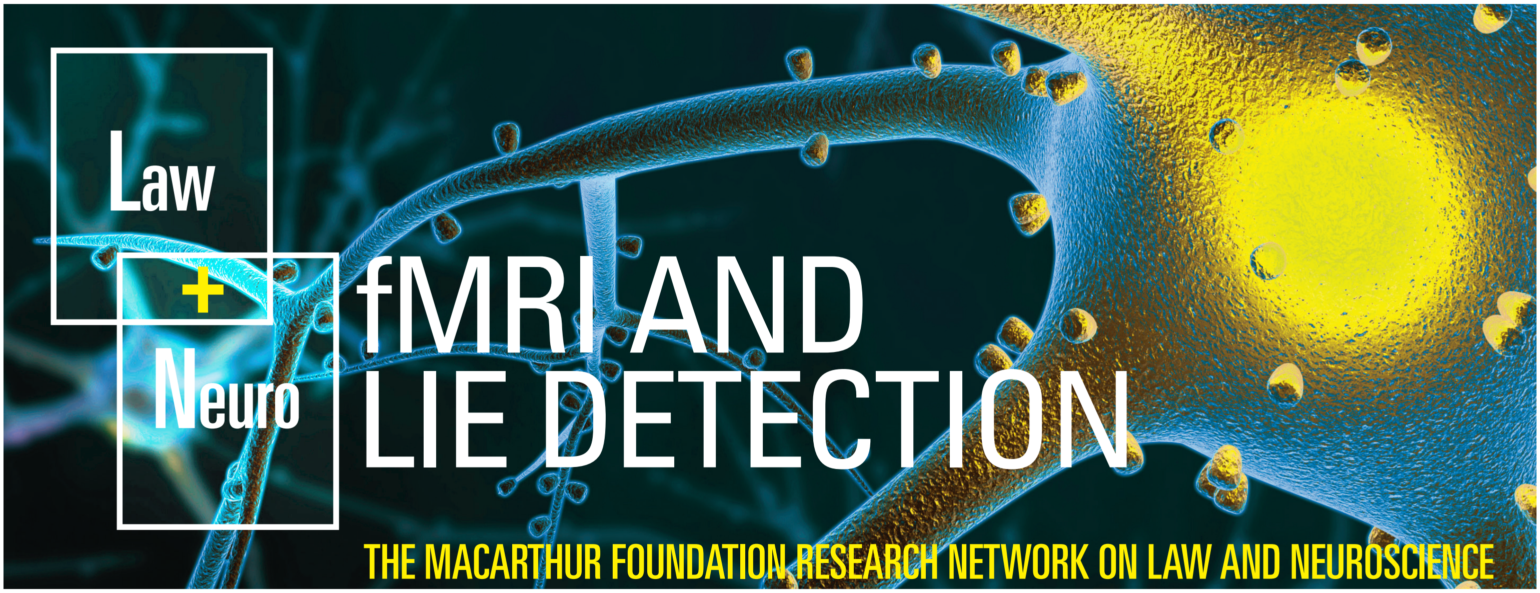

fMRI AND LIE DETECTION

THE MACARTHUR FOUNDATION RESEARCH NETWORK ON LAW AND NEUROSCIENCE

In September 2012, the Sixth Circuit Court of Appeals, citing Federal Rule of Evidence 702 and Rule 403, agreed with the trial court's exclusion of fMRI-based lie detection evidence in the fraud case of *United States v Semrau.*

A scant month earlier, Judge Eric M. Johnson of the Maryland Sixth Judicial Circuit, Montgomery County, had refused to admit potentially exculpatory fMRI lie detection evidence in the murder trial of *State v Gary Smith.* Citing the *Frye* standard, Johnson wrote, "It is clear to the Court that the use of fMRI to detect deception and verify truth in an individual's brain has not achieved general acceptance in the scientific community."

While research on fMRI-based lie detection has continued, the general consensus in the scientific community regarding its probative value remains the same. This brief explores why.

WHAT IS fMRI?

For more than a decade now, scientists have been exploring the potential of functional magnetic resonance imaging, or fMRI, to assess increased activity in brain regions associated with the cognitive processes required for lying.

fMRI does not measure neural activity directly. Instead, it measures small and variable changes in the ratio of oxygenated to deoxygenated blood in the brain when a particular task is performed or stimulus presented—the so-called BOLD, or blood oxygen level-dependent, response. Firing neurons, like working muscles, require oxygen; follow the trail of oxygenated hemoglobin, and you find neural activity.

LIES, DAMNED LIES, AND BEING COOPERATIVE

The most fundamental question scientists raise when reviewing fMRI lie detection research is this: Do these experiments actually examine lies?

The typical experimental paradigm involves "instructed" lies: a subject is given detailed instructions about how and when to lie, then placed in a scanner. Does conscientiously following those instructions constitute lying? Many researchers worry that the answer is no, rendering the experimental results irrelevant.

A distinct but related question arises from the poorly defined nature of the real-world lie. Two equally false statements—"Of *course* I remember you" and "No, I didn't kill him"—may be as distinct neurally as they are morally. Similarly, an often-repeated lie or one first told many years ago might look markedly different from an unpracticed or recent lie.

A statement based on faulty memory ("I never said that") may not trigger any neural activity associated with deception at all. There is some evidence to suggest that fMRI scanning will detect the subject's belief, even if that belief isn't borne out by the objective truth. In a 2010 memory experiment supported by the Research Network and conducted by neuroscientist Jesse Rissman and colleagues, the brain activity observed when subjects recognized a face was comparable to that observed when subjects *believed* they had seen a face before but hadn't.

PROBLEMS OF INFERENCE

It is impossible to infer a specific mental process solely on the basis of brain activity in a particular region, or even in a particular set of brain regions. A single brain region is often involved in a number of mental processes, and a mental process often involves multiple areas of the brain.

In 2014, neuroscientist Martha J. Farah and colleagues published a meta-analysis of the fMRI-based lie detection literature to date. Like the meta-analysis performed by neuroscientist Shawn Christ and colleagues in 2009, the study reveals both variability in the particular brain regions activated across experiments and some notable consistency. The regions that consistently showed deception-related activity were the ventrolateral and dorsolateral prefrontal cortex, inferior parietal lobe, anterior insula, and medial superior frontal cortex. Predictably, those regions are activated during other cognitive processes, as well, in particular, those processes that form part of what we call "executive control," e.g., planning, working memory (the system that provides for temporary storage and manipulation of information), inhibitory control (the ability to suppress actions and resist interference from irrelevant stimuli), and attention. Even the instructed lie is cognitively complex: a subject must remember a set of circumstances, attend to stimuli that vary in their significance or salience, decide to lie, suppress the truth, and choose among relevant and plausible details.

CONFOUNDS: DO WE KNOW WHAT WE'RE MEASURING?

Even if instructed lies *are* lies, and there is some common physiological ground shared by all lies, experimental confounds in most of the studies to date make it impossible for researchers to know whether the neural activity measured is associated with lying or with something else.

A 2008 experiment by neuroscientist Jonathan Hakun and colleagues, for example, included the following finding: Brain activation was observed *whenever* the target or "lie" stimulus was presented, independent of whether the subjects were actually lying about the stimulus at the time. Was the brain activation a result of deception, then, or attention, that is, the salience of the stimulus? This study calls into question many prior published reports that used a similar paradigm, as the brain activity in those studies may not reflect neural responses to deception.

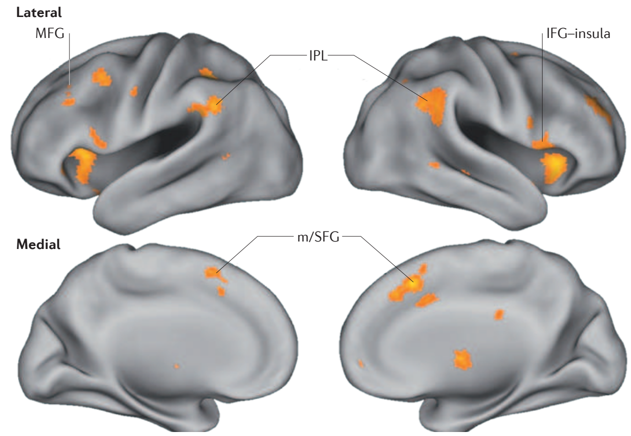

FIGURE 1. Results of the ALE analysis of the functional MRI "deception" literature revealing regions consistently implicated in deception across studies. The meta-analysis was performed over 321 foci from 28 independent statistical contrasts between lie and truth conditions reported in 23 different studies. As noted by others, no region was active in all, or nearly all, studies.

Neuroscientist F. Andrew Kozel and colleagues analyzed data from three independent "mock theft" experiments in which subjects were instructed to look at two objects, select one, take it from a drawer, hide it in a locker containing the subject's personal belongings, and then deny having taken either object. Accuracy rates for those mock theft experiments range from 71 to 90 percent. But when subjects have more and richer memories of one object than another, how much of what's being detected is deception and how much memory? A subsequent 2012 study by Mathias Gamer and colleagues suggests that memory may be a critical confound in many prior studies.

Variables that can prejudice results aren't limited to those inadvertently introduced in research studies. Blood flow itself is influenced by a variety of factors independent of neural activity, including age, vascular capacity, and medication. The fMRI results offered in the Semrau case included a confound likely to be unavoidable in civil or criminal applications of the technology: the length of time between the fMRI and the event in question. Relatively little research has been done on how such variables as subject fatigue, anxiety, fear, the presence of a perceived threat, or practice affect fMRI results.

The uninstructed lie

In contrast to nearly all other studies to date, one fMRI data set shows brain activity during genuine dishonesty—that is, dishonesty related to a freely exercised choice to lie. It was the result of an ingenious experiment published in 2009 by neuroscientists Joshua Greene and Joseph Paxton.

The pair asked participants to predict the outcome of random computerized coin flips while undergoing fMRI. The experiment was presented as an inquiry into paranormal ability to predict the future; the supposed hypothesis was that predictive ability improved when predictions were not made public in advance and were associated with financial gain or loss.

It was a cover story that both encouraged participant honesty (to test the hypothesis adequately required them to tell the truth) and gave them the opportunity to lie (in some trials, they believed they would be self-reporting their success at prediction). In reality, the study was an attempt to determine what makes people behave honestly when they are confronted with an opportunity for dishonest gain.

Throughout a series of "opportunity" (the "opportunity" being to lie) and "no opportunity" trials, participants made their predictions, believing them to be either private or public, depending on the trial. Researchers then classified the participants as honest, dishonest, or ambiguous based on the probability of their self-reported percentage of wins in the opportunity trials. Subsequent fMRI data analysis revealed that increased activity in the prefrontal cortex—anterior cingulate and dorsolateral and ventrolateral prefrontal cortices—was associated with the decision to lie in the dishonest group. Interestingly, an even greater increase in prefrontal cortex activity in this group was observed in connection with the decision to refrain from lying. In other words, when individuals who had shown themselves willing to lie passed up the opportunity and instead reported a loss, prefrontal cortical activity was even higher than when they lied. (Whether this increase is due to considering deception, resisting temptation, or something else is currently unknown.) In the honest group, no significant effects were observed when choosing not to lie.

COUNTERMEASURES: DETECTING A LIAR AND A CHEAT

Another serious obstacle to using fMRI for lie detection in the real world is that very little research exists on countermeasures, actions taken to make test results misleading or unusable. Moving during scanning or not following instructions can ruin a test, but they're also likely to be spotted. More worrisome is whether unnoticeable physical or mental strategies could nonetheless effectively interfere with patterns of neural activity or signal strength.

One study that looked at countermeasures with respect to fMRI lie detection, conducted by Giorgio Ganis and colleagues in 2011, featured prominently in the Gary Smith murder trial. Study participants were instructed to use a series of covert actions, such as imperceptibly moving a left index finger or left toe, just before pressing the response button each time they saw irrelevant dates in a series. In trials without the countermeasure, researchers were able to detect deception with 100 percent accuracy. When the countermeasure was employed, detection accuracy fell to just 33 percent.

A 2015 study by Melina Uncapher and colleagues, this one of memory, showed that participants could successfully conceal or feign memory for faces. Interestingly, and some might say discouragingly, the study showed that both the magnitude of hippocampal activity—a region long known to be important for memory—and distributed neural patterns could be manipulated by retrieval strategies.

POTENTIAL PROBLEMS OF VALIDITY

Many scientists argue that the conclusions drawn from fMRI "lie detection" experiments conducted to date are only valid within the context of the experimental data.

Group data might not be able to tell us what we need to know about an individual. The holy grail of lie detection is to distinguish truth from lie reliably at the level of the individual subject and at the level of the individual question. But most of the studies conducted on deception to date focus on truth vs. lie differences averaged over multiple subjects and trials.

A sufficient amount of group-averaged data can indicate that a certain pattern of neural activity is frequently associated with a particular experimental condition. However, they cannot tell us whether the pattern of activation is not also common to other experimental conditions (or mental processes). Nor, for the moment, can they shed much light on whether fMRI can reliably detect lies at the level of the individual subject or question. In his testimony during the Semrau trial, Cephos Corporation CEO Steven Laken, who conducted the fMRI lie detection tests submitted as evidence, confirmed that they did not indicate whether Dr. Semrau responded truthfully as to any specific question and that it was "certainly possible" that Dr. Semrau was lying on some of the particularly significant questions.

Experimental conditions often poorly approximate the real world. To date, fMRI studies have focused on detecting lies about an event that just occurred. The event often has no personal relevance and no consequences. Real-world fMRI lie detection focuses on events or facts that are likely to have occurred months or even years before, are deeply relevant to the subject, and have serious consequences. Little is known about whether real-world and experimental conditions yield similar results.

The sensitivity and specificity of fMRI lie detection have not been established. No diagnostic tool is perfectly accurate. Antiviral software sometimes detects threats that aren't there; mammograms miss tumors. The probative value of fMRI-based evidence depends on knowing how many lies the tool misses and how often it identifies the truth as a lie; few research studies to date have reported such data.

Findings may not be generalizable to other populations. fMRI studies typically are conducted on undergraduates and other healthy younger adults. Even if we know that there is neural activity in particular regions under the condition of lying when subjects are younger and healthy—a matter of debate, as already discussed—do we know anything at all about what to expect from a woman of 70, or someone with a mental illness?

PRINCIPLED OBJECTIONS

At present, many of the issues that concern the scientific community with respect to the use of fMRI for lie detection are likely to be problematic for the legal community, at least in most contexts. In fact, much of the existing research on deception has no bearing on the question that matters most to judges, lawyers, defendants, and juries, i.e., "Can fMRI-based lie detection methods provide a legally relevant answer to a specific question?"

Most scientists—including many who have reported detecting lies in the laboratory with a high degree of accuracy—agree that more and different research will need to be conducted before fMRI-based lie detection is ready for its day in court.

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This brief is produced by the MacArthur Research Network on Law and Neuroscience. Supported by the John D. and Catherine T. MacArthur Foundation, the network addresses a focused set of closely-related problems at the intersection of neuroscience and criminal justice: 1) investigating law-relevant mental states of, and decision-making processes in, defendants, witnesses, jurors, and judges; 2) investigating in adolescents the relationship between brain development and cognitive capacities; and 3) assessing how best to draw inferences about individuals from group-based neuroscientific data.

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