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Brain Imaging for Judges: An Introduction to Law and Neuroscience

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It has become increasingly common for brain images to be proffered as evidence in civil and criminal litigation.[1] This article offers some general guidelines to judges about how to understand brain-imaging studies—or at least avoid misunderstanding them. (An appendix annotating a published brain-imaging study, in order to illustrate and explain, with step-by-step commentary, is available in the full text online.[2])

Brain images are offered in legal proceedings for a variety of purposes, as Professors Carter Snead and Gary Marchant have usefully surveyed.[3] 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*,[4] 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.*,[5] 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*,[6] 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.*,[7] involving a dispute over the sale of land, the defendant introduced brain images to prove mental incompetency, resulting in a voidable contract.

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.[8] 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*,[9] a defendant accused of strangling his wife and throwing her from a 12th 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,*[10] 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.

Brain images have also been proffered at the sentencing phase of criminal cases, in furtherance of mitigation. For example, in *Oregon v. Kinkel*,[11] 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*,[12] 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*[13] and *People v. Morgan*[14] 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.

For better or worse, the full complement of cases at the

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Footnotes

1. 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 31. Professor Shen's article in this issue provides an updated compendium of useful resources. Francis X. Shen, *Keeping Up with Neurolaw: What to Know and Where to Look*. 50 CT. REV. 64 (2014).
2. The article annotated is: Joshua W. Buckholtz, Christopher L. Asplund, Paul E. Dux, David Zald, John C. Gore, Owen D. Jones & René Marois, *The Neural Correlates of Third-Party Punishment*, 60 NEURON 930 (2008).
3. 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://tinyurl.com/sneadlink. 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).
4. 404 F. Supp. 2d 1051 (N.D. Ill. 2005).
5. No. 227592, 2003 Mich. App. LEXIS 884 (Mich. Ct. App. Apr. 8 2003).
6. 410 F.3d 1173 (9th Cir. 2005).
7. No. 215512, 2000 Mich. App. LEXIS 2369 (Mich. Ct. App. May 5, 2000).
8. 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).
9. 591 N.Y.S.2d 715 (N.Y. Sup. Ct. 1992).
10. 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).
11. 56 P.3d 463 (Or. Ct. App. 2002).
12. 17 S.W.3d 193 (Tenn. 2000).
13. 918 So. 2d 163 (Fla. 2005).
14. 719 N.E.2d 681 (Ill. 1999).

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.[15] 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.

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.

Part I of the article provides some very brief background on modern brain imaging, with particular emphasis on one widespread 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 judges will need to master, for the specific contexts in which brain images are (potentially) legally relevant.[16]

Instead, we will aim here to focus on what a judge 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.

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 missteps 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.[17] 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 judges approaching this interdisciplinary nexus for the first time.

"We are concerned that brain imaging can be misused by lawyers. . . and misunderstood by judges and jurors."

The online appendix to this article then provides a concrete illustration of how to read an fMRI study. We will not overclaim. 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.

Specifically, the core of the online 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 judges 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.

15. One of the many efforts underway, 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.

16. *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).

17. 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).

> **"The physical principles underlying fMRI are quite complex."**

To facilitate that learning in this concrete application, the *Stanford Technology Law Review* 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

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.

PET, 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.)

EEG and *MEG,* short for electroencephalography and magnetoencephalography respectively, record electromagnetic fluctuations in various parts of the brain, as the brain is functioning, using non-invasive sensors applied to the scalp.[18] 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.[19]

fMRI (functional magnetic resonance imaging[20]) 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.

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.[21] Changes in demand for oxygen are widely considered to be reliable proxies for inferring the fluctuating activity of the underlying neural tissue.[22]

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,[23] 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 birdcage 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

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18. 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).
19. 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.
20. The leading "f" remains lowercase, by convention.
21. *See generally* HUETTEL ET AL., *supra* note 16.
22. 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 17; Poldrack et al., *supra* note 17.
23. 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.

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

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

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.

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.

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.

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?

"[A]dmissibility of brain images is not simply a matter of whether they are scientifically sound."

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.

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?)

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.[24]

B. THE BIOLOGICAL CONTEXT

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:[25]

24. 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.

25. 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).

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

- 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.[26]
- 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

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.[27]

- 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)

With that brief but foundational background, drawing attention to the legal and biological contexts, and to their interaction, we can now turn to discuss key concepts about brain imaging that judges should know:[28]

1. **Anatomical imaging and functional imaging are importantly different.**

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 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 100,000 voxels within the brain, and what typically matters is how neural activity within those voxels is varying over time, in relation to some task a subject undertakes 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.**

There is more to a thought than blood flow and oxygen.

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26. 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.
27. *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).
28. For more details, see sources cited *supra* note 16.

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.[29]

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

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.**

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.**

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 1,000 that the difference between brain activations in this voxel, between conditions, is due to random chance. Or, yellow might mean that there is one chance in 20 that the difference is due to random chance.[30]

"[W]e have some confidence about what a typical brain looks like, and how a typical brain functions."

6. **fMRI brain images do not speak for themselves.**

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.**

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.**

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 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

29. 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).

30. 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.

"[T]he issues for the legal system are simply the same as they long have been: What might the proffered evidence tell us . . . ?"

average, requiring less cognitive effort?

9. Correlation is (still) not causation.

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 70% 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.

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.

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.

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.

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

We have provided above a very brief introduction to the intersection of brain imaging and law principally intended for those judges relatively new to this interdisciplinary intersection. This article also provides some scientific context for the other articles in this special issue of *Court Review*.

As reflected in the numerous citations and descriptions of neuroscience matters in the other articles in the special issue, 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.

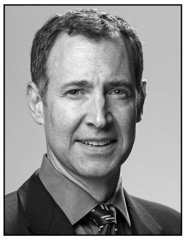
On one hand, the issues for the legal system are simply the same as they long have been: What might the proffered evidence tell us that may help us to answer legally identified questions in fair, effective, and efficient ways? Brain imaging is simply the latest high-tech tool to be offered for its potential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

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.

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,[31] such as those populating the MacArthur Foundation Research Network

31. *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*

on Law and Neuroscience,[32] the Gruter Institute for Law and Behavioral Research,[33] and the Society for Evolutionary Analysis in Law (SEAL).[34] And, fortunately, many efforts are underway. In the meantime, judges 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.



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34. Society for Evolutionary Analysis in Law, http://www.sealsite.org.