Functional MRI as a lie detector: Its potential as evidence for or against malingering

A head-injury lawyer looks at how brain mapping may impact cases in the future.

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This article will take an in-depth look at the use of fMRI (a neuroimaging technique that accurately represents the locations where cognitive processing is going on within the human brain in real time) for lie detection and malingering.

Background information on MRI and fMRI as tools for studying the brain

Functional MRI (fMRI) is a relatively new variant of the older MRI scanning technology that took snapshots of brain structure based on differences in the tissue characteristics between gray matter, white matter and cerebro-spinal fluid. Like MRI, fMRI generates a powerful magnetic field and uses electro-magnetic pulses into the brain to momentarily realign the atoms in brain fluids and detect a magnetic resonance (MR) signal from the atoms as they spin back to their original position and release energy. But instead of providing a static depiction of the appearance of brain structures like old MRI, fMRI is used as a tool for measuring the real time brain functions that correlate with human behavior.

Sensory perceptions, cognitive operations and emotional experiences in the brain require selective activation of brain cells (gray matter) connected by axonal pathways (white matter tracts). When neurons become active, blood flow is increased to those neurons to deliver more oxygen from the hemoglobin in capillary red blood cells. The increase begins one to two seconds after neuronal activation and peaks at about six seconds, after which blood flow returns to baseline. This physiologic change affects the local magnetic environment and is detectible by fMRI. The red blood cells contain a combination of oxyhemoglobin (hemoglobin plus oxygen) and deoxyhemoglobin (hemoglobin which has already delivered its precious cargo of oxygen).

The oxyhemoglobin is diamagnetic, whereas the deoxyhemoglobin is paramagnetic. A diamagnetic substance is one that has a very weak and negative response to a magnetic field, and is very slightly repelled by one. A paramagnetic substance is one that has a small and positive response to a magnetic field and is slightly attracted to one. This creates a small difference in MR signal in the blood depending on the degree of oxygenation. When neurons are activated, there is a local increase in blood flow which leads to a relative decrease in the concentration of deoxyhemoglobin in the activated brain region.

In 1990, Ogawa and Lee at AT&T Bell Labs discovered that deoxyhemoglobin could be used as an endogenous marker of brain activity during the use of fMRI. This means no external contrast agent had to be injected. They called the technique BOLD which stands for *blood oxygen level dependent* imagery. The temporal resolution of fMRI is practically real time (just 10s of milliseconds behind the physiologic changes being measured) and the spatial resolution is 3mm or less in almost all cortical and subcortical structures of the brain. All measurements are made by computer so no human interpretation is required. Unlike PET scans, fMRI does not require injection of radioisotopes or other substances into the bloodstream. Thus fMRI is capable of a safe, painless, non-invasive investigation of brain function during the performance of a mental task.

So how does fMRI map brain function? By honing in on and highlighting the particular areas of the brain that are drawing the most oxygen from capillary red blood cells within a six-second window of the commencement of the selected brain function, be it a private unspoken answer to a question; an audible, spoken answer to a question; a fear response to a scary photograph; an anxiety response to a highly personal question; or a pleasure response to a sexy photo.

Existing clinical uses of fMRI

The most common use of fMRI in the United States is pre-surgical mapping of areas of the brain that must be spared (such as speech and motor centers) during surgery for a brain lesion, a tumor, an atrio-venous malformation or to stop

epileptic seizures, or during surgery on the brain to stop seizures by removing brain tissue.

Experimental non-legal uses of fMRI

The technology behind fMRI; the medical, business and legal applications of fMRI; and the studies attempting to validate those applications; are still in their relative infancy. The next few years will likely show revolutionary advances in these three areas. Neuro-radiologist, Scott Faro, M.D., has predicted that new, smaller, portable fMRI machines may one day be used at airports to supplement x-ray detection for weapons or bombs. Laurence Tancredi, M.D., clinical professor of psychiatry at NYU Medical School, has predicted the accuracy of fMRI as a lie detector will be enhanced in the future when it is coupled with transcranial magnetic stimulation (TMS). TMS is being used clinically to treat medication-refractive depression, migraine headaches and other medical conditions. Dr. Tancredi notes it has the capacity to block or allow specific areas of the cortex to function (much like injection of a local anesthetic) and this could be used to enhance memory function in the hippocampus (to help with people who have tried to suppress memories) as well as isolate the activity of the anterior cingulate, one part of the brain that resolves conflicts and which is known to be active during lying.

Some medical clinics are currently trying out fMRI as a new method of biofeedback to control chronic pain. Henry Greely, professor of law and genetics at Stanford, has predicted that one day fMRI may be used forensically to determine whether or not a compensation claimant's assertion that he suffers chronic pain is valid, by showing whether or not pain-sensing fibers are firing and transmitting messages to pain-detecting areas of the brain. He has also predicted that fMRI might one day be used during voir dire either as a lie detector or as a means of detecting racial bias or other bias in the minds of potential jurors.

fMRI has already made it into the business world. Two start-ups, called Sales Brain of San Francisco (www.salesbrain.net) and Neurosense (www.neurosense.com) of Oxford, England, are using fMRI as consultants in neuro-marketing to measure the brain response of test group consumers to advertising. They purport to measure unconscious brain responses to packaging, point-of-sale displays, marketing buzz words, commercial jingles, ad photos and other advertising tools. The idea is to see which version of a marketing campaign most strongly and consistently lights up the parts of the brain associated with the desire to get, have or consume something. Will this work? Only time will tell.

The existing methods of lie detection

• ***Polygraph***

The world over, the most commonly used device to detect lying is the polygraph machine. It is being used right now in Iraq and Afghanistan by American forces during interrogation to test the veracity of volunteer informants and POWs believed to have important information**.** The term *polygraph* refers to the fact that the machine measures several different bodily responses to interrogation at the same time. The first crude polygraph was invented by American, James Mackenzie, in 1902. Invention of the modern polygraph has been attributed to John Larson, a UC medical student, in 1921. Just four years later, the police began using polygraph in criminal interrogation and investigation.

The modern polygraph gathers three kinds of data to assess the probability a person is lying. These are changes in heart rate (HR) and blood pressure, which are measured by a blood pressure cuff; changes in depth of and rate of respiration (RR) measured by a pneumograph wrapped around the subject's chest; and changes in galvanic skin response (GSR) which are measured by electrodes attached to the subject's finger tips. When a person is aroused emotionally, his sympathetic nervous system is activated, and it activates the sweat glands in the skin, which make his skin a better conductor of electricity. The theory goes that when a person is lying, he experiences stress that raises his heart rate, makes him breathe faster and sweat more.

Some contemporary polygraph operators prefer the term, *psychophysiological detection of deception,* to *polygraph*. The polygraph rests on the assumption that psychophysiologic changes consisting of increases in heart rate, respiratory rate and electrical conductivity of the skin in response to certain questions are the result of lying, rather than other mental states such as fear related to being suspected, being tested or being asked highly personal and embarrassing questions.

Experienced, qualified polygraph operators boast an accuracy rate of 95 percent or better in lie detection, but independent studies have shown a low of 70 percent and a high of 85 to 90 percent. New Mexico is the only state that generally allows polygraph evidence. The other 49 states either ban it outright or allow it into evidence by stipulation only.

California Evidence Code section 351.1 allows polygraph evidence in court by stipulation only. A state by state summary of statutes and legal rulings on polygraph admissibility is available online at www.polytest.org. This summary is provided by Global Polygraph Network (GPN), the largest provider of polygraph services and referrals in the world, in business since 1987.

In *United States v. Scheffer* (1998) 523 U.S. 303, the U.S. Supreme Court held that a rule of evidence applicable solely to military courts that banned all use of polygraph evidence was constitutional, but the 4-3 majority had no consensus on

the rationale. Judicial skepticism of the reliability of polygraphs dates back to the Frye decision of the U.S. Circuit Court of the District of Columbia in 1923, which banned it from evidence in a murder trial on the grounds that the rationale for the test had not been generally accepted by the relevant scientific community. What few people know is that the *polygraph* at issue in Frye was not the kind that measures HR, RR and GSR, but simply a blood pressure cuff utilized by William Marston during a jailhouse interview of the criminal defendant. There is a fascinating description of the facts of the Frye case at http://jimfisher.edinboro.edu/forensics/frye.html

Guidelines for proper administration and interpretation of polygraph have been published by the American Polygraph Association and, more recently, by ASTM. While polygraph results are rarely used in court, they are used out of court for many purposes. These include verification or impeachment of witness testimony; pre-trial negotiation and plea bargains; monitoring of sex offenders; employee security clearance by law enforcement agencies and some private companies; theft investigations; parole violation and child custody hearings; cheating and infidelity in relationships (especially where concern about STDs and AIDs exists); and testing of sports participants for suspected violation of contest rules and use of illegal, performance-enhancing substances. If you have legal questions about polygraph, you may want to contact attorney Gordon Vaughan, general counsel for GPN, who works at the Colorado law firm of Vaughan & DeMuro.

What concerns exist about the validity of polygraph (its ability to accurately measure intentional deception)? The result of a polygraph depends on interaction between an interrogator and a suspect and interpretation of data by the polygraph operator, which may lead to false positives. The major concern is that the best the polygraph operator can do is to infer lying from psychophysiologic changes that occur during response to particular questions; yet there is no one pattern of such changes that is unique to lying. In 2003 the National Research Council (NRC) published a report finding the polygraph unreliable for screening government employees at the Department of Energy that began in the wake of the Wen Ho Lee spy scandal.

The NRC was troubled because of their finding that there is no single underlying process for all the psychophysiologic factors that polygraph measures, and that the test subject can use conscious control to affect the results. Critics of polygraph worry that hardcore criminals (sociopaths) may be able to stay calm during the exam, while innocent people who are vulnerable to intimidation or anxiety may look like liars on the test, because their stress level rises from undergoing the procedure. Gary Ridgeway, the Green River Killer, and CIA double agent Aldrich Ames both passed polygraph tests and resumed their criminal activities.

• EEG and lie detection

In 1988, researchers Emmanuel Donchin and Lawrence Farwell used an EEG helmet to find the equivalent of "guilty knowledge" in test subjects, such as crime scene details very few people knew. They called their technique "brain fingerprinting." When a person is confronted with a bit of information he has been concealing and does not expect anyone else to know, the surprised brain emits a specific brainwave pattern on EEG called a MERMER (a memory and encoding-related multifaceted encephalographic response), which is also called P300 for short. Although this technique has never made it past the Frye test or the Daubert test for admissibility of reliable scientific evidence, it was used successfully in 2000 to free a man named Terry Harrington from an Iowa prison where he had served 22 years of a sentence for a murder he did not commit. When questioned about crime scene details only the killer would know, Harrington did not emit a MERMER and when asked questions about his alibi he did, which tended to exculpate him from guilt and corroborate his alibi. When this evidence was presented to the key witness for the prosecution, he recanted his false testimony and Harrington was acquitted.

• Near-infrared brain scans

In 2003, Dr. Britton Chance, a biophysicist at the University of Pennsylvania, tried out a device consisting of a headband with near-infrared light emitters and detectors. The sensors were used to read small changes in an area of the pre-frontal cortex that gets stimulated by lying. The stimulus is detected when the person decides to lie, which occurs before he even tells the lie. The device is still in the developmental stage, but Dr. Chance has high hopes for it.

• Thermal imaging

In 2002, investigator A.A. Moenssens reported using a heat-sensitive camera to detect lies by finding increased blood flow (with increased heat) around the eyes that occurs when a person lies. This technique is also in the developmental stage.

Can fMRI give us greater certainty that we are really measuring deception?

There are three corporations now using fMRI to detect lying. Cephos of Tyngsboro, MA (www.cephoscorp.com) and No Lie MRI of Tarzana, CA (www.noliemri.com) use fMRI only, based on their belief that polygraph is unreliable. Their technique uses fMRI as a stand-alone test for detection of lying. The third company, Truth Test Technologies of Philadelphia, PA (www.truthtesttech.com) – also known as T3 – uses polygraph and fMRI. By using both, T3 says it can boost the overall accuracy of lie detection from an average of 80 percent (with polygraph only) to approximately 95 percent (the accuracy level of DNA fingerprinting). T3 acknowledges that polygraph is not a wholly reliable means of detecting lies. On the other hand when fMRI is used with polygraph,

T3 is certain of accurate testing results. Their consultant for polygraph is Nathan Gordon, a Master of Science in Criminology and the founder/director of the Academy for Scientific Training in Philadelphia with branches worldwide. Gordon has personally done over 11,000 polygraph examinations. He has published a textbook and many articles on polygraph, and has testified as a polygraph expert in county, state, federal and military courts.

What research exists to substantiate the validity of fMRI as a lie detector? The very first abstract on the subject was by Liu, H. et al., Lie Detection Using fMRI, in Proc. Intl. Soc. Mag. Reson. Med. (9) 2001. The very first research paper on fMRI as a lie detector was by Spence, S.A. et al., Behavioral and Functional-Anatomical Correlates of Deception in Humans in Neuroreport 12 (13) 2849-2852 (2001). A seminal and oft-quoted paper on Neuroimage in 2002 was by Daniel Langleben, an associate professor of psychiatry at University of Pennsylvania Medical School. He had a group of 18 volunteers draw cards and then deny or confirm, truthfully or falsely, that they did or did not hold certain cards while in the fMRI machine. The questions were relayed through headphones. The participants answered by pushing one of two buttons, which enabled them to respond without moving their heads in the machine. Langleben was able to identify five areas of the brain that became activated in liars that were not activated in the brains of truth tellers, including the anterior cingulated gyrus which is involved in attention and self-monitoring. Langleben was excited about the potential of fMRI for lie detection services, but cautioned that it would take years to work the kinks out, not the least of which was the non-portability of the huge and heavy fMRI machines and the high cost of scans.

Board-certified neuroradiologist, Scott Faro, M.D., is one of the founders of the American Society of Functional Neuroradiology and the Director of the Functional Brain Imaging Center at Temple University School of Medicine in Philadelphia, PA. Dr. Faro and his group began fMRI lie detection research in 1999. On November 29, 2003, he presented their research paper to the Radiological Society of North America in which he described his use of fMRI in lie detection. Dr. Faro had 11 normal volunteers. At his request, six of them fired a toy gun that shot blank bullets and lied about it, while the other five did not fire a gun and told the truth. The result was that polygraph and fMRI both correctly distinguished the liars from the truth tellers in 10 cases. The eleventh was inconclusive.

The fMRI showed robust activation of 14 different areas in the brains of the liars, whereas truth telling activated only seven: The pre-frontal area, where we make inferences about what is in the minds of others as well as executive decisions about how we will behave in a given set of circumstances; the caudate nucleus (the part of the basal ganglia that inhibits action, and could inhibit the urge to tell the truth); and the amygdala (the brain's fear processing center) were highly active in the brains of liars. Why would lying recruit double the number of brain areas? Dr. Faro says that intentional deception is a more complex cognitive process than simply telling the truth.

To lie means to understand what is being asked, to determine what the correct response is, to entertain the thought of giving an incorrect response, to structure a phony response in the most plausible way, to assess the probability of being caught in the lie, to weigh the consequences of lying vs. admitting the truth, to make the decision to lie, to inhibit the urge to tell the truth and then pull the trigger (i.e. execute the lie while making every effort to stay calm and not spill the beans). Just as there is no one identifiable seat of consciousness in the brain, there is no one lie center. Deception involves a whole network of different brain regions, with individual variation. It is the cognitive complexity of lying versus telling the truth that makes fMRI an accurate means of lie detection. Dr. Faro believes strongly enough in the accuracy of fMRI for lie detection that he is serving as a consultant in functional neuroimaging to T3.

Costs and benefits

The average cost of a polygraph is $750, whereas the range for fMRI is between $5,000 and $10,000. T3 is planning to charge a flat fee of $5,000. At this moment in time, polygraph is admissible only by stipulation and no rulings on the admissibility of fMRI for the purpose of lie detection have been made. Dr. Scott Faro has been quoted as saying: "People say fMRI will cost me more than a polygraph, but what's the cost of a six-month jury trial? What's the cost to America for missing a terrorist? If this is a more accurate test, then I don't see any moral issues at all. People who can afford it and believe they are telling the truth are going to love this test." Faro is sensitive to the concerns of civil libertarians regarding fMRI, but says it has real social utility, akin to the use of DNA fingerprinting by the Innocence Project to help innocent people get out of jail. If you are convinced of your innocence and willing to take a test to prove it, he believes fMRI can be of real help. For criminal suspects who are indigent, they would have to seek governmental assistance in paying for the test.

Where things stand right now

Neuroscientists differ in their view of when fMRI will be ready for forensic use, such as interrogation of criminal suspects. Some say it is ready or nearly ready, while others say it will be many years before this can happen if it ever can. Lawyers have raised the issue of whether use of fMRI will trigger the protection of the Fifth Amendment privilege against self- incrimination and require Miranda type warnings, unlike fingerprint and DNA evidence which can be legally compelled during criminal investigation.

Not everyone is convinced of the validity and reliability of fMRI as a lie de-

tector. Sean A. Spence of the Longley Center at the University of Sheffield in England has written a paper questioning the forensic use of fMRI as a lie detector, published in Legal and Criminal Psychology, vol. 13(1) Feb. 2008, pp 11-25. In his article, Spence says there are 16 peer-reviewed research papers on fMRI as a lie detector which have varying results and which have not been able to discern a distinctive fMRI pattern associated with telling the truth. He makes the point that accurate lie detection should involve a demonstration that the neural pattern associated with truth telling did not appear when the subject responded. Spence claims the investigators have not been able to replicate their successes in lie detection using fMRI. Another concern raised by some people is that using fMRI to find the liars, when you have a closed group of 10 subjects and you know in advance that half are lying, is like shooting ducks in a barrel. It is way easier than determining whether one individual is lying in an open-ended situation, where you just don't know. Where is the literature showing that one person can be subjected to highly accurate lie detection by fMRI?

Dr. Faro has answers that address these concerns. He says that the variability one sees in the peer-reviewed literature is a result of different fMRI methodologies. Each of the three companies now offering fMRI services for lie detection uses slightly different methodologies which at this time are intellectual property secrets. All three companies have patent applications pending. He believes that within the next few years, the patent issues will be sorted out and cleaned up, and we will either have a situation where all three companies are allowed to operate on the basis of separate patents or the three companies merge into one company using one method. He expressed confidence that the resolution of the patent issues will not hold up the industry, which has been described as having one of the "breakthrough ideas" for 2008 by the Harvard Business Review.

Dr. Faro says the published studies performed so far have looked at changes in regional brain blood flow in a group of subjects (group analysis), and there is no published literature at this time describing the results of individual subjects who are taking part in a lie detection test. This is not because the research hasn't been done. It's because the researchers have deliberately withheld publication. Why? Because of the pendency of their patent applications. Dr. Faro has assured me that the companies offering fMRI for lie detection have done single-subject testing and have worked out their own methodologies to perform it. Although he could not discuss T3's methodology for single-subject testing, he indicated that it took into account the kind of slight individual variation in neuroanatomy and neurophysiology one sees in the brains of different people.

Privacy concerns about fMRI

On top of questions about the validity and reliability of fMRI, certain bioethicists have raised privacy concerns, claiming that fMRI could be abused as a mind reading tool and that when used for lie detection, fMRI could uncover a variety of brain conditions (tumors, aneurysms, blood vessel malformations or early Alzheimers) that trigger a complex series of policy decisions about medical privacy, whether to disclose, how to disclose and so forth. Dr. Faro says that IRBs. (Institutional Review Boards) are capable of balancing individual privacy concerns with other societal interests, and coming to a reasonable conclusion. IRBs have authorized all of his group's fMRI research projects and those of other groups who have published in this area.

Could fMRI be used someday to test for malingering?

In personal injury lawsuits and workers' compensation proceedings, a certain percentage of cases turn on whether the plaintiff or the applicant is consciously faking bad, i.e. deliberately feigning symptoms or exaggerating the severity of symptoms, to obtain compensation that he does not deserve. Neuropsychologists have devised a number of written test instruments that purport to uncover malingering, such as the MMPI Fake Bad Scale.

The MMPI FBS makes a questionable link between certain types of psychopathology evident from the test and the probability of malingering. Tests like the MMPI FBS are controversial for a number of reasons.

First, someone who has pre-existing psychopathology can still sustain a real physical injury with real pain; and someone with chronic pain can develop anxiety, depression, or both, as a consequence. Secondly, non-existent or mild findings on objective tests do not necessarily prove lack of injury or pain. They may just indicate that our detection technology is still not sensitive enough to find an organic correlate of clinical dysfunction.

Another type of written test instrument (like the picture recognition test known as the TOMM or test of memory malingering) rests on an inference of malingering if the examinee scores worse than someone who responded by the chance flip of a coin. Do such tests really prove malingering and are they sensitive to the presence of mild brain injury? Plaintiff and defense experts disagree.

While defense experts say the only plausible explanation for doing worse than chance is deliberate fakery, plaintiff experts say such a result can occur due to fatigue, learned helplessness and other factors. They also say that no one written test can answer the question of malingering, and that a test like the TOMM must be viewed within the context of all other written test results: the clinical history before and after the incident; occupational history before and after; statements of fact witnesses who knew the plaintiff well before and after; auto accident reconstruction of traumatic force applied to the head and neck; whether the plaintiff's behavior is expected or unexpected following a concussion; and other relevant factors.

If fMRI is one day accepted as an accurate test of lying on specific questions, could it also be used to prove malingering of a medical, neurological or psychiatric condition or to enhance the credibility of a plaintiff claiming to have sustained such a condition from an injury caused by the defendant? This is a complex subject, and one would expect that plaintiff and defense lawyers will come up with different answers.

The legal framework that may govern use of fMRI

On the criminal side, commentators predict that the Fourth, Fifth and Sixth Amendments will be implicated by the use of fMRI in lie detection. The Fourth Amendment, which prohibits searches of a person's private space without a valid search warrant, could be used to block fMRI on the grounds that it reads minds, and thus violates mental privacy.

The Fifth Amendment privilege against self-incrimination could be raised on the grounds that reading a person's mind with fMRI violates the criminal suspect's privilege to remain silent. The Sixth Amendment right to jury trial in criminal cases may be used to exclude fMRI evidence as invading the province of the jury on the issue of the defendant's guilt. How these rights would be balanced against the people's right to indict, try, convict and punish criminals for their crimes cannot be predicted.

What about the civil side? The issue regarding jury trial could be raised via state constitutions that have a provision similar to the Seventh Amendment guaranteeing jury trials in certain kinds of civil cases. One interesting area would be balancing the plaintiff's right of mental privacy versus the defendant's right to hire an expert to conduct a mental examination of the plaintiff in cases where the plaintiff has put his mental condition in issue. Traumatic Brain Injury (TBI) cases and psychiatric injury cases are both the kinds of personal injury cases that do put the plaintiff's mental status in issue, and in many states the defense has been able to obtain court orders allowing their neurologist, psychiatrist and/or neuropsychologist to interview and test the plaintiff. On the other hand, plaintiffs have been able to exclude certain interview topics as irrelevant and harassing; and they have kept out certain types of tests as "junk science" that does not meet their state's standard for reliable scientific proof, be it a Frye standard or a Daubert standard.

Based on how such issues have been handled with other techniques, I assume there would be quite a bit of state to state variation on how courts will rule. Opportunities abound for knowledgeable attorneys on both sides of personal injury cases to make law and leave an impact in this fascinating brave new world where cutting-edge neuroscientific technologies suddenly invade the courtroom. Dr. Faro and I are in agreement that if fMRI test results are admitted for establishing or impeaching credibility or for tending to show or not show malingering, there should be a limiting instruction by the judge that the fMRI evidence is but one piece of evidence that should be viewed within the context of all the other evidence bearing on the issue, and should not be given undue weight or used to decide an issue without regard to other relevant evidence.

One reason for this is that even if a person is lying, we don't know why. Is it because he is faking testimony to avoid jail or faking an injury to obtain compensation he doesn't deserve, or is it because he wants to conceal personally embarrassing information, to make himself look better than he really is, to protect the reputations of others, to spite the examiner or other reasons that do not equate with guilt? Another reason is that allowing a machine to decide a highly complex fact question for the jury without the input of an experienced neuropsychologist, neuropsychiatrist or other expert on the proper use and abuse of mental test results, would invade the province of the jury and deprive them of useful explanatory testimony that put the fMRI result in perspective.

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