 (Feb. 6, 2012), available at http://downloads.hindawi.com/journals/rerp/2012/659652.pdf (discussing the increased awareness of traumatic brain injuries and how various legislative bodies and sport's governing bodies have adopted rules aimed at preventing them).

16 Traumatic Brain Injury, Ctrs. for Disease Control and Prevention, http://www.cdc.gov/TraumaticBrainInjury/severe.html (last updated Aug. 15, 2013).

17 Id.

18 960 N.E.2d 782, 789 (Ind. 2012).

19 See id. at 789-90 (referencing a neuropsychologist's creation of a head injury severity scale for his head trauma rehabilitation program).

20 2011-2012 NCAA Sports Medicine Handbook, The Nat'l Collegiate Athletic Ass'n, available at http:// www.ncaapublications.com/productdownloads/MD11.pdf (last visited Oct. 15, 2013).

21 Severe Brain Injury, Headway, https://www.headway.org.uk/severe-brain-injury.aspx (last visited Oct. 15, 2013).

22 Concussion and Mild TBI, Ctrs. for Disease Control and Prevention, http://www.cdc.gov/concussion/index.html (last updated Aug. 15, 2013).

23 Pham v. Wal-Mart Stores, Inc., No. 2:11-CV-01148-KJD-GW, 2012 WL 1957987 at *5 (D. Nev. Aug. 28, 2012).

24 Kimberly G. Harmon et al., American Medical Society for Sports Medicine Position Statement: Concussion in Sport, Clin. J. Sport Med. (2013).

25 See Weeks Marine, Inc. v. Am. S.S. Owners Mut. Prot. & Indem. Ass'n, No. 08 Civ. 9878 (NRB), 2011 U.S. Dist. LEXIS 95358, at *31 (S.D.N.Y. Aug. 25, 2011) (noting that research on the subject of concussions has not led to a universally accepted definition of what constitutes the condition).

26 See Sahler & Greenwald, supra note 15, at 2 (defining a mild TBI as a "complex pathophysiologic process affecting the brain, induced by traumatic biomechanical forces secondary to direct or indirect forces to the head.").

27 Concussion in Sports, Ctrs. for Disease Control and Prevention, http://www.cdc.gov/concussion/sports/index.html (last updated Jul. 22, 2013).

28 Injury Prevention & Control: Traumatic Brain Injury, Ctrs. for Disease Control and Prevention, http://www.cdc.gov/concussion/sports/ (last visited may 13, 2013).

29 Concussion and Mild TBI, supra note 22.

30 Harmon et al., supra note 24, at 16-17.

31 Id. at 17.

32 John M. Parisi & Douglas R. Bradley, Ringing the Bell on Concussions, Trial, Aug. 2012, at 15 (quoting Quality Standards Subcomm. of Am. Acad. Of Neurology, Practice Parameter: The Management of Concussion in Sports, Mar. 1997, at 581, 582).

33 Harmon et al., supra note 24, at 15.

34 Id. at 17.

35 Alexander N. Hecht, Legal and Ethical Aspects of Sports-Related Concussions: The Merril Hoge Story, 12 Seton Hall J. Sport L. 17, 23 (2002).

36 See generally Barkhoudarian et al., The Molecular Pathophysiology of Concussive Brain Injury, 30 Clinics in Sports Med. 33, 34-36 (describing the physiological effects of a concussion). A diffuse axonal brain injury is both one of the most common and one of the most severe types of injuries, and can lead to death. Diffuse Axonal Brain Injury, Brain Injury Institute.org, http://www.braininjuryinstitute.org/Brain-Injury-Types/Diffuse-Axonal-Brain-Injury.html (last visited Sept. 10, 2013). An axonal brain injury is referred to as diffuse because unlike some other brain injuries that are focused in one generalized area, an axonal brain injury is widespread and affects a larger area. Id.

37 Edward M. Wojtys et al., Concussion in Sports, 27 Am. J. Sports Med. 676, 676 (1999).

38 See Barkhoudarian et al., supra note 36, at 42 (summarizing the potential impact of concussions).

39 See Alain Ptito et al., Contributions of Functional Magnetic Resonance Imaging (fMRI) to Sport Concussion Evaluation, 22 NeuroRehabilitation, 217, 218 (2007) (demonstrating the evolution of understanding the potential consequences of concussions from temporary consciousness effects to enduring cognitive effects).

40 Traumatic Brain Injury, Ctrs. for Disease Control and Prevention, http://www.cdc.gov/traumaticbraininjury/ (last updated Aug. 15, 2013).

41 Ptito et al., supra note 39, at 217.

42 See generally Anish Chandra et al., Consumers' Perceptions and Opinions of Sports Injuries: An Exploratory Empirical Study, Hosp. Topics 32, 32 (2008) (explaining that millions of individuals play sports or are involved in strenuous physical activities on a regular basis); see also Eckstein et al., Sports Sociology's Still Untapped Potential, 25 Sociological Forum 500, 501 (2010) (explaining the importance of sociological analysis of sports due to sports' prominence in today's society).

43 Chandra et al., supra note 42, at 32 (citing Am. Acad. of Orthopedic Surgeons, 2007).

44 Sport Injury Statistics, Children's Hosp. of Wis., http://www.chw.org/display/PPF/DocID/21759/router.asp (last visited Sept. 19, 2013).

45 See Hecht, supra note 35, at 18-20 (explaining how not until recently was there legitimating scientific research or a heightened degree of social awareness concerning sports-related concussions); see also Bob Cook, The Counter-Freakout to the Football Concussion Freakout is Underway, Forbes (Aug. 23, 2013, 4:18 PM), http://www.forbes.com/sites/bobcook/2013/08/23/the-counter-freakout-to-the-football-concussion-freakout-is-under-way/ (explaining that until recent scientific evidence and media coverage emerged, head injuries were not taken as seriously as they should have been).

46 Hecht, supra note 35, at 23.

47 Sahler & Greenwald, supra note 15, at 2.

48 Id.

49 Id. See also NFL Concussion Poll: 56 Percent of Players Would Hide Symptoms to Stay on Field, Sporting News (Nov. 11, 2012 at 9:53 PM EST), http://www.sportingnews.com/nfl/story/2012-11-11/nfl-concussions-hide-symptoms-sporting-news-midseason-players-poll (demonstrating that 56% of NFL players would try to hide concussion symptoms in order to stay in a game).

50 Sahler & Greenwald, supra note 15, at 2

51 Id. at 3.

52 Id.

53 Hecht, supra note 35, at 23.

54 Carly Weeks, Most Sports-Related Brain Injuries Occur in Hockey, Study Finds, Globe And Mail, http://www.theglobeandmail.com/life/health-and-fitness/health/most-sports-related-brain-injuries-occur-in-hockey-study-finds/article10530575/ (last updated Mar. 28, 2013, 6:03 PM EDT) (explaining how a recent study finding that hockey is the biggest contributor to sports-related brain injuries in minors prompted calls for major changes to how the game is played).

55 Ptito et al., supra note 39, at 218.

56 Harmon et al., supra note 24, at 18.

57 Id.

58 Id.

59 Id.

60 Id.

61 Id.

62 Harmon et al., supra note 24, at 18

63 Id. at 18-19.

64 See, e.g., J.T. Matser et al., A Dose-Response Relation of Headers and Concussions with Cognitive Impairment in Professional Soccer Players, 23 J. Clinical & Experimental Neuropsychology 770, 770 (2002) (demonstrating that more than half of amateur soccer players in the U.S. suffered at least one concussion over two seasons via a 1998 study by Boden, Kirkendall, and Garrett).

65 Sports-Related Head Injury, Am. Ass'n of Neurological Surgeons, http://www.aans.org/Patient%20Information/Conditions%20and%20Treatments/Sports-Related%20Head%20Injury.aspx (last visited May 13, 2013).

66 Id.

67 Id.

68 Id.

69 Id.

70 Id.

71 Id.

72 Neuropsychological Testing, Penn State Hershey, http://www.pennstatehershey.org/web/neurology/patientcare/specialtyservices/neuropsychologicaltesting (last visited Sept. 9, 2013).

73 Id.

74 Id.

75 See, e.g., Matser et al., supra note 64, at 772-73 (finding that both headers and concussions may contribute to "cognitive impairment").

76 Ptito et al., supra note 39, at 218.

77 Parisi & Bradley, supra note 32, at 15.

78 Id.

79 Id.

80 Harmon et al., supra note 24, at 18.

81 Id.

82 Id.

83 Id.

84 Hecht, supra note 35, at 24.

85 Second impact syndrome is a condition which occurs when an athlete sustains an additional blow to the head after suffering an initial concussion. Terry Zeigler, Second Impact Syndrome, sportsmd, http:// www.sportsmd.com/articles/id/38.aspx (last visited May 11, 2013). The second injury need not be strong to put the effects in motion; the athlete may be the subject of only a minor blow to the head or a hit to the chest that snaps the head enough to have the brain rebound within the skull. Id.

86 Id.; see also Zeigler, supra note 85 (demonstrating the high mortality rate of second impact syndrome in young athletes).

87 See Robert Cantu, Return to Play Guidelines After a Head Injury, 17 Clinics in Sports Med. 45, 51-54 (1998) (demonstrating that when an individual still has symptoms from a prior head injury, fatal brain swelling can occur even from a second minor head trauma).

88 130 S.W.3d 642, 644 (Mo. Ct. App. 2007).

89 Id. at 644.

90 Wojtys et al., supra note 37, at 677.

91 See Harmon et al., supra note 24, at 24 (demonstrating potential risks involved in returning an athlete to play too soon after a head injury including brain herniation that could lead to death).

92 Hecht, supra note 35, at 24.

93 Id. at 25.

94 Id.

95 Ann C. McKee et al., Chronic Traumatic Encephalopathy in Athletes: Progressive Tauopathy After Repetitive Head Injury, 68 J. Neuropathology & Experimental Neurology 709, 709 (2009).

96 It is fairly well known that professional and amateur boxers can incur permanent brain damage. Sports-Related Head Injury, supra note 65. A professional boxer's punch is equivalent to "being hit with a thirteen-pound bowling ball traveling twenty miles per hour, or about fifty-two times the force of gravity." Id.

97 Michelle Saulle & Brian Greenwald, Chronic Traumatic Encephalopathy: A Review, Rehabilitation, Res. & Prac. 1, 1 (2012).

98 Id. at 3-4.

99 David S. Cerra, Unringing the Bell: Former Players Sue NFL and Helmet Manufacturers Over Concussion Risks in Maxwell v. NFL, 16 Mich. St. U. J. Med. & L. 265, 267-68 (2012).

100 See McKee, supra note 95, at 720 (describing a number of common neuropathologic features of CTE, including "a reduction in brain weight" and atrophy of the frontal, temporal, and occipital lobes).

101 Id. at 732.

102 Press Release: CDC Announces New Initiative to Help High School Coaches Recognize and Manage Concussions, Ctrs. for Disease Control & Prevention, (Sept. 22, 2005, 12:00 PM), http://www.cdc.gov/media/pressrel/r050922.htm; Hecht, supra note 35, at 20.

103 Harmon et al., supra note 24, at 17.

104 Id.

105 Id. (citing Andrew E. Lincoln et al., Trends in Concussion Incidence in High School Sports, 35 Am. J. Sports Med. 958 (2011), available at http://www.medstarsportshealth.org/documents/Am_J_Sports_Med-2011-Lincoln-0363546510392326%5B1%5D.pdf).

106 Cantu, supra note 87, at 45.

107 Id.

108 Hecht, supra note 35, at 25.

109 Id. at 26.

110 Id.

111 Id.

112 Id. at 26-27.

113 Id.

114 Id. at 27.

115 Christopher Nowinski, Head Games: Football's Concussion Crisis, Brainline.org, http://www.brainline.org/content/2008/08/head-games-footballs-concussion-crisis_pageall.html (last visited May 6, 2013).

116 Id.

117 Id.

118 Id.

119 Id.

120 Id.

121 David Williamson, New Study at UNC Shows Concussions Promote Dementias in Retired Professional Football Players, Univ. N. C. Chapel Hill (Oct. 10, 2005), http://www.unc.edu/news/archives/oct05/guskie101005.htm.

122 Id.

123 Id.

124 Harmon, supra note 24, at 16.

125 Jennifer M. Hootman et al., Epidemiology of Collegiate Injuries for 15 Sports: Summary and Recommendations for Injury Prevention Initiatives, 42 J. Athletic Training 311, 311 (2007).

126 See Harmon, supra note 24, at 20 (emphasizing the importance of concussion awareness for players, coaches, and physicians in sports).

127 Brain Injury In Sports, Brain Injury Res. Ctr., http:// www.headinjury.com/sports.htm.

128 Hecht, supra note 35, at 37.

129 Id.

130 Hecht, supra note 35, at 45.

131 Id.

132 See Am. Acad. of Neurology, Practice Parameter: The Management of Concussion in Sports, 48 Neurology 581, 581, available at http:// www.neurology.org/content/48/3/581.full.pdf+html (This article was released by the American Academy of Neurology as a guideline for athletic coaches and trainers to use when assessing a player who is showing concussion-like symptoms).

133 Id. at 584.

134 Id. at 582.

135 Id.

136 Id.

137 Id. at 583.

138 Id.

139 Id. at 582.

140 Id.

141 Id. at 582-83.

142 Id.

143 Press Release: AAN Issues Updated Sports Concussion Guideline: Athletes with Suspected Concussion Should Be Removed from Play, Am. Acad. of Neurology (June 2, 2013), http://www.aan.com/PressRoom/Home/PressRelease/1164.

144 Id.

145 Id.

146 Id.

147 Harmon, supra note 24, at 16.

148 Id. at 20.

149 See id. at 20-22 (explaining the various tests that can be used to evaluate and treat concussions).

150 Id. at 26.

151 Id.

152 Id. at 21.

153 Id.

154 Id.

155 Id.

156 Id.

157 Id. at 23.

158 Id.

159 Id.

160 Hecht, supra note 35, at 48.

161 Id.

162 Id.

163 See id. at 49 (explaining the three grades for concussion severity).

164 Id. at 48-49.

165 Id. at 49.

166 Id.

167 Id.

168 Kimberly G. Harmon, Assessment and Management of Concussion in Sports, 60 Am. Fam. Physician 887, 887 (1999).

169 Hecht, supra note 35, at 49.

170 See Robert C. Cantu, Posttraumatic Retrograde and Anterograde Amnesia: Pathophysiology and Implications in Grading and Safe Return to Play, 36 J. Athletic Training 244, 245 tbl. 2 (2001) (displaying the three level Colorado Medical Society Grading System for Concussions).

171 Id.

172 Hecht, supra note 35, at 49.

173 Id.

174 Id.

175 Id.

176 Id. at 50.

177 Id.

178 Id.

179 Id.

180 Judy Battista, N.F.L. Will Expand Concussion Efforts During Games, N.Y. Times (Feb. 26, 2013), http://www.nytimes.com/2013/02/27/sports/football/nfl-will-use-ipads-to-expand-in-game-concussion-testing.html?ref=headinjuries.

181 Id.

182 Id.

183 Id.

184 Id.

185 Id.

186 Id.

187 Id.

188 Id.

189 Id.

190 Id.

191 Id.

192 Id.

193 Id.

194 Id.

195 Id.

196 Id.

197 See Albert C. Hergenroeder, The Preparticipation Sports Examination, 44 Pediatric Clinics Of N. Am. 1525, 1535 tbl. 4 (1997) (listing a number of pre-participation physical evaluation questions).

198 See generally id. at 1525 (explaining the procedures a physician must employ in the preparticipation examination to decide if an athlete is healthy enough to participate in sports).

199 Id. at 1526.

200 Id.

201 Harmon, supra note 168, at 887.

202 See id. (explaining that grades vary by which guideline is used).

203 Hecht, supra note 35, at 53.

204 Id. (quoting Michael W. Collins et al., Current Issues in Managing Sports-Related Concussions, 282 J. Am. Med. Ass'n. 2283, 2283 (1999)).

205 Id.

206 Hecht, supra note 35, at 54.

207 See Battista, supra note 180 (providing some doctors' concern that the NFL concussion tests just involve a checklist of items).

208 Id.

209 Id.

210 Id.

211 Id.

212 Id.

213 Id.

214 Paul McCrory et al., Consensus Statement on Concussion in Sport: the 4th International Conference on Concussion in Sport held in Zurich, November 2012, 48 J. Athletic Training 554, 555 (2013); Associated Press, Expert: No Head Shots Before14, ESPN (Nov. 2, 2012), http://espn.go.com/espn/story/_/id/8584853/concussion-expert-stresses-age-limit-blows-head (demonstrating that FIFA hosted the conferences and advisors to the NFL and NHL were in attendance).

215 McCrory et al., supra note 214, at 555-56.

216 Id. at 556.

217 Id.

218 Id.

219 Id.

220 Id.

221 Id.

222 Id.

223 See id. at 556 (noting that it may take several hours for symptoms to appear, and as a result, the injury should be viewed as evolving in the acute stage).

224 Id.

225 Id.

226 This procedure involves the following:
Functional magnetic resonance imaging, or fMRI, is a technique for measuring brain activity. It works by detecting the changes in blood oxygenation and flow that occur in response to neural activity - when a brain area is more active it consumes more oxygen and to meet this increased demand blood flow increases to the active area. fMRI can be used to produce activation maps showing which parts of the brain are involved in a particular mental process.
Hannah Devlin, What is Functional Magnetic Resonance Imaging (fMRI)?, PsychCentral, http://psychcentral.com/lib/2007/what-is-functional-magnetic-resonance-imaging-fmri/ (last visited Sept. 14, 2013).

227 McCrory et al., supra note 214, at 556.

228 MRS is used to examine central nervous system disorders. Clinical Policy Bulletin: Magnetic Resonance Spectroscopy (MRS), Aetna, http://www.aetna.com/cpb/medical/data/200_299/0202.html (last visited Oct. 15, 2013). This diagnostic imaging modality is non-invasive and employed to exam metabolic alterations in brain tumors, seizure disorders, depression and other illnesses affecting the brain. Id.

229 A PET scan is a diagnostic test of function that utilizes a radioactive substance to look at organs and tissues to see how they are working. PET Scan, Medline Plus, http://www.nlm.nih.gov/medlineplus/ency/article/003827.htm (last visited Oct. 15, 2013).

230 McCrory et al., supra note 214, at 556 (explaining that these technologies have "demonstrat[ed] some compelling findings, [but] are still at early stages of development.").

231 Heads Up: Concussion, Ctrs. for Disease Control and Prevention, http://www.cdc.gov/concussion/headsup/index.html (last updated Sept. 24, 2012).

232 See, e.g., Concussion in Sports: How Can I Recognize a Possible Concussion?, Ctrs. for Disease Control and Prevention, http:// www.cdc.gov/concussion/sports/recognize.html (last updated Dec. 8, 2009) (listing tips on concussion recognition).

233 See Heads Up: Concussion in Sports, Ctrs. for Disease Control and Prevention, http://www.cdc.gov/concussion/HeadsUp/youth.html (last updated May 24, 2012) (listing an online training course, factsheet, posters, quizzes, and other resources for high school coaches as part of the tool kit).

234 Concussion in Sports: What Should I Do if a Concussion Occurs?, Ctrs. for Disease Control and Prevention, http:// www.cdc.gov/concussion/sports/response.html (last updated May 16, 2012).

235 See Sports Med. Advisory Comm., Nat'l Fed'n of State High Sch. Ass'ns, Suggested Guidelines for Management of Concussions in Sports 2, 5 (Jan. 2011), http://www.schsl.org/2010/concussion3-17-11.pdf (listing the "Heads Up: Concussion in High School Sport" program as an additional resource).

236 Id. at 2.

237 Id.

238 Parisi & Bradley, supra note 32, at 16.

239 See Heads Up Concussion - Clinicians Training, Ctrs. for Disease Control and Prevention,http:// www.cdc.gov/concussion/HeadsUp/clinicians/index.html (last visited Sept. 22, 2013) (including interactive training on concussion diagnosis, management, and prevention).

240 Id.

241 Id.

242 Harmon, supra note 24, at 15.

243 Id. at 16.

244 Id.

245 Id. at 18-19 (discussing various concussion risk factors).

246 Id.

247 Id. at 16.

248 Id.

249 Id. at 23.

250 Id. at 21, 26.

251 Id. at 25.

252 Id.

253 Id. at 26.

254 Id. at 23-24.

255 See Timothy Davis, Tort Liability of Coaches for Injuries to Professional Athletes: Overcoming Policy and Doctrinal Barriers, 76 UMKC L. Rev. 571, 592 (2008) (discussing various lawsuits by NFL players for compensation for injuries, including concussions, as a result of playing in the NFL).

256 See id. at 596 (providing some of the difficulties professional athlete plaintiffs face in suits again their team or coaches).

257 See supra notes 108-114 and accompanying text.

258 Hecht, supra note 35, at 21.

259 Id.

260 Id. at 29.

261 Id.

262 Id.

263 Id.

264 Id.

265 See Davis, supra note 255 (discussing the obstacles professional athletes face when brining state tort claims regarding concussions); see, e.g., Smith v. Houston Oilers, Inc., 87 F.3d 717, 717 (5th Cir. 1996) (dismissing the suit on preemption grounds based on a collective bargaining agreement).

266 694 F.3d 557, 559 (5th Cir. 2012).

267 Id. at 560.

268 Id.

269 Id.

270 Id. 560-61.

271 Id. at 561.

272 Id. at 561-62.

273 Id. at 562-63.

274 Id. at 559-60.

275 Id. at 560.

276 679 N.W.2d 198, 202 (Neb. 2004).

277 Id. at 200-01.

278 Id.at 201.

279 Id.

280 Id.

281 Id.

282 Id.

283 Compare id. at 207 (affirming the district court's that the coaches' conduct met the standard of care and that the School was not negligent.), with Hecht, supra note 35, at 26.

284 Cerny, 679 N.W.2d at 207.

285 Id. at 206-207.

286 Hecht, supra note 35, at 30.

287 Id.

288 Id.

289 Id. at 30-31.

290 Id. at 31.

291 Id.

292 Id.

293 Lister v. Bill Kelley Athletic, Inc., 485 N.E.2d. 483, 483 (Ill. App. Ct. 1985).

294 Id. at 487.

295 619 S.W.2d 435, 437 (Tex. Civ. App. 1981).

296 Id. at 440-441 (showing that based on the evidence, a jury could find that the manufacturer was grossly negligent).

297 Id. at 439.

298 See, e.g., Cerny v. Cedar Bluffs Junior/Senior Pub. Sch., 679 N.W.2d 198, 206 (Neb. 2004).

299 670 N.Y.S.2d 308, 309 (N.Y. Dist. Ct. 1998).

300 Id.

301 Id. at 310.

302 Hecht, supra note 35, at 33.

303 See generally 165 F.3d 93, 93-95 (1st Cir. 1999) (discussing Lindros's injury history).

304 Hecht, supra note 35, at 33 (citing Boston Mut. Ins. Co., 165 F.3d at 94-95).

305 Boston Mut. Ins. Co., 165 F.3d at 96 (stating the district court's ruling in the case). The First Circuit upheld the district court's ruling. Id. at 99.

306 721 N.Y.S.2d 107, 107 (N.Y. App. Div. 2001).

307 Id. at 107-08.

308 Id. at 108.

309 Id.

310 Id.

311 Id.

312 Avila v. Citrus Cmty. Coll. Dist., 131 P.3d 383, 392 (Cal. 2006) (citing Kahn v. E. Side Union High Sch. Dist., 75 P.3d 30, 39 (Cal. 2003)).

313 Zemke v. Arreola, No. B182891, 2006 WL 1587101, at *2-3 (Cal. Ct. App. June 12, 2006). See e.g., Lamorie v. Warner Pac. Coll., 850 P.2d 401, 401-03 (Or. Ct. App. 1993) (reversing summary judgment so that a jury could determine if the exacerbation of a preexisting injury to a plaintiff athlete's eye was foreseeable to his coach). But see, Stephenson v. Commercial Travelers Mut. Ins. Co., 893 So. 2d 180, 186-87 (La. Ct. App. 2005) (holding that school officials had a duty to withhold a student from further play due to an ankle injury, but granting summary judgment on other grounds).

314 Zemke, 2006 WL 1587101, at *1.

315 Id.

316 Id.

317 Id..

318 See id. at *3-4 (finding that the medical and coaching staff were not put on notice because Zemke did not disclose his head injury).

319 Stowers v. Clinton Cent. Sch. Corp., 855 N.E.2d 739, 746-47 (Ind. Ct. App. 2006) (upholding a lower court's ruling that a genuine issue of material fact existed as to whether a plaintiff youth football player who died of dehydration during a practice was contributorily negligent for ignoring warnings to drink fluids and not reporting feeling sick to coaches).

320 No. 3:06cv2480, 2008 WL 2444503, at *1 (M.D. Pa. June 13, 2008).

321 Id.

322 Id.

323 Id.

324 Id.

325 Id.

326 Id.

327 Id.

328 Id.

329 Id.

330 Id.

331 Id. at *5.

332 Id. at *6.

333 600 So. 2d 1389, 1390 (La. Ct. App. 1992).

334 Id.

335 Id. at 1390-91.

336 Id.

337 Id.

338 Id.

339 See Halper v. Vayo, 568 N.E.2d 914, 920-21 (Ill. App. Ct. 1991) (finding that a triable issue existed as to whether a coach was reckless when said coach failed to contact an injured student's parents or paramedics and instead attempted to repair the injury himself).

340 See, e.g., Cerny v. Cedar Bluffs Junior/Senior Pub. Sch., 628 N.W.2d 697, 705-06. (Neb. 2001) (holding that coaches must make a reasonable determination whether to withhold a student athlete complaining of concussion-like symptoms from further play until the athlete can be assessed by a physician), abrogated by Cerny v. Cedar Bluffs Junior/Senior Pub. Sch., 679 N.W.2d 198 (Neb. 2004) (affirming lower court's finding of fact that coaches did not negligently fail to withhold plaintiff from return to play).

341 See Yatsko v. Berezwick, No. 3:06cv2480, 2008 WL 2444503, at *5 (M.D. Pa. June 13, 2008) (discussing that liability could possibly be imposed had the plaintiff alleged that coaches "used their authority to force her to play").

342 Lesley Lueke, High School Athletes and Concussions, 32 J. Legal Med. 483, 491-92 (2011) (discussing unsuccessful attempts at federal legislation).

343 See Press Release, Office of Senator Jay Rockefeller, Rockefeller Introduces Legislation to Protect Young Athletes From Concussion (May 22, 2013), http://www.rockefeller.senate.gov/public/index.cfm/press-releases?ID=02b69aac-ece7-4a48-8ad3-c73285213f1a (describing the legislation proposed by the Senator).

344 Id.

345 Udall, Rockefeller Introduce Bill to Help Protect Young Athletes from Sports-Related Traumatic Brain Injuries, Tom Udall Senator for N.M. (May 22, 2013), http://www.tomudall.senate.gov/?p=press_release&id=1305 (last visited Oct. 16, 2013).

346 See Marvez, supra note 2 (demonstrating that Washington was the first state to pass legislation of this kind).

347 Zackery Lystedt Law, Wash. Rev. Code § 28A.600.190 (2010) (setting concussion and head injury guidelines and requiring that youth athletes "who [are] suspected of sustaining a concussion" be removed from competition and not be allowed to return until "evaluated by a licensed health care provider").

348 See Associated Press, NFL, NCAA Lobby for Concussion Laws, ESPN (Jan. 12, 2012), http://espn.go.com/nfl/story/_/id/7454729/nfl-ncaa-urge-states-pass-concussion-laws (describing lobbying efforts by the NFL as well as the influence of the Lystedt Law amongst the states).

349 See Concussion Legislation by State, NFL Evolution, http://www.nflevolution.com/article/concussion-legislation-by-state?ref=767 (last updated July 22, 2013) (demonstrating that forty-eight states have passed youth concussion legislation).

350 Id.; see also Summary Matrix of State Laws Addressing Concussions in Youth Sports, The Network for Public Health Law (effective December 31, 2012), http://www.networkforphl.org/_asset/7xwh09/StateLawsTableConcussions_2-19-13.pdf (summarizing the legislative steps taken by each individual state); Traumatic Brain Injury Legislation, National Conference of State Legislatures (last updated July 2013), http://www.ncsl.org/issues-research/health/traumatic-brain-injury-legislation.aspx (also summarizing the steps taken by the individual states).

351 Zackery Lystedt Law, Wash. Rev. Code § 28A.600.190 (2010).

352 See, e.g., Colo. Rev. Stat. Ann. § 25-43-103 (West Supp. 2012) (requiring coaches to receive training in concussion recognition).

353 See, e.g., Conn. Gen. Stat. Ann. § 10-149b (West Supp. 2013) (requiring annual training for coaches in order to review current information on head injuries).

354 See, e.g., Ariz. Rev. Stat. Ann. §15-341 (Supp. 2012) (requiring that "[g]uidelines, information and forms" be developed "in consultation with a statewide private entity that supervises interscholastic activities").

355 Compare Colo. Rev. Stat. Ann. § 25-43-103 (West Supp. 2012) (requiring coaches from both public and private schools, as well as volunteer coaches at private or public clubs and athletic leagues to take a course annually), with Conn. Gen. Stat. Ann. § 10-149b (West Supp. 2013) (requiring only those coaches holding a coaching permit issued by the State Board of Education to take a course, followed by annual updates and a refresher course within five years for reissuance of that permit).

356 Compare Ala. Code §22-11E-2 (LexisNexis Supp. 2012), and Alaska Stat. §14.30.142 (2012), and Ariz. Rev. Stat. Ann. §15-341 (Supp. 2012), and Colo. Rev. Stat. Ann. § 25-43-103 (West Supp. 2012) (all not requiring regular updates to outreach programs), with Conn. Gen. Stat. Ann. § 10-149b (West Supp. 2013) (requiring the state Board of Education to update its materials regarding concussions annually and coaches to review the new material approved by the Board of Education annually).

357 See Lisa Kocian, State Revises Concussion Reporting After Weak Response From Schools, Bos. Globe, July 11, 2013, http://www.bostonglobe.com/metro/regionals/west/2013/07/10/state-revises-concussion-reporting-after-weak-response-from-massachusetts-schools/cnetImdeVhGs552ms3HQQP/story.html (discussing the lack of compliance by athletic directors with new concussion reporting laws).

358 See Phoebe Anne Amberg, Protecting Kids' Melons: Potential Liability and Enforcement Issues With Youth Concussion Laws, 23 Marq. Sports L. Rev. 171, 183 (2012) (discussing the lack of recourse should coaches or school systems fail to comply).

359 Id. Hosea Harvey, a professor at Temple University Beasley School of Law, noted in the American Journal of Public Health that "Youth sports traumatic brain injury laws have generally taken a one-size-fits-all approach." Concussion: State Laws Ignore Science, TBI Blog (May 25, 2013), http://tbiblog.sossisson.com/2013/05/concussion-state-laws-ignore-science.html. "The laws do not incorporate scientific consensus that youth concussions vary on the basis of age, the type of sport, and whether the athlete is male or female." Id. Also, "there is no agreed-upon traumatic brain injury diagnostic metric, and there are no uniform national traumatic brain injury reporting protocols." Id. The article also demonstrated that many of these state laws don't draw on evidence around what works. Id. For instance, the vast number of laws creates a minimum 24-hour period of removal of the athlete from sports, but there is no scientific consensus about the optimal minimal time someone who has suffered a sports-related TBI should be removed from sports. Id.; see also Reducing Traumatic Youth Sports Injuries, Q and A with Hosea Harvey, New Pub. Health (May 23, 2013), http:// www.rwjf.org/en/blogs/new-public-health.html?t=topics%3A371.

360 See supra Part III (describing the scale and damage associated with concussion issues in athletics).

361 See supra Part III.A (describing the broad scope of concussion issues).

362 See supra Part V (noting the importance of awareness in reducing the damage done by concussions).

363 See supra Part V (describing how the appropriate methods of evaluation and treatment could have extended Troy Aikman's career).

364 See supra Part VI.A (discussing the numerous approaches to concussion evaluation and the need for a more streamlined approach).

365 See supra Part VIII (noting that there remain jurisdictions without effective concussion legislation).

Mauricio R. Delgado and James G. Dilmore, Social and Emotional Influences on Decision Making and the Brain, 9 Minnesota Journal of Law, Science and Technology 899 (Spring 2008)[4]

INTRODUCTION

How do we make decisions? How do we judge what is right or wrong and how does this judgment translate to behavior? Over the last decade, research on the human brain has begun to shed light on such questions. Those research efforts build on a strong foundation of animal research responsible for the delineation of neural circuitry involved in processing information about rewards and punishments. Animal research also provided for the development of an understanding of how such circuitry operates during simple decision-making, such as pressing a lever to receive a reward.

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Advances in technology, chiefly the advent of neuroimaging techniques such as functional magnetic resonance imaging (fMRI), have allowed researchers to investigate similar matters regarding the operation of the human brain. Furthermore, research using these techniques may be extended in new directions to address questions not easily explored in animals, such as those involving the more complex decisions that occur in human society, (e.g., trusting an individual during a business transaction). These research efforts have introduced interdisciplinary collaborations and considerations, ranging from philosophy to economics, into the field of cognitive neuroscience. The contributions of these diverse fields do much to shape current thinking on human decision-making. In this paper, we will discuss how social information can modulate traditional ways of thinking about rational and economic decision-making specifically by affecting the neural systems of ***900** reward. First, we present an overview of the neural circuitry underlying human reward systems. Next we present a description of an experiment where social impressions affect trust judgments and decision-making. Finally, we address potential implications of the experimental findings to the legal field and discuss the potential of future interdisciplinary collaborations across law and neuroscience.

THE REWARD SYSTEM OF THE BRAIN

A "reward" may be operationally defined as any stimulus with desirable properties that can drive behavior. Based on this definition, it is postulated that the purpose of rewards in the environment is to (1) induce hedonic feelings that (2) encourage exploratory behavior and (3) shape learning to ensure exploitation of previously rewarded behaviors.[1] For example, a laboratory rat placed in an operant conditioning chamber (e.g., a "Skinner box" containing a lever that releases food pellets) will be driven to explore the environment and press an available lever because of the potential for a reward.[2] After gaining a food pellet, the rat learns to associate behavior and reward (action-outcome), resulting in an increase in the frequency or intensity of lever-pressing.[3] In 1954, Olds and Milner conducted "self-stimulation" experiments where, instead of a food reward, animals were electrically stimulated in the medial forebrain bundle (a group of neural fibers containing dopamine that connect midbrain dopaminergic centers such as the ventral tegmental area with forebrain structures such as the nucleus accumbens) during the pressing of a lever.[4] Those authors found that the reinforcing properties of the electrical stimulation led the animals to increase their response frequencies.[5]

Such self-stimulation studies, in addition to various ***901** pharmacological experiments, lent credence to the "dopamine hypothesis of reward," which postulated that reinforcing effects in the brain of various stimuli (e.g., addictive drugs) were caused by the release of the neurotransmitter dopamine in the brain. Electrophysiological recordings of neuronal activity of these dopaminergic cells, helped refine the relationship between dopamine and reward. While recording in the non-human primate brain, Wolfram Schultz and colleagues made the observation that dopaminergic cells in the midbrain, specifically in two distinct nuclei called the substantia nigra and the ventral tegmental area, were active when an unexpected reward was delivered.[6] In the experiment, these cells displayed bursts of activity once a monkey received an unexpected reward, such as a drop of juice.[7] However, once a light cue predicted the delivery of the juice (an instance of classical conditioning), the dopaminergic neurons no longer displayed the burst of activity at the time of

reward.[8] Instead, after learning of the association, bursts of activity by the dopaminergic cells were observed at the time of the light cue--in other words, the earliest predictor of the reward.[9] Finally, if an expected reward failed to occur (e.g., if juice was not delivered following presentation of the light cue), then a depression in the activity of the dopaminergic cells was observed, signaling a prediction error.[10] Dopaminergic neurons are therefore thought to aid in reward-related learning by providing a prediction error that can adjust expectations and guide behavior.[11]

Some of the primary targets of dopaminergic neurons include prefrontal cortical regions and the striatum, a structure located deep in the brain below the cortex and known for its heterogeneity in connectivity and functionality. For example, research has implicated the striatum in motor, cognitive, and motivational processes,[12] suggesting that the striatum may be ***902** a potential venue for the integration of movement and motivational information. While most of this research was conducted in animals, recent investigations of striatal function have extended to the human brain. Neuropsychological and neuroimaging techniques represent two primary methods used to probe the human striatum.[13] Neuropsychological research programs take advantage of pharmacological or anatomical lesions of brain regions and allow for an investigation of the necessity of the structure for proper performance to occur.[14] For instance, patients suffering from Parkinson's disease display striatal dysfunction due to a deterioration of the dopaminergic projection to the striatum.[15] This diminished dopaminergic input into the striatum leads to well-characterized motor deficits such as prominent tremors,[16] as well as to problems in cognitive processes such as learning from feedback in typical trial and error tasks.[17] Such behavioral results in humans mirror the electrophysiological data from animals, which suggest that dopamine processes a prediction error signal that impacts learning.[18]

The other methodology commonly used to investigate the functionality of the human striatum (as well as other brain regions) is neuroimaging, including both positron emission tomography (PET) and fMRI. Recent studies using PET, which allows imaging of neurotransmitter levels in the brain during cognitive tasks, have demonstrated that dopamine is released in the striatum during highly arousing situations that elicit motivation, such as food delivery when one is hungry[19] or while playing a video game for monetary rewards.[20] Another technique to study the human brain is fMRI, which takes ***903** advantage of the magnetic properties of blood to allow experimenters to measure the brain's activity indirectly through an assessment of the hemodynamic responses, also known as the blood-oxygenated level dependent (BOLD) response.[21] Briefly, fMRI builds on the idea that changes in blood flow in a specific brain region correlate with neural activity in that same region,[22] although a direct correlation is still under investigation.[23]

Using fMRI, investigators have been able to extend findings in animals to humans using both primary rewards (e.g., juice)[24] and secondary rewards (e.g., money).[25] For example, increases in oxygen demand, and thus brain activity, have been observed in the human striatum while subjects are anticipating a potential juice reward[26] or a potential monetary reward.[27] The striatum has also been associated with coding the differential response between a positive and negative consequence of an action, that is, whether the action led to a reward or a punishment.[28] Those data suggest that the striatum, specifically the dorsal region of the striatum called the caudate nucleus, rather than

processing the reward per se, may be involved in learning associations between behaviors and potential rewards.[29] The idea that the human striatum is important for reward-related learning is consistent with the findings from animal studies. In fact, the prediction error ***904** signal communicated by dopaminergic neurons[30] has been observed in the human striatum in fMRI paradigms,[31] further linking the human striatum with learning the value of stimuli or actions that predict rewards.[32]

THE SOCIAL MIND: HOW SOCIAL FACTORS MAY MODULATE NEURAL SYSTEMS OF REWARD

While early neuroimaging studies confirmed animal studies and extended those concepts into the human brain, research has now started to focus on the various ways in which social factors can contribute to reward processing in humans. Suffice it to say that this literature is beyond the scope of the present paper. A more comprehensive review on both the evolution of neuroeconomics[33] and social neuroscience[34] can be found elsewhere. The focus of this paper is the transition from simple processes performed by the striatum, such as learning that an action leads to a reward, to more complex processes observed in typical human society, such as learning that an individual predicts a potential reward during a business or legal proceeding.

Social stimuli are known to engage the brain's reward system, be they beautiful faces,[35] money[36] or status symbols such as extravagant sports cars.[37] Notably, modulation of the activity of brain regions such as the striatum is observed ***905** during social interaction.[38] For instance, activation of the striatum is particularly prominent during cooperation of two individuals during the so-called prisoner's dilemma game, where the two people interact and can either cooperate or defect toward a reward that varies in size according to their respective choices.[39] Striatum activation also increases when individuals are presented with the faces of previous cooperators[40] and even when exacting revenge on defectors,[41] an activity that was interpreted by the authors as a rewarding feeling resulting from the punishment of perceived unfairness.[42]

One interesting experiment of social interaction involved a game known in economics as the “trust game”[43] In a typical trust game, an investor is faced with a choice of how much money to transfer to another player, the trustee.[44] The transferred money gets tripled and the trustee can either defect from the interaction and keep the investment or he can send back some of the money to the investor, thus ensuring a profitable transaction for both players.[45] In multi-round exchanges, a reputation for players is built, thus each move has to be considered carefully.[46] In an elegantly designed experiment, King-Casas and colleagues found that reciprocity inspires learning during transactions, which leads to formation of reputations.[47] The authors found that an intention to trust signal was being computed in the striatum.[48] That is, subjects learned that a player was trustworthy and that was reflected as an investment in the next trial. Interestingly, the intention ***906** to trust signal shifted in time as learning progressed, similar to the temporal prediction error signal exhibited by dopamine, further suggesting that the striatum is involved in learning about reward-related stimuli in a social setting.[49]

Thus, research suggests that social factors map cleanly onto the existing knowledge of basic reward circuits. It is unclear, however, how information such as moral beliefs or social perceptions influence decision-making and the neural circuitry of reward processing. It has been observed, for example, that people are willing to forgo part of wages if they believe that their employer's mission is praiseworthy.[50] This type of behavior cannot be accounted for by rational theory,[51] and other variations (e.g., choosing to drive to a more distant department store because one does not like the policies of the nearest store) have been replicated elsewhere.

In order to study this phenomenon, we conducted a study where participants were instructed they would play a variation of the trust game with three different partners portrayed as having different levels of moral aptitude.[52] In our variation of the trust game, participants were given a dollar and told that they could either keep (i.e., defect) or share (i.e., invest) the money. If they chose to share it with a partner, the money would be tripled, and the participant would then receive feedback on whether the partner shared back and split the profits (positive feedback) or defected (negative feedback). The subjects were instructed they would play with three fictional partners twenty-four times each. The partners were portrayed as having a certain personality that may or may not match the actual behavior displayed by the partner. Participants saw a computer screen with the face and name of a partner and were given the decision to keep or share money. After registering their choice, participants were then presented with the feedback from the partner (positive or negative) before a new ***907** trial would commence.

After being allowed practice trials to facilitate understanding of the rules and operation of the trust game, participants were given three bios that included a photograph (counterbalanced across the study), a name, and a blurb that described the partner's moral aptitude, as well as a recent newspaper article detailing an event in the partner's life. For example, one partner was described as a volunteer who had recently saved a woman from a club fire, which suggested that this partner was morally praiseworthy (“good” partner). Another partner was a business school graduate who attempted to sell heat-insulating tiles from of the space shuttle Columbia on internet auction sites (“bad” partner). The third partner was involved in a similarly arousing story (e.g., supposed to be in a plane that crashed but he missed the flight), although it contained no information to form biases regarding expected moral behavior (“neutral” partner). The bios, created by economist Robert Frank,[53] were extremely effective at creating social expectation and irrational impressions of each partner's behavior. However, despite their apparently disparate moral aptitudes, the partners all played with the same reinforcement schedule (50%). That is, they all shared or kept game money at the same frequency. Thus, based on outcomes alone, participants should have learned over time to adjust their expectations for the fictional partner's moral behavior and adapt decision-making appropriately.

A manipulation check (e.g., questionnaire asking how trustworthy a partner was perceived to be) showed that subjects learned at some level that all three partners were essentially equivalent in their behavior. Specifically, during a pre-experimental session, the subjects rated the partners on moral aptitude differentially and according to the fictional bios. However, following the twenty-four trials with the partners, those differential ratings were abolished. Nevertheless, during game play the participants were still more trusting of the “good” partner, making more share decisions with the

“good” rather than the “bad” partner. This observation was maintained across the entire game and was still evident in the trials as the game was nearing an end. The behavioral result suggests that social perceptions are strong modulators of behavior and can significantly influence economic decision- ***908** making. Using concurrently performed fMRI, we were also able to pinpoint the biological mechanisms that led to this behavior.

As discussed above, the striatum plays an important role in reward-related learning. Thus, it is no surprise that striatum activation was observed when participants were receiving feedback from partners; such feedback was being used to guide future decision-making. When participants were interacting with the neutral partner, for instance, increases in BOLD signal were observed in the striatum following positive feedback, while a decrease was observed following negative feedback. This pattern mimics the previously characterized signal in the striatum that differentiates between rewards and punishments, suggesting that the human striatum is valuating the current feedback to guide future decision-making. In the case of the neutral partner, there was no information that could bias behavior. Participants thus had to learn through trial and error what the outcome of interacting with the neutral partner would be. As a result, participants shared and kept about 50% with the neutral partner, as one would expect based on random sampling.

During trials in which subjects had been provided the fictional biographies, however, the differential signal in the striatum was not observed. This suggests that the brain's trial and error learning system may have been inhibited during the game by the availability of prior social information. Participants may have bypassed the current feedback (e.g., good partner did not share with me on this trial) due to the overwhelming prior social information. Consequently subjects did not update their decision-making, preferring instead to conform to their original biases created by irrational social expectations. Thus, perceptions of moral character can influence the neural systems of reward and learning by creating social expectations that are more difficult to update. This finding raises the following important consideration for studies in the social domain that involve interactions: humans have biases, and the strength of those biases can modulate how we make decisions. Future designs must take such issues into account.

IMPLICATIONS FOR THE LAW

A fundamental consideration in many, if not all, legal ***909** undertakings is the assessment of the credibility of evidence. In many circumstances, evidence is presented to a judge or jury through a witness to aid in the explanation. The behavioral results reported here parallel a well-known phenomenon--namely, that the perception of the personal attributes of a witness directly impacts their credibility. As the presentation of a series of events or facts fundamentally shapes the case before a judge or jury, the credibility of the witness used to communicate those details is central to the task of the trial attorney. While the experiments reported here were conducted in a controlled laboratory setting, they may nonetheless remind legal professionals of the significance of moral perception in legal proceedings.

The present experiments emphasize the importance of establishing the credibility of the witness early in their presentation to a court. The previously published results demonstrate that the pre-established perception of the moral aptitude of a game character influences the behavior of human participants over an extended period of time.[54] Indeed, if the game character is perceived as trustworthy, then the human subjects continued to trust the character in the form of investments (i.e., “share” decisions) throughout the course of the game. Extending this observation to the court room, once a perception of a witness is established with a jury or judge, it subsequently impacts all later interpretations of that witness's testimony and behavior. As is well known by trial attorneys, the cultivation of a witness's image early in a proceeding as a trustworthy, moral, and upright individual may reap rewards throughout the trial. Indeed, the moral aptitude of a witness is often central to a criminal trial where the actions of the accused are being evaluated for criminal intent. Similarly, attorneys should not neglect the cultivation of the image of scientific or technical experts in civil trials, such as patent infringement cases.

While the presentation of a witness provides the attorney with the opportunity to shape perceptions in a court room, the individual members of a jury also arrive at court with preconceived notions. The data presented here emphasize that such preconceptions may have a lingering effect on the later behavior of the jury. A voir dire examination provides the attorney with the opportunity to assess those biases and to ***910** plan for trial accordingly. A voir dire examination usually refers to the examination by the court or by attorneys of prospective jurors to determine their qualifications for jury service and whether cause exists to excuse particular jurors, as well as to provide information about the jurors to the attorneys.[55] When performed before a trial, a carefully crafted voir dire examination allows the attorney to determine what perceptions the potential member of a jury possesses before presenting any portion of the case. By recognizing that the preconceived notions have a long-term impact on the actions and perceptions of the potential jurors, an attorney may well invoke his right to excuse jurors whose preconceived notions would directly impact the heart of the case to be presented. By excluding such individuals from the jury pool, the eventual reception of the attorney's case would thereby be improved.

FINAL THOUGHTS AND FUTURE DIRECTIONS WITH RESPECT TO THE LAW

With certain variations, the experiments reported here may be used in the future to help establish strategies for the presentation and cross-examination of witnesses. In the results presented here, the human subjects behaviorally maintained their trust throughout the entire course of the experiments. Future experiments could investigate what behavior on the part of the fictional character would be required to best establish this trust and credibility. The fictional characters used in the experimental paradigms could even be crafted to mimic the actual participants in a trial, including their actual physical, mental, and personality traits. Subsequently, attorneys could experiment with different ways of presenting the witness to see if the various approaches would impact the credibility and moral aptitude of the witness as perceived by experimental subjects acting as a mock jury.

Additionally, the fictional character may be fashioned after one of the witnesses to be used by opposing counsel. Attorneys could then employ a variety of approaches in the context of the trust

game to investigate how most effectively to disrupt the credibility of the witness. The attorney might then draft a cross-examination of that witness according to the most effective approach. By performing these preliminary ***911** experiments in the controlled (and relatively inexpensive) setting of a laboratory, the attorney would gain a wealth of information about potential jury perceptions and thus be able to prepare for a mock trial or actual trial more effectively.

Footnotes

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1 Wolfram Schultz, Getting Formal with Dopamine and Reward, 36 Neuron 241, 242 (2002).

2 Burrhus F. Skinner & William H. Morse, Concurrent Activity Under Fixed-Interval Reinforcement, 50 J. Comp. & Physiological Psychol. 279, 279 (1957).

3 Id. at 279-80.

4 James Olds & Peter Milner, Positive Reinforcement Produced by Electrical Stimulation of Septal Area and Other Regions of Rat Brain, 47 J. Comp. & Physiological Psychol. 419, 419 (1954).

5 Id. at 423-25.

6 Wolfram Schultz et al., A Neural Substrate of Prediction and Reward, 275 Science 1593, 1594 (1997).

7 Id.

8 Id.

9 Id.

10 Id.

11 See P. Read Montague & Gregory S. Berns, Neural Economics and the Biological Substrates of Valuation, 36 Neuron 265, 265-72 (2002); Schultz, supra note 1, at 243-44.

12 See Mark Packard & Barbara Knowlton, Learning and Memory Functions of the Basal Ganglia, 25 Ann. Rev. Neuroscience 563, 568-69 (2002).

13 See, e.g., Daphna Shohamy et al., Role of the Basal Ganglia in Category Learning: How Do Patients with Parkinson's Disease Learn?, 118 Behav. Neuroscience 676, 676 (2004); Nora Volkow et al., “Nonhedonic” Food Motivation in Humans Involves Dopamine in the Dorsal Striatum and Methylphenidate Amplifies this Effect, 44 Synapse 175, 176 (2002).

14 See, e.g., Shohamy et al., supra note 13, at 676.

15 Id. at 683.

16 Id.

17 Id. at 682.

18 Schultz et al., supra note 6, at 1594.

19 See Volkow et al., supra note 13, at 176-78.

20 See Matthias Koepp et al., Evidence for Striatal Dopamine Release During a Video Game, 393 Nature 266, 266-67 (1998).

21 Nikos Logothetis et al., Neurophysiological Investigation of the Basis of the fMRI Signal, 412 Nature 150, 150 (2001).

22 Kenneth Kwong et al., Dynamic Magnetic Resonance Imaging of Human Brain Activity During Primary Sensory Stimulation, 89 Proc. Nat'l Acad. Sci. U.S. 5675, 5675 (1992).

23 See, e.g., Logothetis et al., supra note 21, at 150.

24 See John O'Doherty, Reward Representations and Reward-Related Learning in the Human Brain: Insights from Neuroimaging, 14 Current Opinion Neurobiology 769, 771 (2004); Mauricio Delgado, Reward-Related Responses in Human Striatum, 1104 Annals N.Y. Acad. Sci. 70, 73 (2007).

25 See Delgado, supra note 24, at 74.

26 John O'Doherty et al., Neural Responses During Anticipation of a Primary Taste Reward, 33 Neuron 815, 817-19 (2002).

27 Brian Knutson et al., Anticipation of Increasing Monetary Reward Selectively Recruits Nucleus Accumbens, 21 J. Neuroscience, at RC159, RC159:1 (2001).

28 Mauricio Delgado et al., Tracking the Hemodynamic Responses to Reward and Punishment in the Striatum 84 J. Neurophysiology 3072, 3076 (2000); Elizabeth Tricomi et al., Modulation of Caudate Activity by Action Contingency, 41 Neuron 281, 287-89 (2004).

29 Mauricio Delgado et al., An fMRI Study of Reward-Related Probability Learning, 24 Neuroimage 862, 862 (2005).

30 Schultz et al., supra note 6, at 1594.

31 Samuel McClure et al., Temporal Prediction Errors in a Passive Learning Task Activate Human Striatum, 38 Neuron 339, 339 (2003); John O'Doherty et al., Temporal Difference Models and Reward-Related Learning in the Human Brain, 38 Neuron 329, 329 (2003).

32 Montague & Berns, supra note 11, at 265.

33 See, e.g., Paul Glimcher & Aldo Rustichini, Neuroeconomics: The Consilience of Brain and Decision, 306 Science 447 (2004); Alan Sanfey et al., Neuroeconomics: Cross-Currents in Research on Decision-Making, 10 Trends Cognitive Sci. 108 (2006).

34 See, e.g., Matthew Lieberman, Social Cognitive Neuroscience: A Review of Core Processes, 58 Ann. Rev. Psychol. 259 (2007).

35 Itzhak Aharon et al., Beautiful Faces Have Variable Reward Value: fMRI and Behavioral Evidence, 32 Neuron 537, 537 (2001).

36 John O'Doherty et al., Abstract Reward and Punishment Representations in the Human Orbitofrontal Cortex, 4 Nature Neuroscience 95, 95 (2001).

37 Susanne Erk et al., Cultural Objects Modulate Reward Circuitry, 13 Neuroreport 2499, 2500-01 (2002).

38 E.g., James Rilling et al., A Neural Basis for Cooperation, 35 Neuron 395, 395 (2002).

39 Id.

40 Tania Singer et al., Brain Responses to the Acquired Moral Status of Faces, 41 Neuron 653, 653 (2004).

41 Dominique de Quervain et al., The Neural Basis of Altruistic Punishment, 305 Science 1254, 1254 (2004).

42 Id.

43 See, e.g., Colin Camerer & Keith Weigelt, Experimental Tests of a Sequential Equilibrium Reputation Model, 56 Econometrica 1 (1988); Joyce Berg et al., Trust, Reciprocity, and Social History, 10 Games & Econ. Behav. 122 (1995).

44 See Berg et al., supra note 43, at 123.

45 Id.

46 See Camerer & Weigelt, supra note 43, at 1-2.

47 Brooks King-Casas et al., Getting to Know You: Reputation and Trust in a Two-Person Economic Exchange, 308 Science 78, 82 (2005).

48 Id. at 81.

49 Id. at 82.

50 Robert Frank, What Price the Moral High Ground? Ethical Dilemmas in Competitive Environments 76-84 (2004).

51 Id. at 77 ("From the perspective of strict economic theory ... the price one actually pays should not depend ... on the prices one is able to pay."); see also Robert Frank, Passions Within Reason: The Strategic Role of the Emotions 178 (1988).

52 See Mauricio Delgado et al., Perceptions of Moral Character Modulate the Neural Systems of Reward During the Trust Game, 8 Nature Neuroscience 1611, 1611 (2005).

53 Id. at 1616.

54 Id. at 1611.

55 Black's Law Dictionary 1605 (8th ed. 2004).

Raymond Singer and Dana Darby Johnson, Recognizing Neurotoxicity 42 Trial 62 (March, 2006)[5]

Neurotoxicity—poisoning of the brain and nervous system—is a well-documented effect of exposure to many widely used chemicals, yet doctors (and lawyers) often fail to recognize it. Chemically injured clients often report a confusing array of symptoms, with no medical diagnosis. The symptoms may seem vague and unconnected, leading you to wonder, "Could these symptoms really

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be caused by a chemical exposure?" Once you recognize the signs and understand them in context—as a constellation of symptoms resulting from a toxic injury—you will have greater confidence in bringing your client's case to justice.

A person who has suffered a serious chemical injury is likely to have sustained considerable damage to his or her brain and nervous system. This is important for a lawyer to know, because doctors often recognize only the person's physical illness, not realizing that serious brain and nervous system damage may have also occurred.

Neurotoxicity can be documented, but perhaps not in the way you might think. A person's ability to think, perceive, control emotions, plan, and manage his or her life can diminish drastically without anything being visible to a radiologist or neurologist on an MR I or a CT scan.[1]

The most reliable and widely accepted way to assess actual brain function is through neuropsychological evaluation. (This is true for head-injury patients and ***63** those suffering from dementia, as well as those affected by exposure to toxic chemicals.)

Researchers have noted that imaging techniques are often of little value in evaluating neurotoxicity.[2] In our and others' experience, imaging techniques can occasionally pick up abnormalities caused by neurotoxicity and may be helpful for forensic purposes, but they are not cost-beneficial for routine screening.[3]

Neuropsychological testing tends to be more sensitive to brain injury than CT and routine MRI scans, which provide only a static and relatively gross view of neural structure. In one study of six head-injury cases, CT and/or MRI scans yielded little or no evidence of neuropathology as detected by neuropsychological testing.

Positron emission tomography (PET) scans, however, corroborated the impaired function.[4] PET and SPECT (single photon emission computed tomography) scans offer a more dynamic look at brain structure, but both of these tests still need interpretation as to the cause of the abnormality (which could be benign).

Common symptoms

What do chronic pain, anxiety, neurological problems, confusion, psychiatric symptoms, and cognitive declines have in common? They can all result from neurotoxic chemical exposure.

Symptoms of neurotoxicity include memory and concentration problems; confusion; multiple sclerosis or MS-type symptoms; impaired control of the limbs, bladder, or bowels; headaches or migraines; sleep disorders, including sleep apnea; eye problems that are neurological in origin; balance and hearing problems; muscle weakness; anxiety or panic attacks; depression; and other psychiatric or neurological symptoms.[5]

Other symptoms that could be caused by chemical injury include multi-organ system malfunction; lower or upper respiratory problems, such as chronic sinus problems; multiple chemical sensitivity (MCS); liver or kidney problems; and fibromyalgia or other pain disorders.

Along with nervous system dysfunction, the temporal association of any of these conditions with toxic chemical exposure tends to support the theory that the overall cause of the client's injuries is a toxic insult to the body.

The illness you probably need to know the most about is MCS, both because it is common among chemical injury patients, and because doctors often don't recognize it in their patients. The MCS diagnosis is still rejected by many doctors in part because it is difficult to quantify objectively—but then, so are headaches.

Many doctors are not aware of the significant research that shows MCS is common and quite real.[6] MCS is similar to other disabling illnesses. People who have it can become very ill from exposures to everyday chemicals, such as perfumes, paint, pesticides, and cleaning products.

Under some conditions, MCS is recognized as a potentially disabling condition by the Social Security Administration, the U.S. Department of Housing and Urban Development, and the Americans with Disabilities Act.[7]

Documenting a chemical injury

There are various ways you can document the presence and course of a neurotoxic injury. All of them will help you build your case.

Conduct a neuropsychological evaluation. This procedure reveals both the most detailed view and the most subtle problems of the working brain.

A forensic neuropsychological evaluation usually includes a full battery of tests that can take up to 12 hours to complete. It can assess brain function, including memory; concentration; the ability to learn new information; executive function (the ability to plan, manage, and carry out a plan); perceptual functions, such as spatial awareness; motor functions, such as dexterity; and personality, emotion, and motivation. This evaluation can often detect whether changes have occurred that may be a result of toxic injury.

Be aware that some neuropsychologists consider someone impaired only if his or her cognitive functioning is well below average. Such an approach is inadequate when the person was once high-functioning.

For example, a client with a superior IQ—such as a doctor or scientist— who now is unable to do his or her job will not benefit from an evaluation that interprets an “average” level of intelligence as “normal.” Or your client may be someone who previously functioned at an average level but now

is considered below average or has more marked problems in particular areas of brain function, such as emotion, personality, or executive function. These individuals benefit from more complex and subtle evaluations.

Several red flags can signal that the brain is not working as well as it should. For example, if a client's vocabulary skills are high but his or her ability to process new information is at the 50th percentile, this discrepancy suggests a decline in information-processing skills. If the client was previously a successful engineer, a neuropsychological evaluation will give you findings that point to a decline in brain function.

Assess personality and emotional *64 function. Chemically injured people can suffer personality changes induced by brain damage. The nenropsycbologist needs to take a thorough history and conduct a record review to determine whether any personality disorders were preexisting or caused (or exacerbated) by the chemical injury.

The Minnesota Multiphasic Personality Inventory-2 (MMPI-2) is often used to assess personality.[8] But this instrument was not standardized on brain-injured people or those with neurological disorders, so the results must be interpreted carefully.

For example, if a “normal” person showed many neurological symptoms, he or she might correctly be characterized as mentally ill. But it would be normal for a chemically injured person to report an array of neurological symptoms.

The patient with “too many” symptoms can get a diagnosis of “somatic disorder”—that is, having physical symptoms caused by psychological conditions. This misdiagnosis says that psychological problems are the underlying cause of the illness.

Neurotoxicity patients may well have psychological problems, but these are often the result, not the cause, of their condition. The true cause—organic (physical) brain dysfunction, or neurotoxicity—is too easily overlooked. When interpreting the MMPI-2, the expert must consider the person's medical and neurological conditions before reaching conclusions.

Also, some common interpretations of the MMPI-2 might overdiagnose malingering.[9] An improper diagnosis of malingering can make it difficult to prove an injury.

It is not unusual for patients suffering front neurotoxicity to be misdiagnosed as having psychological problems because of their depression and anxiety levels, the sheer number of their symptoms, and their belief that chemicals made them ill. To minimize this error, choose among the most qualified experts you can find: Psychologists, neuropsychologists, or psychiatrists who are familiar with chemical injury, neurotoxicity, and MCS.

“Image” the brain. It would be ideal to have an X-ray that would show what's gone wrong in the chemically injured brain. Unfortunately, brain scans are usually not helpful, because we don't have

the technology to “take a picture” of most brain injuries. (Even damage caused by traumatic brain injuries, such as from an automobile accident, may not show up in brain imaging.) A weak correlation exists between neuroimaging findings and neurocognitive outcome.[10] Neurotoxic damage does not necessarily affect brain structure at the level we can see on a brain scan.

PET and SPECT scans are often more sensitive to brain injury than either MRIs or CT scans,[11] but even if they show an abnormality, they don't show what caused it. Such scans have limited utility in court as proof of damage.[12] The meaning of the abnormality still needs to be explained via neuropsychological assessment. A brain MRI often can be useful to rule out the possibility of another brain disorder.

Test the body. Searching for physical evidence of a chemical injury has been compared to searching for a bullet shot through someone's body: The bullet may be gone, but the havoc it wreaked is still there. Blood and urine can be tested for residue of the chemical in question and its breakdown products, or for a range of chemicals, but usually this testing is effective only while the client is still being exposed or after recent exposure.

The body may store toxicants in the fat and tissues, longer-lasting storage sites than the blood or urine. Tissue samples can be taken and occasionally are helpful, but these procedures can be difficult, painful, and expensive. Hair analysis may be helpful, but it is often controversial.[13] Immunological testing can determine whether the client has elevated antibodies to some molds, suggesting high levels of exposure to toxic mold.[14]

Test and analyze the exposure location. When analyzing an exposure location for toxic substances (such as might be found in the air or on surfaces), it is better to hire your own consultants to perform the work. They can control many important variables that could be ignored by other service providers.

Earlier tests conducted by the defendant may be available, but the results might not be valid for various reasons, even if the tests were conducted by a government agency. A potential defendant, alter discovering that its site would be tested, may have aired out the building and washed down all the surfaces before testing. Unfortunately, the tests that government agencies perform are often woefully inadequate.

Analyze the site carefully. Is there adequate ventilation? Is there a clean-air exchange? Is the ventilation system blowing contaminated air into the client's breathing space?

Some toxic chemicals may be heavier than air, so ventilation in those circumstances should exhaust air out of the room from the level of the floor, not the ceiling. One of our clients suffered severe brain damage after using solvents outdoors on his boat. Most people think that applying solvents outside is safe. However, our client applied them while lying on his back, under the boat. Because the solvent was heavier than air, this amounted to lying in a dense cloud of neurotoxic gas, and

friends had to pull him out front under his boat. The toxic exposure caused injuries that rendered him ***66** completely disabled.

Under *Daubert v. Merrell Dow Pharmaceuticals, Inc.*,[15] the expert should present published research showing that the chemical implicated in the case has caused the same damage that your client suffered. But there is room for some flexibility.

For example, in a 2001 federal toxictort case, the court admitted testimony that experts do not always need extensive, specific research on a particular product to arrive at an opinion.[16] Instead, the chemical's toxicity can be deduced from general toxicology and basic logic: The substance was an organic solvent; organic solvents are neurotoxic; therefore, this solvent is neurotoxic.

In our experience, neuropsychological testimony is routinely admitted under *Daubert* rules.[17] Its application to neurotoxicology is well established but may be challenged. We are not aware of cases where this testimony has been excluded on *Daubert* grounds, but individual states' requirements will vary.

In one case, the Ohio Supreme Court unanimously ruled that a witness who is not a physician, but who qualifies as an expert under state evidence rules, may give evidence that would be relevant to diagnosis of a medical condition if the testimony is within the expertise of the witness.[18]

Usually, the statute of limitations does not start running until the client has received a diagnosis stating that his or her condition was caused by a chemical exposure. In many cases, it takes years for this diagnosis to be made.

In other situations, the client is so seriously injured that he or she cannot seek out appropriate medical or legal help. The very symptoms of neurotoxicity—memory problems, inability to concentrate or think clearly, and difficulty processing information—impede the injured person's ability to understand what happened to him or her and can decrease his or her intellectual and emotional capacity to pursue litigation. In such cases, you may need to file a statement of mental incompetence to extend the statute of limitations.

What to expect from the defense

Invariably, the defense will seek to minimize the link between your client's symptoms and the toxic substance he or she was exposed to and will try to play down the product's harmfulness. Expect arguments like these:

"This product cannot damage your health." The Material Safety Data Sheet (MSDS), required by law of every manufacturer, is a good place to start when seeking documentation of a chemical's adverse health effects, because often the MSDS lists them.[19] But sometimes the MSDS doesn't even hint at a product's real dangers, and you will need to conduct further research. The neurotoxicity of common products is discussed in various texts.[20]

“If this product caused ill health effects, it would not be marketable.” In fact, hundreds of neurotoxic products ***67** are promoted and sold. More than 850 industrial and commercial chemicals are known to cause neurobehavioral disorders.[21]

“Ninety-five percent of the ingredients are inert, so what's the problem?” There are two issues here. One is whether 5 percent of an active ingreclient is toxic enough to cause health effects—and often it is, because toxic substances can be harmful in small amounts.

The other issue is the meaning of “inert.” So-called inert ingredients can be more toxic than the “active” ones. By labeling an ingredient “inert,” a company may be trying to avoid admitting that there is a noxious ingredient in its product. The manufacturer may call its formulation a “trade secret.”

Try to obtain a list of the inert ingredients by subpoena and have a laboratory analyze the product. Once yon establish what the inert ingredients are, your consultants should assess their toxcity.

“But we didn't exceed government standards for exposure.” “Safe” levels of exposure are a compromise between an industry's commercial needs and consumer protection and do not guarantee that an injury cannot occur. These standards generally become stricter with every passing decade, and incidents of reported chemical injury are what cause them to change.

Furthermore, safe levels are routinely set to protect a healthy male worker. But some people are more susceptible than others. Women, for instance, tend to be more sensitive than men, and different bodies react differently to toxins.[22] Variations in sensitivity are even observable in rats. Also, there may be no safe level at which a person can inhale a particular substance.

The MSDS typically will state that if a person shows signs of illness, you must remove him or her from the area immediately. This suggests that it is generally recognized that some people will become ill even when they are working under the recommended safe-exposure guidelines.

“This amount was far too small to damage anyone's health.” Chronic exposure ***68** to low levels of some toxic chemicals can be even worse than a single acute exposure, because brain damage is cumulative over time.

“The plaintiff had preexisting conditions.” Plaintiffs in these cases often do. It makes sense that people whose health is already compromised are the most vulnerable to poisons, because their bodies' detoxification systems—especially the liver and kidneys—are already stressed. People with a preexisting condition suffer further deterioration of their health. Your expert should document the preexisting condition thoroughly—this may require extensive review and analysis of the medical record—and document what new symptoms emerged and what preexisting symptoms became worse.

"Just smelling the chemical could not have caused this." Actually, inhalation and skin contact are often more effective routes of entry for a poison than swallowing. When something is swallowed, it is partly neutralized by stomach acids. The body then attempts to detoxify it through the liver, kidneys, and other organs. But inhalation and skin contact allow a substance to enter the bloodstream directly, without any filtering. For example, doctors now use skin patches to administer morphine and birth control.[23] And sniffing glue (solvents) can produce an instantaneous high and cause immediate and permanent brain damage.

"A neurologist found nothing wrong." Few neurologists have training in toxicology, and they rarely recognize the symptoms of neurotoxicity. A patient who suggests his or her symptoms were caused by a chemical exposure may encounter a brick wall of denial, bordering on hostility.

Some neurologists won't pay attention unless a patient's symptoms are extreme: For example, the patient cannot tell what day it is or walk in a straight line. Even then the neurologist may misdiagnose the patient as normal, even if neuropsychological testing shows serious functional deficits. Still, a neurologist's exam may help rule out non toxicological causes of a neurological illness or document certain physical signs, such as seizures or gait disturbances.

"Chronic pain is not a symptom of brain or nerve damage." The term "chronic pain" may seem vague, outside the realm of most doctors, and potentially confusing to a jury. But chronic pain can certainly be a symptom of brain damage and toxic exposure.

Damage to the brain and nerves can disrupt the nerve signals themselves or the way the brain interprets those signals.[24] Resulting sensations can be tingling, burning, or debilitating pain, which one of my chronic pain patients described as "like a thousand razor blades." Chronic pain can be a terrible ordeal and may require strong painkillers whose side effects could cause more damage.

"It is ludicrous to believe that neurotoxic chemicals can cause such disparate symptoms as insomnia, chronic fatigue, and gastrointestinal problems." On the contrary, the brain and nervous system control all bodily functions. The autonomic nervous system controls the involuntary part of bodily processes, including digestion, blood circulation, and the "fight or flight" response.

"Multiple chemical sensitivity does not exist." Studies indicate that almost 16 percent of the U.S. population report having unusual reactions to common chemicals.[25] About 6.3 percent have been diagnosed with MCS or declared disabled from it.[26] There is considerable research on, and international recognition of, this condition.

"The plaintiff is malingering." Every competent forensic neuropsychological assessment includes tests for malingering. When assessing a potential client, consider that a chemical injury would be one of the most difficult injuries to fake. Doctors who recognize the symptoms are few and far between.

You will probably find that your client has tried to find a cure, sincerely wants to return to work, and is seeking litigation as a last resort. The “invalid” label is profoundly depressing to most people. Nevertheless, you must always rule out the possibility of malingering and psychosomatic disorders.

“The plaintiff has a personality disorder (or is mentally ill).” Ironically, a plaintiff's personality disorder may be evidence of injury, not a reason to dismiss the case. Brain damage can result in such disorders, psychiatric symptoms, and even schizophrenia. Establish the patient's mental health before the exposure to help determine whether the exposure caused or exacerbated the psychiatric symptoms. In any case, it is not surprising when a person with a chronic illness, adjusting to a devastating life change, develops what may be diagnosed as a personality disorder.

On the other hand, some patients with a diagnosis of a psychiatric disorder don't actually have one. A patient may have received that diagnosis precisely because he or she claimed to be hurt by chemicals and was labeled “delusional.”

Compensation and cure

There is no cure for chemical injury, but conventional medical treatments may help some symptoms and promote modest improvement. Alternative medicine treatment for neurotoxicity is quite controversial, but in our experience, nutritional therapy and natural medicines may be the only things that help extremely sensitive patients. Your clients should receive enough compensation to pay for continuing treatment, including less conventional approaches, such as medically supervised detoxification, infrared saunas, visits to rehabilitation centers, and possibly hyperbaric ***69** oxygen treatments.

Compensation should include lost salary, lost savings, and medical bills that will probably continue for a lifetime. It should cover counseling or psychotherapy to help patients adjust to being chronically ill; losing their jobs, their friendships, and possibly their homes; straining their marriages; and being unable to continue with hobbies. But they generally should avoid psychiatric drugs. Chemically sensitive patients may react to pharmaceuticals (usually petroleum derivatives) as they do to chemicals.

Your familiarity with neurotoxicity and chemical injury will help you guide your client to the clearest assessment of his or her disability. Choosing the right experts and testing will contain litigation costs and further your goals of obtaining justice and compensation.

Footnotes

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1 *See, e.g.*, Bernhard Voller et al., *Neuropsychological, MRI, and EEG Findings After Very Mild Traumatic Brain Injury*, 13 BRAIN INJURY 821 (1999) (finding only 3 of 12 patients with brain dysfunction demonstrated an abnormal MRI).

2 *See, e.g.*, Joseph C. Arezzo & Herbert H. Schaumburg, *Screening for Neurotoxic Disease in Humans*, 8 J. AM. C. TOXICOLOGY 147 (1989); *see also* Pamela Reed Gibson, *Disability-Induced Identity Changes in Persons with Multiple Chemical Sensitivity*, 15 QUALITATIVE HEALTH RES. 502, 503-04 (2005).

3 *See generally* RAYMOND M. SINGER, NEUROTOXICITY GUIDEBOOK (2d ed. 2005).

4 Ronald M. Ruff et al., *Computerized Tomography, Neuropsychology, and Positron Emission Tomography in the Evaluation of Head Injury*, 2 NEUROPSYCHIATRY, NEUROPSYCHOL. & BEHAV. NEUROLOGY 103 (1989).

5 *See generally* SINGER, *supra* note 3. The Neurotoxicity Screening Survey provides a complete checklist of possible signs and symptoms, *available at* www.neurotox.com/OLD%20SITE/nss.pdf (last visited Jan. 23, 2006).

6 *See, e.g.*, Stanley M. Caress & Anne C. Steinemann, *Prevalence of Multiple Chemical Sensitivities: A Population-Based Study in the Southeastern United States*, 94 AM. J. PUB. HEALTH 746 (2004); Nancy Fiedler et al., *Responses to Controlled Diesel Vapor Exposure Among Chemically Sensitive Gulf War Veterans*, 66 PSYCHOSOMATIC MED. 588 (2004); Howard M. Kipen et al., *Prevalence of Chronic Fatigue and Chemical Sensitivities in Gulf Registry Veterans*, 54 ARCHIVES ENVTL. HEALTH 313 (1999); Richard Kreutzer et al., *Prevalence of People Reporting Sensitivities to Chemicals in a Population-Based Survey*, 150 AM. J. EPIDEMIOLOGY 1 (1999); William J. Meggs et al., *Prevalence and Nature of Allergy and Chemical Sensitivity in a General Population*, 51 ARCHIVES ENVTL. HEALTH 275 (1996).

7 *See, e.g.*, letters and memoranda to and from Department of Housing and Urban Development, *available at* www.usdoj.gov/crt/foia/tall05.txt (last visited Jan. 23, 2006).

8 The MMPI-2 is *available at* www.pearsonassessments.com/tests/mmpi_ 2.htm#norms (last visited Jan. 23, 2006).

9 *See, e.g.*, James N. Butcher et al., *The Construct Validity of the Lees-Haley Fake Bad Scale: Does This Scale Measure Somatic Malingering and Feigned Emotional Distress?* 18 ARCHIVES CLINICAL NEUROPSYCHOL. 473 (2003).

10 *See, e.g.*, Voller et al., *supra* note 1; Paul A.M. Hofman et al., *MR Imaging, Single-Photon Emission CT, and Neurocognitive Performance After Mild Traumatic Brain Injury*, 22 AM. J. NEURORADIOLOGY 441 (2001); Shelli R. Kesler et al., *SPECT, MR, and Quantitative MR Imaging: Correlates with Neuropsychological and Psychological Outcome in Traumatic Brain Injury*, 14 BRAIN INJURY 851 (2000) (finding a modest but significant correlation between memory and intellectual impairments and number of brain abnormalities evidenced by quantitative magnetic resonance, magnetic resonance (MR), and all imaging studies combined (but not SPECT alone) and noting a positive correlation between psychological distress and MR abnormalities, most frequently in the frontal lobes).

11 *See* Donald J. Nolan & Tressa A. Pankovits, *High-Tech Proof in Brain Injury Cases*, TRIAL, June 2005, at 26.

12 Brickford Y. Brown et al., *Are We Out of the Gray Area Yet? Recent Developments in the Use of PET and SPECT Scans to Prove Causation and Injury in Toxic Tort Litigation, available at* www.morankikerbrown.com/CM/Articles/Articles67.asp (last visited Jan. 23, 2006). For an alternate perspective, see Garo Mardirossian & Joseph Martin Barrett, *The Use of Functional Brain Imaging of Organic Brain Injury: A Primer, available at* www.caala.org/DOCS/3-98mardirossian.pdf (last visited Jan. 23, 2006); *see also* Charles G. Monnett III & Kristin M. Jordan, *Scientific Evidence Following* Daubert vs. Merrell Dow: *Are PET Scans Admissible to Establish Traumatic Brain Injury?, available at* www.carolinalaw.com/CM/Articles/article-scientific-evidence.asp (last visited Jan. 23, 2006).

13 *See generally* SIDNEY A. KATZ & AMARES CHATT, HAIR ANALYSIS: APPLICATIONS IN THE BIOMEDICAL AND ENVIRONMENTAL SCIENCES (1988).

14 Raymond Singer, *Clinical Evaluation of Suspected Mold Neurotoxicity*, in BIOAEROSOLS, FUNGI, BACTERIA, MYCOTOXINS & HUMAN HEALTH: PROC. OF THE FIFTH INT'L BIOAEROSOL CONF. 78 (2005); *see also* Raymond Singer. *Forensic Evaluation of a Mold (Repeated Water Intrusions) Toxicity Case*, 20 ARCHIVES CLINICAL NEUROPSYCHOL. 808 (2005).

15 509 U.S. 579 (1993).

16 Bonner v. ISP Techs., 259 F.3d 924 (8th Cir. 2001); *see also* www.daubertontheweb.com (last visited Jan. 23, 2006).

17 *See generally* Bruce H. Stern, *Admissibility of Neuropsychological Testimony After* Daubert *and* Kumho, 16 NEUROREHABILITATION 93 (2001).

18 Shilling v. Mobile Analytical Servs., Inc., 602 N.E.2d 1154, 1156-57 (Ohio 1992).

19 *See* www.msds.com (last visited Jan. 23, 2006).

20 *See, e.g.*, Raymond Singer, *Neurotoxicity Guidebook, in* 1 NEUROTOXICITY OF INDUSTRIAL & COMMERCIAL CHEMICALS (John L. O'Donoghue ed., 1985).

21 Kent Anger & Barry Johnson, *Chemicals Affecting Behavior, in* 1 NEUROTOXICITY OF INDUSTRIAL & COMMERCIAL CHEMICALS (John L. O'Donoghue ed., 1985).

22 *See, e.g.*, Mark R. Cullen & Carrie A. Redlich, *Significance of Individual Sensitivity to Chemicals: Elucidation of Host Susceptibility by Use of Biomarkers in Environmental Health Research*, 41 CLINICAL CHEMISTRY 1809 (1995); Timothy T. Iyaniwura, *Individual and Subpopulation Variations in Response to Toxic Chemicals: Factors of Susceptibility, available at* www.riskworld.com/Nreports/2004/Iyaniwura.htm (last visited Jan. 23, 2006); Michael K. Robinson, *Intra-Individual Variations in Acute and Cumulative Skin Irritation Responses*, 45 CONTACT DERMATITIS 75 (2001); Michael K. Robinson, *Population Differences in Acute Skin Irritation Responses: Race, Sex, Age, Sensitive Skin, and Repeat Subject Comparisons*, 46 CONTACT DERMATITIS 86 (2002).

23 *See, e.g.*, Mayo Clinic Med. Servs., *Birth Control Patch, at* www.mayoclinic.com/index.cfm?id=PR00075 (last visited Jan. 23, 2006).

24 *See* Nat'l Inst. Neurological Disorders and Stroke, *Pain: Hope Through Research, at* www.ninds.nih.gov/disorders/chronic_pain/detail_chronic_ pain.htm (last visited Jan. 23, 2006).

25 *See, e.g.*, Caress & Steinemann, *supra* note 6; Kreutzer et al., *supra* note 6; *see also* Meggs et al., *supra* note 6 (finding 33 percent).

26 *See, e.g.*, Kreutzer et al., *supra* note 6.

Owen D. Jones, Joshua W. Buckholtz, Jeffrey D. Schall and Rene Marois, Brain Imaging for Legal Thinkers: A Guide for the Perplexed 2009 Stanford Technology Law Review 5 (December 14, 2009)[6]

INTRODUCTION

***1** It has become increasingly common for brain images to be proffered as evidence in civil and criminal litigation.[2] This Article offers some general guidelines to legal thinkers about how to understand brain imaging studies--or at least avoid misunderstanding them. And it annotates a published brain imaging study by several of the present authors (and others) in order to illustrate and explain, with step-by-step commentary.[3]

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***2** Brain images are offered in legal proceedings for a variety of purposes, as Professors Carter Snead and Gary Marchant have usefully surveyed.[4] On the civil side, neuroimaging has been offered in constitutional, personal injury, disability benefit, and contract cases, among others. For example, in *Entertainment Software Ass'n. v. Blagojevich*,[5] the court considered whether a brain imaging study could be used to show that exposure to violent video games increases aggressive thinking and behavior in adolescents. In *Fini v. General Motors Corp*,[6] brain scans were proffered to help determine the extent of head injuries from a car accident. In *Boyd v. Bert Bell/Pete Rozelle NFL Players Retirement Plan*,[7] a former professional football player proffered brain scans in an effort to prove entitlement to neuro-degenerative disability benefits. And in *Van Middlesworth v. Century Bank & Trust Co.*[8], involving a dispute over the sale of land, the defendant introduced brain images to prove mental incompetency, resulting in a voidable contract.

***3** In criminal cases, brain images are sometimes invoked to support an argument that a defendant is incompetent to stand trial. In *United States v. Kasim*, for example, Kasim was found to be demented, and incompetent to stand trial for Medicaid fraud, on the basis of medical testimony that included brain images.[9] Brain images are also increasingly proffered by the defense at the guilt-determination phase, in an effort to negate the mens rea element of a crime, and to thereby avoid conviction. For example, in *People v. Weinstein*,[10] a defendant accused of strangling his wife and throwing her from a twelfth floor window sought to introduce images of a brain defect, in support of an argument that he was not responsible for his act. And in *People v. Goldstein*,[11] a defendant sought to introduce a brain image of an abnormality, in an effort to prove an insanity defense, after he pushed a woman in front of a subway train, killing her.

***4** Brain images have also been proffered at the sentencing phase of criminal cases, in furtherance of mitigation. For example, in *Oregon v. Kinkel*,[12] a boy convicted of killing and injuring fellow students in a high school cafeteria sought to introduce brain images of abnormalities, in an effort to secure a more lenient sentence. Brain images have been offered--in *Coe v. State*,[13] for example--to argue that a convicted murderer is not competent to be executed. And accessibility to brain imaging technology has even been litigated--in *Ferrell v. State*[14] and *People v. Morgan*[15] for instance--in the context of a claim that a defense counsel's failure to procure a brain image for the defendant amounted to ineffective assistance of counsel.

***5** For better or worse, the full complement of cases at the intersection of neuroscience and law is now too large for comprehensive overview--in part because many of the cases do not result in reported decisions.[16] While there is no denying that brain imaging is a powerful tool, whether used for medical or legal purposes, it is also clear that, like any tool, brain imaging can be used for good or for ill, skillfully or sloppily, and in ways useful or irrelevant.

***6** We are concerned that brain imaging can be misused by lawyers (intentionally or unintentionally) and misunderstood by judges and jurors. Consequently, our aim in this Article is to provide information about the operation and interpretation of brain imaging techniques, in hopes that it will increase the extent to which imaging is properly interpreted, and conversely decrease the extent to

which it is misunderstood or misused. We provide this information across two Parts and one Appendix.

***7** Part I of the Article provides some very brief background on modern brain imaging, with particular emphasis on one wide-spread and powerful technique, known as functional magnetic resonance imaging (fMRI). The physics of fMRI, and the statistics accompanying the analyses that generate brain images, are complicated. We will make no effort to provide a comprehensive or detailed exploration of the subject. There are many existing textbooks that cover this material to great depths, often far greater than legal thinkers will need to master, for the specific contexts in which brain images are (potentially) legally relevant.[17]

***8** Instead, we will aim here to focus on what a lawyer needs to know, in order to have a basic understanding of what works how and why. Our goal is to present this in an accessible way, recognizing (as we trust our readers to allow us) that simplifying discussions are illustrative of general principles, but obviously ignore the richer detail that enables deeper appreciation of important caveats and subtleties.

***9** Part II of this Article then turns to provide, in brief and accessible overview, a variety of key concepts to understand about the legal, biological, and brain imaging contexts at this particular law/neuroscience intersection, as well as a variety of guidelines we (and in some cases others) recommend to help avoid the various factual errors, logical traps, and analytic mis-steps that can all too quickly lead away from sound and sensible understandings of what brain images can mean--and equally what they cannot. Make no mistake: we are not the only researchers concerned about potential misunderstandings of brain images.[18] A great many cautions have been swirling about in the literature, often offering multiple versions of key and basic points about the limitations of the technologies, and we hope here to distill some of those, add others, and explain the set in a way that we hope provides a concise and useful introduction to legal thinkers approaching this interdisciplinary nexus for the first time.

***10** The Appendix to this Article then provides a concrete illustration of how to read an fMRI study. We will not over-claim. Some of the details of fMRI defy short descriptions, involve technical details unlikely to be relevant in legal contexts, or both. On the other hand, much of the technical jargon, and many of the basic concepts one will encounter in an fMRI study, are clear with just a little explanation, oriented toward the audience we anticipate. We attempt to provide this in an accessible, informative way--assuming no particular scientific sophistication of the reader.

***11** Specifically, the core of the Appendix is a 2008 fMRI study (co-authored by three of us and others) that used fMRI techniques to investigate how brains are activated during punishment decisions. Though we do not anticipate that the substantive findings will necessarily find immediate utility in litigation, we believe that legal thinkers reading an fMRI study will learn most from a study that inherently addressed matters relevant to law--in this case, the decision whether or not to punish someone for criminal behavior and, if so, how much.

***12** To facilitate that learning in this concrete application, the *Stanford Technology Law Review* has generously afforded us the unique opportunity to annotate the Article in the margin with explanations of various terms and contexts, as they appear throughout the study.

I. BRAIN-IMAGING: A VERY BRIEF OVERVIEW

***13** There are many kinds of brain images. All readers are likely familiar with the way x-rays, and the closely aligned technique known as computed tomography (CT) scanning, can show various structural anomalies in the body, including in the brain. In these techniques, radiation aimed at and passing through the body forms images on photographic film. The varying density of different tissues in the body results in varying levels of radiation reaching the film--creating, in turn, an image of internal structures. (For example, bone tissue appears as white, while soft tissue appears gray.) CT scanning varies from conventional x-rays by virtue of collecting images from multiple angles rotating around the body, which images are then combined by computers into cross-sectional representations. These techniques (like magnetic resonance imaging, which will be discussed in a moment) are used for information about how various parts of the body are structured. They can show whether structures are intact, and can reveal damage, atrophy, intrusions, and developmental anomalies. They do not, however, collect or provide information about how those body parts are actually functioning.

***14** *PET scanning*, which refers to positron emission tomography, is one of the techniques that enable researchers to learn about how the brain *functions*, as it is actually doing so. With PET, a researcher injects a subject with radioactive tracers that move through the bloodstream and accumulate in different locations and concentrations in the brain, over time, as different parts of the brain increase and decrease activity (such as glucose metabolism) that is associated with brain function. (A similar technique, known as *SPECT*, uses single photon emission computed tomography.)

***15** *EEG* and *MEG*, short for electroencephalography and magnetoencephalography respectively, records electromagnetic fluctuations in various parts of the brain, as the brain is functioning, using non-invasive sensors applied to the scalp.[19] In research laboratories, the EEG signals can be analyzed in relation to stimuli or responses to obtain *event-related potentials* (ERP) which were used before brain imaging was developed to make inferences about the brain processes underlying perceptual, cognitive and motor processes.[20]

***16** *fMRI* (functional magnetic resonance imaging[21]) uses the technology of regular magnetic resonance imaging adapted to detect changes in hemodynamic (literally “blood movement”) properties of the brain occurring when the subject is engaged in very specific mental tasks. In a nutshell (and with a reminder that we are over-simplifying for heuristic purposes) here's how it works.

***17** At its most basic, fMRI can be understood as a tool for learning which regions of the brain are working, how much, and for how long, during particular tasks. In much the same way that the body

delivers more oxygen to muscles that are working harder, the body delivers more oxygen to brain regions that work harder. The fMRI technique measures blood oxygenation levels--within small cubic volumes of brain tissue known as “voxels”--as those levels change across time with the varying metabolic demands of active neurons.[22] Changes in demand for oxygen are widely considered to be reliable proxies for inferring the fluctuating activity of the underlying neural tissue.[23]

***18** The physical principles underlying fMRI are quite complex. But in general terms the technology works as follows: An fMRI machine creates and manipulates a primary magnetic field,[24] as well as several smaller magnetic fields (one in each three-dimensional plane) that can be quickly varied in orientation and uniformity. Recall (from basic physics) that protons within the nuclei of atoms spin on an axis and carry a positive charge. As they spin, these electric charges form what can be thought of as tiny magnets. When a person is inserted (typically horizontally) into the open bore of an fMRI machine, the previously random axes of spin, for many protons, align, like iron filings along a magnet. That is, the axes begin to point in the same direction. Researchers then administer to the subject's head brief radio frequency pulses (which usually originate from a device looking rather like a small bird-cage that surrounds the subject's head). Those pulses deflect the protons' axes of spin temporarily. When the pulses stop, the axes gradually return to their original orientation, releasing energy during that “relaxation” process. The machine can detect characteristics of the released energy because it depends on a proton's “local” magnetic environment, and this environment is affected by the relative concentrations of oxygenated and deoxygenated blood in local brain tissue. Crucially, as these concentrations are affected by regional changes in brain activity, they provide indirect markers of neural activity that form the basis of the fMRI signal. The machine enables localization of these signals in space--i.e. “spatial resolution”--by collecting them from many different “slices” of the brain. And the technique enables localization of these signals in time--i.e., “temporal resolution”--by recording the signals many times over a period of several seconds for each mental event. A “stack” of slices comprising the whole brain is acquired every couple of seconds or so, enabling the rapid collection of many of these three-dimensional “volumes” of brain activity over the period of an experimental paradigm.

II. KEY CONCEPTS AND GUIDELINES

***19** This Part is divided into four sections. These address the legal context, the biological context, the intersection of law and biology, and finally, with that preparatory background, the brain imaging context. We proceed in this way because one cannot gain a clear understanding of brain imaging, and its intersection with the legal system, without first considering the underlying legal and biological contexts, and their background interactions.

A. The Legal Context

***20** With terrific, new, whiz-bang technology--which can reveal inner structures and workings of the brain--it is all too tempting to jump past the more mundane legal issues, and to race to apply new techniques to solve new problems in new ways.

***21** But hold the horses. Although our principal purpose here is to discuss how to read (and not read) brain imaging evidence, we would be remiss not to first anchor the discussion in the legal contexts in which those images might, arguably, be admissible. The territory here is broad, and could occupy us for some time. But to be brief, there are a variety of questions to keep in mind, at the outset, in order to understand the specific legal context in which brain imaging might be considered in the courtroom.

***22** The threshold consideration, of course, is: *Are the proffered brain images relevant?* Because behavior comes from the brain, and the legal system often cares not only about how someone acted but also why, it is tempting to assume that brain images of people important to the litigation will provide legally relevant information, of one sort or another. But this is, in fact, not a decision to reach lightly.

***23** *What specific legal questions do the images purportedly address?* Contexts vary considerably, even within the civil and criminal halves of the docket (each of which bears differing underlying standards of proof). Within civil cases, for example, there are a wide variety of different legal purposes into which brain images might conceivably plug. Are brain images proffered to help establish liability, such as in the case of a medical malpractice action? To demonstrate a pre-existing condition, such as in the case of a dispute over insurance coverage? To help estimate damages, such as in the case of a car accident? And within criminal cases, are brain images proffered during the liability phase, in an effort to defeat the prosecution's claim that the defendant had (and was therefore capable of having) the mental state requisite for conviction? Are they instead proffered during the sentencing phase, in an effort to mitigate penalty? Are they proffered as evidence of lying or truthfulness?

***24** It is important to remember that the admissibility of brain images is not simply a matter of whether they are scientifically sound. The potential relevance and hence admissibility of brain images will vary, according to *the specific legal issue at hand* within civil and criminal contexts. Put another way, the admissibility of brain images depends largely on their perceived potential relevance (if any) to the issue to be determined, *independent of* (and often before) considering the quality and interpretation of the specific images themselves.

***25** *What, specifically, do the images allegedly demonstrate, and how well does that connect to the legal issues at hand?* Some of the many variables that may come into play here include: Are these structural or functional images? When were they taken? (For example, before or after events in question?) How recently? Under what circumstances were they procured? (For example, what specific mental tasks was the subject executing during functional imaging?) What is being compared to what? (For example: Are these before and after images of the same brain?; Are these comparisons between a party's brain and a group-averaged composite, for contrast?)

***26** *What are the applicable standards for the admissibility of scientific evidence?* As is well known, the federal and state systems can have (and often do have) different standards for the admission of scientific evidence. And the state standards vary among the states. It is therefore necessary to note that the backdrop of all that follows below is the specific legal regime under which images are to be evaluated for potential relevance, within the specific context of the specific matters in dispute. Although it is not our purpose here to explore the applicability of scientific evidence law to brain images, we would be remiss not to flag the centrality of evidentiary rules and contexts to all that follows. Interested readers will find comprehensive discussion of scientific evidence generally in the treatise Modern Scientific Evidence.[25]

B. The Biological Context

***27** Understanding the potential relevance of brain images to law also requires a few words of general background about the relationship between biology and behavior generally. Key things to keep in mind (generally speaking) include[26]:

• All behavior results from the interaction of genes, environments (including social contexts), developmental history, and the evolutionary processes that built the brain to function in the ways it does.

• Behavior originates in the physical and chemical activities of the brain.[27]

• All behavior is thus "biological."

• Understanding behavior as biological in nature does not mean that behavior is "biologically determined" in a reductionist or reliably predictive way.

• The brain is an evolved information-processing organ that, generally speaking, and through differing processes, associates various environmental inputs with various behavioral outputs.

• Those environmental influences are (generally speaking) unique for each individual.

• Each person's brain, though highly flexible, is both anatomically and functionally specialized. (That is, brains do not consist of undifferentiated all-purpose tissue.)

• Humans share, across the species, a common brain plan of anatomical and functional specialization,

• Each brain is slightly different in size, shape, and other anatomical features.

• One area of the brain can affect multiple behaviors.

• A given behavior arises from multiple areas of the brain.

• Different individuals can use different parts of the brain, in different ways, on the same cognitive tasks.

• Behavior is a complex phenomenon, neither attributable to single causes, nor easily parsed among multiple causes.

• Cognitive phenomena rarely originate from a single region in the brain.

C. The Intersections of Biology and Law

***28** The potential relevance of brain imaging to law must be evaluated against the broader background of the intersections of law and human biology (both structural and behavioral) generally.[28]

• Like the rest of behavior, both criminal and law-abiding behavior originates in the brain.

• There is no brain structure, or set of brain structures, that is specifically "for" criminal or law-abiding behavior (since those categorizations of behavior are socially determined).

• To say that brain features influence behavior relevant to crime does not mean that brain features can necessarily explain why certain individuals behaved criminally.

• No explanation of any kind, brain-based or otherwise, has an automatic bearing on justification or exculpation or mitigation in law.

• Legal responsibility for behavior is a legal conclusion, not a scientific finding.

• Establishing a "biological basis" for behavior carries no automatic, normative relevance to anything (legal or otherwise).

• Norms, though influenced by biology, can never be justified by biology alone.

D. The Brain Imaging Context (using fMRI)

***29** With that brief but foundational background, drawing attention to the legal and biological contexts, and the interaction of them, we can now turn to discuss key concepts about brain imaging that legal thinkers should know[29]:

1. Anatomical imaging and functional imaging are importantly different.

***30** Two anatomical images, taken one minute apart, will ordinarily look identical. Yet two functional images, from data collected one minute apart, could look completely different. One reason this is so is simply that, in the latter case, brain activity changes rapidly. Another reason is because

fMRI brain images are built statistically, not recorded photographically. In the typical fMRI case, hundreds of recordings are made of each voxel in the brain, at slightly different times (e.g., every two seconds). Each recording of each voxel within a given trial is analogous to a single frame in a movie. Learning what happens within each voxel, over time, is akin to watching motion seem to emerge from the observation of successive snapshots that comprise a moving picture. But that metaphor only captures part of the fMRI technique, because there are subsequently many repeat recordings of that voxel, under similar conditions, on many consecutive trials--the results of which are typically then averaged across trials. Complicating matters further is that there are about one hundred thousand voxels within the brain, and what typically matters is how neural activity within those voxels is varying over time, in relation to some task the subject(s) undertake while being scanned. Furthermore, within each voxel are millions of neurons of different types, interacting in ways that could be mechanistically different but indistinguishable from the measure of fMRI. In the end, fMRI brain images lay the result of any one of many possible statistical tests overtop of an anatomical image of a selected slice of the brain. That is, an fMRI image is a composite of an anatomical image, of the researcher's choosing, and a statistical representation of the brain activity in that image, also of the researcher's choosing.

2. Functional brain imaging is not mind reading.

***31** There is more to a thought than blood flow and oxygen. fMRI is very good at discovering where brain tissue is active (commonly by highlighting differences between brain activations during different cognitive tasks). But differences are not thoughts. fMRI can show differences in brain activation across locations, across time, and across tasks. But that often does not enable any reliable conclusion about precisely what a person is thinking.[30]

3. Scanners don't create fMRI brain images; people create fMRI brain images.

***32** Images are only as good as the manner in which the researcher designed the specific task or experiment, deployed the machine, collected the data, analyzed the results, and generated the images. It is important to remember that fMRI images are the result of a process about a process. Multiple choices and multiple steps go into determining exactly what data will be collected, how, and when--as well as into how the data will be analyzed and how it will be presented.

4. Group-averaged and individual brain images are importantly different.

***33** Most brain imaging research is directed toward understanding how *the average brain*, within a subject population, is activated during different tasks. This is not at all the same thing as saying either that all brains performing the same task activate in the average way, or saying that the activation of a single brain can tell us anything meaningful about the operation of the average brain. Consequently:
Do not assume that the scan of any individual is necessarily representative of any group.

Do not assume that the averaged scan of any group will necessarily be representative of any individual.

5. There is no inherent meaning to the color on an fMRI brain image.

***34** fMRI does not detect colors in the brain. fMRI images use colors--of whatever segment of the rainbow the researcher prefers--to signify *the result of a statistical test.* By convention, the brighter the color (say, yellow compared to orange) the greater the statistical significance of the differences in brain activity between two conditions. Put another way, the brighter the color, the less likely it is that the differences in brain activity in that voxel or region, between two different cognitive tasks, was due to chance alone. As with any color-coded representation, accurate interpretation requires knowing exactly what each color represents in absolute terms. The researcher specifies what each color will represent, and this matters. Yellow might mean that there is only one chance in one thousand that the difference between brain activations in this voxel, between condition, is due to random chance. Or, yellow might mean that there is one chance in twenty that the difference is due to random chance.[31]

6. fMRI brain images do not speak for themselves.

***35** No fMRI brain image has automatic, self-evident significance. Even well-designed, well-executed, properly analyzed, properly generated images must have their import, in context, interpreted.

7. Classification of an anatomical or behavioral feature of the brain as normal or abnormal is not a simple thing.

***36** Because we have learned a great deal about the brain, from dissection, imaging, and the like, we have some confidence about what a typical brain looks like, and how a typical brain functions. But even without full anatomical scans of everyone on the planet, we know there is considerable variation--both anatomically and functionally--within some general parameters. That means that it can be (with some exceptions, such as a bullet lodged in the brain) difficult to say with precision *how* uncommon a given feature or functional pattern may be, even if it appears to be atypical. Base rates for anatomical or functional conditions are often unknown. For example: suppose brain images show that a defendant has an abnormal brain feature. We often do not have any idea how many people with nearly identical abnormalities do not behave as the defendant did. How, then, to make a reasonable conclusion about the causal effect of the brain condition?

8. Even when an atypical feature of function is identified, understanding the meaning of that is considerably complex.

***37** Brain images can show unique features and functions of a person's brain. But the meaning of them is rarely self-evident. Determining which of those are important, and how, depends not only on the legal context for which the images are offered, but also on expert analysis of what the images do and do not mean. For example, suppose that measurement of the fMRI-detected signal during a

given cognitive task indicates that a person has less neural activity in a given region than does the average person. Does that mean that the person is somehow cognitively impaired in that region? Or might it alternatively indicate that the person has more expertise or experience than average, requiring less cognitive effort?

9. Correlation is (still) not causation.

***38** The fact that two things vary in parallel tells us little about whether the two are necessarily causally related and, if so, which causes which. For example, suppose brain imaging reveals that seventy percent of inmates on death row for homicide have atypical brain activation in a given region, compared to normal, unincarcerated subjects. That statistic does not mean that the brain activation pattern causes homicidal behavior. It might mean that having murdered affects brain activations, or that being incarcerated for long periods of time affects brain activations, or something else entirely.

10. Today's brain is not yesterday's brain.

***39** In all but the most fanciful of contexts, a brain scan likely takes place long after the behavior (such as criminal activity) that gives rise to the scan. Drawing causal inferences is therefore further complicated. People's brains change with age and experience. And some proportion of the population will develop atypical anatomical or functional conditions over time. If a defendant is scanned six months or six years after the act in question, and the scan detects an abnormality, it is not a simple matter to conclude with confidence that the same abnormality was present at the time in question or-- even if one assumes so, arguendo--that it would have meaningfully affected behavior.

11. Scanners (in theory) detect what they are built, programmed, and instructed to detect, in the way they are built, programmed, and instructed to detect it.

***40** Scanners are highly complex and often unique pieces of machinery. So (as in other areas of science) are the people who calibrate, program, operate, and interpret collected data. It is important to recognize that the product of these intersecting complexities may or may not be reliable, generalizable, and replicable.

12. fMRI brain imaging enables inferences about the mind, built on inferences about neural activity, built on the detection of physiological functions believed to be reliably associated with brain activity.

***41** It is important to remember that fMRI does not provide a direct measure of neuronal activity--as do, for example, invasive techniques that measure single neuron recordings. fMRI detects fluctuations in oxygen concentrations thought to be reliably associated with neuronal activity. But the precise relationship between metabolic demands and neuronal function remains poorly understood.

***42** Even if regional activations in brain images reflect true neural activity, it should also be kept in mind that our ability to confidently infer the cognitive process that must have led to such regional activation is highly constrained. This is because neuroscientists still understand so little about what the various regions of the human brain contribute to a particular cognitive function.

CONCLUSION

***43** We have provided above a very brief introduction to the intersection of brain imaging and law (and provide in the Appendix a step-by-step tour of a neurolaw brain-imaging study) principally intended for those relatively new to this interdisciplinary intersection.

***44** Courts are already frequently confronted with issues concerning the admissibility and proper interpretation of brain images. And all present indicators suggest that brain images will be proffered by more lawyers in more cases in more contexts for more purposes in the future.

***45** On one hand, the issues for the legal system are simply the same as they long have been: What might the proffered evidence tell us that may help us to answer legally identified questions in fair, effective, and efficient ways? Brain imaging is simply the latest high-tech tool to be offered for its potential assistance in this age-old enterprise.

***46** On the other hand, brain imaging represents a perfect storm of power, to be used or abused. It combines the authoritative patina enjoyed by scientific evidence generally, and the allure of all-modern brain science specifically, with the seductive power of visual images.

***47** How the legal system will ultimately deal with the exogenous shock of such technologically, rhetorically, and visually powerful information remains to be seen. To deal with it well, however, the legal system will need the combined efforts and advice of many legal and neuroscientific scholars,[32] such as those populating the MacArthur Foundation Law and Neuroscience Project,[33] the Gruter Institute for Law and Behavioral Research,[34] and the Society for Evolutionary Analysis in Law (SEAL).[35] And, fortunately, many efforts are underway. In the meantime, legal thinkers likely to encounter brain images in their work would be well-advised to lay carefully constructed mental templates, on which to hang existing and future information emerging from brain-imaging communities. We hope that what we have discussed here will provide a useful means for doing so.

Footnotes

1 Owen D. Jones is Professor of Law and Professor of Biological Sciences at Vanderbilt University. Joshua W. Buckholtz is a neuroscience graduate student at Vanderbilt University. Jeffrey D. Schall is E. Bronson Ingram Professor of Neuroscience at Vanderbilt University. Rene Marois is Associate Professor of Psychology at Vanderbilt University. Jones, Schall, and Marois are members of the MacArthur Foundation Law and Neuroscience Project, of which Jones also serves as Co-Director. The first two authors contributed equally to this Article. Correspondence to: owen.jones@vanderbilt.edu or rene.marois@vanderbilt.edu. This Article was prepared for the Stanford Technology Law Review 2009 Symposium on *Neuroscience and the Courts: The Implications of Advances in Neurotechnology*.

We received helpful comments from Gary Marchant and Teneille Brown, as well as from participants at conferences of the MacArthur Foundation Law and Neuroscience Project, the 2008 and 2009 Conferences on Empirical Legal Studies, and the Arizona State University College of Law conference "Law and Ethics of Brain Scanning: The Next Big Thing Coming Soon to a Courthouse Near You?" Bailey Spaulding and Francis Shen provided valuable research assistance.

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2 For an overview of issues, see Jeffrey Rosen, *The Brain on the Stand*, N.Y. Times Mag., Mar. 11, 2007, at 49; Stacey A. Tovino, *Functional Neuroimaging and the Law: Trends and Directions for Future Scholarship*, 7 Am. J. Bioethics 44 (2007). A sampling of the rapidly-growing scholarship at the law/neuroscience intersection appears *infra* note 32.

3 The full complement of authors is: Joshua W. Buckholtz, Christopher L. Asplund, Paul E. Dux, David Zald, John C. Gore, Owen D. Jones, and Rene Marois. The article was published as *The Neural Correlates of Third-Party Punishment*, 60 Neuron 930 (2008).

4 A very useful survey, on which we draw in part in the paragraphs that follow, has been prepared by Professor Carter Snead. *See* Carter Snead, Neuroimaging and the Courts: Standard and Illustrative Case Index, (2006), http://www.ncsconline.org/d_research/stl/June06/Snead.doc . Our research also benefitted from Gary Marchant, Brain Scanning and the Courts: Criminal Cases, Presentation to the Research Network on Legal Decision Making, MacArthur Foundation Law and Neuroscience Project (Oct. 11, 2008).

5 404 F. Supp. 2d 1051 (N.D. Ill. 2005).

6 No. 227592, 2003 Mich. App. LEXIS 884 (Mich. Ct. App. Apr. 8 2003).

7 410 F.3d 1173 (9th Cir. 2005).

8 No. 215512, 2000 Mich. App. LEXIS 2369 (Mich. Ct. App. May 5, 2000).

9 United States v. Kasim, No. 2:07 CR 56, 2008 U.S. Dist. LEXIS 89137 (N.D. Ind. Nov. 3, 2008). *See also* McMurtey v. Ryan, 539 F.3d 1112 (9th Cir. 2008); United States v. Gigante, 982 F. Supp. 140 (S.D.N.Y. 1997).

10 591 N.Y.S.2d 715 (N.Y. Sup. Ct. 1992).

11 786 N.Y.S.2d 428 (N.Y. Sup. Ct. 2004), *overruled on other grounds*, 6 N.Y.3d 119, 843 N.E.2d 727, 2005 N.Y. LEXIS 3389 (2005).

12 56 P.3d 463 (Or. Ct. App. 2002).

13 17 S.W.3d 193 (Tenn. 2000).

14 918 So.2d 163 (Fla. 2005).

15 719 N.E.2d 681 (Ill. 1999).

16 One of the many efforts under way, within the MacArthur Foundation Law and Neuroscience Project, is a study by Hank Greely and Teneille Brown to find all actual and attempted uses of neuroimaging in criminal cases in California after January 1, 2006, regardless of whether such uses are mentioned in published opinions.

17 *See, e.g.*, Scott A. Huettel et al., Functional Magnetic Resonance Imaging (2d ed. 2009); Alfred L. Horowitz, MRI Physics for Radiologists: A Visual Approach (3d ed. 1995); Functional MRI: An Introduction to Methods (Peter Jezzard et al., 2001). Useful introductions to broader cognitive neuroscience, of which brain-imaging is but a part, appear in: Michael S. Gazzaniga et al., Cognitive Neuroscience: The Biology of the Mind (3d ed. 2008); Jamie Ward, The Student's Guide to Cognitive Neuroscience (2006); Essentials of Neural Science and Behavior (Eric R. Kandel et al. eds., 1995); Marie T. Banich, Cognitive Neuroscience and Neuropsychology (2d ed. 2004); Mark F. Bear et al., Neuroscience: Exploring the Brain (3d ed. 2006); Neuroscience (Dale Purves et al. eds., 4th ed. 2007).

18 The limits of brain imaging techniques are widely known to brain imaging researchers, and many brain imaging researchers are broadly concerned about misunderstandings among laypeople. A non-exhaustive list of important cautionary and explanatory articles, which have influenced some of our approaches below, include: John T. Cacioppo et al., *Just Because You're Imaging the Brain Doesn't Mean You Can Stop Using Your Head: A Primer and Set of First Principles*, 85 J. Personality and Soc. Psychol. 650 (2003); Dean Mobbs et al., *Law, Responsibility, and the Brain*, 5 PLoS Biology 693 (2007); Eric Racine et al., *fMRI in the Public Eye*, 6 Nature Revs. Neuroscience 159 (2005); J.D. Trout, *Seduction Without Cause: Uncovering Explanatory Neurophilia*, 12 Trends Cognitive Sci. 281 (2008); Society of Nuclear Medicine Brain Imaging Council, *Ethical Clinical Practice of Functional Brain Imaging*, 37 J. Nuclear Med. 1256 (1996); Michael S. Gazzaniga, *The Law and Neuroscience*, 60 Neuron 412 (2008); Joseph H. Baskin et al., *Is A Picture Worth A Thousand Words? Neuroimaging in the Courtroom*, 33 Am. J.L. & Med. 239 (2007); Russell A. Poldrack et al., *Guidelines for Reporting an fMRI Study*, 40 NeuroImage 409 (2008); Nikos K. Logothetis, *What We Can Do and What We Cannot Do With fMRI*, 453 Nature 869, (2008); William R. Uttal, Neuroscience in the Courtroom: What Every Lawyer Should Know about the Mind and the Brain (2008). One of the works most critical of how brain imaging results can be interpreted is William R. Uttal, The New Phrenology: The Limits of Localizing Cognitive Processes in the Brain (2003).

19 This signal is used in conjunction with measures like heart-rate and skin electrical conductance to constitute the polygraph procedure that is used commonly in a context of detecting deception. Although used commonly by the U.S. government and police departments, the fundamental limitations of these procedures have been thoroughly described. *See, e.g.*, Comm. to Review the Scientific Evidence on the Polygraph, Nat'l Research Council, The Polygraph And Lie Detection (2003)

20 Steven J. Luck, An Introduction to the Event-Related Potential Technique (2005). Some have attempted to use ERP signals in legal settings, but the limitations of this approach are well-known and can serve as lessons for the interpretation of brain imaging information.

21 The leading "f" remains lower-case, by convention.

22 *See generally* Huettel et al., *supra* note 17.

23 There are varying opinions in the neuroscience community about how conclusive an understanding there is of the fMRI signal's relationship to the activity of neurons, and about how much fMRI can reveal--beyond where brain activation occurred--about behavior and mental states. *See, e.g.*, Logothetis, *supra* note 18; Poldrack, *supra* note 18.

24 Magnetic fields are described in Tesla units. A 3-Tesla machine (which uses super-cooled electrical coils) generates a magnetic field roughly 60,000 times the magnetic field of the Earth.

25 Modern Scientific Evidence: The Law and Science of Expert Testimony (David L. Faigman et al., eds., 2006). Chapter One provides an excellent overview of the "general acceptance" and validity tests. It examines the cases that established those tests and discusses subsequent cases that applied and further developed those tests.

26 Interested readers can find further information about these background principles in a variety of sources (as well as in the citations that they, in turn, provide). *See, e.g.*, Jeffrey D. Schall, *On Building A Bridge Between Brain And Behavior*, 55 Ann. Rev. Psych. 23 (2004).

27 Yes, the alert reader will point out that some behavior, such as reflexes, leaps right out of the spinal cord. In the text, we are speaking in generalities.

28 *See, e.g.*, Owen D. Jones & Timothy H. Goldsmith, *Law and Behavioral Biology*, 105 Colum. L. Rev. 405 (2005). *See also* Law & the Brain (Semir Zeki & Oliver Goodenough, eds., 2006); Law, Mind, and Brain (Michael Freeman & Oliver Goodenough, eds., 2009); The Impact of Behavioral Sciences on Criminal Law (Nita Farahany ed., 2009); Owen D. Jones, *Behavioral Genetics and Crime, In Context*, 69 L. & Contemp. Problems 81 (2006); bibliographic sources compiled on the website of *The Society for Evolutionary Analysis in Law* (www.sealsite.org).

29 For more details, see sources cited *supra* note 17.

30 There appear to be some exceptions. *See, e.g.*, John-Dylan Haynes et al., *Reading Hidden Intentions in the Human Brain*, 17 Current Biology 323 (2007) (determining through brain imaging, with up to 71% accuracy, which of two tasks a person is covertly intending to perform); Y. Kamitani & F. Tong, *Decoding the Visual and Subjective Contents of the Human Brain*, 8 Nature Neuroscience 679 (2005) (determining through brain imaging, with near 80% accuracy, which of two overlapping visual patterns a person is paying attention to); S. A. Harrison & F. Tong, *Decoding Reveals the Contents of Visual Working Memory in Early Visual Areas*,458 Nature 632-35 (2009) (determining through brain imaging, with 83-86% accuracy, which of two visual patterns a person is actively maintaining in memory).

31 Consider this quote from a popular account:

With PET, for example, a depressed brain will show up in cold, brain-inactive deep blues, dark purples, and hunter greens; the same brain when hypomanic however, is lit up like a Christmas tree, with vivid patches of bright reds and yellows and oranges. Never has the color and structure of science so completely captured the cold inward deadness of depression or the vibrant, active engagement of mania.

Kay Redfield Jamison, An Unquiet Mind: A Memoir of Moods and Madness 196 (1995). Our point here is that the colors used are arbitrary, and may have been represented in this way to create precisely this impression.

32 *See, e.g.*, Law and the Brain (Semir Zeki & Oliver Goodenough, eds., 2006); Law, Mind, and Brain (Michael Freeman & Oliver R. Goodenough eds., 2009); Neuroscience and the Law: Brain, Mind, and the Scales of Justice (Brent Garland ed., 2004); George J. Annas, *Foreword: Imagining a New Era of Neuroimaging, Neuroethics, and Neurolaw*, 33 Am. J.L. & Med. 163 (2007); Bruce A. Arrigo, *Punishment, Freedom, and the Culture of Control: The Case of Brain Imaging and the Law*, 33 Am. J. L. & Med. 457 (2007); Abram S. Barth, Note and Comment, *A Double-Edged Sword: The Role of Neuroimaging in Federal Capital Sentencing*, 33 Am. J.L. & Med. 501 (2007); Nita Farahany, *Cruel and Unequal Punishments*, 86 Wash. U. L.R. 859 (2009); Neal Feigenson, *Brain Imaging and Courtroom Evidence: On the Admissibility and Persuasiveness of fMRI*, 2 Int'l J. L. Context 233 (2006); Brent Garland & Paul W. Glimcher, *Cognitive Neuroscience and the Law*, 16 Current Opinion In Neurobiology 130 (2006); Steven Goldberg, *MRIs and the Perception of Risk*, 33 Am. J.L. & Med. 229 (2007); Oliver R. Goodenough, *Mapping Cortical Areas Associated with Legal Reasoning and Moral Intuition*, 41 Jurimetrics J. 429 (2001); Henry T. Greely, *Neuroscience and Criminal Justice: Not Responsibility but Treatment*, 56 U. Kan. L. Rev. 1103 (2008); Henry T. Greely, *Remarks on Human Biological Enhancement*, 56 U. Kan. L. Rev. 1139 (2008); Henry T. Greely & Judy Illes, *Neuroscience-Based Lie Detection: The Urgent Need for Regulation*, 33 Am. J.L. & Med. 377 (2007); Joshua Greene & Jonathan Cohen, *For the Law, Neuroscience Changes Nothing and Everything*, 359 Phil. Transactions Royal Soc'y London B: Biological Sci. 1775 (2004); Charles N. W. Keckler, *Cross Examining the Brain: A Legal Analysis of Neural Imaging for Credibility Impeachment*, 57 Hastings L.J. 509 (2006); Laura Stephens Khoshbin & Shahram Khoshbin, *Imaging the Mind, Minding the Image: An Historical Introduction to Brain Imaging and the Law*, 33 Am. J.L. & Med. 171 (2007); Adam J. Kolber, *Therapeutic Forgetting: The Legal and Ethical Implications of Memory Dampening*, 59 Vand. L. Rev. 1561, 1623-24 (2006); Adam Kolber, *Pain Detection and the Privacy of Subjective Experience*, 33 Am. J.L. & Med. 433 (2007); Jennifer J. Kulynych, *The Regulation of MR Neuroimaging Research: Disentangling the Gordian Knot*, 33 Am. J.L. & Med. 295 (2007); Jonathan H. Marks, *Interrogational Neuroimaging in Counterterrorism: A "No-Brainer" or a Human Rights Hazard?*, 33 Am. J.L. & Med. 483 (2007); Terry A. Maroney, *The False Promise of Adolescent Brain Science in Juvenile Justice*, 85 Notre Dame L. Rev. (forthcoming 2010); Dean Mobbs et al., *Law, Responsibility, and the Brain*, 5 PLoS Biology 693 (2007); Stephen Morse, *Brain Overclaim Syndrome and Criminal Responsibility: A Diagnostic Note*, 3 Ohio St. J. Crim. L. 397 (2006); Erin Ann O'Hara, *How Neuroscience Might Advance the Law*, 359 Phil. Transactions Royal Soc'y London B: Biological Sci. 1677 (2004); Purvak Patel et al., *The Role of Imaging in United States Courtrooms*, 17 Neuroimaging Clinics N. Am. 557 (2007); Mark Pettit, Jr., *FMRI and BF Meet FRE: Brain Imaging and the Federal Rules of Evidence*, 33 Am. J.L. & Med. 319 (2007); Richard E. Redding, *The Brain-Disordered Defendant: Neuroscience and Legal Insanity in the Twenty-First Century*, 56 Am. U. L. Rev. 51 (2006); Robert Sapolsky, *The Frontal Cortex and the Criminal Justice System*, 359 Phil. Transactions Royal Soc'y London B: Biological Sci.1787 (2004); Alexander McCall Smith, *Human Action, Neuroscience, and the Law*, in The New Brain Sciences: Perils and Prospects 103 (Dai Rees & Steven Rose eds., 2004); O. Carter Snead, *Neuroimaging and the "Complexity" of Capital Punishment*, 82 N.Y.U. L. Rev. 1265 (2007); Sarah E. Stoller & Paul Root Wolpe, *Emerging Neurotechnologies for Lie Detection and the Fifth Amendment*, 33 Am. J.L. & Med. 359 (2007);

33 The Law & Neuroscience Project, http:// www.lawandneuroscienceproject.org (last visited Apr. 14, 2009).

34 Gruter Institute, http://www.gruterinstitute.org (last visited Apr. 14, 2009).

35 Society for Evolutionary Analysis in Law, http://www.sealsite.org (last visited Apr. 14, 2009).

Adam Teicher, Weaving Functional Brain Imaging into the Tapestry of Evidence: A Case for Functional Neuroimaging in Federal Criminal Courts 80 Fordham Law Review 355 (October, 2011)[7]

Recent advances in brain imaging technologies allow researchers to "peer inside" a defendant's brain. Although functional neuroimaging evidence is frequently used in civil litigation, federal courts have been hesitant to admit it into evidence in criminal trials. Scholars and commentators alike continue to debate the merits, detriments, and general admissibility of functional neuroimaging evidence in the criminal context. Meanwhile, federal judges repeatedly admit various forms of forensic science into evidence without evaluating them under the appropriate admissibility standards. This Note argues that this has created a double standard for evidence admissibility. Functional neuroimaging evidence may, in fact, be more scientifically reliable than some of the forensic science evidence currently admitted at trial. Accordingly, this Note proposes that judges should consider the disparity in evidentiary standards when considering the admissibility of functional neuroimaging evidence, and should carefully and fairly examine such evidence when proffered in federal criminal trials.

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*357 Introduction

At approximately 2:30 PM on March 30, 1981, six shots were fired outside of the Washington Hilton Hotel. John Hinckley, Jr. attempted the assassination of President Ronald Reagan, wounding the President and three others.[1] During his trial fifteen months later, Hinckley's defense attorney called to the stand a radiologist who showed the jury a computer axial tomography (CAT) scan depicting atrophy of Hinckley's brain.[2] With the images projected on a screen in the courtroom, the doctor testified that the atrophy was abnormal, suggesting "organic brain disease,"[3] a term used to describe impaired mental functioning. Although the presiding judge initially barred the images from being displayed in the courtroom for fear that the jury might grant them too much weight, he later decided to allow the images because they might help give the jury "a complete picture" of the evidence bearing upon Hinckley's guilt.[4] Three weeks later, the jury found Hinckley not guilty by reason of insanity.[5]

Since the Hinckley trial, the use of neuroscience in the courtroom has drawn significant public attention. Although the potential uses for functional neuroimaging in the courtroom have increased dramatically,[6] actual use has not. Critics decry the use of neuroimaging as too nascent of a science and too prejudicial or unreliable to meet admissibility standards,[7] though some say it will meet admissibility standards in the near future.[8] Proponents argue that functional neuroimaging evidence

has significant probative value and may even satisfy the federal evidentiary standard, and should be admitted.[9]

However, the debate surrounding the admissibility of functional neuroimaging evidence seems misguided, and critics have held neuroimaging evidence to unusually restrictive admissibility standards.[10] At the very least, the admissibility standards have been applied to functional neuroimaging evidence more strictly than they have been applied to other forensic evidence offered in criminal trials.[11] As the evidentiary ***358** maxim goes: "A brick is not a wall,"[12] meaning that an item of evidence is relevant to the overall structure of the evidence but is not in itself the basis of all the evidence. Accordingly, judges should view functional neuroimaging as an evaluative tool, one of many bricks used to build the tower of evidence. This would provide litigants with the tools necessary to fully present and effectively argue their case and would allow juries to evaluate and consider useful functional neuroimaging evidence during the course of a trial.[13] After all, the purpose of scientific evidence is to elucidate the facts by providing the fact-finder with all relevant information to arrive at the truth,[14] and functional neuroimaging likely can aid in that endeavor.[15] Moreover, much of the scientific evidence currently admitted in criminal trials--specifically, forensic individualization sciences--is unreliable at best and dismal at worst.[16] Yet despite the scientific flaws and unreliability, courts often admit such evidence, and sometimes by judicial notice, without ever analyzing the evidence under the federal standard for admissibility.[17] Much of forensic individualization evidence has little, if any, scientific basis, but is often admitted based on a history of admission[18] in lieu of evidentiary merits.[19] Furthermore, admissibility challenges are largely biased in favor of the prosecution.[20]

Judges should strongly consider admitting functional neuroimaging evidence to balance the spectrum of evidence presented at trial and restore a fair adversarial process. Of course, proper safeguards such as carefully crafted jury instructions[21] should be instituted and maintained to prevent ***359** undue reliance on neuroimaging evidence, and independent external regulatory entities should be established to supervise imaging methodologies and govern their courtroom use.[22] Even when no forensic individualization evidence is offered, judges should consider admitting the evidence to avoid a double standard for admitting scientific evidence.[23] This would ensure that the fact-finders--both juries and judges alike--have the information necessary to help them arrive at a decision on the legal issue at hand while using appropriate safeguards to narrow the scope of functional neuroimaging evidence.[24]

Much has been written about neuroscience evidence admissibility in general,[25] but no work known to this author examines neuroscience evidence in light of forensic individualization evidence. Doing so would help guide judges on how to handle functional neuroimaging evidence to maintain a fair and balanced adversarial system. As brain imaging technology continues to improve, attempts to admit functional neuroimaging evidence in criminal trials will likely increase. Especially in light of a recent governmental report addressing the significant shortfalls of forensic sciences and its continued use in the courtroom,[26] judges should reassess their reluctance to admit functional neuroimaging into evidence in criminal trials.

Part I of this Note introduces the reader to brain imaging in general and describes neuroscience's impact on the law. Part I.B discusses functional neuroimaging, its numerous methodologies, and how it can be used in the courtroom. Part I.C briefly surveys the federal admissibility standards for scientific expert testimony, which governs functional neuroimaging evidence. Because this Note focuses on applications of functional neuroimaging to criminal law in federal cases, Part I.D discusses how the ***360** federal admissibility standards are currently applied to a foundational aspect of criminal law evidence: forensic individualization sciences.

Part II outlines the arguments both in favor and against admitting functional neuroimaging as evidence. This part includes arguments about the evidence's reliability, relevance, utility, and its potential to mislead, confuse, or prejudice the jury. Part II also illustrates how functional neuroimaging is currently analyzed under federal evidentiary standards by federal criminal courts.

Part III suggests that judges should carefully consider admitting functional neuroimaging evidence when offered in criminal trials, especially in light of the quality of forensic evidence currently used in such cases. This Note concludes by suggesting that although functional neuroimaging evidence likely should be admissible, a governing body should be created to establish guidelines to regulate its use.

I. Neuroscience and the Evidence Admissibility Standards

A. Structural and Anatomical Brain Imaging and Its Impact on the Law

Neuroimaging technology is not new. The first images of the brain appeared in the early part of the twentieth century,[27] and, with the advent of computerized tomography (CT), brain imaging technology rapidly progressed as a full-fledged science in the early 1970s.[28] Technological advancements soon led to the development of nuclear magnetic resonance (NMR) imaging, known as “magnetic resonance imaging” (MRI).[29] With the ability to produce exquisitely precise anatomic detail, MRI soon became the preferred method for imaging the brain.[30]

MRI and other imaging technologies, such as positron emission tomography (PET), electroencephalography (EEG), and single photon emission computed tomography (SPECT), soon led to functional imaging of the brain.[31] By the 1990s, neuroscience in general and neuroimaging technologies in particular underwent such unprecedented growth that President George H.W. Bush officially proclaimed the 1990s the “Decade of the Brain.”[32]

***361** Structural and anatomical brain imaging is currently used for diagnostic and investigative purposes, such as detecting brain lesions and improving the diagnosis and treatment of neurological diseases.[33] It has also impacted the legal system's understanding of criminal responsibility. Consider the case of Ron, a schoolteacher from Virginia.[34] For forty years, Ron led a conventional lifestyle

without showing any signs of deviant behavior.[35] Inexplicably, once he turned forty, Ron developed a keen interest in child pornography and was subsequently arrested and convicted for making sexual advances toward his stepdaughter.[36] He was remanded to a rehabilitation clinic for sex offenders but was soon expelled because he was unable to control his urges, propositioning everyone with whom he came into contact.[37] The day before Ron was scheduled to appear before the court for sentencing, he admitted himself to the emergency room complaining of a terrible headache.[38] Ron told his doctors that he was afraid he would rape his landlady and that he was unable to control himself.[39] Eventually, the doctors ordered a brain MRI. What they found shocked them. Ron had a tumor the size of an egg pressing against the right frontal lobe of his brain.[40]

After surgeons removed the tumor, Ron lost his uncontrollable urges and his pedophilia, and he easily completed his rehabilitation program.[41] He even moved back in with his wife and stepdaughter.[42] Seven months later, his chronic headaches returned, and he secretly began collecting pornography.[43] Another brain scan revealed that Ron's tumor had partially grown back.[44] A second surgical procedure successfully removed the tumor and relieved him of his urges.[45]

***362** Ron's case illustrates how brain imaging can and does impact societal perceptions of criminal responsibility. If not for the egg-sized tumor pressing against his brain, Ron most likely would have been incarcerated for his "moral failing."[46] Instead, when the MRI revealed the tumor in his brain, Ron received a second chance and escaped prosecution even though he broke the law.[47] A case like Ron's challenges conventional notions of criminal responsibility for offenders with demonstrated physical abrasions or defects in the brain. Although brain tumors do not conclusively cause immoral behavior or make one unable to abide by the law,[48] a causal relationship is likely.[49] This is especially true when a physical abrasion or tumor such as Ron's afflicts an individual.[50] However, admitting evidence of brain damage or dysfunction absent any physical or "external" factor[51] is more problematic. It is in this context that functional brain imaging enters the discussion.

B. Functional Brain Imaging and Its Impact on the Law

Functional brain imaging is used frequently in cognitive neuroscience, which is "the field of scientific endeavor that is trying to understand how the brain enables the mind."[52] As brain imaging technologies progress, cognitive neuroscientists use functional brain imaging to study the human brain in action.[53] This provides doctors and scientists with the tools to help ***363** them diagnose brain damage or disease when physical damage is absent.[54] But as critics of functional brain imaging point out, the results of these scans are not entirely dispositive--a causal relationship between specific brain functionality and criminal behavior has not yet been definitively determined.[55] The problem is less pressing when the results of functional brain scans are coupled with results indicating structural brain damage.[56] Nevertheless, functional brain imaging can significantly impact the law in its own right.[57]

1. Methods of Functional Brain Imaging

Functional neuroimaging helps scientists understand brain activity by measuring various biochemical and physiological events occurring within the brain.[58] Specifically, scientists measure the rate and volume of blood flow in areas of the brain involved in specific aspects of cognitive functioning and the rate of oxygen consumption in those areas (called a hemodynamic response),[59] or changes in various electrical currents.[60] While structural imaging captures a snapshot of the brain at one point in time, functional imaging tracks patterns of metabolic activity in the brain over a period of time.[61] Functional brain imaging is thus categorically different than structural brain imaging.

Generally, functional brain scans operate as follows: a subject is presented with a situation or performs a specific task, and researchers record the changes in the subject's brain activity as the subject responds or performs the task. Because the changes in brain activity are usually localized and occur over a measurable span of time, the scans yield spatio-temporal brain data.[62] The data is then compared with statistical maps of ***364** "normal" brain activity[63] or the subject's own baseline brain activity[64] by subtracting the normal or baseline reading from the data obtained from the experimental scan.[65] The varying degrees of statistically significant metabolic change are color coded to identify easily and differentiate between levels of activity.[66] This technique identifies areas of the brain engaged in specific mental tasks.[67] What follows is a brief overview of the various methods of functional brain imaging, including PET, SPECT, EEG, quantitative electroencephalography (qEEG), functional magnetic resonance imaging (fMRI), Brain Fingerprinting (BF), and finally, Brain Electrical Oscillations Signature Test (BEOS).

a. Positron Emission Tomography (PET) and Single Photon Emission Computed Tomography (SPECT)

PET and SPECT are older methods of functional brain imaging than the fMRIs of today.[68] For PET and SPECT scans, the subject is injected with organic, radioactive molecules called tracers, which are then dispersed throughout the brain according to metabolic need.[69] When metabolized, the molecules emit gamma rays, which are then detected and interpreted by computers and used to construct three-dimensional models of the working brain.[70] Researchers can use the data from multiple readings collected over a brief time span to determine which areas of the brain are involved in different types of brain activity with a high degree of specificity.[71] Because PET scans measure localized blood volume in specific tissues, they effectively detect nuanced characteristics of specific neurodegenerative diseases.[72]

Like PET, SPECT requires injecting radioactive tracers into the subject's bloodstream. The radioactive isotopes have longer half-lives, allowing SPECT scans to generate images for longer periods of time while exposing ***365** the subject to fewer injections than a PET scan.[73] The tradeoff, however, is that SPECT does not map activity to specific brain areas as accurately as PET scans.[74]

Both PET and SPECT require injecting dangerous radioactive material into human subjects. This prevents multiple trials over a short period of time and thus diminishes the potential accuracy of the

collected data.[75] Furthermore, PET and SPECT are also often prohibitively expensive, leading many researchers to use other less costly--and less dangerous--techniques.[76]

b. Electroencephalography (EEG)

Unlike PET and SPECT, EEG does not measure changes in blood flow in the brain, nor does it measure metabolic rate. Instead, it records the electrical current produced by brain activity measured via electrodes attached to the subject's scalp.[77] However, EEG can only record electrical activity occurring near the scalp and cannot probe deeper into the depths of the skull and brain.[78] It therefore lacks the spatial resolution and specificity of PET and SPECT, but has better temporal resolution, meaning it is better at detecting the nuanced timing differences of measured brain activity.[79]

c. Quantitative Electroencephalography (qEEG)

qEEG is a computer-based method for interpreting EEGs.[80] Digitized recordings of EEGs pass through a series of signal processing algorithms and are classified as normal or abnormal based on numerous factors such as frequency, events, or localization.[81] qEEG can also identify specific patterns of electrical activity associated with brain diseases or neurological disorders, such as slow brain waves associated with dementia.[82] While qEEGs have the added analytical component and power of a computer processor, the recording mechanism is still an EEG and thus has the same temporal superiority and spatial deficiency.

***366** d. Functional Magnetic Resonance Imaging (fMRI)

The most prevalent method of functional brain imaging is fMRI.[83] The scan detects hemodynamic changes in different areas of the brain.[84] The amount of blood present in and flowing to a particular brain region, and the amount of oxygen present in that blood, depends on the level and intensity of brain activity occurring in that particular region of the brain.[85] Researchers interpret increased blood flow as an increase in that region's cellular activity.[86] In other words, if a particular set of neurons increases in activity, so will its metabolic rate. Like its structural and anatomical counterpart,[87] fMRI is widely accepted and broadly used for medical and research purposes.[88]

This method has two major advantages over other forms of functional neuroimaging. First, fMRI has much better spatial and temporal resolution than both PET and SPECT, usually on the order of millimeters and seconds.[89] The brain's hemodynamic response rises and falls over a period of a few seconds, yet fMRI can measure latency differences as small as a few hundred milliseconds.[90] Although the temporal resolution of fMRI is somewhat inferior to EEG and qEEG, its spatial resolution is far superior. Of the available neuroimaging techniques, scholars and researchers alike consider fMRI to provide the best balance of temporal and spatial resolution,[91] and the technology continues to improve.[92] Second, unlike PET and SPECT, fMRI is noninvasive since it does not require injecting radioactive isotopes into subjects.[93] Researchers can therefore conduct ***367**

multiple trials on subjects over a short period of time, enhancing the reliability and validity of results.[94]

e. Brain Fingerprinting (BF)

BF is a more recently developed incarnation of EEG. BF "matches information stored in the brain with information from the crime scene."[95] Electrodes placed on a subject's scalp measure a specific electrical impulse, a brain wave known as P300, that is emitted when a subject "recognizes and processes an incoming stimulus that is significant or noteworthy," but not if the stimulus is "insignificant."[96] BF purports to measure only information processing and not emotional responses, and its creator claims it cannot be manipulated or controlled by the subject.[97] Therefore, BF claims to give an accurate reading of "information present" or "information absent" in the brain.[98] With the potential to be used for brain-based lie detection, BF has already been proffered in at least two cases.[99] However, there is considerable controversy over its use for lie detection purposes.[100] In fact, there is much debate within the scholarly community over whether any brain-based lie detection should be used in the courtroom.[101]

f. Brain Electrical Oscillations Signature Test (BEOS)

Like qEEG and BF, BEOS is a recycled use of EEG. Developed by an Indian neuroscientist and built on techniques similar to BF, BEOS can purportedly distinguish people's memories of events they witnessed from deeds they committed.[102] Electrodes are attached to the subject's head and the subject is presented with stimuli in the form of sentences or pictures. Neutral stimuli are also included to normalize the software so that it can ***368** distinguish memories from normal cognitive function.[103] The test claims to detect both conceptual and experiential knowledge.[104] BEOS has already been used in India to convict at least one person of murder.[105]

2. Functional Brain Imaging in the Courtroom

Functional neuroimaging has serious implications for many legal issues. Researchers have found that several brain regions are functionally impaired in antisocial, psychopathic, and aggressive individuals.[106] Findings such as these have the potential to redefine many legal concepts such as mens rea,[107] addiction,[108] criminal responsibility,[109] and competency to stand trial[110] or be sentenced.[111] Functional neuroimaging also has implications for privacy,[112] bias detection,[113] prediction of future criminal behavior,[114] and lie detection.[115] Functional neuroimaging certainly has many potential ***369** uses in the legal realm. Yet there remains an ever-important hurdle for it to clear. Before any evidence, whether neuroscientific or otherwise, can be used in the courtroom, it must pass the standards for evidence admissibility.

C. Admissibility Standards: The Daubert Trilogy and the Federal Rules of Evidence

Although there are numerous legal applications of functional neuroimaging, if it is to be presented at trial, it must first clear an admissibility hurdle. This section discusses the current federal standard for admitting scientific evidence.

1. The "Daubert Trilogy"

The current standard for scientific evidence and expert testimony admissibility follows what is collectively known as the "Daubert trilogy."[116] In Daubert v. Merrell Dow Pharmaceuticals, Inc.,[117] the U.S. Supreme Court declared that Rule 702 of the Federal Rules of Evidence (Rules) superseded the "general acceptance" test from Frye v. United States.[118] The Frye "general acceptance" test had held that expert testimony was admissible if it was generally accepted as reliable in the relevant scientific community.[119] In Daubert, however, the Court ruled that the appropriate standard was Rule 702, which said that scientific testimony must be "not only relevant, but reliable," thus removing the absolute requirement that the scientific evidence be "generally accepted" in the relevant scientific community.[120] Daubert requires judges to determine whether the "reasoning or methodology" underlying the evidence is "scientifically valid" such that it can be properly applied to the particular case.[121] Because the inquiry is "a flexible one,"[122] judges have discretion ***370** when acting as "gatekeepers" to ensure that the scientific testimony is both relevant and reliable.[123]

As the Court noted, "[i]n a case involving scientific evidence, evidentiary reliability will be based upon scientific validity."[124] Thus, for purposes of satisfying Daubert, scientific reliability depends on whether an investigatory method passes muster as a valid scientific process. The Court determined that when considering the admissibility of scientific evidence, a judge must focus solely on the principles and methodologies utilized in the scientific process and not on the conclusions drawn from those methodologies.[125]

To help judges determine if the proffered evidence is scientifically valid (i.e., based on the scientific method), the Court suggested a number of guidelines for judges to consider. First, the underlying method should be empirical, meaning that the technique should be testable and open to scientific criticism.[126] Second, judges should consider whether the technique is subject to peer review and publication.[127] Third, the technique should have a known or potential rate of error.[128] Fourth, judges should consider whether the technique is standardized or whether regulations control its use.[129] Finally, with a nod to the Frye test, the Court included general acceptance of the methodology within the scientific community as a factor for courts to consider, although this factor is no longer dispositive.[130]

The Court noted that many factors will bear on an admissibility inquiry and it did "not presume to set out a definitive checklist or test."[131] Thus, the Court was careful to grant judges the flexibility to remain relatively subjective in their inquiry while providing an identifiable framework in which to operate.

In its conclusion, the Court addressed the dissenters' concerns about the decision's lasting impact.[132] The dissenting Justices worried that abandoning Frye would "result in a 'free-for-all' in which befuddled juries would be confounded by absurd and irrational pseudoscientific ***371** assertions."[133] The Court dismissed these concerns by reaffirming its faith in the adversary system of the courtroom, labeling naysayers as "overly pessimistic about the capabilities of the jury and of the adversary system generally."[134] Clarity would be achieved through "[v]igorous cross-examination, presentation of contrary evidence, and careful instruction on the burden of proof."[135]

In General Electric Co. v. Joiner,[136] the Supreme Court announced that the correct standard of review for an evidentiary ruling is abuse of discretion.[137] In a concurring opinion, Justice Breyer urged trial judges to take appropriate measures to manage their gatekeeping duties.[138] Justice Breyer advocated appointing reputable experts, or "special masters," to help determine the scientific validity, and thus evidentiary reliability, of scientific evidence.[139]

The last of the "Daubert trilogy," Kumho Tire Co. v. Carmichael[140] extended Daubert to encompass all expert testimony.[141] Kumho Tire involved the analysis and deposition testimony of a tire-failure expert who drew his conclusions after visually inspecting the tires.[142] The Court found that a judge's gatekeeping duties extend to all expert testimony involving "scientific," "technical," or "other specialized" knowledge.[143] Thus, today, whether expert-based testimony is scientific in nature or based on "skill- or experience-based observation," the same evidentiary standard applies.[144]

The Court also reiterated that Daubert's guiding factors were "meant to be helpful, not definitive," and that trial courts have discretion in deciding whether or not evidence is admissible, because that determination is largely fact-dependent.[145] Hence, the notion that the Daubert factors must be applied to every case was categorically rejected.[146]

The Daubert admissibility standard can be distilled to a few key points. Trial judges must assess the relevance of the proffered evidence.[147] They ***372** must also determine the scientific validity underlying the evidence's methodology,[148] and they may appoint an expert to assist the court if necessary.[149] This applies to all forms of expert testimony, holding each expert to the same standards of "intellectual rigor."[150] Once admitted, evidentiary rulings are subject to the deferential "abuse of discretion" standard of review, effectively granting trial judges the final say in evidentiary matters.[151] The story of scientific evidence admissibility, however, does not end there.

2. Post-Daubert Trilogy: The Federal Rules of Evidence

Like most scientific evidence, functional neuroimaging evidence requires an expert to interpret the scans for the jury or testify about the results of the scan.[152] The Rules regulating expert testimony are therefore pertinent to this discussion.

In 2000, Rule 702, which currently requires that any expert testimony "assist the trier of fact to understand the evidence or to determine a fact in issue,"[153] was amended to reflect the Daubert

trilogy.[154] The amendment called for judges to engage in three general categories of inquiry when acting as gatekeepers.[155] The expert testimony must be "based upon sufficient facts or data," it must be the "product of reliable principles and methods," and the testimony must be "reliably [applied] to the facts of the case."[156] However, it does not require that the evidence be "generally accepted" within the relevant scientific community. Neither the Federal Rules of Evidence nor the Daubert trilogy categorically restrict judges from admitting evidence that is not uniformly accepted within the scientific community.

Rule 403 also informs a discussion of brain scan admissibility. Even if evidence is relevant, it may still be excluded "if its probative value is substantially outweighed by the danger of unfair prejudice, confusion of the issues, or [if it is] misleading [to] the jury."[157] Juries can be swayed by the "impressive title[s]" of scientists in the courtroom, attributing greater weight to their testimony than is deserved and creating problems of sophistry.[158] Thus, while evidence may pass admissibility standards under ***373** Daubert and Rule 702, a judge may still exclude evidence under Rule 403.[159] Rule 403 is important to the present discussion because some critics worry that testimony about brain scans will provide an air of infallibility and strongly prejudice or mislead a jury, what some refer to as the "Christmas tree effect."[160]

Rule 704 also informs a discussion of functional neuroimaging evidence.[161] It defines the scope of admissible expert testimony when the expert testimony concerns a defendant's mental state. According to the rule, the expert may not testify as to whether a defendant definitively did or did not have a specific mental state necessary for a specific crime because "[s]uch ultimate issues are matters for the trier of fact alone."[162] While Rule 704 has largely been subsumed by Rule 702's requirement that the testimony "assist the finder of fact"[163] and by Rule 403's protection against misleading or confusing the jury,[164] it still stands to prevent experts from testifying if they will "merely tell the jury what result to reach."[165]

While theoretically simple, the practical impact of Daubert remains unclear, and has created both confusion and controversy.[166] One study of 372 federal and 321 state criminal appellate cases from 1988 to 1999 found no change in admissibility rates under Daubert as compared with the older Frye standard.[167] Scholars and commentators argue that while judges often cite Daubert in their analyses, the standard is not applied in any meaningful way.[168] A recent report found that "[f]ederal appellate courts have not with any consistency or clarity imposed standards ensuring the application of scientifically valid reasoning and reliable methodology in criminal cases involving Daubert questions."[169]

3. The Role of the Jury After Daubert

Daubert requires judges to act as gatekeepers of scientific evidence, but it does not substitute them for the jury or for the adversarial legal system in ***374** general.[170] For example, the judge cannot

decide whether an expert's testimony is factually correct, nor can the judge pass judgment on any conclusions drawn by an expert from a particular methodology.[171] Rather, it is for the jury to decide whether the expert is correct in his or her assessment.[172] The judge must focus solely on how the expert arrived at his or her opinion.[173]

Although courts have inconsistently applied Daubert,[174] they have consistently reaffirmed the jury's role in assessing the reliability of scientific evidence, finding that sufficiently probative evidence will not be excluded despite its potential to mislead or confuse the jury.[175] After all, "Rule 403 is a rule that favors admissibility."[176] In United States v. Starzecpyzel,[177] the court found that evidence was prejudicial because the jury could attribute it "far greater precision and reliability" than is otherwise appropriate.[178] However, the court did not exclude it under Rule 403, stating that, "[w]hile the Court does not take the problem of prejudice lightly, it is also important not to overreact to it."[179] The court took protective measures to mitigate any potential prejudicial effect[180] and admitted the evidence, stating that "'[t]he jury is intelligent enough, aided by counsel, to ignore what is unhelpful in its deliberations."'[181] In that ***375** case, the probative value outweighed the potential prejudicial effect. This reaffirmed the Supreme Court's vote of confidence in the aptitude and utility of the jury and in the adversarial system,[182] which the Court has repeatedly recognized as "'the greatest legal engine ever invented for the discovery of the truth."'[183] Scholars point out that while jurors may not enter the courtroom with extensive scientific or technical knowledge, if any at all, their collective experiences still warrant their participation in "legal decision making," even when the decisions are based on scientific evidence.[184]

D. Forensic Science Evidence Under Daubert

Following Daubert, scholars were both skeptical and critical of the decision's practical impact.[185] One major criticism was that Daubert presumed that science operates on "objective standards that can be clearly understood and applied by judges" when in fact those standards vary widely.[186] Judges often evaluate scientific evidence based on their own assumptions about the nature of the evidence, analyzing the evidence under personalized methods and standards.[187] This creates confusion and discrepancy as "litigants with similar complaints are subjected by gatekeeping judges to substantially different evidentiary standards and validation processes."[188] The forensic sciences provide a salient example ***376** of how judges apply different evidentiary standards and validation processes.

One of the goals of Daubert was to weed out "junk science" from the courtroom.[189] As gatekeepers, judges are supposed to ban empirically unreliable evidence under the strictures of Daubert and Rule 702.[190] But scholars have pointed out that judges have failed to do so, particularly in the criminal context.[191] Studies have shown that judges are especially lax in applying Daubert to forensic evidence proffered by prosecutors in criminal trials.[192] A recent report notes that much of forensic evidence severely lacks scientific validity and reliability, yet the courts have been "utterly ineffective in addressing this problem."[193] Although some district courts have begun to question the scientific underpinnings of forensic science evidence under Daubert, the trend has been slow to reach the

appellate level.[194] To understand the relevance of forensic evidence to functional neuroimaging evidence, forensic evidence must first be understood.

***377** Because functional neuroimaging has great potential for the criminal justice system, and particularly for defendants,[195] the next section of this Note discusses how Daubert affected one of the most important aspects of criminal evidence: forensic science evidence, and in particular, forensic individualization evidence.

1. Forensic Individualization as Scientific Evidence

Forensic science evidence has three main purposes: identification, individualization, and reconstruction.[196] The purpose of forensic identification is to identify a substance and quantify or measure it.[197] For example, a police officer might send a bag of white powder confiscated during an arrest to a forensics lab to determine whether it contains cocaine and if so, how much.[198] Classic forensic sciences such as this are considered highly reliable[199] and are rarely challenged under Daubert or Rule 702 unless there is evidence of negligence or fraud.[200]

Forensic individualization has an entirely different goal. Instead of identifying or quantifying a particular substance based on inherent or objective characteristics, forensic individualization relies on the "expert interpretation of observed patterns"[201] in order to "associate an item of evidence found at a crime scene with its unique source, to the exclusion of all others."[202] Forensic individualization experts rely on principles of basic probability, which state that the likelihood that a unique trait is shared by two different objects is extremely small.[203] Thus, by analyzing the "uniqueness" of an object and comparing it to known samples of the same or similar objects, forensic individualization experts claim to identify the source of the object.[204] This type of analysis makes exclusion easier than association, meaning that it is much easier for an expert to rule out a possible source for the specific object than to definitively "match" it to a source.[205] In fact, "[t]he claim of unique individualization has never been demonstrated for any forensic individualization science through empirical ***378** testing."[206] Yet, as scholars point out, this has not prevented some forensic experts from claiming that they can definitively match an item to its source.[207]

For example, in United States v. Green,[208] prosecutors sought to call a ballistics expert to testify that fourteen shell casings found on a street were all fired from the same weapon.[209] The expert claimed to be able to match the shell casings to a specific firearm "to the exclusion of every other firearm in the world."[210] Recognizing the "sloppy practices"[211] and "serious deficiencies"[212] of the forensic technique, the court nevertheless allowed the expert to testify but prohibited him from testifying that he could identify the gun to the exclusion of all other firearms.[213]

Often called "non-science forensic sciences," forensic individualization sciences include what could be considered a typical lineup of forensic evidence: analyses of fingerprints, shoe prints, bite marks, tool marks, firearms (ballistics), handwriting, hair samples, and DNA, among others.[214] Though they are not based on typical scientific methods of analysis, with the exception of forensic DNA

analysis,[215] forensic individualization ***379** sciences still rely on expert testimony, and are therefore subject to Daubert and Rule 702.[216]

It is widely recognized that forensic individualization has little or no scientific, empirical, or testable foundation,[217] and there have been few if any attempts to improve them with serious research.[218] Although many forensic individualization techniques have been around for a long time,[219] they must still meet the Daubert standards; Daubert carries no "grandfather" clause that would allow the evidence to bypass the admissibility standards.[220] Moreover, the evaluation of the forensic individualization sciences is especially important in criminal Daubert ***380** jurisprudence.[221] The Daubert standard may have been framed in a civil case initially, yet "federal courts should apply [it] with equal force to their criminal docket."[222]

Scholars widely agree that rigorous application of the Daubert standard is severely lacking.[223] Most forensic techniques remain largely untested and their validity under Daubert is questionable at best. Yet they are continually admitted, often based on their long history of judicial acceptance[224] and sometimes by judicial notice.[225] The need for genuine evidentiary analysis grows stronger as an increasing number of convictions, which relied heavily on forensic individualization evidence, are overturned by DNA exonerations.[226] According to Professor David Faigman, "faulty forensic science is second only to eyewitness errors as the leading cause of erroneous convictions."[227]

For example, in 1998, Stephan Cowans was convicted of shooting a Boston police officer.[228] A key item of incriminating evidence offered at trial was a latent fingerprint found at the scene of the shooting.[229] Two separate fingerprint analysts confirmed the match, but the evidence was ***381** never challenged under Daubert.[230] Six years later, DNA test results showed that the prints were wholly inconsistent with Cowans' DNA profile.[231] The fingerprints were reanalyzed and the initial conclusions were found to be not only erroneous, but it was discovered that the conclusions were known to be erroneous during Cowans' trial and during his conviction, though that information was intentionally concealed.[232] While the unfortunate experience of Stephan Cowans is an extreme example of prosecutorial misconduct, it highlights the importance of conducting a Daubert analysis for forensic individualization evidence, and the severe consequences that might accompany a failure to do so. A recent governmental report sums up this point: "[B]ecause accused parties in criminal cases are convicted on the basis of testimony from forensic science experts, much depends upon whether the evidence offered is reliable."[233]

2. Evidentiary Challenges Post-Daubert

The rate of pretrial challenges to forensic evidence admissibility has generally increased post-Daubert, but most of these challenges occur in civil suits.[234] In criminal trials, prosecutors introduce far more forensic evidence than do defendants, and prosecutors also challenge the admissibility of forensic evidence approximately three-and-a-half times more often than defendants.[235]

The success rate of admissibility challenges to forensic evidence in criminal prosecutions mirrors the disparity with which they are brought. Defendant-initiated Daubert challenges succeed less than 10 percent of the time.[236] Challenges by prosecutors, in contrast, succeed more than two-thirds of the time.[237] Although this does not necessarily reflect an inherent unfairness in the judicial system or call into question the wisdom of any ***382** specific court decision, it has raised eyebrows within the scholarly community.[238]

3. 2009 National Research Council Report

The limitations of the forensic individualization sciences have not gone unnoticed. Recognizing a dire need for improvement, Congress passed the Science, State, Justice, Commerce, and Related Agencies Appropriations Act of 2006.[239] Given the significant "absence of data" within the forensic science and legal communities, the statute authorized the National Academy of Sciences (NAS) to conduct a comprehensive study on the forensic sciences and to suggest improvements and guidelines to "help ensure quality and consistency in the use of forensic technologies."[240]

In its report, the National Research Council (NRC), an arm of the NAS, identified numerous weaknesses plaguing the forensic sciences, of which the most prevalent weaknesses were among forensic individualization sciences.[241] The weaknesses identified by the committee include disparity in operation, inconsistent practices, lack of standardization, absence of certification and accreditation, and interpretive problems.[242] The committee also noted that, except for DNA analysis, no forensic technique has rigorously drawn a consistent and reliable connection between forensic evidence and a specific individual or source.[243]

The committee found that no standardization or regulation exists either across the forensic individualization disciplines or within a particular discipline.[244] The committee further noted that forensics are most often based on subjective interpretations of observed characteristics rather than scientific studies to determine their validity, and that this is "a serious problem."[245] Accordingly, the committee declared that "research is required to establish the limits and measures of performance" of the individualization sciences.[246] Given that the legal and judicial communities rely so heavily on forensics, the committee lamented that "the law's greatest dilemma . . . [is] whether--and to what extent--there is science in any given forensic science discipline."[247] The committee made multiple recommendations to improve forensic science evidence in courtrooms, but its initial and primary recommendation was that Congress should ***383** appropriate funds to establish an independent federal entity to supervise, promote, and develop the forensic disciplines into a mature and reliable field of research and practice.[248]

4. Forensic Individualization in the Courtroom

Various courts, including the Supreme Court,[249] have admitted forensic individualization evidence despite recognizing that it has significant weaknesses.[250] While some courts appear to conduct a Daubert analysis, they overlook scientific issues and admit the evidence on non-scientific grounds,

often yielding to its history of past admissibility.[251] For example, in United States v. Crisp,[252] the Fourth Circuit found that both fingerprint identification and handwriting comparison survive Daubert.[253] Although the court appeared to conduct a Daubert analysis,[254] it explicitly stated its reason for admitting the testimony: "[L]ike fingerprint analysis, handwriting comparison testimony has a long history of admissibility in the courts of this country. The fact that handwriting comparison analysis has achieved widespread and lasting acceptance in the expert community gives us the assurance of reliability that Daubert requires."[255] The court recognized the scientific shortcomings of the evidence[256] and noted that a few district courts had recently questioned its viability under Daubert.[257] ***384** Yet in what one scholar calls a "breathtaking[] disregard of Daubert,"[258] the court nevertheless was unwilling to depart from the pedigree of the evidence.[259] As some scholars note, the court blindly accepted the validity of the evidence, stating that its error rate was "negligible" or "essentially zero,"[260] a statement that is "startling" when given without supporting data.[261]

Similarly, in Green, Judge Nancy Gertner strongly implied that expert toolmark testimony[262] should properly be excluded under Daubert,[263] but that she felt "compelled to allow" it because she was "confiden [t] that any other decision will be rejected by appellate courts, in light of precedents across the country" that consistently admit it.[264] Judge Gertner expressed her frustration with the testimony's continued admission despite its obvious Daubert insufficiencies, lamenting: "The more courts admit this type of toolmark evidence without requiring documentation, proficiency testing, or evidence of reliability, the more sloppy practices will endure; we should require more."[265]

A recent district court opinion struck a different chord. In United States v. Willock,[266] Judge William D. Quarles, Jr. adopted the report and recommendation of Magistrate Judge Paul W. Grimm, who conducted an extensive Daubert review of ballistics identification.[267] Noting that the validity of the science "has not yet been fully demonstrated," Judge Grimm found that the expert's testimony still had a "baseline level of credibility" useful to the jury[268] and should be admitted under Daubert, but with strict qualifications.[269] The court allowed the expert to testify in uncertain terms--using the qualifying phrase, "more likely than not"[270]--and mandated that the testimony was to be considered an "estimate" supported by the evidence, which would go to the weight of the testimony.[271] The jury would reach the ultimate question of whether the bullets were fired ***385** from the specific firearm.[272] Responding to concerns about the unreliability of the testimony or its potential to mislead the jury, Judge Quarles said those weaknesses would emerge "through effective cross-examination, or by offering defense experts to challenge [them]."[273]

With the exception of some recent district court decisions,[274] most courts do not question forensic individualization evidence under Daubert, and some argue that to do so would "make the best the enemy of the good."[275] Some commentators agree, suggesting that unreliable forensic evidence is admitted because to "demand more by way of validation [is more] than the disciplines can presently offer."[276] Others voice their disagreement by suggesting that forensic evidence is admitted under a misguided understanding of the Daubert "reliability" requirement as expressed in Rule 702.[277] As will be discussed in Part III.A, the fact that individualization evidence is routinely admitted under

Daubert without subjecting it to a proper admissibility analysis should force judges to carefully consider admitting functional neuroimaging evidence.

II. Admissibility of Functional Neuroimaging

This part discusses the arguments for and against admitting functional brain scans as evidence in the courtroom. This Note avoids potential constitutional issues posed by such evidence[278] and focuses instead on federal criminal cases in which such evidence is used, admissibility issues raised under the federal evidence admissibility standards, and implications of such evidence for the criminal justice system at the federal level.

While courts are quick to admit neuroscience evidence,[279] courts have been more circumspect about admitting functional neuroimaging ***386** evidence.[280] Functional neuroimaging is "too new, too uncertain, and too laden with troubling questions to earn easy admission to the courts."[281] Further, most of the criminal cases in which functional neuroimaging evidence is admitted are state cases, not federal, though it has been admitted in civil litigation at both the state and federal level.[282]

A. Arguments for Excluding Functional Neuroimaging Evidence

1. Lack of Methodological and Interpretive Standardization

Critics question the validity and reliability of the underlying science of functional neuroimaging,[283] and often refer to an analytical or deductive gap between the imaging studies and the courtroom testimony.[284] As noted earlier, neuroimaging techniques have either a temporal delay or imperfect spatial resolution, or a combination of both.[285] Critics argue that courtroom use is premature because the scans necessarily involve expert interpretations,[286] which depend heavily on the methods employed by the individual scientists and researchers conducting the scans.[287] Individual assumptions, they argue, can influence the results of a scan because numerous choices and considerations contribute to determining how the scans will be conducted, what data will be collected, and how that data will be analyzed.[288] As the studies get more complex, so does the data, which in turn increases the subjectivity and disparity in interpreting the results.[289] With little standardization among neuroimaging techniques, it is difficult to compare objectively the results of a scan conducted by one researcher with those of another scan conducted by a different researcher.[290]

***387** Critics also argue that individual differences among subjects are important in law, and functional neuroimaging insufficiently accounts for them.[291] Thresholds demarcating statistically significant brain activity[292] are not standardized, so deviation from arbitrarily established norms may not reliably indicate whether a subject has normal or dysfunctional brain activity.[293] As one scholar noted, "Anyone dealing with the application of neuroscience to law has to remember that most studies are about group averages, but there is no 'group' in the witness box or the defendant's seat.

Moving from the group average to the individual will be very hard."[294] The brain is a composite of influences incorporating numerous social, cultural, and personal experiences.[295] When introduced in legal settings such as courtrooms, these individual characteristics and unique qualities are prioritized and they become exceedingly important, so even the slightest nuances in brain function are highly relevant.[296] Basing comparisons and results on arbitrarily established "normal" levels as is the case with functional neuroimaging is therefore unhelpful.[297]

2. Complexity and Interconnectedness of the Brain

Furthermore, critics oppose functional neuroimaging evidence because even if scans can accurately detect specific patterns of brain activity in individuals, the brain is too complex to localize behavior to a specific brain region.[298] Moreover, critics argue that scientists can only draw correlations between brain function and human behavior; direct causation cannot be traced.[299] With the interconnectedness between brain regions and brain ***388** function insufficiently understood, the risk of error in reaching legal conclusions based on inferences about brain function is high.[300]

3. Minimal Probative Value

Even if functional brain scans can accurately associate brain function with activity in a specific area of the brain, critics are not convinced that such findings would have probative value to "assist" the fact-finder as Rule 702 requires.[301] As Professor Michael Gazzaniga argues, law is concerned with individual actions and responsibility, a social-legal construct that "does not exist in the neuronal structures of the brain."[302] Functional neuroimaging is therefore unhelpful unless it can provide "actual proof that the defendant is unable to appreciate the nature and quality or the wrongfulness of his acts."[303] Compounding this difficulty, current neuroimaging techniques measure brain activity indirectly, either by blood flow, metabolic activity, or electrical signals, and are thus "necessarily attenuated from the ultimate object of interest--namely, cognitive function."[304] Critics therefore oppose admitting functional neuroevidence about a defendant's inability to have formed the requisite intent to commit a crime.[305]

***389** 4. Potential to Mislead and Confuse the Jury

Finally, critics argue that functional neuroimaging should be excluded under Rule 403[306] because it can mislead the jury.[307] Even if the actual images are not admitted as evidence, there is concern that any neuroscience-based evidence--either the scans themselves or the expert testimony interpreting those scans--will unduly prejudice or mislead the jury.[308] If the actual scans are presented to a jury, critics fear a "Christmas tree effect," whereby jurors may be so impressed by the visual display of a colorful brain scan that they accept the scan as authoritative evidence without considering the merits of the expert's accompanying testimony.[309] Moreover, jurors might confuse differences in degree for differences in kind, mistaking delicate, nuanced changes in brain activity for a simplified dichotomy indicating that brain activity is present or absent.[310] In other words, a jury might think that a scan irrefutably supports the expert's testimony about a defendant's mental state

when in fact it might only suggest the increased likelihood that a defendant either possessed a particular mental state, or that a defendant might not be capable of possessing a particular mental state.[311]

5. Criminal Cases in Which Federal Courts Excluded Functional Neuroimaging Evidence

It is difficult to accurately assess how functional neuroimaging is used in federal litigation because most cases never reach trial, fewer complete a trial, and even fewer are reported.[312] Of those that are reported, only a fraction conduct or record evidentiary hearings.[313] Of the few federal ***390** criminal cases that have conducted Daubert analyses, most have excluded functional neuroimaging evidence and its corresponding testimony due to unreliability[314] or irrelevance,[315] or the courts found that it had minimal probative value because the evidence could not accurately assess a defendant's past mental state.[316]

In United States v. Mezvinsky,[317] PET scan evidence was introduced to show that the defendant, who was accused of multiple counts of fraud, was incapable of intentionally deceiving a person or institution, which was the requisite mens rea for his crime.[318] The district court found the scans unhelpful and irrelevant since they could not provide concrete information concerning the defendant's capacity to deceive.[319] Accordingly, the PET scans were inadmissible for lack of reliability and for irrelevance to the specific legal question at issue.[320]

Similarly, in United States v. Puerto,[321] the Eleventh Circuit affirmed the lower court's decision to exclude the defendant's expert under a Daubert analysis.[322] In an attempt to demonstrate that the defendant could not have formed the mens rea necessary for fraud and money laundering, the defendant sought to introduce expert testimony about his diagnoses of progressive vascular dementia.[323] The defendant wanted to show a brain scan indicating that a region of his brain was "cavitated out" and the brain tissue was replaced by fluid, indicating damage to numerous brain functions, including comprehension and executive planning.[324] The defendant also sought to introduce an EEG scan to pinpoint the causes of the dementia.[325] The district court excluded the testimony and the neuroimaging evidence under Daubert and Rule 702 for lack of relevance.[326] The Eleventh Circuit affirmed, finding that the experts were unable to testify "with any medical certainty" that the defendant lacked the requisite intent at the time of the offenses and that the evidence could not ***391** "help the jury decide a factual dispute."[327] In both Mezvinsky and Puerto, functional brain scans were excluded under Daubert for lack of relevance.[328]

B. Arguments for Admitting Functional Neuroimaging Evidence

Although many scholars and commentators oppose introducing functional neuroimaging into the courtroom,[329] others advocate for its admission.[330] This section discusses arguments in favor of admitting functional neuroimaging. Proponents argue that functional neuroimaging evidence may be sufficiently reliable,[331] relevant, and useful,[332] and that its probative value outweighs the risk of prejudicing or misleading the jury.[333]

1. Criticism Is Not Based on Legal Doctrine

Substantial research supports the notion that functional brain scans reliably report on brain function,[334] but the legal community has been slow to accept this. Some contend that the legal community's reluctance to embrace functional neuroimaging is not so much about the substance of the science as it is an unwillingness or hesitance to build a collaborative bridge between science and the law.[335] Professor Oliver Goodenough and Vermont Assistant Attorney General Micaela Tucker suggest that lawyers are "too bound by current paradigms to see the leaps that could be made in doctrine and practice"[336] by incorporating scientific findings into the legal arena. Resistance to neuroimaging evidence, they argue, may be based more on intransigence than on legal doctrine.[337]

***392** 2. Functional Neuroimaging Is Sufficiently Reliable to Pass Daubert

Responding to critics' concerns about experts' use of probability and inference when interpreting functional neuroimaging,[338] Professors Erica Beecher-Monas and Edgar Garcia-Rill concede that the testimony is necessarily couched in terms of probability, inference, and correlation rather than certainty.[339] They argue that this is standard scientific practice: causality cannot be determined with certainty, so probability and inference are necessary to reach conclusions.[340] Using probability and inference "do[es] not . . . make [the observations] useless or unrealistic."[341] Beecher-Monas and Garcia-Rill argue that when judges act as gatekeepers, they must allow for the "probabilistic nature of science" when considering the admissibility of functional neuroimaging evidence.[342] Echoing Daubert, they argue that the judge's role as gatekeeper is not to decide whether the proposed scientific theory is correct, but only to determine whether it meets the criteria qualifying it as a "sound science."[343] So long as the proffered testifying experts can present their opinions with sufficient supporting data and explain how the hypotheses were tested while accounting for conflicting opinions in true scientific fashion, functional neuroimaging meets Daubert standards and should be admitted.[344]

3. Excluding Functional Brain Imaging Would Deny Defendants Their "Right to Voice"

Defendants would be more likely than prosecutors to introduce functional neuroimaging evidence, primarily about past mental states.[345] Proponents argue that excluding such evidence would deprive defendants of their right to testify on their own behalf, coined by one scholar as a defendant's "right to voice."[346] In Rock v. Arkansas,[347] the Supreme Court affirmed a ***393** defendant's right to testify on his or her own behalf, holding that that defendants must be able to present "[their] version of the events for which [they are] on trial" unless they are "so untrustworthy" or "immune to the traditional means of evaluating credibility."[348] Supporters suggest that functional neuroimaging evidence provides experts with scientific facts upon which they can draw inferences "that not only support the defendant's story but may be the only source for it."[349] Excluding such evidence would "deprive the criminal defendant of the voice the Constitution guarantees."[350] Furthermore, with no easy or direct way to assess accuracy about a defendant's past mental state, an expert could offer the judge

and jury important information about the defendant based on the expert's professional experience and through the expert's opinion informed by the neuroimaging evidence.[351]
In United States v. Sandoval-Mendoza,[352] the Ninth Circuit found that the district court abused its discretion when it excluded the defendant's functional neuroimaging evidence.[353] The court concluded that without the evidence, the jury could not reach a reasonable conclusion about whether the defendant possessed the requisite mental state, whether the defendant was liable, or whether he had a valid defense.[354] Because the district court excluded the evidence, the Ninth Circuit found that he was "'deprived . . . of a fair opportunity to defend himself."'[355]

4. Functional Brain Imaging Has Probative Value

Proponents also assert that functional neuroimaging evidence is relevant to contested legal questions at trial. Neuroimaging evidence is not a "brain-print in isolation from all other evidence" that independently proves a defendant's guilt or innocence.[356] Rather, it is "one factor among many" that can help the finder of fact reach an informed decision about a defendant's innocence or guilt.[357] For example, such evidence can show that a defendant has impaired brain function, indicating an increased ***394** likelihood of disinhibition or aggressive behavior.[358] It would be up to the fact-finder to decide how to weigh the evidence or whether to rely on it at all.[359] If the question concerns a defendant's mental state at the time of the incident, functional neuroimaging can help the jury reach an ultimate conclusion about whether the defendant was or was not of a particular frame of mind.[360]

5. Probative Value of Functional Neuroimaging Outweighs Its Prejudicial Risk

Responding to those who wish to exclude functional neuroimaging under Rule 403,[361] proponents assert that such evidence will not overly mislead or prejudice the jury.[362] Others believe that jurors would be no less capable of critically evaluating functional neuroimaging evidence than they would be at critically evaluating other types of scientific evidence.[363] Still others argue that the probative value of the evidence is much too strong to exclude it based on a possible prejudicial effect, and certainly too strong for per se exclusion.[364] Professor Neal Feigenson even suggests that the best way to obtain reliable functional neuroimaging-based testimony and to decrease its prejudicial effect is to admit more of that type of evidence and allow the experts and lawyers to educate the jurors.[365] Professor Feigenson aligns himself with Daubert and states that the best way to evaluate the merits of functional neuroimaging evidence is to present competing opinions to argue over the interpretations and results of the brain scans.[366] This, he argues, ***395** would not only encourage juries to view the testimony critically, but would also allow legal judgments to "be rendered consistently with the best available scientific knowledge."[367] Scholars also counter critics' concern about the "Christmas tree effect"[368] by pointing out that admitting functional neuroimaging evidence would not prevent fact-finders from reaching a guilty verdict if they feel it is deserved,[369] a result corroborated by numerous cases.[370]

III. Bringing Functional Neuroimaging into the Courtroom: Necessary and Useful

Brain imaging technologies have progressed rapidly over the past thirty years.[371] One can only assume that the technology will continue to progress in the future, likely at a faster rate than before.[372] When it comes to bringing functional neuroimaging into the courtroom, scholars and judges alike have resisted doing so under Daubert and the federal admissibility standards.[373] At the same time, forensic individualization evidence is continually admitted at trial despite significant and egregious scientific failings.[374] Only a few courts subject the evidence to proper Daubert hearings, and even fewer still conduct evidentiary analyses.[375] This has resulted in an evidentiary double standard in federal criminal courts in which the forensic individualization evidence gets a "free pass" around Daubert while functional neuroimaging evidence cannot even leave the starting gate. This double standard should not be allowed to continue.

Part III argues that federal judges should carefully consider admitting functional neuroimaging evidence when it is offered in criminal trials, ***396** especially in light of the suspect quality of forensic evidence currently streaming into the courtroom. Admissibility should not be given carte blanche, however. Proper evidence standards must be maintained. Functional neuroimaging evidence can be potentially confusing and courts do have the right to control such evidence, but it should not be excluded per se. Fully utilizing the adversarial process of our court system would help the judge and the jury alike understand the nature, assumptions, and consequences of functional neuroimaging evidence.

A. Balancing the Evidence Presented to the Jury

The NRC's report thoroughly documented the dearth of significant or verifiable science[376] underlying the aptly named "non-science forensic sciences" known as forensic individualization.[377] Yet, as discussed above, there have been few attempts to improve these practices.[378] Forensic individualization sciences are still frequently admitted in federal courtrooms, often without undergoing a Daubert analysis; for those that do conduct a Daubert inquiry, the analysis is certainly not a rigorous one.[379] The lax admissibility threshold imposed on prosecutors[380] has led to many wrongful convictions, some of which have been overturned.[381] It remains unclear, however, just how many convictions premised on faulty or fraudulent forensic evidence are never revisited due to a lack of DNA or other exculpatory evidence.[382]

These deplorable consequences of evidence standards gone awry can be partially mitigated by leveling the evidentiary playing field. Functional neuroimaging evidence could provide defendants with the opportunity to present a fuller defense to the jury. Often unable to testify about their own mental state, defendants could offer functional neuroimaging evidence as the only source for such evidence and their only hope for presenting it before a judge or jury.[383]

It seems unlikely that judges will ban forensic individualization evidence in the near future, especially because most judges readily and even blindly admit it without first examining it under Daubert.[384] The NRC report clearly lays out the dangers and wholly inadequate science behind the widely admitted forensic individualization sciences.[385] Hopefully, future litigation will directly

address the report to help turn the tide of this evidentiary debacle, but any change surely will be slow. The case law demonstrates the judicial system's long-running allegiance to the forensic ***397** sciences, however misplaced that allegiance may be.[386] As one scholar mused, "We have been marinated in a culture of faith in the validity of the non-science forensic sciences."[387] With this in mind, Judge Gertner's lament reverberates with renewed urgency: "[W]e should require more" from our criminal justice system.[388] The NRC's recommendation for federal oversight and regulation[389] is not only appropriate; it is necessary. If heeded, it will usher in a marked improvement in the reliability and validity of forensics.

Contrast forensic evidence's free ride into federal courts, bypassing Daubert, with one scholar's call for a moratorium on admitting all neuroscience into evidence until a regulatory agency can verify its reliability according to federal standards.[390] Such a moratorium is an unnecessarily drastic measure, especially considering the scientific validity underlying functional neuroimaging methodologies.[391] Absent a similar ban on forensic individualization evidence, courts should be even more willing to admit functional neuroimaging evidence. Judges should at least be no more hesitant to admit functional neuroimaging than they are to admit forensic individualization evidence. Doing so would add needed balance to the currently ravaged vista of criminal evidence.

This imbalance is compounded by the pro-prosecution bias in evidentiary hearings.[392] A defendant has little chance of presenting a useful defense at trial if judges employ an almost knee-jerk response in rejecting their challenges to forensic evidence while mostly granting prosecutors' motions to exclude defendants' forensic evidence.[393] Providing a jury with functional neuroimaging evidence would help the jury develop a more complete understanding of the defendant.[394] For example, if the prosecution presents the jury with particularly incriminating, yet scientifically questionable, forensic evidence, it would be a disservice to justice to silence the defendant by excluding functional neuroimaging evidence. Forensic evidence can be used to place the defendant at the scene of the crime[395] and would essentially be the "smoking gun" to a jury--unless the defendant can try to counterbalance it with evidence that he may not have been able to form the requisite intent, was unaware of his actions, or should not be held as accountable as someone with no evidence of brain dysfunction. Perhaps the jury will find that the defendant's aggression was partially caused by brain dysfunction, and perhaps not. Whether the jury ***398** will find such evidence persuasive is a separate issue, and beyond the scope of this Note. The important point is that the evidence should be presented to the jury. After all, a verdict can wholly depend on whether any single piece of evidence places some amount of doubt in the jury's mind.[396]

The critiques raised against functional neuroimaging evidence[397] apply with just as much force--perhaps even more--to forensic individualization evidence. Critics argue that no regulations govern the use and interpretation of functional neuroimaging.[398] Yet forensic individualization also lacks standardization and regulations governing its use.[399] Opponents claim that functional neuroimaging is unreliable because it necessarily involves interpretations based on correlations rather than direct causation, relying on comparisons drawn from a generalized "normal" population.[400] Yet forensic individualization rests entirely on probability and draws extensively from

the expert's subjective analysis.[401] Critics also reject functional brain scans for their inability to represent a defendant's past mental state accurately, given the dynamic and prohibitively complex interconnectedness of the brain.[402] However, forensic individualization depends heavily on highly similar methods of analysis. Forensic experts may analyze physical, unique traits observed on physical objects,[403] but experts usually have access only to samples, which are often incomplete and sometimes even temporally dynamic.[404] For example, bite marks on the skin change over time.[405] They can be easily distorted by the elasticity of the skin, distribution of force of the bite, variations in swelling and healing, time, fitness of the victim, and other factors.[406] When forensic experts analyze these marks, they necessarily draw inferential connections similar to those drawn by functional brain imaging experts, analyzing the measured and collected results and formulating conclusions drawn from their subjective experiences, observations, and training.[407]

The analyses of these two types of forensic evidence may involve similar methods, but the validity of the scientific methodology employed for functional neuroimaging and forensic individualization differs greatly. The NRC report,[408] numerous scholars and commentators,[409] and recently even ***399** some courts[410] have documented the almost complete dearth of scientific support for forensic individualization. Daubert requires that scientific evidence be scientifically reliable to be admissible, but forensic individualization evidence is nothing if not unscientific. Functional neuroimaging, on the other hand, is based on scientifically sound methodologies.[411]

B. Normative, Not Scientific, Issues

Not only will functional neuroimaging restore balance to the palette of evidence admitted in criminal trials, but it would also properly restore fact-finding duties to the jury.[412] Judges who exclude the evidence without conducting proper Daubert analyses evaluate the merits and conclusions drawn from the evidence as opposed to the underlying methodologies. Daubert specifically prohibits judges from doing just that.[413] If the evidence were admitted, juries would be free to use it as they see fit.[414] Experts would testify about the implications of the brain scans and how the scans might help the jury reach an ultimate conclusion about a defendant's mental state;[415] the expert's testimony, however, would by no means be dispositive.[416] The jury would decide what to do with the evidence and how much weight to grant it.[417] In other words, jurors would decide how to weave the functional neuroimaging evidence into the fabric of the rest of the evidence presented to them--that is, if the jury decides to consider the evidence at all.

When faced with functional neuroimaging evidence, a judge should not allow scientific questions to cloud his gatekeeping duties.[418] Those questions have already been answered with ample research supporting the scientific methodologies employed.[419] Even if a court were to reject the supporting scientific research, the evidence most likely would pass Daubert's requirements for scientific validity. Thus, judges should view the evidence from a normative or judicial standard, rather than a scientific one, and let the jury evaluate it. Jurors are the arbiters of truth, the fact-finders who must determine normative questions of how to weigh a piece of evidence, and ultimately, of culpability.[420]

Treating the evidence ***400** normatively mitigates concern for misleading the jury because the jury could simply discard the evidence as unpersuasive.[421]

Furthermore, litigating parties should use cross-examination and the adversarial system to focus and clarify the issue for the jury.[422] As Professor Feigenson advocates, juries should be presented with more, not less, neuroimaging evidence.[423] The Supreme Court has endorsed this jurisprudential philosophy, both in Daubert and elsewhere,[424] declaring that the adversarial nature of our legal system is keenly capable of discovering the truth.[425] Thus, courts should consider admitting neuroimaging evidence not only because it likely passes Daubert's "science" requirements,[426] but also because at trial, both sides can properly present and explain the evidence so it does not mislead or prejudice the jury.

In Sandoval-Mendoza,[427] the Ninth Circuit placed a premium on admitting functional neuroimaging evidence so that the jury could reach a reasonable conclusion about the defendant's mental state.[428] Viewing the evidence normatively, the court recognized that only the jury could evaluate the evidence; excluding it therefore constituted reversible error.[429] That the court reversed the evidentiary decision is significant because the standard of review for evidentiary hearings is abuse of discretion.[430] The reversal was thus a resounding vote of confidence in favor of admitting the evidence and its utility in assisting the jury.[431] As highlighted by Sandoval-Mendoza, the jury should not be underestimated, and neither should the jury nor the defendant be denied the possible benefits of functional neuroimaging evidence per se.

This Note does not advocate for judges to freely admit functional neuroimaging evidence. But, since the evidence most likely survives a Daubert analysis,[432] and assuming that the evidence is sufficiently probative,[433] federal judges should strongly consider admitting it more frequently in criminal trials. Judges should also strive to ensure that admitted evidence continues to be reliable, and if necessary, to regulate the extent of the testimony through procedural methods such as carefully crafted jury instructions[434] or directed verdicts.[435] Furthermore, agencies ***401** such as the Institute of Medicine should establish regulatory boards to govern the research, development, and application of functional neuroimaging evidence and to supervise the imaging methods.[436] Doing so would ensure continued reliability while serving the interests of justice by allowing litigating parties to introduce relevant and probative evidence.

Conclusion

Courts considering functional neuroimaging evidence have applied an evidentiary double standard. Charged with gatekeeping duties under Daubert, they are supposed to prevent empirically unreliable evidence from entering the courtroom. But in federal criminal trials, judges often turn a blind eye towards unscientific forensic individualization evidence, refusing to analyze it under Daubert. Instead, it is often inappropriately admitted into evidence because of its pedigree. Functional neuroimaging evidence, however, has been met with a more skeptical eye and subjected to

significantly stricter Daubert standards than its forensic counterparts. This has resulted in an unfair, and pro-prosecution, evidentiary bias.

Meanwhile, scholars and commentators continue to debate the merits and detriments of functional neuroimaging evidence. But most critics of functional neuroimaging evidence do not consider the disparity in evidentiary standards that exists in federal criminal trials. Accordingly, judges should carefully and fairly examine functional neuroimaging evidence when offered in federal criminal trials. It should not be excluded out of hand. As is frequently the case in criminal trials where this type of evidence can make a difference, the stakes will be high and the needs will be immediate. Jurors should be presented with the evidence--all the evidence possible--so that they can determine how best to weave together the various pieces to create a complete tapestry of evidence.

John Hinckley, Jr. was found not guilty by reason of insanity after his lawyers showed the jury pictures of his atrophied brain. Was the jury correct in finding him not guilty? Was the verdict largely due to the pictures of his brain that were displayed to the jury? Those questions remain unanswered. But now, thirty years later, when both sides have a better understanding of neuroimaging evidence and can more fully prepare for its use in court, neither juries nor defendants should be denied the benefits provided by functional neuroimaging evidence.

Footnotes

a1 J.D. Candidate, 2012, Fordham University School of Law; B.A., 2009, University of Pennsylvania. Thanks to Professor John Pfaff for his guidance. I would like to thank my family and friends for their constant support and encouragement. Special thanks to A.Z., S.P., and especially to Ellie, for their friendship and support--both academic and otherwise--throughout this process. Most of all, thanks to my wife, Jenny, for her keen interest in my topic, for her many useful editorial comments and suggestions, and for her love and support throughout, despite being beyond busy with planning a wedding. This Note is dedicated to her.

1 Howell Raines, Reagan Wounded in Chest by Gunman; Outlook ‘Good’ After 2-Hour Surgery; Aide and 2 Guards Shot; Suspect Held, N.Y. Times, Mar. 31, 1981, at A1.

2 See Stuart Taylor, Jr., CAT Scans Said to Show Shrunken Hinckley Brain, N.Y. Times, June 2, 1982, at D19.

3 Id.

4 Id.

5 Stuart Taylor, Jr., Hinckley Cleared but Is Held Insane in Reagan Attack, N.Y. Times, June 22, 1982, at A1.

6 See generally Henry T. Greely, Law and the Revolution in Neuroscience: An Early Look at the Field, 42 Akron L. Rev. 687 (2009) (describing numerous legal applications and implications of the latest brain imaging technologies); David M. Eagleman, Neuroscience and the Law, Hous. Law., Mar.-Apr. 2008, at 37, 37-40 (same); infra Part I.B.2.

7 See infra Part II.A.

8 See, e.g., Michael S. Pardo, Neuroscience Evidence, Legal Culture, and Criminal Procedure, 33 Am. J. Crim. L. 301, 337 (2006); Laurence R. Tancredi & Jonathan D. Brodie, The Brain and Behavior: Limitations in the Legal Use of Functional Magnetic Resonance Imaging, 33 Am. J.L. & Med. 271, 291-93 (2007).

9 See infra Part II.B.

10 See infra Part II.B.2.

11 See infra Part I.D.4.

12 See Charles T. McCormick, McCormick on Evidence 339 (John W. Strong ed., abr. 4th ed. 1992) (describing the threshold for relevant evidence as low and that to be relevant, evidence only needs to make a determination of the fact in question more or less probable than it would be without the evidence).

13 See Daubert v. Merrell Dow Pharm., Inc., 509 U.S. 579, 589 (1993) ("'The Rules [of Evidence] were designed to depend primarily upon lawyer-adversaries and sensible triers of fact to evaluate conflicts.'" (quoting Jack Weinstein, Rule 702 of the Federal Rules of Evidence Is Sound; It Should Not Be Amended, 138 F.R.D. 631, 631 (1991))).

14 Id.

15 See Paul S. Appelbaum, The New Lie Detectors: Neuroscience, Deception, and the Courts, 58 Psychiatric Services 460, 461 (2007) (arguing that judges must consider other factors in addition to whether neuroscientific evidence passes the Daubert test, specifically, "whether [the evidence] is likely to help the judge or jury resolve the legal issue in question").

16 See infra Parts I.D.1, I.D.3.

17 See Jane Campbell Moriarty & Michael J. Saks, Forensic Science: Grand Goals, Tragic Flaws, and Judicial Gatekeeping, 44 Judges' J., Fall 2005, at 16, 17, 29 (lamenting that forensic sciences are notoriously unreliable yet rarely questioned under Daubert standards); infra Part I.D.4, notes 223-25 and accompanying text.

18 This can be called an "evidentiary pedigree." See infra notes 251-61 and accompanying text.

19 See infra notes 224, 249-65 and accompanying text.

20 See infra notes 192, 234-37 and accompanying text.

21 See United States v. Williams, 583 F.2d 1194, 1200 & n.13 (2d Cir. 1978) (describing jury instructions, which stated that the forensic evidence presented at trial was for the jury's "assistance only and could be rejected if found unreliable"); United States v. Starzecpyzel, 880 F. Supp. 1027, 1049 (S.D.N.Y. 1995) (finding that narrowly tailored jury instructions could adequately address concerns that admitting forensic handwriting evidence would unfairly prejudice the jury); Moriarty & Saks, supra note 17, at 31; Michael J. Saks, Protecting Factfinders from Being Overly Misled, While Still Admitting Weakly Supported Forensic Science into Evidence, 43 Tulsa L. Rev. 609, 625 (2007) (suggesting that the problem of misleading a jury with weak forensic evidence can be "ameliorated somewhat" by appropriate jury instructions); E. Spencer Compton, Note, Not Guilty by Reason of Neuroimaging: The Need for Cautionary Jury Instructions for Neuroscience Evidence in Criminal Trials, 12 Vand. J. Ent. & Tech. L. 333, 347-50 (2010) (arguing that careful jury instructions should be used when dealing with neuroscience-based evidence).

22 See Laura Stephens Khoshbin & Shahram Khoshbin, Imaging the Mind, Minding the Image: An Historical Introduction to Brain Imaging and the Law, 33 Am. J.L. & Med. 171, 190-92 (2007).

23 Both functional neuroimaging and forensic individualization are types of scientific evidence that should be subject to identical evidentiary standards. See infra notes 219-22 and accompanying text.

24 See Starzecpyzel, 880 F. Supp. at 1049 (noting that the jury is fully capable of ignoring unhelpful evidence in its deliberations, and respecting the jury's ability to do so); see also Appelbaum, supra note 15, at 461 (noting the jury is the ultimate arbiter of the truth).

25 The MacArthur Foundation Research Network on Law and Neuroscience has compiled, and continues to update, an exhaustive annotated bibliography of past and current literature on the subject of neuroscience and the law. See Law and Neuroscience Bibliography, MacArthur Foundation Research Network on Law & Neuroscience, http://www.lawneuro.org/bibliography.php (last visited Sept. 21, 2011).

26 See infra Part I.D.3-4.

27 Erin D. Bigler, Introduction to Neuroimaging I: Basic Science 1, 1 (Erin D. Bigler ed., 1996).

28 Id. at 2.

29 Id.

30 Id.; Duane D. Blatter et al., A Normative Database from Magnetic Resonance Imaging, in Neuroimaging I: Basic Science, supra note 27, at 79 ("Without controversy, magnetic resonance (MR) imaging achieves exquisite approximation of gross anatomy.").

31 See Bigler, supra note 27, at 2. As opposed to structural brain imaging, functional brain imaging allows neuroscientists to "peer inside" the living, working brain to detect specific patterns of brain activation. Doing so provides insight into how the brain operates. See Andrew C. Papanicolaou, Fundamentals of Functional Brain Imaging: A Guide to the Methods and Their Applications to Psychology and Behavioral Neuroscience 5 (1998). This Note briefly reviews these technologies in Part I.B.1.

32 Proclamation No. 6158, 55 Fed. Reg. 29,553 (July 20, 1990).

33 See Purvak Patel et al., The Role of Imaging in United States Courtrooms, 17 Neuroimaging Clinics N. Am. 557, 557 (2007).

34 See Lewis Barker, Biological Psychology, in 2 21st Century Psychology: A Reference Handbook 114, 114 (Stephen F. Davis & William Buskist eds., 2008); Doctors Say Pedophile Lost Urge After Brain Tumor Removed, USA Today (July 28, 2003, 6:46 AM), http://www.usatoday.com/news/health/2003-07-28-pedophile-tumor_x.htm.

35 Greely, supra note 6, at 700.

36 Id.

37 Id.

38 Id.

39 Sandra Aamodt & Sam Wang, Welcome to Your Brain: Why You Lose Your Car Keys but Never Forget How to Drive and Other Puzzles of Everyday Life 174 (2008).

40 USA Today, supra note 34. The frontal lobe is known to regulate impulsive behavior. Damage to the prefrontal cortex is associated with disinhibition, antisocial behavior, and greater proclivity to break the law. See Robert M. Sapolsky, The Frontal Cortex and the Criminal Justice System, in Law & the Brain 227, 233-34, 237-38 (Semir Zeki & Oliver Goodenough eds., 2006); Liane Young et al., Damage to Ventromedial Prefrontal Cortex Impairs Judgment of Harmful Intent, 65 Neuron 845, 845 (2010).

41 Greely, supra note 6, at 701; USA Today, supra note 34.

42 USA Today, supra note 34.

43 Greely, supra note 6, at 701.

44 USA Today, supra note 34.

45 Id. Many other case studies describe how frontal lobe damage severely impacted an individual's behavior. See, e.g., Joseph H. Baskin et al., Is a Picture Worth a Thousand Words? Neuroimaging in the Courtroom, 33 Am. J.L. & Med. 239, 250-63 (2007); O.Carter Snead, Neuroimaging and the "Complexity" of Capital Punishment, 82 N.Y.U. L. Rev. 1265, 1295-96 (2007).

46 Barker, supra note 34, at 114.

47 See Greely, supra note 6, at 701. In Virginia, making sexual advances toward a minor is a felony, as is possession of child pornography. Va. Code Ann. § 18.2-370(A) (2010) (sexual advances toward minors); § 18.2-374.1:1(A) (possession of child pornography).

48 See Yaling Yang et al., Brain Abnormalities in Antisocial Individuals: Implications for the Law, 26 Behav. Sci. & L. 65, 74 (2008) ("[T]he causal relationship between structural/functional deficits and antisocial behavior remains unclear.").

49 See, e.g., Sapolsky, supra note 40, at 239 ("What the literature about the [prefrontal cortex] shows is that there is a reductive, materialistic neurobiology to the containment, resulting in the potential for volitional control to be impaired just as unambiguously as any other aspect of brain function. It is possible to know the difference between right and wrong but, for reasons of organic impairment, to not be able to do the right thing.").

50 See, e.g., Young et al., supra note 40, at 845-46 (finding that patients with lesions in their ventromedial prefrontal cortex--understood to be an essential moral-processing center in the brain--have difficulty delivering normal moral judgments and instead view attempted harms as morally permissible); see also Fairchild v. Workman, 579 F.3d 1134, 1150-51 (10th Cir. 2009) (suggesting that if the defendant's lawyer had presented the jury with evidence of physical brain damage as a partial explanation for the defendant's crime, it "could have provided an important explanation for the jury").

51 See Greely, supra note 6, at 701 (suggesting that a brain tumor may be considered an "external cause" even though it is inside one's skull).

52 Michael S. Gazzaniga, What Is Cognitive Neuroscience?, in A Judge's Guide to Neuroscience: A Concise Introduction 2, 2 (Andrew S. Mansfield ed., 2010) [hereinafter A Judge's Guide].

53 Id. at 3.

54 See Teneille Brown & Emily Murphy, Through a Scanner Darkly: Functional Neuroimaging as Evidence of a Criminal Defendant's Past Mental States, 62 Stan. L. Rev. 1119, 1127-28 (2010).

55 See Michael S. Gazzaniga, The Ethical Brain 87-102 (2005); Lydia D. Johnson, Guilty or Innocent? ... Just Take a Look at My Brain--Analyzing the Nexus Between Traumatic Brain Injury and Criminal Responsibility, 37 S.U. L. Rev. 25, 30-32 (2009); Stephen J. Morse, Moral and Legal Responsibility and the New Neuroscience, in Neuroethics: Defining the Issues in Theory, Practice, and Policy 33, 33-34 (Judy Illes ed., 2006) [hereinafter Neuroethics]; infra notes 298-305 and accompanying text.

56 See, e.g., Fulks v. United States, No. 4:02-992, 2010 WL 3069390, at *16 (D. S.C. Aug. 3, 2010) (quoting a neuroscientist who testified that abnormalities in both brain structure and function "explain a lot of the behaviors, and the cognitive and emotional deficits" of the defendant).

57 See generally Law, Mind and Brain (Michael Freeman & Oliver R. Goodenough eds., 2009); Oliver R. Goodenough & Micaela Tucker, Law and Cognitive Neuroscience, 6 Ann. Rev. L. Soc. Sci. 61 (2010); Read Montague, How Is Neuroscience Likely to Impact Law in the Near Future?, in A Judge's Guide, supra note 52, 60, 60-65; Adina Roskies, How Is Neuroscience Likely to Impact the Law in the Long Run?, in A Judge's Guide, supra note 52, at 66, 66-70.

58 See Papanicolaou, supra note 31, at xi-xii.

59 Snead, supra note 45, at 1285.

60 See Papanicolaou, supra note 31, at 5.

61 See id. at 4-6.

62 Owen D. Jones et al., Brain Imaging for Legal Thinkers: A Guide for the Perplexed, 2009 Stan. Tech. L. Rev. 5, P 18.

63 Donald Reeves et al., Limitations of Brain Imaging in Forensic Psychiatry, 31 J. Am. Acad. Psychiatry L. 89, 90 (2003) ("Statistical maps of brain activity are a common and popular way to illustrate how an individual brain compares with an average brain. A statistical map is a probability function compared with a defined norm. In brain imaging, the norm is obtained by pooling and averaging the brain images of normal people." (citation omitted)).

64 See Papanicolaou, supra note 31, at 6-9.

65 Id.; Brown & Murphy, supra note 54, at 1136 n.63.

66 Brown & Murphy, supra note 54, at 1136 n.63; Jones et al., supra note 62, P 34. By convention, brighter colors are used to depict differences in activity that are more statistically significant.

67 Jones et al., supra note 62, P13.

68 Papanicolaou, supra note 31, at 66 (describing PET scans); Brown & Murphy, supra note 54, at 1136 (describing PET and SPECT as older scan methods).

69 Pananicolaou, supra note 31, at 67. Areas of the brain that are used more intensely have higher metabolic rates. Id.

70 Brown & Murphy, supra note 54, at 1136.

71 Jane Campbell Moriarty, Flickering Admissibility: Neuroimaging Evidence in the U.S. Courts, 26 Behav. Sci. & L. 29, 31-32 (2008).

72 Noel Shafi, Neuroscience and the Law: The Evidentiary Value of Brain Imaging, 11 Graduate Student J. Psychol. 27, 34 (2009).

73 Moriarty, supra note 71, at 32.

74 Mark Pettit, Jr., FMRI and BF Meet FRE: Brain Imaging and the Federal Rules of Evidence, 33 Am. J.L. & Med. 319, 320 (2007).

75 See Snead, supra note 45, at 1284.

76 Id.

77 Brown & Murphy, supra note 54, at 1136.

78 Id. at 1137.

79 Id. at 1136-37.

80 Scott T. Grafton, Has Neuroscience Already Appeared in the Courtroom?, in A Judge's Guide, supra note 52, at 54, 55.

81 Id.

82 Id.

83 Snead, supra note 45, at 1284.

84 Papanicolaou, supra note 31, at 47-49.

85 Id.; John C. Gore, Principles and Practice of Functional MRI of the Human Brain, 112 J. Clinical Investigation 4, 4-5 (2003).

86 Technically speaking, levels of oxygenated hemoglobin in the blood in specific brain areas decrease compared to the levels of deoxygenated hemoglobin in the same area. Papanicolaou, supra note 31, at 48; Snead, supra note 45, at 1285.

87 See supra note 33 and accompanying text (describing medical and research uses of MRI).

88 See Brown & Murphy, supra note 54, at 1127-28; Marcus Raichlie, What Is an fMRI?, in A Judge's Guide, supra note 52, at 5, 6 ("A recent check on the number of scientific publications in which fMRI ... imaging was used revealed over twelve thousand publications since its introduction in 1992.").

89 Neal Feigenson, Brain Imaging and Courtroom Evidence: On the Admissibility and Persuasiveness of fMRI, in Law, Mind and Brain, supra note 57, at 23, 24; Snead, supra note 45, at 1284.

90 Henry T. Greely & Judy Illes, Neuroscience-Based Lie Detection: The Urgent Need for Regulation, 33 Am. J.L. & Med. 377, 382 (2007).

91 Judy Illes & Eric Racine, Imaging or Imagining? A Neuroethics Challenge Informed by Genetics, Am. J. Bioethics, Mar.-Apr. 2005, at 5, 7; Snead, supra note 45, at 1286.

92 Powerful new tools of statistical analysis are now being applied to fMRIs, yielding an ever-deeper understanding of the human brain. Additionally, recent techniques have combined both EEG and fMRI to produce an even more accurate imaging technology. Annabelle Belcher & Walter Sinnott-Armstrong, Neurolaw, 1 Wires Cognitive Sci. 18, 18, 21 (2010).

93 Snead, supra note 45, at 1285-86.

94 Id.; cf. supra note 75 and accompanying text (describing danger of repeated PET and SPECT scans).

95 Interview with Dr. Lawrence Farwell: Frequently Asked Questions About Brain Fingerprinting Testing, Brain Fingerprinting Laboratories, http:// brainwavescience.com/FreqAskedQuestions.php (last visited Sept. 21, 2011).

96 Brain Fingerprinting Laboratories: Scientific Procedure, Research, and Applications, Brain Fingerprinting Laboratories, http:// brainwavescience.com/TechnologyOverview.php (last visited Sept. 21, 2011).

97 Id.

98 Id.

99 See Harrington v. State, 659 N.W.2d 509, 512 (Iowa 2003); Slaughter v. State, 2005 OK CR 6, 108 P.3d 1052, 1054 (Okla. Crim. App.).

100 Compare Greely & Illes, supra note 90, at 387-88 (documenting the shortcomings of brain fingerprinting and how it should not be used for lie detection in courts), with Judy C. Barillare, Comment, As Its Next Witness, the State Calls ... the Defendant: Brain Fingerprinting As "Testimonial" Under the Fifth Amendment, 79 Temp. L. Rev. 971, 1003-04 (2006) (arguing that BF may have some pitfalls, but it has the potential to be an effective tool in ensuring justice in certain circumstances).

101 See generally Jane Campbell Moriarty, Visions of Deception: Neuroimages and the Search for Truth, 42 Akron L. Rev. 739 (2009) (arguing that fMRI-based lie detection is currently insufficiently reliable to be used in court); infra note 115.

102 Anand Giridharadas, India's Novel Use of Brain Scans in Courts Is Debated, N.Y. Times, Sept. 15, 2008, at A10.

103 Id.

104 Johnson, supra note 55, at 34-35.

105 Id.

106 See Erica Beecher-Monas & Edgar Garcia-Rill, The Law and the Brain: Judging Scientific Evidence of Intent, 1 J. App. Prac. & Process 243, 268 (1999) (citing studies); Yang et al., supra note 48, at 74. See generally Adrian Raine & Yalin Yang, The Neuroanatomical Bases of Psychopathy: A Review of Brain Imaging Findings, in Handbook of Psychopathy 278, 278 (Christopher J. Patrick ed., 2006) (finding functional brain abnormalities in psychopathic individuals); Sapolsky, supra note 40, at 236-38; John Matthew Fabian, Neuropsychological and Neurological Correlates in Violent and Homicidal Offenders: A Legal and Neuroscience Perspective, 15 Aggression & Violent Behav. 209 (2010); Young et al., supra note 40.

107 See, e.g., United States v. Williams, No. CR 06-00079, 2009 WL 424583, at *5-6, 12 (D. Haw. Feb. 20, 2009) (suggesting that fMRI and EEG could provide, and possibly with sufficient reliability, evidence of a defendant's inability to form requisite intent). See generally Brown & Murphy, supra note 54.

108 See Floyd E. Bloom, Does Neuroscience Give Us New Insights into Drug Addiction? in A Judge's Guide, supra note 52, at 42, 42-45 (suggesting that functional neuroimaging will help scientists understand addiction, which will likely effect changes in both law and policy regarding addiction).

109 Adrian Raine, From Genes to Brain to Antisocial Behavior, 17 Current Directions Psychol. Sci. 323, 327 (2008) (suggesting that criminals with brain dysfunction should not be held criminally responsible for their actions).

110 United States v. Kasim, No. 2:07 CR 56, 2008 WL 4822291, at *19-20 (N.D. Ind. Nov. 3, 2008) (using SPECT scan to determine competency to stand trial), supplemented by 2010 WL 339084 (N.D. Ind. Jan. 21, 2010).

111 United States v. Gigante, 996 F. Supp. 194, 229, 237-38 (E.D.N.Y. 1998) (admitting PET scan to show defendant's competency to be sentenced, but ultimately finding it unpersuasive).

112 See, e.g., Roskies, supra note 57, at 67 ("Privacy law is apt to become important with respect to these technologies."); Stacey A. Tovino, The Confidentiality and Privacy Implications of Functional Magnetic Resonance Imaging, 33 J.L. Med. & Ethics 844 (2005).

113 See, e.g., Eagleman, supra note 6, at 39; Henry T. Greely, Prediction, Litigation, Privacy, and Property: Some Possible Legal and Social Implications of Advances in Neuroscience, in Neuroscience and the Law: Brain, Mind and the Scales of Justice 114, 137-38 (Brent Garland ed., 2004) [hereinafter Neuroscience and the Law].

114 Henry T. Greely, The Social Effects of Advances in Neuroscience: Legal Problems, Legal Perspectives, in Neuroethics, supra note 55, at 245, 246-50.

115 See generally Emilio Bizzi et al., Using Imaging to Identify Deceit: Scientific and Ethical Questions (2009) (discussing implications of neurological-based lie detection); Sarah E. Stoller & Paul Root Wolpe, Emerging Neurotechnologies for Lie Detection and the Fifth Amendment, 33 Am. J.L. & Med. 359 (2007) (discussing constitutional concerns of brain-based lie detection); Leo Kittay, Note, Admissibility of fMRI Lie Detection: The Cultural Bias Against "Mind Reading" Devices, 72 Brook. L. Rev. 1351 (2007) (arguing that neurological lie detection should be admitted as evidence).

116 See, e.g., Truck Ins. Exch. v. MagneTek, Inc., 360 F.3d 1206, 1209 (10th Cir. 2004) (identifying the "Daubert trilogy").

117 509 U.S. 579 (1993).

118 293 F. 1013 (D.C. Cir. 1927).

119 Daubert, 509 U.S. at 584-85, 587. Although Rule 702 became the federal standard, the states have disagreed regarding the proper standard to apply. Most adopted Daubert or a similar standard, but a minority of states and the District of Columbia continue to use the Frye test. A few states have combined the Daubert and Frye tests, and still others have created their own tests entirely. See Brown & Murphy, supra note 54, at 1176; Maxine D. Goodman, A Hedgehog on the Witness Stand--What's the Big Idea?: The Challenges of Using Daubert to Assess Social Science and Nonscientific Testimony, 59 Am. U. L. Rev. 635, 644 n.36 (citing sources that illustrate jurisdictional differences in standards for expert testimony, and listing states that still use the Frye test); Patel et al., supra note 33, at 560-61.

120 Daubert, 509 U.S. at 589.

121 Id. at 593; see also Margaret A. Berger, The Supreme Court's Trilogy on the Admissibility of Expert Testimony, in Reference Manual on Scientific Evidence 9, 11-12 (Fed. Judicial Ctr., 2d ed. 2000).

122 Daubert, 509 U.S. at 594.

123 Id. at 589 & n.7.

124 Id. at 590 n.9.

125 Id. at 595.

126 Id. at 593. This is an important factor to determine whether evidence is scientifically valid because testing and criticism is part of scientific inquiry, which leads to further scientific progress. See David Goodstein, How Science Works, in Reference Manual on Scientific Evidence, supra note 121, at 67, 70 ("[S]cience makes progress uniquely by proving that good ideas are wrong so that they can be replaced by even better ideas.").

127 Daubert, 509 U.S. at 593. However, the Court was keen to emphasize that "[p]ublication ... is not a sine qua non of admissibility; it does not necessarily correlate with reliability ... and in some instances well-grounded but innovative theories will not have been published." Id.

128 Id. at 594.

129 Id.

130 Id.; Berger, supra note 121, at 12-13 ("[G]eneral acceptance of the methodology within the scientific community is no longer dispositive ....").

131 Daubert, 509 U.S. at 593-94. Additional guidelines are mentioned in the advisory committee's notes to Rule 702. See Fed. R. Evid. 702 advisory committee's notes.

132 Daubert, 509 U.S. at 595.

133 Id.

134 Id. at 596.

135 Id.; see also Pettit, Jr., supra note 74, at 325. The Court also mentioned that judges can issue directed verdicts or grant summary judgment as "conventional devices" of the courtroom to protect against the intrusion and preponderance of "pseudoscientific" science. Daubert, 509 U.S. at 595.

136 522 U.S. 136 (1997).

137 Id. at 139.

138 Id. at 150 (Breyer, J., concurring).

139 Id. at 149-50; see Fed. R. Evid. 706. However, judges have been reluctant to appoint such experts. See, e.g., Ass'n of Mex.-Am. Educators v. California, 231 F.3d 572, 590, 612-14 (9th Cir. 2000) (Tashima, J., dissenting) (noting that court-appointed experts are appropriate in "rare" cases, and there is fear they could take away from the role of the judge or jury).

140 526 U.S. 137 (1999).

141 Id. at 141.

142 Id. at 146.

143 Id. at 141.

144 See Berger, supra note 121, at 18.

145 Kumho Tire, 526 U.S. at 150-51; see also Daubert v. Merrell Dow Pharm., Inc., 509 U.S. 579, 593-94 (1993).

146 See Berger, supra note 121 at 19.

147 Daubert, 509 U.S. at 593-94.

148 Id. at 592-93, 595.

149 Gen. Electric Co. v. Joiner, 522 U.S. 136, 150 (1997) (Breyer, J., concurring). See generally Sheila Jasanoff, Hidden Experts: Judging Science After Daubert, in Trying Times: Science and Responsibilities After Daubert 30, 30 (Vivian Weil ed., 2001).

150 Kumho Tire, 526 U.S. at 152.

151 Id. at 142 (citing Joiner, 522 U.S. at 143).

152 See Pettit, Jr., supra note 74, at 323 ("[B]rain-imaging evidence seems necessarily to entail presentation by expert witnesses ....").

153 Fed. R. Evid. 702.

154 Fed. R. Evid. 702 advisory committee's notes.

155 Christopher B. Mueller et al., Evidence: Practice Under the Rules 719 (3d ed. 2009).

156 Fed. R. Evid. 702.

157 Fed. R. Evid. 403.

158 Kenneth R. Foster & Peter W. Huber, Judging Science: Scientific Knowledge and the Federal Courts 209, 250 (1997).

159 See, e.g., United States v. Pohlot, 827 F.2d 889 (3d Cir. 1987) (finding evidence of brain abnormality to be reliable and relevant but excluding it because of its potential to mislead the jury); United States v. Mezvinsky, 206 F. Supp. 2d 661, 674-77 (E.D. Pa. 2002) (denying proffered PET scans due to their potential to mislead the jury).

160 See infra Part II.A.4 (presenting arguments that functional neuroimaging should be excluded under Rule 403). But see infra Part II.B.5 (presenting counterarguments).

161 Fed. R. Evid. 704.

162 Id.

163 Fed. R. Evid. 702.

164 Fed. R. Evid. 704 advisory committee's notes.

165 Id.

166 Comm. on Identifying the Needs of the Forensic Scis. Cmty., Nat'l Research Council, Strengthening Forensic Sciences in the United States: A Path Forward 11 (2009) [hereinafter NRC Report] (describing inconsistency among federal courts in applying, misapplying, or not applying Daubert in criminal cases).

167 See Edward K. Cheng & Albert H. Yoon, Does Frye or Daubert Matter? A Study of Scientific Admissibility Standards, 91 Va. L. Rev. 471, 478-79 (2005).

168 See, e.g., NRC Report, supra note 166, at 11; Cheng & Yoon, supra note 167, at 479 n.25.

169 NRC Report, supra note 166, at 11.

170 See Mueller, supra note 155, at 716. A defendant's right to a trial by jury is an underlying principle of our criminal justice system. See U.S. Const. amend. VI.

171 See Daubert v. Merrell Dow Pharm., Inc., 509 U.S. 579, 595 (1993) ("The focus, of course, must be solely on principles and methodology, not on the conclusions that they generate."); Smith v. Ford Motor Co., 215 F.3d 713, 719 (7th Cir. 2000) ("It is not the trial court's role to decide whether an expert's opinion is correct. The trial court is limited to determining whether expert testimony is pertinent to an issue in the case and whether the methodology underlying that testimony is sound.").

172 See Ford Motor Co., 215 F.3d at 719.

173 See Daubert, 509 U.S. at 594-95. Failure to focus solely on how the expert arrived at his or her conclusions can constitute reversible error. See, e.g., Deputy v. Lehman Bros., 345 F.3d 494, 508 (7th Cir. 2003) (finding that the district court incorrectly excluded expert testimony for reasons relevant to valuing the testimony rather than questioning its method of analysis).

174 See supra notes 166-69 and accompanying text (discussing the confusion and disparity in applying Daubert).

175 See, e.g., United States v. Ochoa-Ramirez, 386 F. App'x 641, 642 (9th Cir. 2010) (admitting prejudicial evidence because it had probative value and its prejudicial effect was mitigated by limiting jury instructions); United States v. McRae, 593 F.2d 700, 707 (5th Cir. 1979) ("Relevant evidence is inherently prejudicial; but it is only unfair prejudice, substantially outweighing probative value, which permits exclusion of relevant matter under Rule 403."); United States v. Starzecpyzel, 880 F. Supp. 1027, 1029 (S.D.N.Y. 1995) (describing the same).

176 Daniel J. Capra, Exclusion and Admissibility Under Rule 403, 212 N.Y. L.J. 3, 3 (1994).

177 880 F. Supp. 1027 (S.D.N.Y. 1995).

178 Id. at 1029.

179 Id. at 1049.

180 The court mitigated the prejudicial effect of the evidence by giving the jury specific instructions not to grant the testimony more weight than was appropriate, and the court noted that it could also restrict the degree of certainty with which the expert testifies. Id. at 1049-50.

181 Id. at 1049 (quoting 3 Jack B. Weinstein & Margaret A. Berger, Weinstein's Evidence § 702[03], at 702-03 (1989)); see also United States v. Mitchell, 365 F.3d 215, 245 (3d Cir. 2004) ("'[A] party confronted with an adverse expert witness who has sufficient, though perhaps not overwhelming, facts and assumptions as the basis for his opinion can highlight those weaknesses through effective cross-examination."' (quoting Stecyk v. Bell Helicopter Textron, Inc., 295 F.3d 408, 414 (3d Cir. 2002))).

182 See supra notes 134-35 and accompanying text.

183 White v. Illinois, 502 U.S. 346, 356 (1992) (quoting California v. Green, 399 U.S. 149, 158 (1970)); see also Melendez-Diaz v. Massachusetts, 129 S. Ct. 2527, 2536 (2009) (recognizing that cross-examination is a constitutionally guaranteed method of testing the reliability of forensic evidence).

184 Patricia M. Ayd & Merle M. Troeger, Are Jurors Smart Enough to Understand Scientific Evidence?, in Expert Witnessing: Explaining and Understanding Science 38 (Carl Meyer ed., 1999); see also Richard D. Friedman, Squeezing Daubert Out of the Picture, 33 Seton Hall L. Rev. 1047, 1061-64 (2003) (arguing that jurors would not be unfairly prejudiced or misled by such evidence and should be presented with the evidence because they still effectively serve as finders of fact).

185 See, e.g., Christopher Slobogin, Proving the Unprovable: The Role of Law, Science, and Speculation in Adjudicating Culpability and Dangerousness 139-43 (2007) (describing Daubert's potential damage to the criminal justice system); Friedman, supra note 184, at 1047 (describing how the admissibility model created by the Daubert trilogy "is not a useful one"); Jasanoff, supra note 149, at 30-31; see also Andrew Jurs, Judicial Analysis of Complex & Cutting-Edge Science in the Daubert Era: Epidemiologic Risk Assessment as a Test Case for Reform Strategies, 42 Conn. L. Rev. 49, 52, 69-84 (2009) (identifying multiple weaknesses displayed by courts when applying Daubert).

186 Jasanoff, supra note 149, at 44; see also id. at 45 ("[D]espite Daubert's suggestions to the contrary, there are no universally applicable rules for evaluating scientific validity in all litigation contexts."); see also Friedman, supra note 184, at 1047-48 (remarking how the Daubert admissibility standard is both insufficient and inappropriately applied because trial courts are ill suited to sort the good from the bad, and it misdirects the appropriate focus for a useful evidentiary standard).

187 Jasanoff, supra note 149, at 44.

188 Id.

189 Gen. Electric Co. v. Joiner, 522 U.S. 136, 153 & n.6 (1997); see also Amorgianos v. Nat'l R.R. Passenger Corp., 303 F.3d 256, 267 (2d Cir. 2002) ("The flexible Daubert inquiry ... [helps] ensure that the courtroom door remains closed to junk science while admitting reliable expert testimony that will assist the trier of fact.").

190 See supra notes 126-31 and accompanying text (summarizing the judge's gatekeeping role).

191 See, e.g., Paul C. Giannelli, The Supreme Court's "Criminal" Daubert Cases, 33 Seton Hall L. Rev. 1071, 1072, 1073 n.12 (noting the difference in admissibility standards between civil and criminal cases and how experts offered by the prosecution have been "largely insulated from any change in pre-Daubert standards"); see also Jane Campbell Moriarty, Daubert, Innocence, and the Future of Forensic Science, 43 Tulsa L. Rev. 229, 229-30 (2007) (listing scholars who discuss how judges have been lax in their gatekeeping role).

192 See David L. Faigman et al., Modern Scientific Evidence: The Law and Science of Expert Testimony § 1:35 (2009-2010 ed.); NRC Report, supra note 166, at 11 ("[T]he vast majority of the reported opinions in criminal cases indicate that trial judges rarely exclude or restrict expert testimony offered by prosecutors; most reported opinions also indicate that appellate courts routinely deny appeals contesting trial court decisions admitting forensic evidence against criminal defendants."); see also Giannelli, supra note 191, at 1111.

193 NRC Report, supra note 166, at 53. Despite the fact that these problems were first acknowledged almost twenty years ago, little has been done to change the frequency of their courtroom use. See Michael J. Saks & Jonathan J. Koehler, What DNA "Fingerprinting" Can Teach the Law About the Rest of Forensic Science, 13 Cardozo L. Rev. 361, 372 (1991) (noting that forensic scientists need to "subject their claims to methodologically rigorous empirical tests" that should then be "published and debated," but until such steps are taken, their claims should be "regarded with far more caution than they traditionally have been"); cf. infra notes 224-25 and accompanying text (citing cases where forensic science continues to be used in the courtroom without much attention paid to scientific reliability).

194 See, e.g., Ege v. Yukins, 380 F. Supp. 2d 852, 871 (E.D. Mich. 2005) (finding bitemark evidence "unreliable and not worthy of consideration by a jury"), aff'd in part, rev'd in part on other grounds, 485 F.3d 364 (6th Cir. 2007); United States v. Hidalgo, 229 F. Supp. 2d 961, 967 (D. Ariz. 2002) (finding that handwriting analysis fails to pass Daubert); United States v. Llera Plaza, 188 F. Supp. 2d 549, 558, 576 (E.D. Pa. 2002) (excluding and then admitting fingerprint evidence, finding it sufficiently reliable under Daubert only when subject to "careful trial court oversight"); United States v. Saelee, 162 F.Supp. 2d 1097, 1103, 1105-06 (D. Alaska 2001) (finding that handwriting analysis fails to pass Daubert); see also Deputy v. Lehman Bros., 345 F.3d 494, 509 (7th Cir. 2003) (noting disparity in admissibility of handwriting analysis between circuit courts and district courts).

195 See supra notes 106-15 and accompanying text.

196 Moriarty & Saks, supra note 17, at 17. This Note focuses on forensic individualization and compares it to functional brain scans.

197 See Faigman et al., supra note 192, §30:19; Moriarty & Saks, supra note 17, at 17.

198 See, e.g., Melendez-Diaz v. Massachusetts, 129 S. Ct. 2527, 2530-31 (2009) (describing forensic identification of cocaine); United States v. Rivera-Rodriguez, 617 F.3d 581, 599, 607 (1st Cir. 2010) (reviewing forensic analyst's description of crack cocaine), cert. denied, 131 S. Ct. 968 (2011).

199 NRC Report, supra note 166, at 135; Moriarty & Saks, supra note 17, at 17.

200 Moriarty & Saks, supra note 17, at 17. As a recent student note points out, "[t]he American criminal justice system is no stranger to forensic falsification." Kristen Bolden, Note, DNA Fabrication, A Wake Up Call: The Need to Reevaluate the Admissibility and Reliability of DNA Evidence, 27 Ga. St. U. L. Rev. 409, 417 (2011).

201 NRC Report, supra note 166, at 7.

202 Moriarty & Saks, supra note 17, at 17; see also Faigman et al., supra note 192, §30:19.

203 Moriarty & Saks, supra note 17, at 18.

204 Id. Forensic individualization experts use similar methods to identify a specific subpopulation of people who share the unique trait. Id.

205 Id. at 18-19.

206 Michael J. Saks, Explaining the Tension Between the Supreme Court's Embrace of Validity as the Touchstone of Admissibility of Expert Testimony and Lower Court's (Seeming) Rejection of Same, 5 Episteme 329, 331 (2008).

207 See, e.g., NRC Report, supra note 166, at 141-43 (stating that fingerprint experts often testify in objective terms such as "absolute certainty" or "zero error rates," assertions that are "not scientifically plausible" and "[c]learly ... unrealistic"); Moriarty & Saks, supra note 17, at 20 (describing same); see also Duncan v. Ornoski, 528 F.3d 1222, 1237 (9th Cir. 2008) (recounting fingerprint expert's testimony and court's reliance thereon that fingerprints "can be ascribed to a specific individual with certainty"), aff'd, 286 F. App'x 361 (9th Cir. 2008); United States v. Hall, 905 F.2d 959, 963 (6th Cir. 1990) (Kennedy, J., concurring) (quoting handwriting expert's testimony that was "'virtually certain that [the defendant] wrote it"'); United States v. Hugh, No. 03-829, 2009 WL 212420, at *2 (E.D. Pa. Jan. 28, 2009) (mentioning a fingerprint expert's claim of an "exact match"); United States v. Green, 405 F. Supp. 2d 104, 107 (D. Mass. 2005) (describing officer's testimony that he could match shell casings to the weapon from which it was fired "to the exclusion of every other firearm in the world"); United States v. Havvard, 117 F. Supp. 2d 848, 854 (S.D. Ind. 2000) ("The government claims the error rate for the [fingerprint] method is zero."), aff'd, 260 F.3d 597 (7th Cir. 2001). However, some forensic experts do testify to a "reasonable degree" of scientific or technical certainty. See, e.g., Norwood v. Artis, 487 F. Supp. 2d 321, 326 (W.D.N.Y. 2007).

208 405 F. Supp. 2d 104, 107 (D. Mass. 2005).

209 Id.

210 Id.

211 Id. at 109.

212 Id. at 108.

213 Id. at 124. While the ballistics expert was allowed to testify, Judge Nancy Gertner's ruling is significant because it is one of the few instances where a court recognized the failings associated with forensic science and took corrective measures. See infra note 274 (citing other cases that took similar measures).

214 Moriarty & Saks, supra note 17, at 18; Saks, supra note 206, at 329-30.

215 Saks, supra note 206, at 330. Even DNA analysis, the "gold standard" of modern forensic evidence, is not without its own analytical deficiencies. A recent study has shown that even DNA samples can be fabricated and more rigorous verification methods are necessary. See Dan Frumkin et al., Authentication of Forensic DNA Samples, 4 Forensic Sci. Int'l: Genetics 95 (2010); see also NRC Report, supra note 166, at 130-33. See generally Natasha Gilbert, DNA's Identity Crisis, 464 Nature 347 (2010) (questioning the reliability of DNA evidence from ever-smaller human traces); Bolden, supra note 200 (describing deficiencies in DNA analysis and the need to reevaluate its use in court).

216 See Faigman et al., supra note 192, §30:2; Moriarty & Saks, supra note 17, at 17; supra notes 143-44 and accompanying text. Forensic individualization sciences would also be subject to Rules 403, 704, and others.

217 See, e.g., NRC Report, supra note 166, at 14-18; Craig M. Cooley & Gabriel S. Oberfield, Increasing Forensic Evidence's Reliability and Minimizing Wrongful Convictions: Applying Daubert Isn't the Only Problem, 43 Tulsa L. Rev. 285, 292-94 (2007); Michael J. Saks & Jonathan J. Koehler, The Individualization Fallacy in Forensic Science Evidence, 61 Vand. L. Rev. 199, 203-07 (2008). See generally Mara L. Merlino et al., Meeting the Challenges of the Daubert Trilogy: Refining and Redefining the Reliability of Forensic Evidence, 43 Tulsa L. Rev. 417 (2007); Jennifer L. Mnookin, Of Black Boxes, Instruments, and Experts: Testing the Validity of Forensic Science, 5 Episteme 343 (2008); Moriarty & Saks, supra note 17; D. Michael Risinger et al., Exorcism of Ignorance as a Proxy for Rational Knowledge: The Lessons of Handwriting Identification "Expertise," 137 U. Pa. L. Rev. 731 (1989); Michael J. Saks, The Legal and Scientific Evaluation of Forensic Science (Especially Fingerprint Expert Testimony), 33 Seton Hall L. Rev. 1167 (2003); Adina Schwartz, Firearms and Toolmark Identification Cannot Be Made to a Reasonable Degree of Certainty, Champion Mag., Nov.-Dec. 2008, at 44.

218 See, e.g., NRC Report, supra note 166, at 108-09 ("'[T]he undeniable reality is that the community of forensic science professionals has not done nearly as much as it reasonably could have done to establish either the validity of its approach or the accuracy of its practitioners' conclusions,' and the courts have been 'utterly ineffective' in addressing this problem." (quoting Jennifer L. Mnookin, The Validity of Latent Fingerprint Identification: Confessions of a Fingerprinting Moderate, 7 L. Probability & Risk 127, 139 (2008)); see also Saks, supra note 206, at 329, 330-31 ("'[In] [a]ll the areas of forensic [identification] science ... little rigorous, systematic research has been done to validate the discipline's basic premises and techniques, and in each area there is no evident reason why such research would be infeasible."' (quoting Paul Giannelli & Edward Imwinkelried, Scientific Evidence: The Fallout from Supreme Court's Decision in Kumho Tires, 14 Crim. Just. 12, 40 (2000))).

219 For example, fingerprint evidence was first admitted in an American appellate proceeding in 1911. See People v. Jennings, 96 N.E. 1077, 1082 (Ill. 1911); Faigman et al., supra note 192, § 33:2 n.9. Forensic handwriting identification has been used in litigation since at least 1832, but the first empirical study to examine handwriting identification was conducted in 1939. See Strother v. Lucas, 31 U.S. 763, 767 (1832); Risinger et al., supra note 217, at 734 n.14, 740-43.

220 See United States v. Williams, 506 F.3d 151, 162 (2d Cir. 2007) ("[E]xpert testimony long assumed reliable before Rule 702 must nonetheless be subject to the careful examination that Daubert and Kumho Tire require."); see also Richard Bjur & James T. Richardson, Expert Testimony Involving Chemists and Chemistry, in Expert Witnessing: Explaining and Understanding Science, supra note 184, at 67, 75; Beecher-Monas & Garcia-Rill, supra note 106, at 275 ("Lower courts cannot blindly accept pre-Daubert approved notions of expertise."); Gianelli, supra note 191, at 1096-99.

221 Faigman et al., supra note 192, § 1:35 ("[T]he vitality of Daubert itself might be assessed on whether the courts embrace the gatekeeping function seriously enough to challenge forensic scientists to live up to the title 'scientist.'").

222 Id.

223 See, e.g., id. § 1:30 (noting "courts' general abdication of any serious critical review of the non-DNA forensic identification sciences."); Giannelli, supra note 191, at 1111 ("Paradoxically, and perhaps shamefully, [Daubert] has not been consistently imposed in criminal cases.").

224 NRC Report, supra note 166, at 106-09; see, e.g., United States v. Pena, 586 F.3d 105, 110 (1st Cir. 2009) (admitting fingerprint evidence despite the court's reservations about its reliability because "the case law is overwhelmingly in favor of admitting fingerprint experts under virtually any circumstance"); United States v. Prime, 431 F.3d 1147, 1154 (9th Cir. 2005) (same for handwriting identification); United States v. Crisp, 324 F.3d 261, 268 (4th Cir. 2003) (same); Faigman et al., supra note 192, §33:3 (describing how judges are convinced of the reliability of fingerprint analysis and avoid conducting a Daubert analysis); see also D. Michael Risinger, Cases Involving the Reliability of Handwriting Identification Expertise Since the Decision in Daubert, 43 Tulsa L. Rev. 477, 561 (2007) (noting that cases are decided by "authority and case citations," often foregoing the proper admissibility analyses and instead admitting evidence by stare decisis).

225 See, e.g., United States v. Janis, 387 F.3d 682, 689-90 (8th Cir. 2004) (suggesting that fingerprint evidence can be admitted by judicial notice); Brooks v. State, 748 So. 2d 736, 746-47 (Miss. 1999) (Smith, J., concurring) (citing numerous cases where the court took judicial notice of forensic odontology--expert analysis of bite marks--without conducting any evidentiary hearing under either Frye or Daubert).

226 See Faigman et al., supra note 192, § 1:35. As of February 1, 2009, the Innocence Project has found that "[o]f the first 225 wrongful convictions overturned by DNA testing, more than 50% (116 cases) involved unvalidated or improper forensic science." See Wrongful Convictions Involving Unvalidated or Improper Forensic Science that Were Later Overturned Through DNA Testing, The Innocence Project, http://www.innocenceproject.org/docs/DNA_Exonerations_Forensic_Science.pdf.

227 Faigman et al., supra note 192, § 1:35.

228 Cowans v. City of Boston, No. 05-CV-11574, 2007 WL 28419, at *1 (D. Mass. Jan. 4, 2007).

229 Id.

230 Id.; Brief for the Innocence Project, Inc. as Amici Curiae Supporting Petitioner, Holmes v. South Carolina, 547 U.S. 319 (2006) (No. 04-1327), 2005 WL 879501, at *13-14 [hereinafter Innocence Project Brief]; Jonathan Saltzman & Mac Daniel, Man Freed in 1997 Shooting of Officer: Judge Gives Ruling After Fingerprint Revelation, Bos. Globe, Jan. 24, 2004, at A1.

231 Innocence Project Brief, supra note 230, at *14.

232 Cowans, 2007 WL 28419, at *1; Innocence Project Brief, supra note 230, at *13-14.

233 See NRC Report, supra note 166, at 109.

234 Faigman et al., supra note 192, § 1:35.

235 Id.

236 Id.

237 Id.; see Cooley & Oberfield, supra note 217, at 285, 291 (finding that the prosecution's success rate is much higher). The disparity is emphasized when compared with Daubert challenges to forensic evidence in civil trials. In federal civil trials, forensic evidence was excluded under Daubert 41 percent of the time, compared with 25 percent of the time pre-Daubert. Challenges made by defendants succeed approximately two-thirds of the time, compared with a success rate of less than half for challenges posed by plaintiffs. Faigman et al., supra note 192, §1:35; see also Michael L. Perlin, "His Brain Has Been Mismanaged with Great Skill": How Will Jurors Respond to Neuroimaging Testimony in Insanity Defense Cases?, 42 Akron L. Rev. 885, 906-07 & 907 n.139 (2009). These statistics underscore the observation that "courts have been, at best, lackadaisical and, at worst, disingenuous in carrying out their gatekeeping duties toward forensic science [in criminal cases]." See Faigman et al., supra note 192, §1:30.

238 See, e.g., Faigman et al., supra note 192, § 1:35 (offering possible explanations for this disparity); Perlin, supra note 237, at 906-07; Saks, supra note 206, at 335-41 (explaining why courts accept forensic evidence despite its lack of validity).

239 Pub. L. No. 109-108, 119 Stat. 2290 (codified as amended in scattered sections of 42 U.S.C. and 15 U.S.C.).

240 S. Rep. No. 109-88, at 46 (2005).

241 See NRC Report, supra note 166, at 6.

242 Id. at 5-8.

243 See id. at 7; supra note 206 and accompanying text. But see supra note 215 (noting deficiencies in DNA analysis).

244 NRC Report, supra note 166, at 7.

245 Id. at 8.

246 Id.

247 Id. at 9.

248 Id. at 81-82.

249 See Melendez-Diaz v. Massachusetts, 129 S. Ct. 2527, 2537 (2009) (noting that although there are "[s]erious deficiencies" in the forensic evidence used in criminal trials, confrontation and the adversarial process can weed them out).

250 See, e.g., United States v. Berry, 624 F.3d 1031, 1041, 1043 (9th Cir. 2010) (noting serious criticisms of lead bullet forensic analysis are "no more than impeaching evidence"); United States v. Ford, 481 F.3d 215, 218 n.5 (3d Cir. 2007) (admitting forensic individualization evidence but noting that Daubert "might be a fruitless exercise" due to "some of the difficulties inherent in this type of science"); United States v. Crisp, 324 F.3d 261, 270 (4th Cir. 2003) (noting that while additional research "would be welcome," it would be foolish to exclude the evidence); United States v. Willock, 696 F. Supp. 2d 536, 568 (D. Md. 2010) (finding that although forensic toolmark analysis may not be "sufficiently reliable to be called a 'science,"' it is consistently admitted and may still be useful to the jury); see also Faigman et al., supra note 192, § 1:30 ("Although the scholarly literature is increasingly demonstrating the paucity of data underlying many forensic fields, courts blithely ignore the empirical realities.").

251 See, e.g., United States v. Prime, 431 F.3d 1147, 1154 (9th Cir. 2005) (holding that district court's finding that handwriting testimony was admissible "was consistent with all six circuits that have addressed [its] admissibility"); United States v. Rogers, 26 F. App'x 171, 173 (4th Cir. 2001) ("[V]irtually every circuit and district court, both before and after Daubert, [has] a longstanding tradition of allowing fingerprint examiners to state their opinion and conclusions.").

252 324 F.3d 261 (4th Cir. 2003).

253 Id. at 271.

254 Id. at 265-68.

255 Id. at 271 (citation omitted). But see id. at 272 (Michael, J., dissenting) (describing how a long history of admissibility should not grant the government a "pass" to show how the evidence satisfies Daubert).

256 Id. at 270 ("[F]urther research into fingerprint analysis would be welcome.").

257 Id. at 270 n.5.

258 Faigman et al., supra note 192, § 34:7 (referring to the court's decision to admit the evidence as adopting the "guild test," meaning that courts defer to the history of the evidence's use in court); see NRC Report, supra note 166, at 110 (noting that judges could be reluctant to conduct proper Daubert analyses due to history of admissibility); see also United States v. Baines, 573 F.3d 979, 992 (10th Cir. 2009) (holding that fingerprint evidence survives Daubert, largely due to its history of admissibility).

259 Id. at 270 ("[L]ike fingerprint analysis, handwriting comparison testimony has a long history of admissibility in the courts of this country.").

260 Faigman et al., supra note 192, § 34:7 (citing Crisp, 324 F.3d at 269).

261 See id. § 33:18; see also NRC Report, supra note 166, at 142 ("[C]laims ... [of] zero error rates are not scientifically plausible.").

262 Toolmarks are generated when a hard object comes into contact with a relatively softer object, leaving an indentation or marking which experts can trace to an individual tool. See NRC Report, supra note 166, at 150.

263 United States v. Green, 405 F. Supp. 2d 104, 109 (D. Mass. 2005).

264 Id. at 108-09.

265 Id. at 109.

266 696 F. Supp. 2d 536 (D. Md. 2010).

267 Id. at 549-74.

268 Id. at 570.

269 Id. at 547 nn.25-26.

270 Id. at 574.

271 Id.

272 See id. at 573-74.

273 Id. at 578.

274 See, e.g., Deputy v. Lehman Bros., 345 F.3d 494, 509 (7th Cir. 2003) (citing several district courts that have rejected handwriting analysis for lack of scientific reliability); United States v. Taylor, 663 F. Supp. 2d 1170, 1180 (D.N.M. 2009) (finding ballistics was not a science but admitting the testimony with similar qualifications); United States v. Glynn, 578 F. Supp. 2d 567, 574-75 (S.D.N.Y. 2008) (same); see also supra note 194.

275 United States v. Baines, 573 F.3d 979, 992 (10th Cir. 2009); United States v. Crisp, 324 F.3d 261, 270 (4th Cir. 2003); see also United States v. Mitchell, 199 F. Supp. 2d 262, 267 n.5 (E.D. Pa. 2002); United States v. Llera-Plaza, 188 F. Supp. 2d 549, 572 (E.D. Pa. 2002).

276 NRC Report, supra note 166, at 109 (citing Crisp, 324 F.3d at 270); Joan Griffin & David J. LaMagna, Daubert Challenges to Forensic Evidence: Ballistics Next on the Firing Line, Champion Mag., Sept.-Oct. 2002, at 20.

277 See, e.g., Dale A. Nance, Reliability and the Admissibility of Experts, 34 Seton Hall L. Rev. 191, 193-219 (2003) (discussing general reliability standard and how it has been misapplied).

278 For example, constitutional issues are raised if scans are used as lie detection devices. See, e.g., John G. New, If You Could Read My Mind: Implications of Neurological Evidence for Twenty-First Century Criminal Jurisprudence, 29 J. Legal Med. 179, 193-98 (discussing Fourth and Fifth Amendment concerns raised by neurologically-based lie detection devices). See generally Stoller & Wolpe, supra note 115 (discussing Fourth and Fifth Amendment implications).

279 See, e.g., Moriarty, supra note 71, at 31 (noting that structural brain scans "are routinely introduced in court to show brain injuries, tumors, and abnormalities"); Patel et al., supra note 33, at 557-58 (noting that brain imaging is used "[i]n courthouses across the United States").

280 See Moriarty, supra note 71, at 29, 32, 48 (noting that few courts have admitted fMRI-based evidence). While Yang and colleagues state that approximately 130 cases have utilized PET or SPECT scans, they do not break down the distribution of cases into state and federal, or civil and criminal. See Yang et al., supra note 48, at 77-78.

281 Moriarty, supra note 71, at 48.

282 See Patel et al., supra note 33, at 561-64 (describing the types of cases in which functional neuroimaging evidence has been admitted).

283 See, e.g., Jay D. Aronson, The Law's Use of Brain Evidence, 6 Ann. Rev. L. Soc. Sci. 93, 100-01 (2010); Khoshbin & Khoshbin, supra note 22, at 171-72; Jennifer Kulynych, Note, Psychiatric Neuroimaging Evidence: A High-Tech Crystal Ball?, 49 Stan. L. Rev. 1249, 1259 (1997).

284 See, e.g., Kulynych, supra note 283, at 1259.

285 See supra notes 61, 70-71, 77-79, 89-91 and accompanying text (describing various neuroimaging techniques and their corresponding temporal and/or spatial resolution).

286 Kulynych, supra note 283, at 1259; See Brown & Murphy, supra note 54, at 1149-52 (discussing the problems of individual differences as they pertain to fMRI lie detection); Greely, supra note 6, at 711-14; Reeves et al., supra note 63, at 90.

287 Baskin et al., supra note 45, at 249; Brown & Murphy, supra note 54, at 1142-43.

288 See Brown & Murphy, supra note 54, at 1143-49, 1152-55; Feigenson, supra note 89, at 32; Greely & Illes, supra note 90, at 383-84; Jones et al., supra note 62, P 32.

289 Baskin et al., supra note 45, at 249; Brown & Murphy, supra note 54, at 1144-49.

290 See Brown & Murphy, supra note 54, at 1143, 1152-55 (discussing variables in methods used); Snead, supra note 45, at 1288-89; see also Jackson v. Calderon, 211 F.3d 1148, 1165 (9th Cir. 2000) (upholding district court's exclusion of defendant's PET scan in part because it "is susceptible to conflicting interpretations"), aff'd after new sentencing hearing sub nom. People v. Jackson, 199 P.3d 1098 (Cal. 2009).

291 Brown & Murphy, supra note 54, at 1150-52; Greely, supra note 6, at 713-14.

292 See supra notes 62-65 and accompanying text (discussing how functional neuroimaging relies on comparisons based on comparing a subject's brain activity with previously collected "normal" activity).

293 See Brown & Murphy, supra note 54, at 1150 (noting the importance of individual differences and their ability to skew results); Greely, supra note 6, at 714; Greely & Illes, supra note 90, at 380-81 (describing numerous reasons why deviations in results may occur).

294 Greely, supra note 6, at 714; see also Brown & Murphy, supra note 54, at 1150-52.

295 See Goodenough & Tucker, supra note 57, at 66.

296 See Greely, supra note 6, at 713-14 (describing how variations occur across individuals, and "as the law mainly cares about individuals, this is a real challenge").

297 See id.; see also Brown & Murphy, supra note 54, at 1150-52 (noting the importance of individual differences).

298 See Steven K. Erickson, Blaming the Brain, 11 Minn. J. L. Sci. & Tech. 27, 32 (2010) ("Brain activity is a global phenomenon, not merely a localized one within compartments of the brain ...."); Amanda C. Pustilnik, Violence on the Brain: A Critique of Neuroscience in Criminal Law, 44 Wake Forest L. Rev. 183, 219-26 (2009) (describing the difficulty of localizing behavior to specific brain regions); Snead, supra note 45, at 1287-88 & 1287 n.110 (same).

299 Baskin et al., supra note 45, at 249; Jones et al., supra note 62, P 38; Snead, supra note 45, at 1287.

300 Aronson, supra note 283, at 94 ("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."); Snead, supra note 45, at 1288.

301 See, e.g., Goodenough & Tucker, supra note 57, at 72; see also Fed. R. Evid. 702; Johnson, supra note 55, at 30-32; Stephen J. Morse, Brain Overclaim Syndrome and Criminal Responsibility: A Diagnostic Note, 3 Ohio St. J. Crim. L. 397, 406 (2006) (arguing that the criteria for criminal responsibility are normative and neuroscience is unhelpful to the jury); Walter Sinnott-Armstrong et al., Brain Images as Legal Evidence, 5 Episteme 359, 362-67 (2008).

302 Gazzaniga, supra note 55, at 102; see also Morse, supra note 301, at 400.

303 Moriarty, supra note 71, at 42. Many scholars debate this issue at length, and legal-philosophical implications about free will and determinism abound. See, e.g., Gazzaniga, supra note 55, at 87-102; Lisa Claydon, Mind the Gap: Problems of Mind, Body and Brain in the Criminal Law, in Law, Mind and Brain, supra note 57, at 55, 55-80; Michael S. Gazzaniga & Megan S. Steven, Free Will in the Twenty-first Century: A Discussion of Neuroscience and the Law, in Neuroscience and the Law, supra note 113, at 51, 51-70; Dean Mobbs et al., Law, Responsibility, and the Brain, in Law, Mind and Brain, supra note 57, at 5, 5-22; Stephen J. Morse, New Neuroscience, Old Problems, in Neuroscience and the Law, supra note 113, at 157, 157-98. Professor Stephen Morse has coined this the "psycholegal error," which is the tendency to think that an actor is not responsible for his actions due to his genes or his brain function. Stephen J. Morse, Criminal Responsibility and the Disappearing Person, 28 Cardozo L. Rev. 2545, 2569 (2007). But see Joshua Greene & Jonathan Cohen, For the Law, Neuroscience Changes Nothing and Everything, in Law & The Brain, supra note 40, at 207 (offering a counterargument that although neuroscience may not challenge the law's stated assumptions, it likely will change the way we think about criminal responsibility).

304 Snead, supra note 45, at 1288.

305 See, e.g., Brown & Murphy, supra note 54, at 1131-32, 1187-88 (arguing that current functional neuroimaging technologies are unable to draw a meaningful conclusion about past mental states); Snead, supra note 45, at 1287 & n.110; Kulynych, supra note 283, at 1259.

306 See supra notes 157-59 and accompanying text (discussing Rule 403).

307 See, e.g., Brown & Murphy, supra note 54, at 1188-1202; Khoshbin & Khoshbin, supra note 22, at 171, 185; Perlin, supra note 237, at 891-92; Reeves et al., supra note 63, at 89; Shafi, supra note 72, at 30; Kulynych, supra note 283, at 1262.

308 See Sinnott-Armstrong et al., supra note 301, at 368-69 (discussing concerns of "neurobabble"); Deena Skolnick Weisberg et al., The Seductive Allure of Neuroscience Explanations, 20 J. Cognitive Neuroscience 470, 476-77 (2008) (finding that evidence supported by neuroscience explanations is more convincing to the lay person than the same evidence without neuroscience explanation).

309 Brown & Murphy, supra note 54, at 1190-91; Goodenough & Tucker, supra note 57, at 72.

310 See Goodenough & Tucker, supra note 57, at 72; see also Snead, supra note 45, at 1289-90.

311 See Eric Bailey, Defense Probing Brain to Explain Yosemite Killings, L.A. Times, June 15, 2000, at A3 ("Jurors can be dazzled by the display. Christopher Plourd, a San Diego criminal defense attorney, remembers well the first time he used PET scans in the early 1990s during a murder trial. 'Here was this nice color image we could enlarge, that the medical expert could point to,' Plourd said. 'It documented that this guy had a rotten spot in his brain. The jury glommed onto that."').

312 Snead, supra note 45, at 1291.

313 See United States v. Montgomery, 635 F.3d 1074 (8th Cir. 2011); United States v. Puerto, No. 07-14097, 2010 WL 3191765 (11th Cir. Aug. 12, 2010); Jackson v. Calderon, 211 F.3d 1148 (9th Cir. 2000), aff'd after new sentencing hearing sub nom. People v. Jackson, 199 P.3d 1098 (Cal. 2009); United States v. Mezvinsky, 206 F. Supp. 2d 661 (E.D. Pa. 2002); United States v. Gigante, 982 F. Supp. 140 (E.D.N.Y. 1997), aff'd, 166 F.3d 75 (2d Cir. 1999); see also United States v. Sandoval-Mendoza, 472 F.3d 645 (9th Cir. 2006) (holding that neuroimaging evidence which could elucidate nature of defendant's brain function was improperly excluded); United States v. Williams, No. CR 06-00079, 2009 WL 424583 (D. Haw. Feb. 20, 2009) (noting "considerable debate exists" about the reliability of functional neuroimaging, but entertaining the thought that it could be relevant).

314 See, e.g., Gigante, 982 F. Supp. at 147-48 (finding that the scans were "dubious, based upon speculative scientific theories lacking full development" and the "opinions of [the] defendant's experts were unreliable").

315 See Mezvinsky, 206 F. Supp. 2d at 674-75; Puerto, 2010 WL 3191765, at *13.

316 See Mezvinsky, 206 F. Supp. 2d at 674-75; Puerto, 2010 WL 3191765, at *13.

317 206 F. Supp. 2d 661 (E.D. Pa. 2002).

318 Id. at 667-69.

319 Id. at 675 ("[T]here is ... no evidence that Mezvinsky's PET-identified brain abnormalities had any pertinence to his capacity to deceive ....").

320 Id. The prosecution argued that the PET scans could mislead and confuse the jury and should be excluded under Rule 403. The court, however, did not reach that question in its analysis. See id.

321 No. 07-14097, 2010 WL 3191765 (11th Cir. Aug. 12, 2010).

322 Id. at *12-13.

323 Id. at *9-10.

324 Id. at *10.

325 Id.

326 Id. at *13.

327 Id.

328 See id.; United States v. Mezvinsky, 206 F. Supp. 2d 661, 677 (E.D. Pa. 2002); see also Trapp v. Spencer, 479 F.3d 53, 58, 62-63 (1st Cir. 2007) (affirming denial of habeas petition seeking new PET scan results in part because the brain scan was conducted twenty years after the murder and may not have been representative of the defendant's brain condition when the defendant committed the crime).

329 See supra Part II.A.1.

330 See, e.g., Feigenson, supra note 89, at 44-48; Goodenough & Tucker, supra note 57, at 80-82; Johnson, supra note 55, at 39-40; Yang et al., supra note 48, at 79-80; see also Beecher-Monas & Garcia-Rill, supra note 106, at 261. See generally Kittay, supra note 115.

331 See, e.g., Frederick Schauer, Can Bad Science Be Good Evidence? Neuroscience, Lie Detection, and Beyond, 95 Cornell L. Rev. 1191, 1205-06 (2010).

332 See, e.g., Goodenough & Tucker, supra note 57, at 80; Erin Ann O'Hara, How Neuroscience Might Advance the Law, in Law & The Brain, supra note 40, 21, 27-31; Shafi, supra note 72, at 29-30.

333 See, e.g., Feigenson, supra note 89, at 44-45, 48.

334 See generally Fabian, supra note 106; Raine, supra note 109; Raine & Yang, supra note 106; Sapolsky, supra note 40; Robert W. Thatcher et al., Quantitative EEG and the Frye and Daubert Standards of Admissibility, 34 Clinical Electroencephalography 1 (2003) (arguing that qEEG is sufficiently reliable to pass evidentiary standards).

335 See Goodenough & Tucker, supra note 57, at 80.

336 Id. at 82; see also Pettit, Jr. supra note 74, at 340 (concluding that brain imaging is constantly evolving and, should brain imaging reach the point of admissibility, courts should be open to this new form of evidence “even if the result is a profound transformation of how [our legal system] operates”).

337 Goodenough & Tucker, supra note 57, at 80-82.

338 See supra Part II.A.1-2.

339 See Beecher-Monas & Garcia-Rill, supra note 106, at 253, 257, 276.

340 Id. at 253 ("The probability that one event caused another can be increased or decreased, depending on how well new evidence fits with the guiding theory, but it cannot be determined with absolute certainty."); see also Nance, supra note 277, at 193 (arguing that courts misunderstand Daubert's reliability requirement and that evidence is not a "binary, all-or-nothing concept of reliability--that evidence is either reliable or unreliable," but that "the reliability of evidence is a matter of degree").

341 Beecher-Monas & Garcia-Rill, supra note 106, at 256.

342 Id. at 257.

343 Id. at 262; see supra note 125 and accompanying text.

344 Beecher-Monas & Garcia-Rill, supra note 106, at 256, 262, 275-76.

345 Defendants could also introduce such evidence to boost their credibility by attempting to show they are not falsifying their testimony, see supra note 115, but that is beyond the scope of this Note.

346 Slobogin, supra note 185, at 40, 53-55 (pointing out that when defendants wish to testify on their own behalf, both First and Sixth Amendment protections are triggered). Slobogin notes that a defendant's right to testify is particularly important when the testimony concerns the defendant's mental state. Id.; see Greely, supra note 113, at 131-32 (discussing a constitutional right, based on the Fifth and Sixth Amendments, for criminal defendants to present evidence in their own defense).

347 483 U.S. 44 (1987).

348 Id. at 61.

349 Slobogin, supra note 185, at 55; see also Beecher-Monas & Garcia-Rill, supra note 106, at 261 ("Mental state is such an important facet of our understanding of criminal responsibility that judges need to be open to the new ideas emerging in the field of brain science.").

350 Slobogin, supra note 185, at 55.

351 Id. at 40, 43-48, 51; Beecher-Monas & Garcia-Rill, supra note 106, at 261.

352 472 F.3d 645 (9th Cir. 2006).

353 See id. at 654.

354 See id. at 656.

355 Id. (quoting United States v. Slaughter, 891 F.2d 691, 698 (9th Cir. 1989)).

356 Yang et al., supra note 48, at 79.

357 Id.; see also United States v. Williams, No. CR 06-00079, 2009 WL 424583, at *5-6 (D. Haw. Feb. 20, 2009) (noting that while it is controversial, functional neuroimaging can potentially enlighten the fact-finder on questions of the defendant's mental intent and culpability); Stephen H. Dinwiddie, Biological Causes of Criminality and Expert Testimony--Some Cautionary Thoughts, in The Science, Treatment, and Prevention of Antisocial Behaviors: Application to the Criminal Justice System 24-1, at 24-9 (Diana H. Fishbein ed., 2000); O'Hara, supra note 332, at 28-30 (describing neuroscience as a contributing factor that can help the fact-finder decide on ultimate issues of culpability).

358 See supra notes 40, 106 and accompanying text.

359 Dinwiddie, supra note 357, at 24-9; see also O'Hara, supra note 332, at 29-30; Note, Reliable Evaluation of Expert Testimony, 116 Harv. L. Rev. 2142, 2153 (2003) (noting that jurors should be the arbiters of as-applied reliability).

360 O'Hara, supra note 332, at 30.

361 See supra notes 157-60 and accompanying text (explaining Rule 403); supra Part II.A.4.

362 E.g., Feigenson, supra note 89, at 44-48; Goodenough & Tucker, supra note 57, at 72 ("[P]otential for prejudice does not make neuroscience evidence inadmissible per se."); Schauer, supra note 331, at 1210; Sinnott-Armstrong et al., supra note 301, at 370.

363 Perlin, supra note 237, at 890 (quoting Dov Fox, Brain Imaging and the Bill of Rights: Memory Detection Technologies and American Criminal Justice, 8 Am. J. Bioethics 34, 36 (2008)); see also Schauer, supra note 331, at 1210 n.103 (citing numerous studies which suggest that juries are not as ill-equipped at evaluating scientific evidence as is commonly assumed).

364 Feigenson, supra note 89, at 44-48; Goodenough & Tucker, supra note 57, at 72 ("[A] potential for prejudice does not make neuroscience evidence inadmissible per se."); see also Schauer, supra note 331, at 1210 ("This reliance on juror incompetence to justify excluding neuroscience evidence seems misplaced ... or, at the very least, premature."); Sinnott-Armstrong et al., supra note 301, at 370 (noting that, if used properly, brain scans might actually inform the jury and lead to more accurate conclusions instead of misleading the jury).

365 Feigenson, supra note 89, at 44-48.

366 Id. at 47-48; see Goodenough & Tucker, supra note 57, at 72 ("[J]urors' biases and misunderstandings are better held in check by more information rather than less."); see also Daubert v. Merrell Dow Pharm., Inc., 509 U.S. 579, 596 (1993) (stating that "[v]igorous cross-examination" and "presentation of contrary evidence" are the "traditional and appropriate means" to challenge scientific evidence).

367 Feigenson, supra note 89, at 48.

368 See supra note 160 and accompanying text (describing what some refer to as the "Christmas tree effect").

369 Feigenson, supra note 89 at 44-48; see Perlin, supra note 237, at 890; see also Ayd & Troeger, supra note 184, at 38 ("Jurors should participate in legal decision making, even when scientific or technical issues are involved."); Friedman, supra note 184, at 1061-64 (arguing that jurors would not be unfairly prejudiced if presented with such evidence, and that they can still effectively serve as finders of fact).

370 See, e.g., United States v. Hammer, 404 F. Supp. 2d 676, 792-93 (M.D. Pa. 2005) (admitting neuroevidence at habeas corpus hearing but ultimately finding it unpersuasive as to defendant's competency), appeal dismissed, 564 F.3d 628 (3d Cir. 2009); State v. Anderson, 79 S.W.3d 420, 429 (Mo. 2002) (despite neurologist's testimony of defendant's brain damage, jury still found defendant guilty and sentenced him to death), aff'd in part, rev'd in part on other grounds, 196 S.W.3d 28 (Mo. 2006); Anemona Hartocollis, Jury Finds Writer Guilty of Sex Attack, Rejecting Psychiatric Defense, N.Y. Times, May 24, 2007, at B3; see also United States v. Sandoval-Mendoza, 472 F.3d 645, 656 (9th Cir. 2006) (reversing the lower court's decision to exclude evidence while noting that the jury is capable of reaching a conclusion and should have been presented with the evidence).

371 See supra notes 27-32 and accompanying text.

372 In fact, researchers recently developed technology that allows for significantly faster fMRI scans. See New Technologies Allow for Faster Brain FMRIs, Medgadget.com (Jan. 12, 2011), http://www.medgadget.com/archives/2011/01/new_technologies_allow_for_faster_brain_ fmris.html.

373 See supra Part II.A.

374 See supra Part I.D.4.

375 See supra Part I.D.4.

376 See supra Part I.D.3.

377 See supra note 214 and accompanying text.

378 See supra notes 217-18 and accompanying text.

379 See supra Part I.D.4.

380 See supra note 223 and accompanying text; supra Part I.D.2.

381 See supra notes 226-32 and accompanying text (discussing wrongful convictions based on faulty forensic evidence later overturned by DNA exonerations).

382 See supra note 200.

383 See supra Part II.B.3; supra notes 352-55 and accompanying text.

384 See supra Part I.D.4; supra note 251 and accompanying text.

385 See supra Part I.D.3.

386 See supra notes 249-65 and accompanying text (discussing federal courts' resistance to challenging the pedigree of forensic evidence despite recognizing the evidence's weaknesses).

387 Saks, supra note 206, at 336.

388 See supra notes 262-65 and accompanying text.

389 See supra notes 244-48 and accompanying text.

390 Greely & Illes, supra note 90, at 395-404.

391 See supra notes 338-44 and accompanying text.

392 See supra notes 191; 234-38 and accompanying text.

393 See supra notes 234-37 and accompanying text.

394 See supra notes 357-59 and accompanying text.

395 See supra notes 228-32 and accompanying text.

396 See supra note 369-70 and accompanying text.

397 See supra Part II.A.

398 See supra Part II.A.1.

399 See supra notes 244-48 and accompanying text.

400 See supra notes 62-65, 291-97 and accompanying text.

401 See supra notes 203-07 and accompanying text.

402 See supra Part II.A.2.

403 This includes blood, bite marks, etchings on tool marks, fingerprints, and the like. See supra Part I.D.1.

404 See Moriarty & Saks, supra note 17, at 26.

405 See NRC Report, supra note 166, at 174. Similar problems of temporal dynamism occur with toolmark analysis. See Moriarty & Saks, supra note 17, at 26.

406 NRC Report, supra note 166, at 174.

407 Moriarty & Saks, supra note 17, at 26 ("[I]t is necessary [for forensic analysts] to use methods of analysis that are capable of making useful estimates about samples or a temporally changing target."). The same holds true for inferential leaps that experts make when they only have partial fingerprints. Id.

408 See supra Part I.D.3.

409 See supra notes 217-18 and accompanying text.

410 See supra notes 262-65, 274 and accompanying text.

411 See Brown & Murphy, supra note 54, at 1177 (noting that the methodology of functional neuroimaging is scientifically sound and would survive both Daubert and Frye analyses); supra Parts I.B.1, II.B.2.

412 See supra notes 174-75 and accompanying text.

413 See supra notes 125, 170-73 and accompanying text.

414 See supra note 172 and accompanying text.

415 See supra Parts II.B.2, II.B.4, note 349 and accompanying text.

416 See supra notes 161-65 and accompanying text.

417 See supra Part II.B.4; see also supra notes 270-73 and accompanying text.

418 Once such question is whether the science of functional neuroimaging is sufficiently reliable to pass Daubert.

419 See supra note 334 and accompanying text.

420 See supra Part I.C.3.

421 See supra note 370 and accompanying text (citing cases where juries disregarded functional neuroimaging evidence); see also supra notes 362-63 and accompanying text.

422 See supra notes 366-70 and accompanying text.

423 See supra notes 365-67 and accompanying text.

424 See supra notes 132-35 and accompanying text.

425 See White v. Illinois, 502 U.S. 346, 356 (1992) (quoting California v. Green, 399 U.S. 149, 158 (1970)).

426 See supra notes 339-44 and accompanying text.

427 472 F.3d 645 (9th Cir. 2006); see supra notes 352-55 and accompanying text.

428 See supra note 354 and accompanying text.

429 Sandoval-Mendoza, 472 F.3d. at 656.

430 See supra notes 137, 151 and accompanying text.

431 See supra note 184 and accompanying text.

432 See supra Part II.B.2.

433 See supra Part II.B.4-5.

434 See supra note 21 and accompanying text.

435 See supra note 135.

436 See supra note 22 and accompanying text.

Bruce Stern, Diffusion Tensor Imaging 289 New Jersey Lawyer 11 (August, 2014)[8]

Over the past 20 years, both clinicians and attorneys have recognized that traumatic **brain injury** poses a serious medical condition.[1] It is so serious that Brent Masel, MD, the medical director of the **Brain Injury** Association of America, calls **brain injury** a chronic disease.[2] It is, therefore, not surprising that claims asserting compensation for traumatic **brain injury** have steadily increased.

Traumatic **brain injury** is defined as an alteration in **brain** function, or other evidence of **brain** pathology, caused by an external force.[3] However, traumatic **brain injury** is a continuum, ranging from mild to severe. Because traditional MRI and CT scans are insensitive to the subtle damage sustained in mild traumatic **brain injury**, these diagnostic test results are usually reported as normal.[4] It is for this reason that mild traumatic **brain injury** has been called the "silent epidemic."[5]

Since the majority of traumatic **brain injuries** are classified as mild, and because diagnostic tests such as MRI and CT scans are usually reported as normal (as are neurologic mental status examinations) demonstrating an individual sustained a traumatic **brain injury** is often difficult. Where the limitation on lawsuit threshold applies, a plaintiff must demonstrate objective proof of medical evidence of a permanent injury. Satisfying this threshold has been difficult. Plaintiffs have had to rely on neuropsychological testing,[6] which ***12** comprises numerous tests designed to measure the functioning of the brain. Because this testing requires the patient put forth his or her best efforts, some defense-oriented doctors have suggested neuropsychological testing is subjective, not

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objective. While this viewpoint has been rejected by mainstream medicine, the argument still prevails.[7]

Despite neuropsychological testing being considered objective proof of injury by mainstream medicine, plaintiff and defense neuropsychologists typically differ in their interpretation of the data. Since the plaintiff has the burden of proof and confusion is always an aid to the defense, reliance on neuropsychological testing to objectively demonstrate traumatic **brain injury** has often proved difficult in court.

With the growth in technology, new neuroimaging techniques can now objectively document and support the clinical diagnosis of traumatic **brain injury**. This has particular relevance in litigating automobile accident cases where a plaintiff has elected the limited threshold, as a permanent injury under N.J.S.A. 39:6A-8a must be proven through objective medical evidence before a plaintiff can recover damages for pain and suffering. This article will discuss one of those new techniques--diffusion tensor imaging (DTI).

What is DTI?

DTI examines the microstructure of the white matter of the brain, allowing for the detection of microscopic pathology or abnormality.[8] Because of its sensitivity, DTI reveals abnormalities in the white matter of the brain that is not detectible on a standard MRI or CT scan. Diffusion tensor imaging sequences are sensitive to traumatic axonal injury secondary to stretch, sheer and compaction forces.[9] DTI measures the direction of movement or flow (known as diffusion) of water molecules through tissue. In the white matter of a normal, healthy brain, the direction of water diffusion is uniform. Injury disrupts the normal structure of white matter, leading to less uniform direction of diffusion.[10]

DTI is based on the basic physics of the flow of water. With no barriers to flow, water will move in an isotropic distribution, which means it will move equally in all directions. If there are barriers to flow it will move anisotropically, or unequally in all directions. White matter of the brain comprises axons, which are long processes extending from the nerve cells, which constitute the gray matter. Axons are organized into thick, tubular tracts, which extend from one brain region to another, similar to electrical cables. Water diffusion is much greater along the long axon than across it and, therefore, has a relatively anisotropic distribution (higher FA). Traumatic **brain injury** induced by sudden acceleration or deceleration of the head often results in widely scattered damage to white matter fibers known as diffuse axonal **injury**. This damage includes segmental breakdown in the outer membrane of the axon, increasing diffusion in the short access dimension leading to more isotropic distribution (decreased FA).[11]

Neuroimaging experts will compare an individual patient's DTI findings against the findings of a normal control group. Where the abnormalities are at least two standard deviations or more from the mean, the findings on the specific patient's DTI are abnormal.[12] “Where a patient's measurement is

two standard deviations or more away from the mean of the normal distribution, there is only a five percent chance that the finding of abnormality is a false positive, or due to inherent variability rather than actual abnormality. Notably, this five percent criterion is the standard for determination of clinically significant findings in medical research."[13]

As expected with any new diagnostic test, diffusion tensor imaging has come under attack by defense courtroom physicians and defense attorneys.

The Standard for Assessing the Admissibility of Expert Testimony

The standard for assessing the admissibility of expert opinion testimony and diagnostic testing is well established in New Jersey. The New Jersey Supreme Court explained that N.J.R.E. 702:

> Sets forth three basic requirements for the admission of expert testimony: (1) the intended testimony must concern a subject matter beyond the ken of average juror; (2) the field testified to must be at a state of the art that an expert's testimony could be sufficiently reliable; and (3) the witness must have sufficient expertise to offer the intended testimony.[14]

While Rule 702 allows a qualified witness to testify "in the form of an opinion or otherwise," N.J.R.E. 703 "'addresses the single quote bases of opinion testimony by experts."'[15]

The New Jersey Supreme Court has admonished courts to construe Rule 702's "requirements" liberally in light of N.J.R.E. 702's tilt in favor of the admissibility of expert testimony.[16]

To meet the second requirement, only expert opinions that are "constructed with a sound scientific methodology and provide the requisite nexus to the disputed issue" will qualify as helpful and be admissible.[17]

The New Jersey Supreme Court ruled that the standard to be utilized in determining the reliability and admissibility of scientific theories focuses on the methodology and reasoning supporting the opinion.[18] The proper inquiry is whether the expert's opinion is based on a "sound, adequately-founded scientific methodology involving data and information of the type relied on by experts in the scientific field."[19] The Court must make inquiry into, and make a determination finding on, whether experts in ***13** the field rely on such data.[20] The trial court should assess "whether the reasoning or methodology underlying the testimony is scientifically valid and whether that reasoning or methodology properly can be applied to the facts in issue."[21]

In New Jersey, there are three ways to prove general acceptance reliability of a methodology: 1) by expert testimony regarding the general acceptance, among those in the

profession, of the premises on which the expert witness based his or her analysis; 2) by authoritative, scientific and legal writings indicating the scientific community accepts the premises underlying the testimony; and 3) by judicial opinions that indicate the expert's premises have gained general acceptance.[22]

DTI Satisfies These Requirements

Over the past decade, numerous medical articles have been published regarding using diffusion tensor imaging to detect **brain** abnormalities in patients with traumatic **brain injury** (TBI). In an article entitled "A Decade of DTI in Traumatic **Brain Injury**: 10 Years and 100 Articles Later,"[23] the authors conducted a PubMed search of all relevant DTI articles through 2011. Using an exclusion criteria, they found 100 articles met the inclusion criteria. From those articles, the authors concluded:

> A unifying theme can be deduced from this large body of research: DTI is an extremely useful and robust tool for the detection of TBI-related brain abnormalities. The overwhelming consensus of these studies is that low white matter FA is characteristic of TBI. This finding is consistent across almost all of the articles we reviewed, despite significant variability in patient demographics, modest differences in data acquisition parameters, and a multiplicity of data analysis techniques. This consistency across studies attests to the robustness of DTI as a measure of **brain injury** in TBI ....
>
> We also found an overwhelming consensus that imaging abnormalities detected with DTI are associated with important clinical outcomes. This further validates DTI as a meaningful measure of clinically important **brain injury**.

In summary, DTI provides a robust measure of clinically important TAI [traumatic axonal injury] at cross-section, despite the variability inherent in characteristics of patients with TBI and injury mechanisms as well as study differences in data acquisition and analysis methods.

The American College of Radiology, the American Society of Neuroradiology ***14** and the Society of Pediatric Radiology have published guidelines for DTI to provide added value for MRI of the brain. The American Society of Functional Neuroradiology (ASFNR) has also issued guidelines for the clinical use of diffusion tensor imaging.[24] The ASFNR found DTI is an acceptable test to be used with other factors in the diagnosis of traumatic **brain injury**. DTI is also used by the U.S. Department of Defense, the Defense Centers of Excellence (DCoE) and the Defense and Veterans **Brain Injury** Center (DVBIC).

DTI Has Been Admitted in Various Courts Throughout the United States

As expected, challenges to the admissibility of diffusion tensor imaging are routinely filed and routinely denied by numerous trial courts throughout the United States. Not one court has disallowed the admissibility of diffusion tensor imaging.

In *Ruppel v. Kucanin*,[25] the plaintiff was severely injured in a motor vehicle crash. The defendants moved to assert the opinion of the plaintiff's neuroimaging expert, Dr. Randall Benson, regarding the plaintiff's condition of a diffuse axonal injury and its causation was unreliable under Rule 702 because it was based on two controversial methods: DTI and fractional anisotropy (FA) quantification from that imaging. The federal district court found that DTI and FA quantification based on comparative scans appeared to be reliable methods for Benson to arrive at his expert opinion of the plaintiff's diagnosis of diffuse axonal injury and the cause of that injury. Relying on *Daubert*, the trial court found "the evidence shows that while DTI is a relatively new technology it is gaining general acceptance as a method for detecting TBI. It is explained in further detail below. First, there have been numerous validation studies, published in peer reviewed journals on DTI to detect diffuse axonal injuries. Second, DTI is regularly used as a diagnostic tool ...."

The court also acknowledged "several decisions in which trial court judges admitted DTI into evidence." For example *Hammar v. Sentinel insurance Company, Ltd*,[26] allowed DTI evidence to be admitted under the *Frye* standard and *Whilden v. Cline*[27] allowed an expert witness to rely on DTI evidence when testifying about the diagnosis of mild TBI and its probable causation from an automobile accident if the expert's opinion was not based solely on DTI. The court reviewed the *Daubert* factors, and found that DTI met the *Daubert* standard.

In *Chiulli v. Newbury Fine Dining, Inc.*,[28] the district court was confronted with a similar motion to bar Benson's testimony regarding his reliance upon diffusion tensor imaging to arrive at a diagnosis of traumatic **brain injury** and its causal relationship to the traumatic event. Like the decision in *Ruppel*, the court denied the defendant's motion.

Defense Arguments Against DTI

Diffusion tensor imaging is a useful diagnostic tool in research and it is evident from group analysis that DTI can identify TBI-associated changes in the **brain** across a range of **injury** severity, from mild to severe DTI. The argument, however, is this finding is based primarily upon group analyses and there is not conclusive evidence to date that DTI can be used for a diagnosis and/or prognostication at the individual patient level. This argument ignores a large quantity of peer-reviewed scientific literature supporting the clinical use of DTI[29] and ignores that diffusion tensor imaging is being used at Walter Reed Army Medical Center to detect and treat wounded service members returning from Afghanistan and Iraq.

Detractors also assert DTI cannot diagnose traumatic **brain injury**. The author believes this is a classic straw man argument, since reputable experts should not rely solely on diffusion tensor imaging or any diagnostic test to make a diagnosis. A diagnosis of traumatic **brain injury** is a clinical diagnosis based on history, review of medical records, clinical examination and diagnostic testing. Utilizing all of these sources, a clinician can make an appropriate diagnosis of traumatic **brain injury**.[30]

Footnotes

a1 ***Bruce H. Stern*** *is a shareholder and member of the accident and personal* ***injury*** *group of Stark & Stark, where he concentrates his practice in the area of traumatic* ***brain*** *and spinal cord* ***injuries*** *and wrongful death.*

1 cdc.gov/TraumaticBrainInjury/; B.H. Stern and J.A. Brown, Litigating **Brain Injuries**, Thomson Reuters (2006).

2 B.E. Masel and D.S. DeWitt, Traumatic **Brain Injury**: a disease process, not an event, *J. Neurotrauma*, 2010 Aug: 27(8) 1529-40.

3 D.K. Menon, K. Schwab, D.W. Wright, and A.I. Maas, Position Statement: Definition of Traumatic **Brain Injury**, *Archives of Physical Medicine and Rehabilitation*, Vol. 91, Issue 11, 1637-1640 (Nov. 2010).

4 M.P. Alexander, Mild Traumatic **Brain Injury**: Pathophysiology, Natural History and Clinical Management, 45 *Neurology* 1253 (1995).

5 M. Goldstein, Traumatic **Brain Injury**: A Silent Epidemic [Editorial], *Ann. Neurol.*, 1990; 27:327.

6 *See* braininjurylawblog.com/braininjury-Iegal-cases-neuropsychologi-cal-testing.html.

7 R.L. Strub and F.W. Black, *The Mental Status Examination in Neurology*, 161-62 (F.A. Davis Co. 3rd Ed. 1993); American Academy of Neurology, 1996. Assessment: Neuropsychological Testing of Adults, Considerations for Neurologists, *Neurology*, 47 (1996), pp. 592-599.

8 Affidavit of Randall Benson, M.D., *Ferrante v. City of Atlantic City*, File No. ATL-L-1892-10.

9 R.R. Benson, R. Gattu, B. Sewick, Z. Kou, N. Zakariah, J.M. Cavanaugh and E.M. Haacke, Detection of Hemorrhagic and Axonal Pathology in Mild Traumatic **Brain Injury** Using Advanced MRI: Implications for Neurorehabilitation, *NeuroRehabilitation* 31 (2012) 261-279.

10 Affidavit of Michael L. Upton, M.D., Ph.D. in *Yang-Weissman v. So. Carolina Prestress Corp.*, Civil Action No: 4:07-CV-03643-RBH (U.S.D.C. Dist. S.C. - Florence Div.)

11 Benson, *supra*.

12 *Id.*

13 *Id.*

14 *Brenman v. DeMello*, 191 N.J. 18, 31-32 (2007), *quoting* *State v. Torres*, 183 N.J. 554, 567-68 (2005).

15 *Polzo v. County of Essex*, 196 N.J. 569, 582 (2008), *quoting* *State v. Townson*, 186 N.J. 473, 494 (2006).

16 *State v. Jenewicz*, 193 N.J. 440, 454 (2008), *citing* *State v. Berry*, 140 N.J. 280, 290-93 (1995).

17 *Dennis v. Pertec Computer Corp.*, 927 F. Supp. 156, 159 (D.N.J. 1996).

18 *Kemp v. State*, 174 N.J. 412, 430 (2002), *citing to* *Landrigan v. Celotex Corp.*, 127 N.J. 404, 425-6 (1992).

19 *Id.* at 430, *citing to* *Rubanick v. Witco Chemical Corp.*, 125 N.J. 421, 449 (1991).

20 *Ryan v. KDI System Pools, Inc.*, 121 N.J. 276, 289 (1990).

21 *Kemp*, 174 N.J. at 426, *citing to* *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 509 U.S. 579, 592-93 (1993).

22 *State v. Harvey*, 151 N.J. 117 (1997).

23 M.B. Hulkower, D.B. Poliak, S.B. Rosenbaum, M.E. Zimmerman and M.L. Lipton, A Decade of DTI in Traumatic **Brain Injury**: 10 Years and 100 Articles Later, *AJNR* (2013) 1-11.

24 asfnr.org/docs/ASFNR_Guidelines-for-DTI.pdf.

25 No. 3:08 CV 00591, U.S.D.C. Northern Division of Indiana, South Bend Division (2011).

26 State of Florida, 13th Judicial Circuit of the State of Florida, Hillsborough County, Civil Action No. 08-019984(Sept. 27, 2010).

27 No. 08-CV-4210 (Col. Ct. Dist. May 10, 2010).

28 Civil Action No. 10-10488-JLT (U.S.D.C. Mas. Sept. 30, 2013).

29 *See* M.B. Hulkower, D.B. Poliak, S.B. Rosenbaum, M.E. Zimmerman and M.L. Lipton, A Decade of DTI in Traumatic **Brain Injury**: 10 Years and 100 Articles Later, *AJNR* (2013) 1-11.

30 Affidavit of Randall Benson, M.D., *Ferrante v. City of Atlantic City*, File No. ATL-L-1892-10.

Mark I. Sirkin, Managing Your Brain - A User's Guide, 82 New York State Bar Journal 38 (September, 2010)[9]

Information about the human brain has increased dramatically over the past 10 to 15 years, radically changing our understanding of its functions and its capabilities. Since lawyers rely on their brains (as opposed to specialized instruments and tools) more than most professionals, this knowledge is particularly relevant to them. What follows is a "user's guide" or primer about neuroscience for the practicing lawyer.

The brain is, far and away, the most complex organ known to man. Some estimates suggest that there are more potential connections in the brain than there are stars in the universe.[1] That's a large number. Even more fascinating than the mere quantity of connections is the way the brain interconnects its systems and subsystems.

One reason the brain is so complex is that several different systems operate simultaneously in living brains. The brain can be understood from an anatomical perspective, a biochemical perspective, and an electrical perspective. Anatomy rules the brain; understanding the place, or position, of its parts is critical to understanding brain function. If you know the topology of the brain, that is, where things are located, you are well on the way to understanding many of its functions. This principle is true even on the cellular level, where the placement and growth of axons (the antennae that bring information into the cell) and dendrites (the transmitters that send information out of the cell) dictate brain function and growth at the micro-level. The biochemical perspective or system deals with the neurochemistry of the brain -- the relevant neuroanatomy here concerns the tiny gaps between axons and dendrites that are filled with chemicals, called neurotransmitters, that excite or pacify the receiving neuron. This is the level at which pharmaceuticals operate. Finally, and perhaps least understood, the brain is an organ of electrical transmission, where brain frequencies (referred to by the Greek terms *alpha*, *beta*, *theta*, *delta*, and *gamma*) facilitate or reflect certain states of preparedness, awareness, and learning. Although well documented, these brain waves are not well understood and their function (for example, are they cause or effect?) is still a mystery. Rather than

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focus on neuroanatomy or neurochemistry, however, let us examine the brain *in vivo*, that is, how the brain functions as it is being used. This article will discuss three areas that warrant special attention: information overload, emotional reactivity, and working with others. But first, what's changed about what we know?

What's New?

When you were in high school or college, you probably were taught that while other parts of the body regenerate naturally, the brain does not regenerate new brain cells. This is no longer considered gospel. The brain does regenerate new cells, as well as rewire and remap existing connections. This is called *neuroplasticity* and the discovery of ***39** this phenomenon lies at the heart of our changing ideas about brain function. Another breakthrough that has changed the way we think about the brain is the fact that new technology, such as functional magnetic resonance imaging (fmri), has allowed us to actually see the brain at work. So what have we been learning?

• We Think in Maps -- Every idea is a group of interconnected neurons that we call maps. Every thought, concept, or idea represents a group of neurons or map. Complex ideas, or concepts built from a number of discrete pieces of information, are larger maps that interconnect smaller maps into a unitary thought. This is how many points in the brain can become interconnected, and a single idea or set of neurons can participate in more than one map. Thinking is the process of creating new maps, and we create millions of new maps every second. A memory, while once thought to be a single idea residing in a single place in the brain, is now known to be made up of many discrete impressions (residing in multiple regions of the brain) all brought together in the single act of remembering.

• Up Close All Brains Are Different -- The brain changes with experience. This is the essence of neuroplasticity. Your brain has been impacted by your unique experiences which have affected your brain, which permanently reflects everything that has happened to it since birth. Even identical twins have different brains due to their unique experiences beginning *in utero*. Everything that has happened to you has affected your brain, for better or for worse. The nanny who gave you ice cream, that professor in law school that influenced you so much, your first case, all have impacted your brain more or less permanently. While we always knew that experience mattered, we never knew that it mattered at such a deep level. The brain is literally shaped by experience; brain cells live or die, and pathways are created and reinforced by repetition. Gerald Edelman, a winner of the Nobel Prize in Medicine, called this phenomenon “neural Darwinism.” The brain literally changes as a function of where an individual puts his or her attention. Professionals in different fields think differently; their brains are different because of their training and their day-to-day mental activity.

• Multi-tasking Is a Myth -- The brain is an excellent sequential processor of information, but attention is like a spotlight that can be focused only on one thing at a time. The brain requires some degree of sustained concentration to process information, first into short-term, or working, memory, then into long-term memory. Multi-tasking is actually a rapid sequencing from one task to another and it is a very inefficient process.[2] (For example, drivers using cell phones are four times more likely to get into accidents; they are the functional equivalent of drunk drivers because of the brain's

inherent information-processing limitations.) In addition, the brain stores new information into short-term memory or working memory, which is quite limited. In our information society, working memory gets filled quickly. When working memory is overloaded, the brain does not function efficiently -- we become forgetful, inattentive, and frustrated.

• The Brain Prefers Certainty -- In some respects the brain is a “difference” engine; it spots and resolves differing or incompatible inputs. When a discrepancy arises, the brain strives to resolve it. This is why we are inveterate problem solvers, even for fun (think crossword puzzles and Sudoku). Established maps are preferred because the brain tends to do things the way it has done them before. Like the law, the brain is inherently conservative. Existing maps (or expectations, to use common parlance) influence the way new information is processed. Conflicting maps irritate, so we are motivated to resolve discrepancies between overlapping maps. Changing old wiring in the brain is difficult, if not impossible, and the more we focus on an idea, even a wrong idea, the more we set it. The good news, however, is that *new* maps are relatively easy to lay down. New ideas, or new maps, are easier to adopt than re-learning or changing an old idea. This may seem to fly in the face of logic, a favorite mode of thought for lawyers. Logic leads to certainty, which neuroscience tells us the brain prefers. Logic has its place; it leads to certainty, which the brain craves. But if you are trying to convince someone of something, it is easier to teach that person a new idea than to get the person to give up an old one.

Attention and the Myth of Multi-tasking

We live in a wired world where new information comes flowing in -- fast and furious. This is no longer your father's law practice with libraries down the hall and an *eminence grise* in the next office who knew everything there was to know about a particular law or client. The amount of information processed by the average lawyer today is many times what it was just a few years ago. Moore's law describes the phenomenon that lets us squeeze more and more data into smaller spaces ever more quickly. This discovery has changed the lawyers' world permanently, forever changing the way law is practiced. What has not changed as quickly, however, is the brain that processes all this information. As lawyers juggle cell phones, BlackBerrys, emails and the like, more and more input is bombarding their brains. It's true, the technology gives us the ability to file and access information more efficiently than ever, but simply trying to ***40** remember what is there, while juggling several things other tasks at the same time, may strain the brain beyond optimal functioning.

Most of the brain's informational inputs reside in working memory which, as we said, is limited. This presents a problem. A complicating factor is that most people believe they can multi-task without degradation of quality or inefficiency. But the brain research disagrees: the brain can focus primarily on one thing at a time, and that's the limit. While it can switch rapidly from one task to the other -- called “serial attention” -- some information is always lost in the switching back and forth. And most people will notice what you are doing and that you are not concentrating fully on the task at hand.

When the limits of working memory are reached, several things can happen. First, information gets lost; there is simply no place to store it effectively, and either the new input gets dropped or the new information pushes out the old. How many of us have had the experience of being told something quite clearly and plainly; we listened, but then got distracted and now we can't remember what it was we just heard. This is not only a common phenomenon, it is becoming more and more common with consequences that range from annoyance to malpractice. In addition, this type of overload has emotional consequences. It is frustrating and stressful to have so much information coming at us at once. Forgetting can be embarrassing, which creates further emotional stress.

What can be done? Here are several suggestions, taking our current knowledge about brain functioning into account, that can help with the problems related to information overload.
1. Care and Feeding: Brains do best on seven to eight hours of sleep each night -- get enough sleep. Caffeine is not food; make sure your brain is well fed with a minimum of carbohydrates and a maximum of protein. Alcohol and the use of other substances do not contribute to the efficient functioning of your brain -- use them sparingly. If you need these substances, including sleep medication or other pharmaceuticals to help you function, you may need a lifestyle change that fits better with the brain you have. In addition, exercising the body may be the single best thing to do for your brain -- it increases blood flow and keeps the brain systems working at peak efficiency.

2. Train the Brain: Working memory can be trained. Although the brain is not a muscle, it behaves like one at times; it improves and gets stronger with practice. Psychologists have been developing games and other methods to help working memory function more efficiently. Some sites that provide brain training are: www.positscience.com, www.lumosity.com, and www.cogmed.com/program.

3. Learn to Relax: Stress is the enemy of efficient brain functioning. The fight-flight mode is activated when the brain is stressed. While this may prepare you to run away or fight someone, it is not effective in today's professional world. Also, stress pumps hormones into your bloodstream that further distract you. There are, however, a number of mind-body disciplines that all contribute to better brain functioning through focused relaxation. Among these are yoga, tai chi, meditation or mindfulness, and biofeedback, to name just few. Try one that interests you, learn the discipline, and then practice it regularly to control your body's reaction to stressful events and information overload.

The Role of Emotions and Emotional Intelligence

If absorbing and using information was a purely cognitive exercise that involved filing and retrieval, modern life would be hard enough. But research shows us that most, if not all, inputs and memories get tagged with an emotional association as well. These emotions, it seems, enable us to process and retrieve information more effectively.

Let's start with some basic brain anatomy. In the 1960s and 1970s we made the exciting discovery that the left brain was primarily analytic, specializing in fact-based and sequential information processing. The right brain was more emotional and holistic, and processed gestalts most effectively.

We have moved beyond the left brain = analytic/right brain = emotion dichotomy. Psychologists now believe that there is more than one type of intelligence. IQ, or what is called cognitive intelligence, is what most people traditionally think of when they say someone is smart. However, recent findings indicate that emotional intelligence, sometimes called EQ, is distinct from, and is not correlated with, cognitive intelligence. But EQ is correlated with strong interpersonal relationships, leadership skills, and positive client interactions. The good news for lawyers, based on preliminary findings by my colleague Dr. Larry Richard at Hildebrandt Baker Robbins, is that lawyers tend to have higher IQs ***41** than the average person. The bad news, however, is that their EQ scores tend to be lower.

Lawyers live in a world where they are taught, and reminded every day, that logic is good and emotions are bad; careful, non-emotional reasoning should trump emotion every time according to this old-school way of thinking. Indeed the law is based on this sort of reasoning. Emotions, if noticed at all, ought to be factored out. But not so fast! Emotions are fundamental to the way people, and their brains, operate. Here are some things scientists have recently concluded about emotions that should give every lawyer reason to pause:[3]

• Emotions are information.

• We can try to ignore emotion, but it doesn't work.

• We can try to hide emotions, but we are not as good at it as we think.

• Decisions must incorporate emotion to be effective.
• Emotions follow logical patterns.

• Emotional universals do exist, but so do specifics (i.e., individual and cultural differences).

As with any life skill, some people are better at using emotions than others (i.e., are born with a higher EQ). And like any other life skill, learning how to use it and practicing it will improve the ability to recognize, use, and track emotional information.

Emotional intelligence, according to one definition, is the set of skills we use to read, understand, and respond effectively to the emotional signals sent to us by others and by ourselves. These skills allow us to understand and adjust our reactions to events and people, and they enable us to anticipate and influence others.[4] If none of these skills and capabilities is important to you then no need to worry about emotional intelligence ... but check your pulse because you may not be a fully functioning human. Interacting with others requires the use of emotional intelligence. The better you are with it, the more you will be able to anticipate, affect, and utilize your own emotions and those of the people with whom you interact.

According to the literature, the four branches of emotional intelligence are:[5]

1. Perceiving and Identifying Emotions -- Knowing your own emotions and reading the emotions of others accurately.

2. Using Emotion to Facilitate Thought -- Understanding how mood affects you and affects situations, and how to create moods to achieve your goals.

3. Understanding Emotions -- Making accurate inferences; predicting emotional reactions in others.

4. Managing Emotions -- Choosing emotional expression appropriate to time and place.

Tests have been developed to assess your own emotional intelligence and diagnose the areas that need strengthening. As with IQ, you can be good at some aspects and not so good at others, thus impacting your overall EQ. But the good news is that, as with any life skill and a good assessment, you can determine what you need to work on and improve.

How can emotional intelligence be improved? Some of the sensitivities required for higher emotional intelligence do not come easily and may be hard to learn. But practice and diligence will pay off. Here are a couple of suggestions:
1. Facial expressions are the key to reading the emotions of others. Practice reading faces and body language, and think about whether there is a match or mis-match between the two. Use the information that is often written on the faces of others. Dr. Paul Ekman (www.paulekman.com) has been studying emotional expressions for his entire career and has developed methods for teaching this skill to others. As an added bonus, if you take his course, you may be able to spot when people are lying to you; emotionally intelligent people will often pick up subtle but real and reliable clues.

2. Keep an emotions journal -- start to study your own emotional reactions to events and their consequences. This does not mean writing down every emotion you have during the day, but rather journaling one stand-out event during the day that engaged you or someone close to you emotionally. Try to do this every day. By writing about it, you will be teaching yourself to be more sensitive to emotional cues and learn how your emotions are connected, one to the other. Remember, focus changes the brain; so, by thinking about your emotions, you are re-wiring your brain to be more emotionally astute.

Motivating and Influencing Others

While it's important to understand the role of emotions in interpersonal interactions, brain science is teaching us things about motivation and influence that we never knew with such certainty before. For example, by reading fmris when people are exposed to various situations, we can tell what they like and how they react. We can recognize a perceived threat as it impacts the brain, regardless of what an individual says or knows about himself or herself.

Remember, the brain is, first and foremost, a difference-analyzing engine. It makes mental maps which are predictions based on expectations based on past experience. If the predictions don't match, the brain sends out an alert that causes the difference to be analyzed until it is understood or resolved. But the brain does not function in a vacuum: we are social creatures that must negotiate a social world whether that is a courtroom, a law firm, or a family home. Research suggests that there are intrinsic, built-in motivators that all humans strive to attain.[6] Having these motivators enhanced or achieved is rewarding, while having them frustrated or diminished is intrinsically ***42** de-motivating. Although the list below may not be complete, these well-documented social motivators must be taken into account in every social situation:

• Status

• Certainty

• Autonomy

• Relatedness

• Fairness

These motivators are easiest to remember as the acronym SCARF, although this is not necessarily in their order of importance. To the extent that you can enhance any one of the SCARF elements -- for yourself, your firm, or your client -- it will be experienced as a social positive or good.

We are programmed by thousands of years of evolution to seek certainty -- and the other elements of SCARF as well. The brain seeks certainty; the brain really likes predictability. That the world, or events, can be anticipated with (a degree of) certainty is intrinsically calming, just as an unpredictable environment typically creates anxiety.

Status is next. We are primates and, as primates, social hierarchies are literally a part of our DNA. As humans, we enjoy status, the more the better, and it is part of the warp and woof of most social organizations, including law firms. Or think of the courtroom, with all the built-in status cues that reinforce the authority of judges. When we want to reward someone, we heighten their status, elevate them so to speak. Status-seeking behavior often motivates professionals, and men especially, to a strong degree.

Professionals tend to over-value autonomy, another intrinsic SCARF motivator. Overlapping a bit with status, autonomy refers to the freedom to act as one chooses with no constraints. The greater the constraints, the more autonomy is diminished.

Relatedness, another intrinsic motivator, is sometimes at odds with status and autonomy. People like to feel connected to each other and this motivates us to be part of a firm or a profession.

Interestingly, significant gender differences are emerging from the research, indicating that women place a higher value on relatedness while men seek status more.

Finally, fairness seems to be an intrinsic motivator, which should come as a reassurance to those who practice law. Primates, and even many mammals, seem to have an innate sense of what is fair and what is not. This may well be the biological and evolutionary basis for the importance of the legal system in civilized societies.[7]

The SCARF model has significant ramifications for how people lead and manage others.

• Compensation systems are usually more about fairness and status than money. What matters most is how people are treated in relation to others of similar status.

• Relatedness is a primary motivator. Firms should be looking for ways to enhance it as it is among the best predictors of efficiency, profitability, and teamwork.[8] Men, and male-dominated organizations, tend to over-emphasize status and under-emphasize relatedness.

• When mentoring or managing others, attend to the SCARF factors. Good mentors naturally seek to enhance SCARF. Notice individual differences; some SCARF factors are more important to some than others (you will improve your skills by working on your emotional intelligence!).
• Reading your emails or scanning or inputting on your BlackBerry while interacting with others has an impact -- it is “de-statusing” and thus not a good relationship enhancer. And considering the limits of working memory and the myth of multi-tasking, it may just push your overflowing brain over the edge. Simply put, it's bad manners and bad neuroscience.

Although there is much more to say about the confluence of neuroscience and the practice of law, attending to the simple facts and suggestions above should give the average lawyer plenty to think about and much to improve.

Footnotes

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1 John J. Ratey, A User's Guide to the Brain: Perception, Attention, and the Four Theaters of the Brain (NY: Vintage 2002).

2 Harold E. Pashler, The Psychology of Attention (Cambridge, MA: MIT Press 1998).

3 David R. Caruso & Peter Salovey, The Emotionally Intelligent Manager (San Francisco: Jossey-Bass 2004).

4 See, e.g., the work of David R. Caruso and John Mayer.

5 Note that there are different approaches to emotional intelligence in the psychology literature. In this article we are focusing on the theories of John Mayer, Peter Salovey, and David Caruso. Others psychologists who have written extensively on this topic include Reuven Bar-on and Daniel Goleman, both with different theories.

6 David Rock, *SCARF: A Brain-Based Model for Collaborating With and Influencing Others*, NeuroLeadership J., Vol. 1 (2008) pp. 44-52.

7 Brain regions associated with primary rewards -- food, pleasant touch or pleasant memories, money, a picture of a loved one -- those same regions were active when people received fair offers, compared to unfair offers of equal level. (*cf.* Golnaz Tabibnia & Matthew D. Lieberman, *Fairness and Cooperation Are Rewarding: Evidence From Social Cognitive Neuroscience*, Annals of the N.Y. Acad. of Sci., 1118, 90-101 (2007)).

8 David Sirota, Louis A. Mischkind & Michael Irwin Meltzer, The Enthusiastic Employee (Philadelphia, PA: Wharton School Publishing 2005).