The John Marshall Law Review

Volume 48 | Issue 3 Article 1

Spring 2015

Overselling Images: fMRI and the Search for Truth, 48 J. Marshall L. Rev. 651 (2015)

Erica Beecher-Monas

Edgar Garcia-Rill

Follow this and additional works at: https://repository.jmls.edu/lawreview

Part of the Criminal Law Commons, and the Law and Psychology Commons

Recommended Citation
Erica Beecher-Monas & Edgar Garcia-Rill, Overselling Images: fMRI and the Search for Truth, 48 J. Marshall L. Rev. 651 (2015)

https://repository.jmls.edu/lawreview/vol48/iss3/1

This Article is brought to you for free and open access by The John Marshall Institutional Repository. It has been accepted for inclusion in The John Marshall Law Review by an authorized administrator of The John Marshall Institutional Repository.

OVERSELLING IMAGES: FMRI AND THE SEARCH FOR TRUTH

ERICA BEECHER-MONAS AND EDGAR GARCIA-RILL, PH.D.*

I. INTRODUCTION

What if we could be sure that every suspect claiming to be innocent was lying? What if we could tell that every witness was telling the truth? Companies like NoLie MRI purport to be able to do exactly that through functional Magnetic Resonance Imaging (fMRI). Proponents of fMRI lie detection believe that brain scans can definitively show us whether a person is lying, making "neurolaw" the *new* new thing in the world of scientific evidence.

The development of fMRI technology has prompted legal scholars and lawyers to advocate neuroscience as the latest legal frontier. This suggests that neuroscience will provide solutions to the age-old questions of detecting deception, assigning criminal responsibility, and rethinking punishment strategies. Relying on the pictures of brain function that fMRI produces, legal scholars began publishing thousands of articles and books about "Neurolaw." The MacArthur Foundation generously funded a "Law and Neuroscience Project."[1] Prestigious law schools are establishing law and neuroscience centers.[2] Conferences on neurolaw are ubiquitous.[3] After the publication of studies purporting to show different patterns of brain activity for truth-telling and lying, two firms leaped to advertise neuroscience-based lie detection services.[4]

While there are relatively few legal cases involving fMRI-based neuroscience,[5] and courts have appropriately excluded fMRI-based lie detection testimony in the few cases where it was proffered, the debates about how neuroscience should inform legal decisions still rage. These debates will continue until legal actors begin to understand the capabilities and limitations of the methodology at issue.

Unquestionably, brain science has progressed enormously in the past few decades.[6] A great deal of this progress stems from the

1. *See* Francis X. Shen, *The Law and Neuroscience Bibliography: Navigating the Emerging Field of Neurolaw,* 38 INT'L J. LEGAL INFO. 352, 357 (2010) (noting the explosion of law and neuroscience and the MacArthur Foundation's $10 million investment in the Law and Neuroscience Project).

2. For example, Vanderbilt has established the Center for Integrative and Cognitive Neuroscience, *see* cicn.vanderbilt.edu; Harvard has a Center for Law, Brain and Behavior, *see* cibb.mgh.harvard.edu; Stanford has its Program for Neuroscience and Society, *see* http://neuroscience.stanford.edu; the University of Pennsylvania has a Law & Neuroscience Winter School, *see* neuroethics.upenn.edu.

3. The MacArthur Foundation maintains a list of neuroscience and law conferences at www.lawneuro.org.

4. Cephos Corporation and NoLie MRI both marketed fMRI-based lie detection as early as 2006. *See* Shen, *supra* note 1 at 357.

5. The published cases, of course, may reflect only a subset of those cases in which fMRI and other brain imaging techniques have been proffered. In addition, neuroscience may be involved in pre-trial decisions and in decisions about prosecution and parole that are outside the reporters' purview. Nonetheless, the reported cases are remarkably few and far between.

6. The development of brain research was stimulated by the formation of the Society for Neuroscience in 1969 that now has over 37,000 members. The first academic neuroscience training program was established at the University of California, San Diego in 1965. The first undergraduate training program in neuroscience was established at Amherst in 1972. Today, there are more than 300 departments and programs around the world. *See, e.g.,* M. GLICKSTEIN, NEUROSCIENCE: A HISTORICAL INTRODUCTION (2014).

development of fMRI.[7] Clinicians now use brain scans to diagnose tumors, strokes, dementia and other functional abnormalities, and to map surgical pathways (e.g., to avoid language centers when removing a brain tumor). Certainly, the legal field should keep up with these developments. Resolving disputes in the real world requires knowledge of how that world works. But most of the massively increased legal attention to fMRI research is founded on a misconception about what the technology is capable of showing.[8] While this article acknowledges and applauds the amazing advances of neuroscience (one of us—Garcia-Rill—is, after all, a practicing neuroscientist), the authors would like to sound a note of caution.

Although fMRI is indeed an astounding technology, producing attractive colored pictures of oxygenated blood flow changes in the brain superimposed on a two- or three-dimensional map of the brain, interpreting these images is not as simple as it appears. These images are not photos of the brain in action; they are statistically built representations of blood flow changes *believed* to be associated with brain activity. What that activity *means* is far from understood.

In addition, while fMRI pictures appear to demonstrate the scanned individual's brain activity, that appearance is deceptive. Although these images are purported to demonstrate the brain activity of an individual, fMRI images are actually averages; they reflect the algebraic summation of multiple episodes of brain activity. Nearly all the fMRI deception studies[9] look at differences in responses of groups of individuals. To say anything about a particular individual in that group requires the use of statistical algorithms that are themselves highly controversial. Drawing inferences about an individual from an fMRI image is fraught with difficulties that have not yet been overcome.[10]

Interpreting the fMRI images requires an understanding of the methodology and the technology, including the computer programming that is used to produce them, and the assumptions that go into the algorithms used to interpret them. Although the visually arresting fMRI images may appear highly useful to defense

7. Magnetic resonance imaging (MRI) is used in radiology to investigate the anatomy of the body, using magnetic fields and radio waves to compute these images. Functional MRI (fMRI) measures changes in blood oxygenation levels rather than static anatomical images.

8. As will be discussed below, fMRI does not directly measure brain activity, but the responses in blood oxygenation levels, which may or may not reflect increases or decreases in brain activity.

9. By "fMRI deception studies" we mean a number of investigations into the brain responses generated by subjects telling the truth versus being deceptive.

10. *See* Francis X. Shen & Owen D. Jones, *Brain Scans as Evidence: Truths, Proofs, Lies and Lessons*, 62 MERCER L. REV. 861, 866 (2011) (discussing the absence of data on the question of whether fMRI can detect lies at the individual subject level).

lawyers who wish to demonstrate their clients' truthfulness, brain defect, or lack of intent (or to government actors intent on detecting deception), it is not so straightforward. The links between brain activation, blood flow, and behavior are far too tenuous to draw inferences about individual behavior.

The basis for fMRI lie-detection is a series of studies concluding that people asked to lie in the scanner have a different pattern of brain activity than when they are telling the truth.[11] There are numerous problems with these conclusions, as Part II will demonstrate. Thus, fMRI-based lie detection is not reliable enough to be used in court. As Part II explains in describing how fMRI works, presumed activity in activated brain areas does not necessarily mean that the subject is lying; the activity could be attributable to many other factors.

In addition, the repetition and averaging required by the fMRI process means that it is not possible to pinpoint the response to any particular question. Further, because of significant anatomical variation, individual scans cannot be compared; the most studies can say is that a group of individuals differs from another group in their averaged response. Moreover, different laboratories use slightly different methods for acquiring, refining, and analyzing an image. They each practice the "art" slightly differently, making use of these images in legal proceedings problematic. Part III assesses the claims made for neuroscience-based lie detection in the cases in which it has been proffered. This section analyzes the courts' responses to the proffered evidence and suggests that, although the courts rejected the testimony, they did so in a way that leaves the courts open to future mistakes. Part IV addresses the use of neuroimaging for legal purposes other than lie detection, such as in mitigation, to demonstrate lack of intent in criminal cases, or its use in civil litigation. Part V addresses the future of neuroscience techniques other than fMRI that might more accurately pinpoint brain activity. Part VI concludes that the current capability of brain imaging to inform our understanding of human thought and behavior has been wildly over-sold.

11. *See* Paul S. Applebaum, *The New Lie Detectors: Neuroscience, Deception, and the Courts,* 58 PSYCH. SERV. 460, 461 (2007) (discussing fMRI studies).

II. HOW LIE DETECTORS WORK

A. Polygraph Lie Detectors

The polygraph lie detector was based on four measures: a) the galvanic skin response that basically measured changes in the conductivity of the skin in response to changes in peripheral blood flow; b) pulse or heart rate variation; c) blood pressure changes; and d) respiratory changes. All of these presumably were altered by the "stress" of lying. The procedure required an initial interview to gain preliminary evidence to be used to determine veracity. The tester then informed the subject on how the method works to "detect lying," followed by an instruction for the subject to lie deliberately, and then the actual test of irrelevant control and "diagnostic" questions.

Every aspect of this process has been questioned for considerable variability and lack of reliability.[12] In addition to the fact that the entire process has glaring opportunities for interrogator bias and capriciousness as well as variable subject responsiveness, the measures are all indirect indications of brain function. For example, the interrogator assumes that the changes in heart rate, respiration, and galvanic skin response are direct measures of a complex brain process. These readouts, however, are remote consequences of what the person was thinking, feeling, remembering, and worrying about at the time. They may not bear a direct causal relationship to telling a lie. These measures do not assess brain activity directly or, for that matter, on a moment-to-moment basis—they only reflect peripheral autonomic responses. Although proponents claim accuracies of lie detection of 90%, the United States National Research Council discredited the polygraph lie detector for absence of reliability, application to only limited populations, and potential for false positives.[13]

Enter the fMRI method now being heralded as a more scientific, brain-based lie detector. A host of fMRI studies, much like the polygraph, boast up to 90% accuracy in lie detection.[14] However,

---

12. UNITED STATES NATIONAL RESEARCH COUNCIL, THE POLYGRAPH AND LIE DETECTION 212 (2003).

13. *See id.,* Chapter 8.

14. *See* Nobuhito Abe et al., *Neural Correlates of True Memory, False Memory and Deception,* CEREBRAL CORTEX 2811–19 (2008); S. Bhatt et al., *Lying About Facial Recognition: An fMRI Study,* 69 BRAIN & COGNITION 382–390 (2008); Davatzikos et al., 2005; Matthias Gamer et al., *Covariations Among fMRI, Skin Conductance, and Behavioral Data during Processing of Concealed Information,* 28 HUMAN BRAIN MAPPING 1287–1301 (2007); G. Ganis et al., *Neural Correlates of Different Types of Deception: An fMRI Investigation,* 13 CEREBRAL CORTEX 830–36 (2003); G Ganis, et al., *Lying in the Scanner: Covert Countermeasures Disrupt Deception Detection by Functional Magnetic Resonance Imaging,* 55 NEUROIMAGE 312–19 (2011); F. Andrew Kozel et al., *A Pilot Study of Functional Magnetic Resonance Imaging Brain Correlates of*

these assertions arise exclusively from studies on laboratory subjects under controlled conditions. These highly controlled studies generally prompted the investigators to conclude that there were differences in brain activation in the "lie" condition compared to the "truth" condition. A number of these studies have addressed various issues such as directing subjects to lie, using situational, object, playing card, or facial recognition protocols, and differing experimental variations, including mock thefts.

In general, these studies find increased signal in the "lie" condition in certain regions of the cortex, usually prefrontal and cingulate cortex[15], but a number of other regions have also been implicated. The technology produces colored patterns of activity over the brain surface when the subject is lying that are different from the activity patterns when the subject is telling the truth. The complexity of the method, coupled with "activity" presumably being generated by the brain and the pretty pseudocolor pictures (the colors are from a selected spectrum and the intensity of the color is displayed in relation to an arbitrary scale) tend to lull the uninformed into believing that the claims made are "scientific."

But these claims can only be evaluated by understanding what data the fMRI records, how the pretty pictures are generated, and what allows the conclusion that a subject is lying versus telling the truth. To evaluate the claims for fMRI lie detection, the technology

---

Deception in Healthy Young Men, 16 J. NEUROPSYCHIATRY CLIN. NEUROSCI. 295–305 (2004); F. Andrew Kozel, et al., *A Replication Study of the Neural Correlates of Deception,* 118 BEHAVIORAL NEUROSCIENCE 852–56 (2005); Daniel D. Langleben et al., *Brain Activity During Simulated Deception: An Event-Related Functional Magnetic Resonance Study,* 15 NEUROIMAGE 727–32 (2002); Daniel D. Langleben, et al., *Telling Truth from Lie in Individual Subjects with Fast Event-Related fMRI*, 26 HUMAN BRAIN MAPPING 262–72 (2005); Tatia M. Lee et al., *Are Errors Differentiablefrom Deceptive Responses When Feigning Memory Impairment? An fMRI Study,* 69 BRAIN & COGNITION 406–12 (2009); Feroze B. Mohamed et al., *Brain Mapping of Deception and Truth Telling about an Ecologically Valid situation: Functional MR Imaging and Ponygraph Investigation—Initial Experience,* 238 RADIOLOGY 679–88 (2006); George T. Monteleone, et al., *Detection of Deception Using fMRI: Better than Chance, But Well Below Perfection* 4 SOC. NEUROSCI. 528 (2009); Izuru Nose et al., *Disclosing Concealed Information on the Basis of Cortical Activations,* 44 NEUROIMAGE 380–86 (2009); Jennifer M. Nunez et al., *Intentional False Responding Shares Neural Substrates with Response Conflict and Cognitive Control,* 25 NEUROIMAGE 267–77 (2005); Sean A. Spence et al., *Behavioral and functional Anatomical Correlates of Deception in Humans,* 12 NEUROREPORT 2849–53 (2001); Sean A. Spence et al., *Speaking of Secrets and Lies: The Contribution of Ventrolateral Prefrontal Cortex to Vocal Deception,* 40 NEUROIMAGE 1411–18 (2008).

15. The prefrontal cortex is located at the front of the brain behind the forehead. It is thought to participate in planning behavior, decision-making, and what are known as "executive functions." The cingulate cortex is located on the medial part of the hemisphere wrapping around the corpus callosum, the main fiber pathway linking the two hemispheres. It is part of the limbic system, which participates in emotional responses, learning, and memory.

involved needs to be understood, the methodology behind the generation of images must be clarified, and the process behind the acquisition of the images revealed. These issues require detailed explanation before fMRI lie detection ever can be considered for judicial proceedings.

B. What Does the fMRI Measure?

MRI is a useful way to visualize regions of the cortex in detail, particularly in pathological conditions. The MRI has advantages over other clinical diagnostic measures in that it does not use radiation, as do X-rays, Computed Tomography (CT), or Positron Emission Tomography (PET) scans. Therefore, the MRI presents virtually no risk to the patient. The fMRI can evaluate blood flow in the cortex safely, noninvasively, and effectively. The MRI is an excellent diagnostic tool that, given enough time to acquire the image, provides a useful image of the pathological condition, whether it is a tumor, stroke, or other damage.[16]

Despite its many benefits, the MRI has limitations. For example, it cannot assess internal or deep brain structures such as the striatum, thalamus, and brainstem.[17] It only can provide images of the cortex overlying the rest of the brain. Also, the MRI can secure an image only if the subject being scanned lies completely still, as any movement can introduce alterations in the image and decrease resolution. For example, under clinical use, movements such as excessive blinking, jaw and mouth movements, or mild tremor will degrade the quality of the image. Clinicians resolve these problems by prolonging the scanning time through repeated sampling and by omitting images with movement artifact from the final average. This requirement is not a major impediment in imaging a patient with a potentially fatal condition since they are likely to be cooperative, but may become prohibitive in uncooperative subjects. Knowledge of this factor could easily be used to defeat any criminal or judicial application.

The MRI also requires that the subject not be claustrophobic since the cylinder is confining and the process is quite loud. This introduces a potential variable among individuals who might suffer

16. The MRI allows anatomical verification of structural changes due to disease, especially tumors and stroke, while the fMRI can assess the blood flow to a particular anatomical region, providing a more "functional" measure.

17. The striatum is located immediately beneath the cortex and is a major component of the basal ganglia, a group of centers in charge of motor planning, sensory filtering, and executive functions. The thalamus is located deep to the striatum and relays sensory and motor signals from the ascending pathways to the cortex, and from the cortex to descending pathways. The brainstem regulates sleep, maintains consciousness, and regulates cardiac and respiratory functions.

from degrees of this condition. Thus, varying feelings of distress might be misinterpreted. The fact that some subjects are initially anxious may prevent scans from being compared across individuals since they have different baseline conditions. The polygraph lie detector is similar limitations since only some individuals showed clear autonomic responses when lying (or when fearful that they would be labeled a liar), while others simply beat the lie detector by being calm and practicing their deceit.

The most significant limitation, however, is that the MRI does not assess neuronal activity[18] directly; it measures blood flow as a consequence of *presumed* neuronal activity. The fMRI is based on the concept that blood that is carrying oxygen behaves differently from blood that has already released its oxygen into the tissues.[19] Higher-oxygenated blood emits a different signal than lower-oxygenated blood. Simply put, the machine aims radio waves at protons, which are electrically charged particles in the nuclei of hydrogen atoms. When the radio waves hit the protons, the protons align, and then the machine emits a burst of radio waves that knocks the protons out of alignment. When the protons fall back in line, or "relax," they emit a signal that the scanner can then detect. The protons in higher-oxygenated hemoglobin in the blood emit stronger signals than those from less-oxygenated blood. The difference in the signal between oxygenated (HbO_2) and deoxygenated (Hb) hemoglobin is only about 3%. This very small difference in signal is what is being calculated to provide an image.

In order to detect such a small signal, the process requires repetition and averaging. That means that one cannot ask a question at one specific point in time in order to assess the veracity of the response.[20] The best procedure is to ask a series of questions over a period of time, perhaps as long as 20–40 minutes, that could, in theory, be interpreted as being deceptive or not. This is a huge problem for the use of fMRI in lie detection, where the issue is invariably whether the answer to a particular question at a particular moment was truthful.

The fMRI measures this difference in blood oxygenation (which presumably reflects brain activity) through computer calculations mapped on a three-dimensional image of the brain while color-coded intensities of the signals emitted are displayed across the brain

18. That is, it does not measure the firing of neurons or the synaptic inputs by transmitters onto other neurons, rather it measures the changes in blood flow that result from such activity, probably for restoring energy stores following neuronal activity.

19. *See* Peter A. Bandettini, *Functional MRI Limitations and Aspirations,* 15, 16 NEURAL CORRELATES OF THINKING (E. Kraft, et al., eds. 2009) (explaining the mechanism of fMRI).

20. *See, e.g.,* United States v. Semrau, 693 F.3d 510 (6th Cir. 2012) (where the expert could not say which questions the defendant had answered truthfully, but only that the defendant had been generally truthful in answering the questions).

surface. The computation *assumes* that blood in vessels and capillaries flows in one direction, but this may not be true. Blood can flow in both directions in small capillaries.

The more "active" in terms of neuronal activity the brain regions are, the more blood flows. This leads to brighter intensity of the colors in these regions.

This technology is excellent for mapping the extent of strokes or tumors in an individual subject when there are no time constraints. It can accurately map a given structure given repeated scanning. The fMRI technician generates an image based on a series of calculations each of which has decision points to "optimize" the image. That is, the fMRI technician makes decisions that can impact what the final image looks like. Such decisions can impact the use of these images in legal proceedings. One question is, does the fMRI technician become a "witness"? Throughout the imaging process there are opportunities for subjective judgments that may alter the image, making the generation of these colorful images as much art as they are science.

C. The Method

1. Scanning Time

Although scanning time is not an issue for clinical applications, outside of the clinical setting, the issue of temporal resolution is quite daunting. Typically, whole brain images are acquired with a repetition time of 2 seconds, and a time series is generated so that a single image represents activity over 5–8 minutes. A typical experiment involves several (5–10) of these time series per session, requiring as many as 12 sessions, or about 45–60 minutes for a single scan. The prolonged period required to detect a difference between conditions means that any process measured is one influenced by brain activity over many minutes. This makes it unfeasible to assess the veracity of the response to a single question.

Using this technology, the most that can be said is that over the course of the session, the person in the scanner was being "deceptive" or not. However, since so many thoughts, memories, ideas, and random events generate activity in the brain, one cannot definitively conclude that is was deception versus anxiety versus other processes that were evoked during the session. The time course used for clinical purposes is intended to generate images that are as clear as possible; for this, the clinician needs repetition, multiple series of scans, and multiple sessions. The time course required as lie detection represents two serious technological problems: first, imprecision in pinpointing when the response is occurring; and second, each repetition generates a lower signal.

To explain: studies by Kozel and others found that within-subject analysis of "Lie" versus "True" generated large variations in areas of significant flow across the group.[21] The variability was attributed to the low number of epochs (an epoch is a series of repetitions) (n=8) used to derive averages of the condition Lie versus True. This suggests that more epochs need to be averaged to decrease noise. Multiple repetitions in the order of minutes may be required to achieve reliable images of True versus Lie conditions. This begs the question: at what point in time during all those repetitions is the "lie" occurring? For example, if someone is thinking about walking on the beach while being questioned, will that affect the result? Further, as we will see in the next section, the blood flow signal decreases with repetition or practice, so that simply repeating the same question will not produce a clearer signal.

2. Image Subtraction

When doing fMRI research to detect cognitive activity, the "control" image generated in a baseline condition is compared—usually *subtracted* from—a second scan generated during the "test" condition. That is, a "control" image generated over tens of minutes is algebraically subtracted from one generated over the same period of time in the "test" condition. The fundamental concept in functional neuroimaging is the statistical comparison of what is expected to happen to the hemodynamic (blood flow) response in relation to a defined function.[22]

Applying such a protocol to the judicial process introduces a number of interpretative problems. What does it mean when the image is generated over such an extended period of time? At what point in time is the "difference" between the "truth" and the "lie" condition detected? For example, if a suspect or defendant is scanned for 8 minutes and asked a series of questions during that time, to some of which the answers are lies, is the final image really a representation of the lie or is it contaminated by tens or even hundreds of thoughts, sensations, and virtual motions over the prolonged scanning time? What happens if the defendant is thinking about his foundering love affair, his vacation, or something else?

What is the relationship between what amounts to an "averaged" blood flow signal and a second "averaged" blood flow signal at some later time? Most neuroimaging studies do not provide a formal analysis that ensures that the particular cognitive process;

21. *See* F. Andrew Kozel, et al., *A Pilot Study of Functional Magnetic Resonance Imaging Brain Correlates of Deception in Healthy Young Men,* 16 J. NEUROPSYCHIATRY CLIN. NEUROSCI. 295–305 (2004).

22. *See* Bandettini, *supra* note 19, at 18 (noting that the "fundamental concept in all of functional imaging creation is the statistical comparison of what is expected to happen in the hemodynamic response, as defined by a 'reference' function or a 'regressor,' with the data, on a voxelwise basis").

e.g., Lie versus True, is being isolated by the subtraction.[23] At best, it could be said that at some point in time the blood flow *changed*. But it is not at all clear that the change was *caused* by telling the truth versus lying. Extraneous thoughts or mood changes could cause such changes.

Because brain speeds are quite rapid, the ideal process would be to ask a question and obtain a response within a second or so. The perception of a simple visual, auditory, or cutaneous input has a latency of about 200 milliseconds.[24] The reaction time to a simple auditory or visual stimulus is in the order of 150 to 300 milliseconds. However, reaction time to complex verbal stimuli requires more processing and can occur 1–2 seconds after the command. One question that arises is when does the brain signal change after a question is posed. If there is a significant latency to the change in activity, is the activity being measured a consequence of the posing of the question or of the response to the question? None of these questions can be definitively answered.

3. Latency

Such problems might be partly resolved by fast scanning of only a single brief event, without "averaging" over multiple scans, series of scans, and sessions. Recent advances are using scanning times of hundreds of milliseconds, with higher magnetic field strengths that increase resolution.[25] It is then important to determine what is being scanned during these brief exposures, how much resolution is lost by the faster scanning, and whether a single brief scan still requires repetitive image acquisition. At present, it is not clear if these brief exposures represent the same or different kind of blood flow calculated from repetitive exposures. We should remember that current methods average many repetitions. Thus, any one trial may not contain a response at all, or may even be opposite in polarity—that is, a decrease instead of an increase in signal. Averaging accumulates many trials, and it is the algebraic

23. *See* Nikos K. Logothetis, *What We Can Do and What We Cannot Do with fMRI,* 453 NATURE 869–78 (2008).

24. K. Sekar, et al., *Cortical response tracking the conscious experience of threshold duration visual stimuli indicates visual perception is all or none,* 110 PROC. NAT. ACAD. SCI. 5642–47 (2013).

25. P. S. Bellgowan et al., *Improved BOLD Detection in the Medial Temporal Region Using Parallel Imaging and Voxel Reduction* 29 NEUROIMAGE 1244–51 (2006); J.Z. De Zwart et al., *Signal to Noise Ratio and Parallel Imaging Performance of a 16-channel Receive-only Brain Coil Array at 3.0 Tesla,* 51 MAGN. RESON. MED. 22–26 (2004); S. Moeller et al., *Application of Parallel Imaging to fMRI at 7 Tesla Utilizing a High ID Reduction Factor,* 56 MAG. RESON. MED. 118–29 (2006); C. Preibisch et al., *Comparison of Parallel Acquisition Techniques Generalizing Autocalibrating Partially Parallel Acquisition (GRAPPA) and Modified Sensitivity Encoding (mSENSE) in Functional MRI at 3 T.,* 27 J. MAG. RESON. IMAGING 590–98 (2008).

summation of these trials that produces the final image. Individual images may not show responses at all, but presumably enough trials produce an increase that adds up to a signal in the final average.

Another issue with repetitive scanning is that the peak of the blood flow signal occurs seconds after the brain activity.[26] After a single event—say, exposure to a short stimulus such as an auditory "click"—the fMRI signal begins to change a full 2 seconds after the event. There is a "pre-undershoot" before the peak of the blood flow signal (this means that during the 2 seconds before the peak, there is a decrease in the signal), and a "post-undershoot" (another decrease in the signal) that can last as long as 1 minute after the peak. These dynamics—i.e., decrease followed by a peak followed by another decrease—are not fully understood.[27]

Importantly, the blood flow changes occur for varying periods after the stimulus, but the peak response is approximately several seconds after the presumed brain activity has taken place. This delay means that the change being measured is only an indirect measure of brain activity that occurred earlier. That is, these changes are a measure of "post-deception" activity, not coincident with the telling of a lie. A defense attorney could argue that these changes occurred because the client was simply nervous about being erroneously accused of lying.

Owing to the variations in the blood vessels in the region, it may take up to four seconds for the hemodynamic response to occur.[28] The type of vasculature sampled also affects the dynamics, location, and magnitude of the signal, with large vessels manifesting a higher amplitude signal than smaller vessels. Large vessels therefore show more activity, or blood flow, than small ones. The significant inter-individual differences represent a significant impediment when comparing signals between individuals because the size of blood vessels varies significantly across individual brains.[29] Because the architecture of blood vessels across individuals is so variable, scans cannot be compared between individuals. That is, most studies can only say that a group of individuals differed from another group in the averaged signal. Therefore, the conclusion that fMRI can be used to detect lie from truth applies only to group comparisons under very controlled conditions, not to particular individuals. This is one of the most serious shortcomings of using fMRI in legal proceedings: the

26. *See* Bandettini, *supra* note 19, at 23 (discussing temporal resolution of fMRI).

27. R.B. Buxton & L. R. Frank, *A Model for the Coupling of Cerebral Blood Flow and Oxygen Metabolism During Neural Stimulation,* 17 J. CEREB. BLOOD FLOW 64–72 (1997); R. B. Buxton et al, *Modeling the Hemodynamic Response to Brain Activation*, 23 NEUROIMAGE S220–S233 (2004).

28. Peter A. Bandettini, *The Temporal Resolution of Functional MRI,* FUNCTIONAL MRI 205–220 (1999).

29. *See* Bandettini, *supra* note 19, at 23.

inability to provide a region or signal change that can represent "lying" across individuals.

If a person is telling a lie, assuming that there is differential brain activity, how long is the differential brain activity, if any, present? Can an individual tell a lie and its effects wane in less than two seconds? Do the consequences of telling a lie leave a trail of brain activity that lasts more than two seconds? This limits the ability of the fMRI to detect a lie immediately after a single question, which in turn limits its usefulness in legal proceedings.

4. Resolution

Another unresolved issue for fMRI lie detection is spatial resolution. Original scans sampled a region of 4x4x4 millimeters, but better software and methodology have increased the resolution of scans to the 1–3 millimeter range. Spatial resolution is measured in voxels, a combination of "volume" and "pixel" that represents a value on a regular grid in three-dimensional space. The smallest voxel that can be measured is a function of the strength of the MRI magnet. Higher resolution and higher sensitivity are achieved by higher magnetic strengths. The magnetic field strength of a typical scanner is measured in "tesla." Most clinical scanners use 1.5 tesla magnets and have a resolution ~ 2 millimeters. Magnets of 3 tesla and 7 tesla improve spatial resolution to 1.5 millimeters and 0.5 millimeters for a voxel, respectively. But higher resolution and sensitivity do not solve the problems of lie detection fMRI.

For one thing, blood flow varies within brain regions, so that spatial changes may differ across regions.[30] Such variability may defeat the purpose of identifying "regions" that are particularly active in one condition versus another condition (e.g., truth versus lie) in some individuals compared to others. It is not known if there are specific regions involved in truth versus lie, or even if the same or different circuits are involved. There is no such thing as the "truth" region or the "lie" region of the cortex. The brain does not work that way, as discussed below.

Another problem is that most fMRI studies involve "spatial smoothing", "spatial normalization," and "multisubject averaging." This effectively reduces the spatial resolution and eliminates the advantages of scanning at high resolution or using higher field magnets.[31] While this may be optimal for producing a clear image, these manipulations require increased repetition.

Moreover, at each point in the analysis, the technician generating the image must decide which thresholds to set and which options to exercise in order to "clarify" the image. This

30. *See* Bandettini *supra* note 19, at 30 (observing that "hemodynamics vary from voxel to voxel").

31. *See id.* at 24–27 (discussing spatial resolution).

"tweaking" introduces personal preference on the part of the technician. This "tweaking" may be why two laboratories performing the same experiment conclude that different brain regions are involved in the same process. That is, they are each practicing the "art" differently. Imagine three painters provided with the same photograph being asked to independently generate an oil painting of the person in the photograph. The individual painters will produce vastly different renditions of the same person. The use of this technology thus presents a problem for use in the judicial process, which requires more standardization.

5. *Brain Activity*

The way brain signals are generated presents a further interpretive issue. The brain works by receiving external inputs that are integrated with ongoing self-generated activity. It has constant background activity and also continuous afferent input from the senses. Visual, auditory, and cutaneous inputs are intermixed with internal signals from joint receptors, muscle receptors, and tendon receptors that signal the position and tone of our muscles. This ongoing brain activity is superimposed on intrinsic membrane oscillations.

Brain cells have ion channels that dictate their behavior, and these generate intrinsic oscillations. The integration of internal intrinsic oscillations with external or sensory driven activity triggers recurring oscillations between regions such as the cortex and thalamus, the cortex and hippocampus, the cortex and cerebellum, the cortex and basal ganglia.

Which regions are called into play depends on the process at work, such as the formulation of a movement or the storing of a memory. All of the sensory input to the brain arises from inputs to the spinal cord and brainstem (except olfactory input, which travels directly to the olfactory cortex). The sensory inputs (other than olfactory) undergo some processing in sensory relay nuclei of the brainstem before being relayed to specific parts of the thalamus. The thalamus is therefore the first major switchboard guiding sensory inputs and integrating them with internal membrane oscillations.

The thalamus is a collection of cell groups that project to separate regions of cortex. The thalamic input from the brainstem travels to a specific region of the cortex and induces activity. That primary input undergoes further processing by being relayed to other regions of the cortex and back to the thalamus. For every fiber arriving from the thalamus, the cortex sends ten fibers back to the thalamus. The cortex therefore acts like an amplifier. The returning wave of activity is processed by the thalamus and "bounced" back to the cortex. This reverberation may occur for hundreds of milliseconds before perception occurs.

Even a simple "click" stimulus produces an astounding amount of activity for hundreds of milliseconds before the stimulus is perceived. Responses can be measured by electrodes placed on the scalp that pick up the underlying activity from thousands of neurons. This technique is known as an "evoked response" that is recorded and averaged following the repeated delivery of a stimulus. For example, a simple auditory "click" stimulus first produces cortical activity in the auditory pathway that is detected by averaging as a peak over the auditory cortex at a 25-millisecond latency. This is known as the "Pa" evoked response.

There is another wave front of activity that arrives at 50 milliseconds also as a positive peak (known as the "P50" potential), and reverberations that produce a negative peak at 100 milliseconds (the "N1" response), followed by positive activity at 200 milliseconds (the "P2" or "P200" potential). These various peaks and troughs represent the sequential "bouncing" of the sensory between the cortex and the thalamus until it is perceived at about 200 milliseconds. This reverberation is akin to striking a bell and setting off ringing across the cortex and thalamus. The reverberations do not just occur between the same location in the thalamus and the same region of cortex. For example, the "Pa" response peaks over the superior temporal cortex on the side of the head just above the ear, but the "P50" response activates the same region in addition to an area at the top of the head called the vertex. The "N1" and "P2" potentials also show peaks in more than one location. This suggests that the ringing is occurring between the thalamus and cortex but not necessarily in the same spot; rather, the reverberations engage multiple cortical and thalamic regions as processing proceeds.

The fundamental question of whether there is any relationship between such brain activity and the fMRI signal remains contested. We simply do not know whether the signal the fMRI measures is due to the question asked (the input), the response to the question (output), or to the process of thinking about the question and/or the answer. We know very little about what brain activity occurs during fMRI scanning.

Regardless of the spatial resolution achieved, the simultaneous use of fMRI and direct electrophysiological recording, such as those described above, in nonhuman primate brains during single stimulus visual stimulation suggests that the signal is more correlated with synaptic activity (local field potentials) than with spiking (action potential) activity.[32] Therefore, the signal generated relates more to the input to the region in the form of synaptic potentials arriving at the dendrites of cells (the "sensory" or "input" elements of neurons) than to the output of cells reflected by action

---

32. Nikos K. Logothetis et al., *Neurophysiological Investigation of the Basis of the fMRI Signal,* 412 NATURE 150–57 (2001).

potentials generated by the initial segment of the cell axon (the "motor" or "output" element of the cell).[33]

That presents the question of whether the differences detected in the True versus Lie condition in fMRI tests represent the "detection" of the lie by the region or the "computation" of the lie by the region. Because the signal is more related to the input, the fMRI signal would appear to be more related to detection than to response. In other words, the brain activity taking place that best correlates with the fMRI signal appears to be due to hearing and assessing the question being asked—e.g., "Did you kill Fred?"—rather than to the answer being formulated.

Simultaneous electrophysiological recordings in animal models reveal a correlation between negative fMRI signal changes and decreased neuronal activity.[34] Some studies showed that a decrease in the fMRI signal correlated with a decrease in actual brain activity. This would bode well for the use of the method if an increase in brain activity always went along with an increase in fMRI signal, and a decrease in brain activity always went along with a decrease in fMRI signal. However, simultaneous electrophysiological recordings, whether the activity of single cells or responses of groups of cells-population responses, in animal models also provided evidence that inhibitory input could cause an increase in cerebral blood flow.[35] Thus a region with increased fMRI signal may actually indicate decreased brain activity.

As far as human subjects are concerned, we do not know under what circumstances an increase in fMRI signal indicates an increase or a decrease in brain activity. For example, an increase in the excitation of neurons may lead to an increase in metabolism that would then be reflected as an increase in blood flow, but an increase in inhibition can also be metabolically demanding, and also signal an increase in blood flow. Therefore, a technician could interpret an increase in fMRI signal as an increase in brain activity when in fact it is the result of a decrease in brain activity. A person relaxing from telling the truth—which may lead to a decrease in activity that is

33. Electrophysiological recordings are methods for detecting the activity of neurons in the brain. Very small electrodes (microelectrodes) can detect the activity of a single nerve cell firing an action potential or "spike". Slightly larger electrodes can detect signals in a group of neurons and this is called a "field" recording. Even larger electrodes such as those placed on the scalp can record the algebraic summation of activity of hundreds of thousand s of neurons beneath the scalp such as is done with the electroencephalogram (EEG).

34. A. Shmuel et al., *Sustained Negative BOLD, Blood Flow and Oxygen Consumption Response and its Coupling to the Positive Response in the Human Brain,* 36 NEURON 1195–1210 (2002).

35. C. Matheiesen et al., *Modification of Activity-Dependent Increases of Cerebral Blood Flow by Excitatory Synaptic Activity and Spikes in Rat Cerebellar Cortex,* 512 J. PHYSIOL. 555–66 (1998). This finding suggests that the changes in blood flow detected with the fMRI can be due to increases OR decreases in activity.

reflected in an increase in fMRI signal—could be erroneously labeled as lying.

A further complication is that fMRI signals reflect the pooled activity of a very large number of neurons, and differences in fMRI signals could be caused by either large changes in the firing rates in a small subpopulation of neurons or small changes in the firing rates in a much larger subpopulation of neurons.[36] Clearly, if excitatory (increase activity) and inhibitory (decrease activity) neurons are highly intermixed in the cortex, then different groups of neurons may be activated by different tasks within a single voxel. But if the same number is activated by different tasks, no difference in activation will be detectable.

In some studies, there was considerable discordance between the spatial extent of the fMRI signal and the recorded neurophysiological signals.[37] That is, the brain activity that was correlated with a peak in blood flow occurred at a location *away from* the peak in blood flow. This may mean that the blood flow change and the brain activity occurred independently, and that their correlation was only in time not space. This casts further doubt on what fMRI is measuring, especially since the blood flow signal is only correlated to brain activity and may not be causally related.

Given this complexity, imagine what happens in the brain when a person is asked, "Did you kill Fred?" To deliver the question takes about half a second, or 500 milliseconds. By the time the entire question is delivered, perception of at least the first three words has been completed. Perceiving, however, is not the same as understanding. Understanding requires language processing by another cortical region, the language area over the temporal lobe. The question itself will not be fully understood until after another half a second or so.

A rapid response—say, "No"—probably takes another 300 milliseconds, since the motor system for speech must be engaged, which takes time.[38] Therefore, the whole process from asking a simple question to responding with a single syllable, at a minimum, may take 2 seconds. The fMRI signal indicating a change in blood flow usually occurs about 4 seconds after the response is delivered, or double the latency. This difference in time, or 2 full seconds, is an eternity in brain processing time. Moreover, it is not clear what leads to the generation of the change in blood flow, since input and output processing has already been accomplished in half the time. What happens during the intervening time period is not known. The

36. Jack W. Scannell & Malcolm W. Young, *Neuronal Population Activity and Functional Imaging,* 266 PROC. R. SOC. LOND. B. 875–81 (1999).

37. Elizabeth A. Disbrow et al, *Functional fMRI at 1.5 Tesla: A Comparison of the Blood Oxygenation level-dependent signal and Electrophysiology,* 97 PNAS 9718 *(*2000).

38. The motor region for the mouth is located on the lateral frontal lobe, it is called "Broca's area."

fMRI change measured and attributed to the subject's "No" could be due to any number of other factors, none of which is well understood.

6. Location

A fundamental goal of fMRI lie detection is to be able to infer precisely where, when, and how much neuronal activity is taking place in the brain on the basis of the measured signal.[39] Because the signal changes depend on variables other than neuronal activity, including hemodynamic coupling and volume in each voxel, this goal is still elusive. The hemodynamics vary from voxel to voxel, so even if a scan demonstrates that within a region there is a relationship between neuronal activity and signal, we cannot say what precisely the neuronal activity is in any particular voxel. To do this, we must calibrate each voxel in relation to brain activity across individual voxels. This, however, has never been done.

The kind of brain activity that ought to be measured is still an open question. Is it local field potentials (the algebraic summation of large ensembles of neurons) or action potentials (the firing of a single neuron)? Is the region being measured acting independently or is it part of a circuit? Is the activity in the measured region the end result of activity in a circuit involving multiple regions? Does that circuit always behave the same or does it change with fatigue, stress, daydreaming, or thinking of something pleasant versus unpleasant? The answers to these questions are not known and may invalidate the process.

---

39. Haynes argues that this is not the goal of fMRI lie detection; that, instead, the goal is to detect overall increased activity in the brain, using a "computer-based classification algorithm." John-Dylan Haynes, *Detecting Deception from Neuroimaging Signals—a Data-driven Perspective*, 12 TRENDS IN NEUROSCIENCE 126–27 (2008). This argument is statistically flawed, however, because if you record enough data points you can achieve statistical significance even with miniscule effect. *See* Erica Beecher-Monas, *Lost in Translation: Statistical Inference in Court*, 46 A.S.U. L. REV. (forthcoming 2015) (explaining that more data for a given effect size results in a smaller p-value—or greater level of statistical significance). For example, "if we test all 50,000 voxels [typical of an fMRI] separately, then by chance alone, 2500 would be expected to cross the threshold of significance at the $p \leq 0.05$ level…This is known as the problem of multiple comparisons and there is no simple solution to it." Martha J. Farah, *Brain Images, Babies , and Bathwater: Critiquing Critiques of Functional Neuroimaging,* 44 HAST. CENT. REP. S19–S30 (2014). An example of the multiple comparison problem is the experiment in which researchers took a dead salmon, put it in an fMRI scanner, asked it to think about the emotions of people displayed in photos, and found regions engaged in perspective-taking at the 0.001 level. Craig M. Bennett et al., *Neural Correlates of Interspecies Perspective Taking in the Post-Mortem Atlantic Salon: An Argument for Proper Multiple Comparisons Correction,* 1 J. OF SERENDIPITOUS AND UNEXPECTED RESULTS 1–5 (2010).

D. Can Arousal Issues be Disassociated From Signals Related to Lie Versus Truth?

Some scientists question the lack of attention that has been paid to changes in arousal or excitability levels in the determination of responses related to deceit.[40] In fMRI lie detection research, the laboratory conditions of all these studies were well controlled and the subjects were generally asked to answer or perform a very specific task. In real world situations, in contrast, there is a continuous ebb and flow to questioning and the interrogation process is marked by a complex sequence of events. There have been few studies that address the arousal level, anxiety related to the questioning, and overall complexity of questioning under pressure.

The central assumption guiding inferences that are made from fMRI data about neuronal activity has been that the fMRI signal is approximately proportional to a measure of local neural activity, averaged over a spatial extent of several millimeters, and over a time period of several seconds.[41] This is referred to as the linear transform model of the fMRI signal. There is, however, no reason to suspect that blood flow will still be linear in the face of a host of changes in excitability, anxiety shifts, and autonomic responses. It may well be that "stress" purportedly arising from lying, or from the fear of being perceived as lying, could induce autonomic responses that would differ from the condition of answering truthfully.

However, the relationship between the fMRI signal and the neuronal activity depends on the MRI acquisition method. As described above, the fMRI signal derives from hemodynamics, which includes blood flow, blood volume, and blood oxygenation. This in turn depends on the distribution of large vessels, small vessels, capillaries, and various sized veins. Variations in the fMRI technique can emphasize or de-emphasize any of these components. There have been few attempts at quantifying the relationships between these techniques.[42]

Attention also may vary from individual to individual and from question to question within the testing parameters. Attentional load can increase baseline activity and the nature of the response to a stimulus for prolonged periods.[43] People who pay more (or less) attention to the questions asked may be able to affect the fMRI measurement of responses to Lie versus Truth.

40. *See* Logothetis, *supra* note 23.

41. David J. Heeger & David Ress, *What Does fMRI Tell Us About Neuronal Activity?,* 3 NATURE 142 (2002).

42. *Id.*

43. For example, Dr. Laken, the expert in *U.S. v. Semrau*, explained the fMRI results indicating that Dr. Semrau was lying based on Dr. Semrau's fatigue from answering questions so early in the morning, and re-tested at a later time in the day. The court was understandably critical of this explanation and this was one of the reasons Dr. Laken's testimony was excluded.

E. How are the fMRI Images Generated? Are They "Preprocessed"?

1. Slice Timing Correction

The process of fMRI scanning acquires different images within a single brain region at different times, so that the images represent brain activity at different times. In order to simplify analysis, a timing correction is applied to bring all slices of the brain region to the same time reference. This is done by assuming that the time course of a voxel is smooth, so that the voxel's intensity value at other times not in the sampled images is calculated by filling in the values to create a continuous line. The problem with this procedure is that the timing correction may vary across labs. The metaphor provided above of the three painters is appropriate here. A photograph of a girl with red hair will lead to three paintings with different colors of hair, eyes, and skin, and her posture will likely differ. The end result will be paintings of three girls who could be sisters, not the same girl. The processing method "fills in" the empty time points. That means that the images are highly manufactured and open to independent "tweaking" by different technicians. No single protocol exists across labs.

2. Motion Correction

To account for motion, the fMRI technician applies a rigid-body transformation algorithm, shifting and rotating the whole volume data, in what is called a correction. The technician statistically compares the transformed volume to the volume at the first sample to determine "how well they match." Applying this "correction" is a further example of the ways in which technician "tweaking" affects the image. Different laboratories apply different thresholds for the correction. Note that seeing "how well they match" is a term that describes personal preference and is not a defined protocol. This is another factor making the process irretrievably subjective.

3. Coregistration Algorithm

To plot the blood flow signal onto the structural image of the brain, the fMRI process uses data derived from structural signals and aligns these data with the magnetic field decay image signals. Because these are two different types of signals, the resolutions of these two types of signals are different, so that the intensity values cannot be compared. Forcing two incompatible signals to align and "create" an image represents another decision point in the way the image is generated. Each decision point represents the different personal preferences of laboratory technicians in different laboratories.

4. Temporal Filtering

The process of temporal filtering involves yet more subjective decision-making. The technician uses this process to remove frequencies (periodic waves) that are not of interest[44] by creating a power spectrum, or Fourier Transform, of the data. Once more, there is no standard protocol and the technician's selection of frequencies to be filtered is subjective and intended to obtain an "optimal" image; that is, one with less noise that is "better looking." This "tweaking" is perhaps the most subjective since the technician is mathematically manipulating the raw signal.

5. Spatial Filtering

By averaging the intensities of nearby voxels, the image is "smoothed" using a Gaussian filter, ensuring that the points fall along a bell curve distribution, in order to improve the image. All of this "preprocessing" of fMRI images is marked by subjective choices at multiple steps in the analysis. Because of the subjectivity involved, it is highly unlikely that identical images in the same individual could be acquired at two different machines. Even if identical interrogation methods were followed, there are likely to be differences between two separate machines and two different analysts.

F. Other Factors

Learning is accompanied by a decrease in fMRI signals.[45] This means that unfamiliar tasks will evoke more easily detectable signals than will familiar tasks. The problem here is that repeated scans using the same interrogation method will not generate the same signal levels. With practice, the signal decreases.[46] In repeated trials, the signal strength decreases. This suggests that, if a guilty subject repeatedly practices telling a lie, the lie will be detected as a decreased signal similar to that of a control question; i.e., a false negative.

Finally, some researchers believe that there is no single subject reliability, and that a scan from one subject can never be

44. The filtering process allows different labs to filter at different frequencies. No studies are available to determine how such decisions alter the final image, making this another aspect of the practice of the "art."

45. M. E. Raichle, *Images of the Mind: Studies with Modern Imaging Techniques,* 45 ANN. REV. PSYCHOL. 333–56 (1994); M. Jueptner, et al, *Anatomy of Motor Learning,* 77 J. NEUROPHYSIOLOGY 1313–24 (1997).

46. S. A. HUETTEL ET AL, FUNCTIONAL MAGNETIC RESONANCE IMAGING (2009)

interpreted based on group data.[47] Conclusions can only be drawn about group averages, not individual brains. This is obviously a problem for legal applications, since the legal question nearly always involves the individual rather than the group.

III. PART III

Neuroscience-based lie detection is not science fiction. It has been the subject of peer-reviewed publications from several laboratories for at least 10 years.[48] The idea is grounded on sophisticated scientific research originating with research scientist Daniel D. Langleben, who theorized that lying is more work (and therefore will result in more blood flow to the brain) than telling the truth.[49] In his initial study on this topic, Dr. Langleben concluded that when subjects in a scanner told a lie, their brains showed more activity than when they were telling the truth.[50] He localized the increased activity to several regions of the brain associated with increased attention, error monitoring, behavioral control, and sensory input monitoring.[51] Later studies by the Langleben group attempted to create a model that would be able to tell whether an individual subject was lying or telling the truth.[52]

A separate group of researchers also found statistically increased brain activity in several regions of the brain when

---

47. Richard Robinson, *fMRI Beyond the Clinic: Will it Ever Be Ready For Prime Time?,* 2 PLOSBIOLOGY 0715 (2004).

48. *See* Henry T. Greely & Judy Illes, *Neuroscience-Based Lie Detection: The Urgent Need for Regulation,* 33 AM. J.L. & MED. 377, 390 (2007) (Noting that fMRI lie detection "has been the subject of significant peer-reviewed literature from several laboratories").

49. *See* Daniel D. Langleben, et al., *Brain Activity During Simulated Deception: An Event-Related Functional Magnetic Resonance Study,* 15 NEUROIMAGE 727, 728–29 (2002) (reporting that in a study of 18 subjects, each given $20 and a 5 of clubs playing card, who were told that they could keep the money if they lied about having the 5 of clubs, but not if they lied about any other card they saw while being scanned in an fMRI scanner, blood flow increased when they were lying).

50. *Id.* at 731.

51. *See id.* at 730–731 (noting increased activity in the anterior cingulate cortex (associated with heightened attention and error monitoring); dorsal lateral prefrontal cortex (behavioral control); parietal cortex (processing sensory input)).

52. *See* Daniel D. Langleben, et al., *Telling Truth from Lie in Individual Subjects with Fast Event-Related fMRI,* 26 HUM. BRAIN MAPPING 262, 262 (2005) (using logistic regression analysis to create a model that could tell true answers from false ones 76.5% of the time, with a 69% specificity and 84% sensitivity); C. Davatzikos, et al., *Classifying Spatial Patterns of Brain Activity with Machine Learning Methods: Application to Lie Detection,* 28 NEUROIMAGE 663 (2005) (using a different method of data analysis to distinguish when individual subjects were lying nearly 90% of the time, with a specificity of 90%, sensitivity 85.8%).

subjects were lying.[53] Using a greater field strength fMRI, they performed a group analysis of the results and found increased activation in five areas of the brain when subjects were lying, and no increased activation when subjects were telling the truth.[54] In a third study from 2005, the Kozel group developed a model that it claimed could detect lying 90% of the time.[55]

In anticipation of potential legal uses for this technique, entrepreneurial neuroscientists launched two commercial entities within the last 5 years.[56] In at least three cases, defense counsel has attempted to introduce fMRI-based lie detection into evidence.[57] So far, no one who has tried to introduce fMRI lie detection in court has succeeded. Why then, should we be concerned about this use of brain imaging? The reason for concern lies with the rationales for exclusion, all of which could be surmounted in future cases, without addressing the underlying limitations of the technology itself.

In *United States v. Semrau*,[58] a doctor accused of healthcare fraud had proffered fMRI-based lie detection testimony to demonstrate that he was telling the truth about his lack of intent to commit fraud. The expert, Dr. Stephen Laken, the founder and CEO of Cephos Corp.,[59] and one of the authors of one of the Kozel studies,

---

53. *See* Kozel, et al., *supra,* note 21 at 295 (finding activation in three brain areas under the lie conditions in a pilot study of eight subjects who were shown five objects in each of two rooms, and told to tell the truth about objects in one room, and lie about those in the other).

54. *See* F. Andrew Kozel, et. al., *Brief Communications: A Replication Study of the Neural Correlates of Deception*, 118 BEHAV. NEUROSCIENCE 852 (2005) (varying the conditions of the pilot study to conclude that brain activation increased in lying but not in telling the truth).

55. *See* F. Andrew Kozel, et al. *Detecting Deception Using Functional Magnetic Imaging,* 58 BIOLOGICAL PSYCHIATRY 605 (2005) (30 subjects used to build the model were told to steal an object from a drawer and, in the scanner, indicate what object they had stolen and instructed to deny taking any object and told they would be paid $50 if their lie was not detected; then the model constructed from their scans was applied to 31 different subjects, yielding lie detection roughly 90% of the time, even when the subjects used self-constructed countermeasures like pretending to themselves that they hadn't taken the object, thinking about some other location, or slowing their breathing).

56. No Lie MRI, according to its website, uses fMRI technology to determine whether a scanned subject's responses to questions are truthful. http://noliemri.com/investors/MarketOpportunity.htm (last visited June 27, 2014). For a while, another commercial entity, Cephos Corporation, also offered fMRI-based lie detection services. *See* Adam B. Shniderman, *You Can't Handle the Truth: Lies, Damn Lies, and the Exclusion of Polygraph Evidence,* 22 ALB. J.J. SCI. & TECH. 433, 471, 471 n.256 (2012) (discussing the commercialization of fMRI-based lie detection). Currently, however, its website advertises only biotechnology assistance. http://cephos.com (last visited 6/27/14).

57. *See, e.g.,* United States v. Semrau, 693 F.3d 510 (6th Cir. 2012) (excluding defense expert fMRI-based lie detection testimony); Wilson v. Corestaff Services, L.P., 900 N.Y S.2d 639 (N.Y. Sup. Ct. 2010) (excluding fMRI-based lie detection testimony).

58. 693 F.3d 510 (6th Cir. 2012).

59. The Sixth Circuit noted that Cephos "holds a patent on a version of an

proposed to testify that the fMRI testing showed that the doctor was generally truthful when he said he was trying to follow the correct billing procedures.[60]

Dr. Laken devised two sets of questions to pose to Dr. Semrau.[61] One set of questions involved whether Dr. Semrau had intentionally used incorrect billing codes, while the other set of questions related to his separate billing for tests that should have been included in regularly scheduled appointments.[62] After practicing answering the questions on a computer, Dr. Semrau entered the scanner, where he was asked the questions in random order.[63] Dr. Semrau apparently passed the first set of questions with flying colors, because Dr. Laken concluded that the results showed that he was "not deceptive."[64]

On the second scan, relating to the testing charges, Dr. Laken found that Dr. Semrau was "being deceptive."[65] Attributing this to fatigue, however, Dr. Laken devised a third set of shorter questions relating to the billed tests and scanned again, this time in the evening (the first two scans had been conducted at 6:00 a.m.). This time, Dr. Laken concluded that Dr. Semrau was not deceptive.[66]

During the evidentiary hearing, however, Dr. Laken conceded that he could not tell whether Dr. Semrau was telling the truth about any specific question in any of the three scans that he performed.[67] This failure, the magistrate judge opined, meant his testimony could not be helpful to the jury.[68] Moreover, by re-testing, the magistrate was concerned that Dr. Laken had violated his own protocols and questioned whether a fourth test would again show Dr. Semrau being deceptive.[69]

The trial judge excluded this testimony, adopting the magistrate judge's decision, based on Federal Rules of Evidence 702

---

fMRI-based lie detection method, which identifies Dr. Laken as its inventor." *Semrau, supra* note 20 at 516. According to the court, Cephos claimed to use "state-of-the-art technology that is unbiased and scientifically validated . . . [and to] have offered expert testimony and have presented fMRI evidence in court [as well as providing] independent, scientific validation that someone is telling the truth." *Id.*

60. *Id.* at 515.

61. United States v. Semrau, 2010 WL 6845092 (W.D. Tenn. June 1, 2010).

62. *Id.* at *2.

63. *Id.* at *5. The expert explained this "practicing" as a way of getting Dr. Semrau comfortable with the procedure. *Id.* Note, however, as discussed *supra* note 20, each time a question is repeated, the signal will decrease, so "practicing" will have the result of decreasing the signal.

64. *Id.*

65. *Id.*

66. *Id.* at *7.

67. *Id.* at *7–8. *See* the discussion of timing in Part II, *supra,* explaining the problem that the time lag inherent in the technology makes it impossible to determine whether the answer to any specific question is being measured.

68. *Id.* at *16.

69. *Id.* at *13.

and 403.[70] The Sixth Circuit upheld the exclusion. In deciding whether Dr. Laken's fMRI lie-detection testimony met the *Daubert* standards,[71] the court found that "the underlying theories behind fMRI-based lie detection are capable of being tested, and at least in the laboratory setting, have been subjected to some level of testing."[72] The error rate and controlling standards of operation, however, the court found more troubling.[73]

Citing Dr. Laken's own publications, and those of the Kozel group, the court emphasized the small size of the studies (none had included more than 30 subjects), the difference of laboratory research scenarios from real world situations and for populations other than the volunteers upon whom the studies were performed.[74] The court also was concerned that "different types of lies may produce different brain patterns."[75]

The court therefore excluded Dr. Laken's testimony, finding that fMRI was "not ready to be used in real-world lie detection."[76] In addition, it held that the evidence would violate Federal Rule of Evidence 403, because the government had not been notified of the testing, so that Dr. Semrau risked nothing in taking the tests (because he would not have released unfavorable results), and because Dr. Laken was unable to identify which questions Dr.

---

70. Federal Rule of Evidence 702 governs the admissibility of expert testimony, while Rule 403 permits the judge to exclude relevant evidence if its probative value is "substantially outweighed" by undue prejudice, confusion, etc.

71. In *Daubert v. Merrell Dow Pharms., Inc.*, 509 U.S. 579 (1993), the Supreme Court held that the Federal Rules of Evidence had superseded the earlier general consensus test for expert admissibility, finding that standard was "an austere standard, absent from, and incompatible with, the Federal Rules of Evidence." *Id.* at 589. Instead, the Court ruled that under Federal Rule of Evidence 702, judges must "ensure that the evidence is not only relevant but reliable." *Id.* To do this, judges must make a preliminary assessment to determine "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." *Id.* at 592–93. Offering some flexible guidelines (explicitly not to be used as a "checklist or test"), for making that assessment, the Court proposed four factors: testability; peer review and publication; the existence of methodological standards, including known or potential error rate; and general acceptance. *Id.* at 594.

72. *Id.* at *10. This is not quite accurate, as noted in Part II, *supra*, because many of the assumptions underlying the use of fMRI for lie detection have never been tested, and we do not yet have the technology capable of testing them.

73. *Id.* at *11.

74. *Id.* (quoting Dr. Laken et al.'s publication, *Mock Sabotage Crime,* which explained that none of the studies involved the level of jeopardy in a real situation, nor whether fMRI deception testing would work for participants taking drugs, outside the 18–50 year age range of the subjects, or who have medical or psychiatric conditions).

75. *Id.* at *12 (quoting the Kozel group's publication, *Detecting Deception*, *supra* note 55).

76. *Id.* (quoting *Detecting Deception*, *supra* note 55).

Semrau had answered truthfully or deceptively.[77]

On appeal, Dr. Semrau challenged the finding that there were no known error rates or controlling standards for the procedure.[78] Referring to the government's biostatistics expert, who had explained that there was "almost no data" about error rates in circumstances like Dr. Semrau's, the Sixth Circuit upheld the magistrate judge's rejection of the error rate testimony.[79] Noting that error rates may vary in research and real world settings, the Sixth Circuit also denied the second basis of Dr. Semrau's appeal, that the magistrate judge had erroneously created such a distinction.[80] Quoting from Dr. Laken's own work, the Sixth Circuit observed that the distinction was widely recognized and that researchers had cautioned about it.[81] Moreover, it questioned not only whether fMRI lie detection had been tested in the real world, but also whether it could be tested.[82]

The Sixth Circuit, affirming the exclusion of Dr. Laken's fMRI lie-detection testimony, focused (in addition to the factors discussed by the lower court opinion) on the fluctuating accuracy rates of the research studies, a "huge false positive problem,"[83] and the absence of research about statements regarding conduct that occurred long before testing.

Dr. Semrau also appealed the magistrate's Rule 403 holding, arguing that the fMRI testimony, far from confusing the issues, corroborated his testimony.[84] Because, however, the fMRI results had been unable to corroborate any particular statement of fact, the Sixth Circuit, noting that the jury was being asked to determine Dr. Semrau's culpability over a number of years, for dozens of discrete acts, found little probative value in the proposed testimony.[85]

In *State v. Smith*,[86] a murder trial, the defendant proffered fMRI lie detection testimony to support his claim that he did not kill his roommate. The trial court, analyzing the admissibility of this testimony under *Frye*'s general consensus admissibility standard[87] and the state's equivalent, *Reed*,[88] excluded it. Although the

77. *Id.* at *16. *See* discussion about the inability of fMRI technology to measure activation from a single question because of the inherent time lag, Part II *supra*.

78. U.S. v. Semrau, 693 F.3d 510, 521 (6th Cir. 2012).

79. *Id.* at 521.

80. *Id.*

81. *Id.*

82. *Id.*

83. *Id.* at 517–18 (noting that Dr. Laken contended that "people who are telling the truth are deemed to be lying around sixty to seventy percent of the time.")

84. *Id.* at 524.

85. *Id.*

86. No. 106589C, Montgomery Cty Cir. Ct., MD (8/2012), on remand from 32 A.3d 59 (Md. 2011)

87. Frye v. United States, 293 F. 1013 (D.C. Cir. 1923).

88. Reed v. State, 283 Md. 374 (1978).

defendant cited twenty-five peer-reviewed published studies, performed by sixteen working groups, the court was not convinced that the technique had achieved general acceptance in the scientific community. Focusing on the "competing motions, expert testimonies, and submitted articles," the court found that they "reveal[ed] a debate that is far from settled in the scientific community."[89] Accordingly, the court excluded the testimony.

Wilson v. Corestaff Services, L.P.[90] involved a lawsuit by a former employee claiming that she had been fired in retaliation for reporting sexual harassment in the workplace to her employment agency.[91] The plaintiff had listed Dr. Laken as an expert witness, and proposed to have him testify about the truthfulness of a key fact witness through fMRI lie-detection testimony. The court declined to admit the testimony, because the expert testimony could not meet the threshold requirement of New York's modified *Frye* test; i.e., that the testimony "would help clarify an issue calling for professional or technical knowledge possessed by the expert and beyond the ken of the typical juror."[92] The court noted that the use of fMRI to show a person's past mental state or to gauge credibility is far from generally accepted.[93] The court also held that because "credibility is solely a matter for the jury," the fMRI testimony must be excluded.[94]

These decisions illustrate two fundamental judicial concerns with the use of fMRI lie-detection testimony. First, there is the concern that such testimony invades the province of the jury to determine credibility (a fundamental concern for many of the prior polygraph cases). Second, there is the concern that the research, whatever its scientific validity in the laboratory, does not generalize to the relevant population.

IV. INVADING THE PROVINCE OF THE JURY

The idea that expert testimony commenting directly on credibility invades the province of the jury has been a conceptual problem for all lie detection evidence, including the polygraph.[95]

89. *Smith* at *5.

90. 900 N.Y.S. 2d 639 (N.Y. Sup. Ct. 2010).

91. *Id.* at 640.

92. *Id.* at 642 (noting also that "New York courts permit expert testimony if it is based on scientific principles, procedures or theory only after the priniciples, procedures or theories have gained general acceptance in the relevant scientific field").

93. *Id.* ("even a cursory review of the scientific literature demonstrates that the plaintiff is unable to establish that the use of the fMRI test to determine truthfulness or deceit is accepted as reliable in the relevant scientific community").

94. *Id.*

95. *See, e.g.,* United States v. Sheffer, 523 U.S. 303 (1998) (observing that polygraph testimony diminishes the role of the jury); U. S. v. Loaiza-Clavijo,

Only one state (New Mexico) currently permits polygraph testimony in court, and the majority of courts exclude expert testimony on credibility.[96]

Whether this is a legitimate concern depends on a number of factors. First, invading the jury's function as credibility assessor would only be a problem if the jury takes the images literally and does not understand the contingent nature of what these images can reveal.[97] Will the jury do this? There has been little published research on this aspect of fMRI lie detection. There is some evidence that jurors are more convinced by neuroscience evidence than they are by psychological testimony.[98] One meta-analysis study examined the influence of neuroimaging testimony about intent on mock juries deciding guilt and concluded that there was a "lack of any impact of neuroimages on the decisions" of the mock jurors.[99] Juries do not appear to be over-awed by PET scans admitted to show brain damage, since they still overwhelmingly convict.

Second, fMRI lie detection would only "invade" the province of the jury if the jury were able to perform the task as well as any fMRI expert. There is no evidence, however, that jurors are particularly good at detecting deception.[100] Nearly everyone believes that they are good at it, but the evidence is to the contrary.[101] Most people's credibility assessments—including people trained in micro-facial expression and body language techniques—is only marginally better than chance.[102] So if the jury's credibility assessments are so

2012 WL 529981 (N.D. Ga.) at *6 ("polygraph evidence necessarily invades the province of the jury"); U.S. v. Warner, 2014 WL 1373634 (N.D. Ga.) at *10 (determination of a witness' credibility is within the exclusive province of the jury).

96. *See* Daniel D. Langleben & Jane C. Moriarty, *Using Brain Imaging for Lie Detection: Where Science, Law, and Policy Collide,* 19 PSYCHOL. PUB. POL'Y & L. 222, 226 (2013) (predicting that "courts will continue to be troubled by testimony that comments directly on credibility").

97. *See* Michael Pardo, *Neuroscience Evidence, Legal Culture, and Criminal Procedure,* 33 AM. J. CRIM. LAW 301, 318 (2006) (contending that fMRI testimony would not establish knowledge or lies directly, so that the jury would still have to consider whether other evidence should override the test results).

98. *See id.*

99. N.J. Schweitzer, et al., *Neuroimages as Evidence in a* Mens Rea *Defense: No Impact,* 17 PSYCHOL., PUB. POL'Y AND L. 357, 382 (2011).

100. *See, e.g.,* Max Minzer, *Detecting Lies Using Demeanor, Bias and Context,* 29 CARDOZO L. REV. 2957, 2571 (2008) (discussing studies showing that relying on demeanor evidence leads to accuracy less than half the time).

101. *See* C. Bond & B. DePaulo, *Accuracy of Deception Judgments,* 10 PERS. SOC. PSYCHOL. REV. 214 (2006) (Most people, including professionals such as lawyers, police, magistrates, and psychiatrists, can distinguish truth from lies only 54% of the time—slightly better than chance).

102. *See* ALDERT VRIJ, DETECTING LIES AND DECEIT 67–69 (2000) (jurors are not able to tell by observing witnesses which of them are telling the truth); Joseph W. Rand, *The Demeanor Gap: Race, Lie Detection, and the Jury*, 33 CONN. L. REV. 1 7–14 (2000) (while subjects had strong beliefs about cues of deception, these beliefs bore little relationship to reality).

important to our justice system, they could use a little help. The question then becomes whether technology might be able to assist them, and that depends on the scientific validity of the technology.

As far as helping the jury with its credibility assessments, we already permit evidence of an accused's character for honesty, if that character has been attacked,[103] and once a witness's credibility has been impeached, we permit credibility-bolstering testimony.[104] Recall that the most that Dr. Laken could say about Dr. Semrau's answers was that he was being generally truthful. It is unclear whether this testimony would prejudice the jury in the face of limiting instructions any more than would another witness testifying that Dr. Semrau had the reputation for truth-telling in the community. Even assuming a scientifically valid fMRI lie detection method, it would invade the province of the jury no more than what a live lay witness is already permitted to do. A jury is still free to make its own determination about credibility, regardless of witness testimony about honesty or truthfulness.

A. Scientific Validity

Scientific validity is a much more salient concern. In many respects, fMRI lie detection appears far more scientific than many forensic techniques widely admissible in court (take bite-mark evidence, for example[105]). It has many of the imprimaturs of science: it is grounded on a technique—fMRI—with important uses outside the courtroom; the research is conducted in the laboratory by neuroscientists; and their studies are peer-reviewed and published. As noted in Part III, however, that does not mean that the technique can do what the experts advertise.

The courts, admittedly, have not been aware of many of these issues. Instead, they tend to focus on generalizability and lack of general consensus. The issues that they have raised are certainly enough to cast doubt on the usefulness of fMRI for courtroom purposes. But even supposing those defects in the technology were curable (and cured), there remain fundamental problems with fMRI lie detection.

1. Generalizability

The *Semrau* court raised two primary issues with

103. Federal Rule of Evidence (FRE) 404(a)(1) permits evidence of an accused's character trait for honesty, but only after it has been attacked (usually on cross-examination).

104. FRE 608(a) permits testimony about a witness's reputation for truthfulness (or an lay opinion about the witness's truthfulness), but only after the witness's credibility has been attacked.

105. *See, e.g.,* Erica Beecher-Monas, *Reality Bites* (discussing the lack of scientific validity behind bite mark evidence).

generalizability: the small numbers of test subjects within the research studies and the artificiality of the tasks the research subjects performed. Were these valid concerns? Small size is certainly a problem for scientific studies, for reasons of replication, diversity, and extrapolation to the general population.

The studies on which the fMRI-based lie detection was based involved no more than thirty-one subjects.[106] The size of the study matters in terms of precision of results and replicability.[107] Random error decreases as the size of the study increases. Power, defined as the probability that the study in which the hypothesis is being tested will reject the alternative hypothesis when it is false, increases with the size of the study. Replicability of small studies is often a problem. As the Sixth Circuit noted, outside laboratories—that is, those not engaged in fMRI lie detection—had not replicated the studies cited by Dr. Laken.[108] The absence of replication appears problematic for identifying a reliable protocol for real world applications.[109]

Small study size also decreases the diversity of the studies. The subjects in most of the studies were convenience samples, that is, student volunteers, mostly white right-handed males. No one tested subjects with mental illness (a large proportion of those convicted of crimes), people over fifty, children, or subjects taking drugs (prescription or otherwise). These student subjects may have had neither incentive nor opportunity to develop skill in deception. We simply do not know if a more diverse population would yield different results.[110]

The courts' second issue with generalizability—the artificiality of the tasks the subjects performed—is also a valid concern. All the experiments involved the researchers directing the subjects to tell a lie. So did the fMRI measure brain responses to lying, or to following researchers' instructions to lie? Is it the question or the answer that

---

106. *See* Henry T. Greely & Judy Illes, *Neuroscience-Based Lie Detection: The Urgent Need for Regulation*, 33 AM. J. L. & MED. 377, 396–402 (describing twelve peer-reviewed articles published through 2007, three of which came from the laboratory of Daniel Langleben and three published by Andrew Kozel's group).

107. *See* KENNETH J. ROTHMAN, EPIDEMIOLOGY: AN INTRODUCTION 75 (2012) (explaining that small size of trials "leads to imprecise results that may not be replicable").

108. *See* Greely & Illes, *supra* note 47, at 402 (noting the lack of replication of the results by other laboratories and cautioning "never believe a result until at least one investigator from outside the original group confirms it.").

109. *See* Elena Rusconi & Timothy Mitchener-Nissen, *Prospects of Functional Magenetic Resonance Imaging as Lie Detector,* 7 FRONTIERS IN HUM. NEUROSCI. 1, 3 (2013) (observing that "it is very unusual to see a brain imaging experiment precisely repeated within and between laboratories [which] may prove especially problematic when trying to identify a well-known and reliable protocol for potential applications in the real world").

110. For a discussion of using unrepresentative groups in research studies, *see* Henrich, et al., *Most People are Not WEIRD,* 29 NATURE 466 (2010).

is activating the brain? Or, as we will discuss in Part III, is the brain responding to something else entirely? The point is that the way the brain works is quite complex and what is being measured may be quite different from what lie detection researchers think they are measuring.

Researchers have identified many different areas of the brain activated during lying. Several studies have identified a network of parieto-frontal areas that become significantly more engaged when the subject is lying than when truth-telling.[111] This region performs a host of other functions, so that it is not clear that this specific region is involved in the process of lying, only that it was activated when subjects were asked to lie. The limbic system may also be more activated with lying than truth-telling.[112] The limbic system is involved in emotion, but it is not clear if this system is active due to deception, to the fear of being perceived as deceptive, or to something else entirely. Just because the area is activated does not mean that the subject is lying.[113] Lots of other things activate the same areas.

Moreover, there is the question of consequences. Although some subjects were told that they would be paid extra for successfully lying, they all knew that there were no real consequences in terms of reputation or retribution. They knew that they were participating in an experiment and would go home at its completion. In addition, they were not lying about very consequential matters: a card's identity or the location of some hidden money or doo-dads. Would the results have differed if the consequence of their answers had been arrest or conviction? We simply do not know.

2. *General Consensus*

Whether fMRI is a valid tool for detecting deception is hotly contested, at least among some neuroscientists. Even among those engaging in fMRI lie detection research, there are debates about its validity for courtroom uses. Obviously, the neuroscientists involved in the start-up lie detection companies thought it was a valid

---

111. *See* Elena Rusconi & Timothy Mitchener-Nissen, *Prospects of functional Magnetic Resonance Imaging as Lie Detector,* 7 Frontiers in Neurosci. 1 (2013) (reviewing the use of neuroscience imaging as lie detectors). Parieto-frontal refers to brain regions in the parietal and frontal lobes; the parietal love is located on the posterior and dorsal surfaces of the cerebrum, while the frontal lobe is the most anterior lobe on the cerebrum. *Id.*

112. *See* J. Hakun et al., *Toward Clinical Trials of Lie Detection with fMRI,* 4 Soc. Neurosci. 518–27 (2009)(finding limbic system activation in ecologically plausible scenarios).

113. *See* Rusconi & Mitchener-Nissen *supra* note 108 at 4 (explaining that activation of parieto-frontal and limbic regions "does not imply in any mechanistic way that a person is lying when the same region . . . activates during a task").

technology, although the website of Dr. Laken's firm, Cephos, no longer advertises lie detection services.

In sum, the research is still far too premature for fMRI lie detection to be useful in court. So far the courts have recognized this, and rejected the technique. Some of these flaws could be remedied with more basic research and better designed studies. There are, however, much more fundamental questions about the use of fMRI imaging for lie detection.

B. What is Deception?

One of the most crucial issues for fMRI lie detection is the failure to define deception and to acknowledge the many kinds of deception that exist. We do not yet have a precise model of the mental processes involved in lying.[114] We may never achieve such a model because, as discussed above in Part III, brain activity is complex. Although the prefrontal, anterior cingulate, and parietal regions have been identified as neural correlates of deception, activity in these regions is an unreliable marker of deception. These regions are responsible for executive processes that are not specific to deception.[115]

Deception involves both communication that is at odds with physical reality and manipulation of another person's beliefs.[116] The deceiver must, therefore, conjecture about the other person's knowledge and state of mind. This is a sophisticated activity, involving cognitive processes such as memory, reasoning, and being able to assess the other person's state of mind (sometimes called a theory of mind).[117] Many areas of the brain are involved in these processes.

The assumption underlying fMRI studies has been that cognitive functions are located in focal brain regions, although that is unlikely to be the whole picture, since most behavioral and

---

114. *See* Kamila E. Sip, et al., *Response to Haynes: There's More to Deception than Brain Activity,* 12 TRENDS IN COG. SCI. 127 (2008) (responding to Haynes argument that the full spatial pattern of brain activity—so-called data driven imaging—makes it unnecessary to detect deception in particular brain regions by pointing out that his methodologies still "depend on the existence of independent categorization of deceptive and non-deceptive intentions in each of the subjects being scanned" as well as the subjects' beliefs about the situation).

115. *See* Tatia M. Lee, et al., *I Want to Lie About Not Knowing You, But My Precuneus Refuses to Cooperate,* 3 SCI. REP. 1 (2013) (noting that "activity in these regions has not been a reliable marker of deception, likely because the neural activity in these areas is not unique to deception").

116. *See* Kamila E. Sip, et al., *Detecting Deception: The Scope and Limits*, 12 TRENDS COG. SCI. 48 (2008).

117. *See id.* at 1 (noting that deception is likely to require "the concerted activity of several neural mechanisms, with activity in different, widely distributed brain regions mediating the various processes underlying deceptive behavior").

psychological processes are not located in a single brain center.[118] Neuroscientists debate about whether this matters in fMRI lie detection. One camp argues that, for "data-driven" fMRI research, all that matters is the "full spatial pattern of brain activity."[119] The other camp contends that there is no independent marker of deception; that the data-driven imaging methodologies depend on the "independent categorization of deceptive and non-deceptive intentions in each of the subjects being scanned" and that the subjects' beliefs also affect their brain activity.[120] As noted in Part II, we simply do not know what the activation means. Is it a response to the question, or to the answer being formulated; is it day-dreaming or anxiety or something else entirely? We don't know.

1. Many Kinds of Lies

People can believe they are telling the truth but be factually wrong. People can think they are lying but be factually correct. Some people believe their own lies. Some intend to deceive. Some lies are spontaneous and some rehearsed. Some lies concern recent events and some concern events that happened long ago. Some kinds of lies involve perception (have you ever seen this person—or thing—before?). Some have important consequences and some do not.

Deception is part and parcel of our social fabric. Every healthy person lies—even babies learn to cry, mimicking pain or hunger, when they want attention. We tell lies to others for a myriad of reasons: to avoid hurt feelings; to lubricate social interactions; to avoid responsibility; for personal gain.[121] It is unclear whether the MRI scanner perceives the difference.

2. Many Kinds of Liars

Some people are more skilled at telling lies than others.[122]

---

118. *See* Laurence R. Tancredi & Jonathan D. Brodie, 33 AM. J. L. & MED. 271, 275 (2007) (discussing the complexity of brain/behavior interfaces).

119. *See* John-Dylan Haynes, *Detecting Deception from Neuroimaging Signals—a Data-Driven Perspective,* 12 TRENDS IN COG. SCI. 126 (2008) (arguing that the computer-based classification algorithm identifies a unique profile of activation that is indicative of deception).

120. *See* Kamila E. Sip, et al., *Response to Haynes: There's More to Deception than Brain Activity*, 12 TRENDS IN COG. SCI. 127 (2008).

121. *See* Greely & Illes, *supra* note 47, at 404 (noting that lies vary tremendously and questioning whether the research is relevant to the kinds of lies people tell in real life).

122. *See* W. Jiang, et al., *A Functional MRI Study of Deception Among Offenders with Antisocial Personality Traits,* 244 NEUROSCI. 90, 91, 96 (2013) (noting that "frequent lying made lying easier" and finding that in an fMRI study of incarcerated men with antisocial personality disorders, brain activities measurably decreased as the skill at deception increased).

Moreover, studies of college students may not generalize to people that have had repeated brushes with the law, or to habitual and skillful liars.[123] Increased skill at lying apparently results in decreased detection in the fMRI.[124]

Moreover, accomplished liars may be able to use counter-measures to evade detection. This has been an ongoing problem in polygraph lie detection. When participants in fMRI studies used countermeasures such as intentionally thinking about something else, the success rate for distinguishing truth from lies decreased dramatically.[125]

People also vary widely in brain physiology. As discussed in Part II, the structure and function of the brain (and in the blood vessels supplying blood to the brain) are highly variable. People also differ in terms of the mental processes involved in their behavior, whether the behavior is lying, daydreaming, or writing poetry.[126] What is purportedly being measured in fMRI lie detection is the average difference between two states: lying and truth-telling. We do not really know if that is what is being measured, or if it is something else that is responsible for the differences in blood flow.[127] Further, because of individual variability, the most that can be inferred is averaged information about the group being studied. This poses a huge problem for use of fMRI technology in court, where the focus is on the individual rather than the group to which the individual belongs.

3. Many Situations

Not only are there many kinds of lies and liars, but situational context is important. Neither deceivers nor truth-tellers respond behaviorally the same way in all situations.[128] People's behavior

---

123. *See* THE ROYAL SOCIETY, BRAIN WAVES MODULE 4: NEUROSCIENCE AND THE LAW 25 (2011) (noting that while experiments on college students may be a necessary first step, they may not generalize to habitual and skillful liars).

124. *See* Jiang, et al., *supra* note 122, at 90 (concluding that "BOLD activities during deception are correlated with the capacity to lie" and noting that this "might challenge the diagnostic accuracy of lie detection").

125. *See* Ganis G. Rosenfield, et al., *Lying in the Scanner: Covert Countermeasures Disrupt Deception Detection by functional Magnetic Resonance Imaging*, NEUROIMAGE 312–19 (2011) (detailing studies).

126. *See* THE ROYAL SOCIETY, BRAIN WAVES MODULE 4: NEUROSCIENCE AND THE LAW 13 (2011) (discussing the implications of individual variation for fMRI lie detection).

127. *See, e.g.,* Elena Rusconi & Timothy Mitchener-Nissen, *Prospects of Functional Magenetic Resonance Imaging as Lie Detector,* 7 FRONTIERS IN HUM. NEUROSCI. 1, (2013) (noting that to be used as lie detection, fMRI researchers would have to be able to show that what is being measured is "actually evidence of deception and not unrelated cognitive processes, and this would have to be determinable for each and every response given by every future individual undergoing fMRI questioning").

128. *See* Kamila E. Sip, et al., *When Pinocchio's nose does not Grow: Belief*

depends on their emotional state, the complexity of the communication, and their need to control the impression they make on others.[129] All of this is not only highly individual, but is context-dependent. As the *Semrau* and *Smith* courts observed, because fMRI experiments are just that—experiments—they lack the emotional weight of real-life situations where the ability to deceive may literally be life or death.

Belief in whether the deception can be detected may also affect the signal that is being measured. In an fMRI experiment designed to determine whether a person's belief in the detectability of their deception affected brain activity, Kamila Sip, et al., had participants commit a theft of either earphones or a USB memory stick.[130] They were told that if they lied without the lie being detected, they could keep the object. They were then interrogated in a scanner.

During some parts of the interrogation, participants believed a polygraph lie detector was activated, and during some parts the participants believed it had been switched off. The "lie detector" was a fake. When the participants believed the (fake) lie detector to be on, the brain activation was significantly greater when they were lying than when they were telling the truth. When the participants believed the (fake) lie detector to be off, however, brain activation from both conditions was reduced, and they were not significantly different from each other, implying that belief in detection affects the fMRI signal.[131] The researchers concluded that the subject's belief in the efficacy of a lie-detection device matters.

In addition to belief in the efficacy of the lie detector affecting the results, it may be that a subject's belief in the lie itself may affect the results. People accused of a crime may be able to convince themselves of their own innocence.[132] This may, in turn, affect the fMRI results. For example, in facial recognition experiments, when the participants believed that they had seen a particular face before, fMRI signals were comparable to when they actually had seen the

---

Regarding Lie-detectability modulates production of Deception, 7 FRONTIERS IN HUMAN NEUROSCI. 1 (2013) ("Deception is inherently social[, involving] not only the creation of a representation that is at odds with physical reality, but also a manipulation of another person's beliefs in a particular context").

129. *See* A. Vrijl, et al., *Cues to Deception and Ability to Detect Lies as a Function of Police Interview Styles,* 31 L. & HUM. BEHAV. 499 (2007) (discussing factors that affect police officers' interviewing accuracy).

130. *See* Kamila E. Sip, et al., *When Pinocchio's nose does not Grow: Belief Regarding Lie-detectability Modulates Production of Deception,* 7 FRONTIERS IN HUMAN NEUROSCI. 1 (2013) (scanning experiment to detect differences in brain activity when participants believed lies could be detected versus when they believed they could not).

131. *Id.* at 6.

132. *See* THE ROYAL SOCIETY, BRAIN WAVES MODULE 4: NEUROSCIENCE AND THE LAW 25 (2011) (raising this issue).

face before.[133] In other words, the truth and lie conditions could not be differentiated.

In sum, deception is a human social behavior. It is complex, and like all complex human behavior, we do not yet know precisely what the connections are to the brain, or how these connections work. The technology is simply not there yet. Neuroscientists are working away at this problem, but the answers are not yet in sight. There is undoubtedly some connection between brain and behavior, but identifying the specifics is still a distant goal. It is far too soon to attempt to demonstrate that linkage through fMRI testimony in court.

V. OTHER COURTROOM USES OF FMRI

A. Criminal Cases: Linking Brain and Behavior

Neuroscience regarding the development of the adolescent brain has had by far the most impact on the justice system. In an important trio of cases, the Supreme Court held that because adolescent brains were still developing, the Eighth Amendment prohibited sentencing juveniles to death (*Roper*)[134] or to life without parole (*Graham*[135] and *Miller*[136]). These cases all relied to some extent on fMRI studies. Notably, the neuroscience involved was general evidence about brain development and the immaturity of executive functions in adolescents rather than any attempt to link brain activity with any particular behavior in any individual. In addition, the inferences drawn from the neuroscience studies were inferences about the group (adolescents) rather than about any individual defendant.

The most common use of brain imaging has been in mitigation at sentencing, especially in death penalty cases. Mitigation evidence

---

133. *See* Rissman et al., *Detecting Individual Memories Through the Neural Decoding of Memory States and Past Experience,* 107 PROC. NAT'L ACAD. SCI. 9849–54 (2010) (discussing experiments).

134. Roper v. Simmons, 543 U.S. 551 (2005), involved an Eighth Amendment challenge to state law permitting the execution of juveniles who were under eighteen at the time of the crime. The amicus briefs of the American Medical Association and the American Psychological association used neuroimaging to argue that adolescents were categorically less blameworthy than adults and therefore did not deserve the death penalty. The briefs, citing neuroimaging research, contended that anatomical immaturity of adolescent brains was related to behavioral immaturity. *See* Brief of the American Medical Association et al. as Amici Curiae Supporting Respondent, *Roper*, 543 U.S. 551 (No. 03-633), at 10; accord Brief of the American Psychological Association & Missouri Psychological Association as Amici Curiae Supporting Respondent, *Roper*, 543 U.S. 551 (No. 03-633) at 9.

135. Graham v. State, 560 U.S. __ (2010).

136. Miller v. State, 567 U.S. __ (2012).

frequently involves brain scan evidence, primarily PET scans,[137] although fMRI testimony is becoming more common. Drawing inferences about behavior from anatomical tools (like PET scans and fMRI) are fraught with difficulties. Apart from the usual problem of distinguishing correlation from causation, there is the problem that multiple brain regions may be involved in a particular function, and that multiple functions may be seen to activate a particular region. Additionally, all the problems of individual variation in brain physiology, lack of standardization of machines and protocols, and the inherent subjectivity of the process of image creation that are problematic in the use of fMRI for lie detection are present in its use for mitigation.

Neuroimaging testimony is often admitted for mitigation, but its effect on the outcome is questionable. The typical argument for mitigation is that dysfunction in an area of the brain (usually linked to the inhibition of violent impulses) diminishes a defendant's culpability. Thus, a life sentence is more appropriate than a death sentence.[138] Juries, however, do not appear to be persuaded.[139]

Despite the seeming futility of presenting neuroimaging studies to the jury, appellate counsel have increasingly based ineffective assistance claims on failure to perform fMRI testing on the defendant. Some of these claims have even succeeded.[140] Curiously, judges may be more impressed with neuroimaging testimony than juries appear to be. In one study, judges asked to sentence a defendant in a hypothetical murder case gave 7% lighter sentences when showed brain scans of the hypothetical defendant than those judges who were not given the brain scans.[141]

---

137. Positron emission tomography (PET) scans measure brain metabolism (glucose and oxygen metabolism and cerebral blood flow. *See* Nora D. Volkow & Laurence R. Tancredi, *Positron Emission Tomography: A Technology Assessment,* 2 INT'L J. TECH. ASSESSMENT HEALTH CARE 577 (1986). It has been around longer than fMRI, but it has a significant drawback: it requires the injection of radioisotopes.

138. *See* O. Carter Snead, *Neuroimaging and the "Complexity" of Capital Punishment,* 82 N.Y.U. L. REV. 1265, 1302 (2007) (discussing the use of fMRI testimony in capital sentencing).

139. *See, e.g.,* Hurst v. State, 147 So.3d 435 (Fla. 2014) (upholding death sentence despite expert PET scan evidence showing brain abnormalities); People v. Smith, 107 P.3d 229, 233–34 (Cal. 2005) (jury sentenced defendant to death despite PET scans showing brain damage); State v. Reid, 2005 WL 1315689 (Tenn. Crim. App. 2005) (despite PET and MRI testimony showing brain shrinkage in the defendant's left temporal lobe, the jury sentenced him to death); Ex Parte Simpson, 136 S.W.3d 660, 661, 665 (Tex. Crim. App. 2004) (sentencing defendant to death despite MRI and EEG testimony); Johnston v. State, 841 So.2d 349, 353–55 (Fla. 2002) (death sentence despite expert PET scan, EEG, and MRI testimony showing decreased frontal lobe activity). In a recent Florida case, however, defense counsel was convinced that fMRI scans of the defendant mitigated the sentence from death to life in prison.

140. *See, e.g.,* Turner v. Epps, 840 F. Supp. 2d 1023 (S.D. Miss. 2012) (granting access to fMRI expertise to support post-conviction petition).

141. *See* Benedict Carey, *Study of Judges Finds Evidence from Brain Scans*

Defense counsels occasionally proffer expert neuroimaging testimony to negate *mens rea*. To prove a crime, the prosecution must prove that the defendant acted with the requisite level of intent.[142] This mental state must be determined by the jury, generally with little to go on other than circumstantial evidence. As with fMRI lie detection, this testimony is rarely admissible. Although PET scans have been offered as *mens rea* defenses in fraud,[143] burglary,[144] and murder[145] cases, and fMRI will undoubtedly be similarly proffered, in none of these cases was the testimony admitted. Even where brain imaging has been admitted for the issue of *mens rea*, it rarely persuades the jury.[146] Jurors are apparently skeptical about the links between anatomical structure and function and behavior.

As well they should be. The relationship between particular structural abnormalities and specific aberrant behavior is far from established.[147] Autopsies of people with severe behavioral difficulties have shown minimal brain abnormalities, while autopsies of people with severe brain damage have shown minor behavioral effects.[148] This does not mean that there is no connection between brain and behavior, only that the connection is complex and not well understood.

There are also profound difficulties in demonstrating a conclusive relationship between the function of any particular brain region and any associated cognitive process.[149] A particular brain region may serve many functions; conversely, many different functions may activate the same region.[150] There is still no direct

---

Led to Lighter Sentences, N.Y. TIMES (Aug. 16, 2012), http://www.nytimes.com/2012/08/17/science/brain-evidence-sways-sentencing-in-study-of-judges.html?_r=0 (reporting on study of judges sentencing a hypothetical murderer).

142. The Model Penal Code requires proof of one of four mental states: acting with purpose or intent; with knowledge; recklessly; or negligently. Model Penal Code § 2.02 (1962).

143. United States v. Mevzinsky, 206 F. Supp. 2d 661, 663 (E.D. Pa. 2002).

144. People v. Herrera, 2003 WL 22962809, at *1 (Cal. Ct. App. 2007).

145. Zink v. State, 278 S.W.3d 170, 177–82 (Mo. 2009).

146. *See, e.g.,* People v. Kumar, 2014 WL 2203744 (Cal. Ct. App. 2014) (jury convicted defendant of first degree murder notwithstanding expert PET scan testimony showing brain damage).

147. *See* Tancredi & Brodie, *supra* note 117 at 288 (noting that "it is highly inferential that the specific abnormal condition relates to a specific set of behaviors").

148. *Id.* (noting that EEG studies have revealed the same kinds of discrepancies).

149. *See, e.g.,* ORRIN DEVINSKY & MARK D'ESPOSITO, NEUROLOGY OF COGNITIVE AND BEHAVIORAL DISORDERS 53–54 (2004) (explaining the difficulty of isolating any particular process because of confounding by the subject engaging in cognitive processes other than the one being studied as well as confounding neural computations).

150. *See id.* at 54–55 (noting that if a "particular brain region is activated by a cognitive process (evoked by a particular task), the neural activity in that

mapping of mental function to specific areas of the brain.[151]

Further, even if there is a connection between brain damage and aberrant behavior, we cannot tell in which direction the connection goes. Whether the observed behavior stems from brain abnormalities or whether behavioral abnormalities affect the structure and function of the brain is still unknown.[152] Thus, inferences about specific links between brain regions and particular behaviors are tenuous at best. The touted potential of fMRI to provide objective insight into socially relevant behaviors remains to be established.

B. Civil Cases

The predominant use of fMRI testimony in civil cases to date has involved challenges to state statutes curbing the sale of violent video games to children.[153] In these cases, defense experts proffered the fMRI evidence to demonstrate a connection between watching violent video games and aggressive behavior in children. Although the testimony was admitted in these cases, the plaintiffs won on First Amendment grounds, while the judges remained unpersuaded about linking violent video games to aggression.[154]

In personal injury cases, while fMRI testimony has not yet made its way into reported decisions, PET scan testimony has been successfully admitted to show brain damage, brain cancer and dementia. Here, imaging techniques are on much more solid footing. fMRI (like PET) is an anatomical tool, and it is quite useful in clinical settings. fMRI testimony will probably find its way into court in these kinds of cases, and as long as the issue is anatomical—was the brain damaged? Where is the damage? What is the extent of the damage?—it should have little difficulty with admissibility. fMRI is an excellent anatomical tool. It is the attempt to link brain activation with behavior that is premature.

---

brain region must depend on engaging that particular cognitive process . . . However, this region may also support other cognitive processes").

151. *See* Poldrak, *Mapping Mental Function to Brain Structure: How Can Cognitive Neuroimaging Proceed?*, 5 PERSPECTIVES ON PSYCHOL. SCI. 753 (2011).

152. *See* Snead, *supra* note 137, at n.101.

153. *See, e.g.,* Entertainment Software Ass'n v. Blagojevich, 404 F. Supp. 2d 1051 (N.D. Ill. 2005) (directing verdict for plaintiff's despite defense expert testimony that fMRI studies showed a link between aggressive behavior and exposure to violent video games in adolescents); Entertainment Software Ass'n v. Granholm, 404 F. Supp. 2d 978 (E.D. Mich. 2005); Entertainment Software Ass'n v. Hatch, 443 F. Supp. 2d 1065 (D. Minn. 2006) (invalidating Minnesota statute); Brown v. Entertainment Merchants Ass'n, 131 S. Ct. 2729(2011) (holding California statute unconstitutional); *but see id.* at 2761–71 (Breyer, J., dissenting) (believing the statute constitutional based on neuroscience studies showing a pattern of aggression after exposure to violent video games).

154. *See Brown,* 131 S. Ct. at 2741 (noting that the fMRI evidence was neither compelling nor conclusive).

VI. IF NOT fMRI, IS THERE A BETTER THOUGHT DETECTOR?

The fact remains that MRI, fMRI, PET, and other diagnostic tools are all anatomical methods that reflect some process distant from actual, physiological brain activity. fMRI measures blood oxygenation levels; PET measures metabolic changes. The assumption made with these techniques is that these changes reflect brain activity.

There are, however, methods that measure actual physiological brain activity in real time. These are electroencephalography (EEG) and magnetoencephalography (MEG). These methods both reflect brain activity in the millisecond range. The EEG measures electrical activity of thousands of neurons immediately beneath the sensor or electrode placed on the scalp.

The EEG, however, has limitations. First, EEG signals can only be measured from the cortex, leaving deep structures of the brain unsampled. Second, the electrical signal emitted by cells in the cortex is distorted by the tissue between the electrodes and the brain. The hair and scalp, the bone and its structure, the brain coverings (dura mater, arachnoid and pia mater), and the overlying blood vessels (arteries and veins) all distort the electrical signals.

Third, the EEG only detects slow activity. The EEG amplifier has high band pass filters that cut off very slow activity occurring at less than once per second, and it has low pass filters that allow only signals that have a slow rise time, cutting out very fast activity. This filtering eliminates the detection of action potentials, so that the EEG signal represents a narrow spectrum made up of slow potentials generated by inputs to dendrites, rather than the action potentials generated as a result of processing in individual cells. This limits the EEG to frequencies of activity in the range of 0.5 per second to 100 per second, too slow for action potentials whose rise time is in the order of one one-thousandth of a second. These limitations make the EEG a good clinical tool, like the MRI, but it is not designed to detect real time action potential firing, only membrane oscillations and dendritic potentials. As such, the technique is not appropriate for measuring complex processes that require real time (millisecond) discrimination, like responding to questions, or identifying photos.

MEG is different. This is a very expensive technique but the only one with the temporal resolution for real time brain physiology. Magnetic sensors can calculate the magnetic signals generated by brain cells.[155] MEGs contain superconductors that work only at very

155. Remember the "right hand rule" in high school physics? The magnetic signal of an electrical event is perpendicular and flows to the right of the electrical axis. This is the theory on which MEG is based.

low temperatures, so that the MEG machine has the sensors immersed in a bath of liquid helium. These sensors detect the small magnetic changes.

The "cap" placed on the subject in MEG tests is actually a 60-gallon hat filled with helium. The detectors pick up minute magnetic signals from the surface of the brain. Because magnetic fields are ubiquitous, the recording must be done in a specially shielded room in order to isolate the magnetic signals to the subject's brain.

MEG also has limitations. First, it is costly, making it available mainly for clinical uses, such as accurately plotting the extent of tumors for surgery, and detecting the initial event in an epileptic seizure, making surgery for epilepsy more accurate and less likely to need follow-up surgeries. Second, subtle changes are beyond current technology. The MEG signal must be extensively analyzed to make it rise above noise levels.

A third limitation of MEG is that the mathematical analysis and processing of the signals has as many decision points and options for "tweaking" as fMRI. Because of the low signal to noise ratio, averaging is required, along with prolonged recording times and difficulties in determining causal events. In technical terms, although not there yet, the MEG is improving and has advantages in determining brain activity in relation to truth versus lying. At present, such reliability and reproducibility is beyond the scope of the method, just as it is beyond the capability of fMRI.

VII. CONCLUSION

Functional brain images—despite their appearance—are not photographs of the brain. The signal measured is a characteristic of blood rather than brain tissue. Poor temporal and spatial resolution makes fMRI a crude representation of neural activity. Despite these shortcomings, fMRI is a great tool for gaining clinical insight into brain structure. fMRI is terrific for revealing areas of brain damage and for surgeons mapping where to resect.

However, using this tool to make inferences about complex human behavior is unwarranted. We make assumptions about the link between blood oxygenation levels and brain activation, and while these are good assumptions in clinical contexts, not much is known about the links between brain activation, blood oxygenation levels and behavior.[156] Deception is complex behavior. We know very little about where it originates in the brain or how it is manifested in action potentials and membrane oscillations.

This is a major problem for neurolaw. Lie detection, mitigation,

156. As one prominent neuroscientist posed the question, "Can one really, truly understand how computers work by opening up a computer chassis and probing the components with a heat gun?" Bandettini, *supra* note 19 at 31.

and even the insanity defense all rely on causal links that have yet to be established. To understand the brain and how it affects behavior, a much wider context is needed. Physiological, environmental and evolutionary factors undoubtedly play a part. fMRI is an anatomical tool, not a behavioral tool. It is a great tool for mapping brain structures and blood oxygenation levels. It cannot, however, reveal our thoughts.