Functional MRI Lie Detection: Too Good to be True?

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Neuroscientists are now applying a 21st-century tool to an age-old question: how can you tell when someone is lying? Relying on recently published research, two start-up companies have proposed to use a sophisticated brain-imaging technique, functional magnetic resonance imaging (fMRI), to detect deception. The new approach promises significantly greater accuracy than the conventional polygraph—at least under carefully controlled laboratory conditions. But would it work in the real world? Despite some significant concerns about validity and reliability, fMRI lie detection may in fact be appropriate for certain applications. This new ability to peer inside someone's head raises significant questions of ethics. Commentators have already begun to weigh in on many of these questions. A wider dialogue within the medical, neuroscientific, and legal communities would be optimal in promoting the responsible use of this technology and preventing abuses.

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Essential to the working of modern legal systems is an assessment of the veracity of the participants in the process: litigants and witnesses, victims and defendants. Falsification or lying by any of these parties can and does occur. Outside the legal system, detection of deception is also of critical importance in the corporate world and in the insurance industry, as illustrated by the practice of hiring private investigators to follow and videotape disability claimants. Because human beings can be very skilled at lying[1,2] and, in general, are poor at determining when they are being lied to,[1–3] scientific, objective methods for determining truthfulness have been sought for decades.

The most widespread objective method for assessing veracity is multichannel physiological recording, commonly known as the polygraph or lie detector.[4,5] This approach is based on the fact that the act of lying can cause increased autonomic arousal. Changes in autonomic arousal are detected by measuring pulse rate, respiration, blood pressure, and sweating (variously known as the galvanic skin response [GSR], skin conductance response [SCR], or electrodermal activity).

The reliability and validity of the polygraph are controversial.[6,7] Estimates of its accuracy range from a high of 95 percent to a low of 50 percent,[6,8] with the best estimate probably around 75 percent sensitivity and 65 percent specificity.[6] This relatively low accuracy is a major reason that polygraph evidence is generally, though not universally, inadmissible in legal proceedings.[3]

The past six years have seen the development of a possible new lie-detection technique that is not based on the measurement of autonomic reactions. This is the application of a widely used tool in neuroscientific research, functional magnetic resonance imaging (fMRI), to the task of obtaining measurements of cerebral blood flow (a marker for neuronal activity) in individuals engaged in deception. Within the past two years, two separate research groups have devised experimental paradigms and statistical methods that they claim allow identification of brain activity patterns consistent with lying. The approaches can be used on individual subjects, and their creators claim approximately 90 percent accuracy. Two commercial enterprises, No Lie MRI, Inc., and Cephos Corporation, were launched in 2006, each with the goal of bringing these techniques to the public for use in legal proceedings, employment screening, and other arenas (such as national security investigations) where polygraphs have been used.

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The announcement of this first potential commercial application for fMRI has attracted a great deal of attention, both from the popular media[9–15] and from bioethicists.[16–26] In June 2006, the American Civil Liberties Union sponsored a forum on the subject of fMRI lie detection and filed a Freedom of Information Act request for government records relating to the use of fMRI and other brain-imaging techniques for this purpose.[27] Much of the concern centers on possible uses and abuses of brain-imaging technologies in interrogation of enemy combatants or other terrorism suspects.

The focus of this article is the potential use of fMRI to detect deception in noninterrogation contexts, specifically in criminal and civil legal proceedings and in the workplace. At the time of this writing, there do not appear to have been any instances of the use of fMRI lie detection in a legal or employment setting. However, there is little doubt that attempts to apply this new technology to real-world situations will be made, most likely in the near future.

The Science Behind the Scans

Very briefly, functional MRI relies on the fact that cerebral blood flow and neuronal activation are coupled. When a region of the brain increases its activity, blood flow to that region also increases. This physiological change can be detected by fMRI due to the blood-oxygen-level-dependent, or BOLD, effect.[28,29] Unlike other functional neuroimaging techniques such as positron emission tomography (PET) or single-photon emission computed tomography (SPECT), BOLD fMRI detects only relative changes in blood flow and thus requires a comparison between two conditions or tasks. However, in contrast to PET or SPECT, fMRI can detect signal changes on a time scale of one to two seconds, rather than minutes.

In the experimental setting, the BOLD signal over the whole brain is acquired while volunteer subjects perform various cognitive tasks.[30] The imaging data are then transformed to a standard brain template and averaged across subjects. Statistical techniques are used to identify a significant change in blood flow to a particular brain region in one condition compared with another. It is also possible to analyze data from within a single subject.

The BOLD signal is both valid and reliable in properly constrained experimental paradigms. There is very good agreement between fMRI and PET for the mapping of regional changes in brain activity.[31] Functional MRI is now being used for presurgical mapping for epilepsy and brain tumor surgeries[32–35] and is being studied for other diagnostic purposes.[36]

Applications to Detecting Deception

Since an initial publication in 2001,[37] several papers on the BOLD fMRI methodology have reported differential patterns of blood flow in various brain regions in experimental paradigms in which subjects were instructed to lie or deceive in one task condition and respond truthfully in another task condition. The task paradigms included forced-choice lies (i.e., responding yes when the truth is no and vice versa)[37,38]; spontaneous lies (i.e., saying Chicago when the true answer is Seattle)[39]; rehearsed, memorized lies[39]; feigning memory impairment[40,41]; and several variations of the Guilty Knowledge Test,[42,43] including lying about having a playing card,[44–47] lying about having fired a pistol (loaded with blanks) before the scanning session,[48] lying about the location of hidden money,[49,50] and lying about having taken a watch or ring.[51]

Some of the experimenters attempted to enhance the emotional salience of the lying task through monetary incentives: in one paradigm the subjects were told they would double their payment from $50 to $100 if they were able to deceive the experimenters[49–51]; in others they were told that they would forfeit their $20 payment if their deception was detected.[44,45] In another study, the experimenters did not manipulate rewards, but put on a demonstration for the subjects before the scanning session that implied that the testers could see the volunteers' brain activation results in real time.[47] The stated purpose of this was to approximate the conditions of a polygraph examination.

The most consistent results of these studies are greater activation of certain prefrontal and anterior cingulate regions in the lie conditions relative to the truth conditions. It has been hypothesized that these regions are recruited for the purpose of inhibiting a prepotent response (i.e., giving a true answer).[52] It has been proposed that this is one of the major cognitive differences between truth and deception:

> The liar is called upon to do at least two things simultaneously. He must construct a new item of information (the lie) while also withholding a factual item (the truth). . . . [T]he truthful response comprises a form of baseline, or prepotent response. . . . We might, therefore, propose that

> responding with a lie demands some form of additional cognitive processing, that it will engage executive, prefrontal systems (more so than telling the truth) [Ref. 52, p 1757].

These studies do not simply measure neural correlates of autonomic arousal. Thus, the technique may have some advantages over conventional polygraph methodology. For example, presumably, mere nervousness in an innocent subject would not create a false positive for deception.

Most of these studies reported only the results of analyses of pooled data from a group of subjects. However, for the method to have any practical value, it must be applied to individuals. Two separate research groups have used different statistical methodologies to do just that.

Kozel *et al.*[51] used a modified Guilty Knowledge Test in which 30 subjects engaged in a mock crime of stealing a watch or ring. (In the debriefing, 60% of the subjects indicated that they thought the crime was real, which supports the validity of the paradigm.) Subjects were then presented 80 different questions visually while being scanned. Yes or no responses were delivered by button press. The subjects were instructed to lie about having taken the item but to answer all other questions truthfully. They were paid $50 for participating, but were told that they would receive an additional $50 if an observer could not tell when they were lying (in actuality, all subjects received $100).

Statistical analysis of the group data identified one anterior cingulate and two prefrontal regions that were more activated in the lie than in the truth condition. The regions were similar to those activated in several of the other lie-detection paradigms mentioned. By analyzing the activations in these regions in each subject (pooled across all of that subject's responses), Kozel *et al.*[51] reported that they were able to predict accurately which item (watch or ring) was taken in 28 of 30, or 93 percent, of the cases. The activity in the same regions was then applied to the data from a new set of 31 subjects scanned under identical conditions. For this group, the method identified the item taken with 90 percent accuracy (28 of 31 subjects).

In their discussion, Kozel *et al.*[51] suggest that their method could be used in real-life settings by first testing the subject with the Guilty Knowledge Test mock crime scenario and then, if the subject's brain activation patterns indicate reliable separation between lies and truth, scanning them again while they respond to questions about the actual topic of interest. This approach has been licensed by the Cephos Corporation.

Davatzikos *et al.*[45] scanned 22 volunteers in a Guilty Knowledge Test paradigm involving lying about having a particular playing card in one's possession. Subjects were told they would be paid $20 only if they successfully concealed the fact that they possessed the card (in fact all subjects were paid). The researchers employed a statistical approach involving the application of machine learning methods to their entire dataset. Using this approach, they reported high accuracy in distinguishing a lie from the truth. Whether applied to single events (i.e., a single button-press response) or to all the data from a single subject, the sensitivity for detection of lying was around 90 percent, and the specificity was around 86 percent. This methodology is used by No Lie MRI, Inc.

Limitations of the Technique

Despite the intriguing results described in the preceding sections, how well fMRI lie detection would work in real-life situations remains an open question. It is important to bear in mind that, like the polygraph, fMRI lie detection requires a willing subject. If an individual refuses to enter the scanner, refuses to respond to the questions presented, or gives nonresponsive answers, the technique cannot be used. Even simply moving one's head during scanning could prevent the collection of usable data.

Over and above these hindrances are more complex questions about transitioning from the research laboratory to the real world. Some of the concerns that have yet to be fully addressed are discussed in the following sections.

Generalizability of the Method

The studies conducted thus far have been carried out on healthy volunteers who were screened for neurological and psychiatric disorders, including substance use. There has been no testing of fMRI lie-detection paradigms in juveniles, the elderly, or individuals with Axis I and/or Axis II disorders, such as substance abuse, antisocial personality disorder, mental retardation, head injury, or dementia. It is unclear whether and how such diagnoses would affect the reliability of the approach. (As mentioned, a potential advantage of the method in comparison with the polygraph is that it does not rely on autonomic reactions, and thus individuals with antisocial personality disorder may lose the advantage of evading detection due to their hyporesponsivity during polygraph testing.[53])

All of the published literature involves scenarios in which the volunteer subjects have been instructed to lie. No literature addresses the question of how this basic fact affects brain activation patterns, in comparison with the more realistic situation in which the person being tested makes a completely free decision about whether to lie and repeats this process for each question asked.

None of the volunteer subjects faced serious negative consequences for unconvincing lying, although in some cases they believed there was a monetary incentive for lying successfully.

Lack of Specificity of the Measurement

The fMRI approach to lie detection does not rely on detecting signs of autonomic arousal or nervousness that can be associated with lying. This approach reduces the chance that a person who is truthful will be classified as deceptive on the basis of his being fearful (for any reason) during testing. However, the other side of this coin is that fMRI lie detection appears to depend at least in part on the suppression of competing responses. It does not directly determine what those competing responses are, and they may not, in fact, be untruths. As pointed out by Grafton *et al.*:

> When defendants testify, they do inhibit their natural tendency to blurt out everything they know. They are circumspect about what they say. Many of them also suppress expressions of anger and outrage at accusation. Suppressing natural tendencies is not a reliable indicator of lying, in the context of a trial [Ref. 54, pp 36–37].

There are presently no data regarding the likelihood of this type of false-positive result.

Effects of Countermeasures

It is hypothesized that much of the frontal lobe activation in imaging studies of deception is related to the suppression of competing responses. Unknown at present is the potential effect of extensive rehearsal. Ganis *et al.*[39] have already demonstrated differential activation patterns between spontaneous and rehearsed lies. The rehearsal in that experiment was brief, on the order of minutes. If a person spent weeks practicing a fabricated story (akin to the preparation an intelligence officer might undertake in assuming a false identity), would the activations associated with response suppression remain as strong? For a person with much at stake and adequate advance warning, it is not unreasonable to assume that extensive rehearsal might be attempted to try to fool the technique. It is not known what effect, if any, such a cognitive countermeasure would have.

Other countermeasures—for example, one analogous to an approach commonly used against polygraph examinations (i.e., attempting to raise the baseline response to nontarget questions, to reduce the differential between target and nontarget responses)—could also be attempted by the subject while in the scanner. There are also no data on what impact such an action would have.

Delusions Versus Lying

In some psychiatric conditions, subjective experience is at odds with objective reality. This dichotomy is most glaring in the case of psychosis. It appears that in the case of a delusion, the technique would not show any deception. Langleben *et al.*[55] described a medical malpractice lawsuit in which a patient accused her former psychotherapist of sexual abuse. Both the patient and the physician took polygraph examinations, and both passed. Other evidence suggested that the patient was most likely suffering from a delusion. Such a situation probably would not be amenable to the use of fMRI lie detection. Other examples where fMRI may not add useful information might include dementias or amnestic disorders with confabulation, somatoform disorders, and the *pseudologia fantastica* seen in some patients with factitious disorders.

Legal Considerations

These unresolved questions suggest that the potential uses of fMRI lie detection in real-life situations will remain relatively restricted for the foreseeable future. A criminal defendant who failed an fMRI lie detector test could still assert reasonable doubt, unlike the case with DNA identification, for example, with which the odds of being identified by chance are on the order of billions to one. Thus, there is little to gain for the state in compelling an unwilling defendant to submit to such a test.

More generally, the present state of the science in this area is unlikely to meet legal standards for admissibility in court proceedings. The literature on the technique is sparse thus far. As we have seen, only two groups have published data on single-subject results. The *Frye v. U.S.*[56] standard, which was applied throughout the nation for seven decades until 1993 and is still the standard in some jurisdictions, requires that a scientific technique have general acceptance in the relevant scientific community for the results to be admissible as evidence. The use of fMRI for lie detection would not pass such a test at present.

The *Daubert v. Merrell Dow Pharmaceuticals, Inc.*[57] standard calls on the trial court to act as a gatekeeper. The court must determine whether the proposed scientific evidence is relevant to the issue at hand and assess its reliability. Under this standard, guidelines for the trial court to use in this assessment include: whether the procedure is generally accepted in the scientific community (as in *Frye*), whether the procedure has been tested under field conditions, whether it has been subject to peer review, the known or potential error rate, and whether standards for the operation of the technique have been developed. At present, fMRI lie detection would be unlikely to meet all of these criteria. The technique has not been tested in the field (i.e., in real civil or criminal cases), but only under laboratory conditions. There is also no standardization of the various techniques and protocols involved in performing and analyzing the scans.

Even if these obstacles are eventually overcome, the technique would face additional hurdles before any use in criminal proceedings. The Fifth Amendment right to avoid self-incrimination appears to rule out compelling a criminal defendant to submit to the technique. Another unresolved question is whether an fMRI scan constitutes a search, with potential Fourth Amendment implications.

Functional MRI lie detection may see its first application in nonjudicial settings, such as employment screening. Despite the caveats described herein, the published studies suggest that the technique may be more accurate than traditional polygraph methods, at least in Guilty Knowledge Test paradigms for which individual subject data have been published. These findings may make it attractive to employers. The fMRI technique could be used in conjunction with polygraphs, either on a routine basis, or in cases in which polygraph results are equivocal. Bioethicist Ronald Green has predicted, "Brain-imaging lie-detection will most likely be used where absolute reliability is not needed and where a predominately naïve population is under scrutiny. . .the technology is likely to supplement or take the place of written honesty tests and polygraphy" (Ref. 23, p 54).

However, there are still significant legal concerns to be addressed before such applications become widespread. Outside of government agencies and companies involved in the provision of security, the routine use of polygraph examinations is generally barred by the Federal Employee Polygraph Protection Act of 1988 (FEPPA).[58] Whether fMRI lie detection is covered under FEPPA is not clear at present. The key language in FEPPA states:

> The term "lie detector" includes a polygraph, deceptograph, voice stress analyzer, psychological stress evaluator, or any other similar device (whether mechanical or electrical) that is used, or the results of which are used, for the purpose of rendering a diagnostic opinion regarding the honesty or dishonesty of an individual. . . . The term "polygraph" means an instrument that—(A) records continuously, visually, permanently, and simultaneously changes in cardiovascular, respiratory, and electrodermal patterns as minimum instrumentation standards; and (B) is used, or the results of which are used, for the purpose of rendering a diagnostic opinion regarding the honesty or dishonesty of an individual [Ref. 58, Section 2001].

Does an fMRI scan, which does not measure psychological stress or the physiological parameters detected by a polygraph, nevertheless qualify as similar to the polygraph for the purposes of the FEPPA? At present, there has been no legally binding interpretation of this question. No Lie MRI, Inc. has taken the stance that the FEPPA does not apply:

> U.S. law prohibits truth verification/lie-detection testing for employees that is based on measuring the autonomic nervous system (e.g., polygraph testing). No Lie MRI, Inc. measures the central nervous system directly and such is not subject to restriction by these laws. The company is unaware of any law that would prohibit its use for employment screening.[59]

Ultimately, whether fMRI lie detection is prohibited by FEPPA may end up being determined by statute or court decisions.

Ethics-Related Considerations

The growing body of scientific literature and the advent of commercial enterprises to market brain imaging-based deception detection has raised several ethics-related concerns.[16–24,60] At the most basic level is the question of whether a precise definition of lying even exists.[20] It has been suggested that different types of lies are reflected in different patterns of brain activity in different individuals. One skeptical commentary offers the opinion that "[w]e just do not understand enough about brain circuits that mediate emotional or cognitive phenomena to interpret our measurements. . . . We are not ready to turn away from the skin and the heart to rely on still mysterious central mechanisms that correlate with a lie" (Ref. 20, p 55).

An argument can be made that this concern reflects an overabundance of caution. The polygraph may be even less specific to deception than fMRI. It is also not clear how allowing the polygraph but prohibiting fMRI lie detection addresses the question of the imprecise definition of deception.

A related matter is the possibility of the premature adoption of a scientifically immature technology. Given the comparatively narrow research base on which fMRI lie detection currently rests, several commentators have urged caution in allowing it to be used for practical applications. One author has recommended that any new lie-detection device go through a complete government approval process, analogous to the Food and Drug Administration's approval process for drugs and medical devices.[22] There are concerns that a rush to apply the technique and the competition for limited government funding could inhibit the conduct of appropriate research in the area. "Premature commercialization will bias and stifle the extensive basic research that still remains to be done" (Ref. 16, p 47).

Commentators have also pointed out the danger of the so-called CSI effect, meaning that the aura of big science and high technology surrounding complex and expensive tests may lead to an overestimation of the reliability and utility of fMRI lie detection among lay people, including law enforcement personnel and other investigators, judges, and jurors. If fMRI lie detection were misinterpreted as being an infallible method of distinguishing truth from falsehood, participants in legal proceedings could experience significant pressure to submit to testing, with refusal being interpreted as evidence of guilt.[16] The reasoning would be: the test detects lies; therefore, anyone who refuses to take it must have something to hide. Although such a conclusion is not at all supported by the actual data, it is not inconceivable that some may draw it.

Another question of ethics concerns the right to the privacy of one's thoughts. Neuroethicists have coined the term cognitive liberty[61] to refer to the "limits of the state's right to peer into an individual's thought processes with or without his or her consent, and the proper use of such information in civil, forensic, and security settings" (Ref. 16, pp 39–40). Under what circumstances should a government agency—or, for that matter, an employer or insurance company—be allowed to look for deception with this technique? Our society has not yet grappled with these critical questions, but if enthusiasm for fMRI lie detection increases, it appears that such a debate will be essential. In the words of one commentator, "Constitutional and/or legislative limitations must be considered for such techniques" (Ref. 21, p 61). Another author has proposed that using a "neurotechnology device to essentially peer into a person's thought processes should be unconstitutional unless it is done with the informed consent of that person" (Ref. 17, p 62).

Related to the concept of cognitive liberty is the possible use of fMRI against the will of the subject. Hypothetical scenarios in which this might occur have been described in the context of national security investigations or other types of high-stakes interrogations.[60,62] It is not inconceivable that terrorism suspects could be restrained and placed in an MRI scanner in such a way that they would be unable to move their heads enough to foil the scan. Even if they refused to answer questions, it might be possible to determine from the brain's response whether the subject recognizes a sensory stimulus, such as a sound or image.

It should be clear from the preceding discussion, however, that lie detection using fMRI requires the subject to answer questions. Furthermore, as in a traditional polygraph examination, a comparison to known truthful responses by the subject is necessary for the technique to work. In any event, the coercive use of brain-imaging technology would certainly be fraught with ethics-related, legal, and constitutional difficulties. Scientific and mental health organizations may soon want to articulate positions on the ethics of nonmedical uses of brain-imaging technology, coercive or not.

Conclusion

With ongoing research, and likely improvements in accuracy in the laboratory setting, it does not seem unreasonable to predict that fMRI lie detection will gain wider acceptance and, at a minimum, replace the polygraph for certain applications. What seems far less likely is the science-fiction scenario in which a criminal defendant is convicted solely on the basis of a pattern of neuronal activation when under questioning.

Thus far, under carefully controlled experimental conditions, an accuracy of 90 percent is the best that has been achieved. Improvements in the technology that would reduce the error rate from 10 percent to something comparable with the billions-to-one accuracy of DNA testing are difficult to conceive of, given the mechanics of the science involved.

Perhaps more important, the technique does not directly identify the neural signature of a lie. Functional MRI lie detection is based on the identification of patterns of cerebral blood flow that statistically correlate with the act of lying in a controlled experimental situation. The technique does not read minds and determine whether a person's memory in fact contains something other than what he or she says it does. The problem of false-positive identification of deception is unlikely to be overcome to a sufficient degree to allow the results of an fMRI lie detection test to defeat reasonable doubt. Furthermore, it is difficult to envision compelling an unwilling criminal defendant to submit to a test, because of the Fifth Amendment right against self-incrimination. If a criminal defendant volunteers to take the test, it is still not clear that the results would be any more admissible under current conditions than the results of a standard polygraph examination would be. It appears to be too early to predict whether fMRI lie detection will ever reach the level of reliability and standardization needed to meet *Frye* or *Daubert* criteria.

If the Federal Employee Polygraph Protection Act is interpreted as applying to fMRI lie detection, it will not be used in the general workplace. Nevertheless, the next few years may see the use of the technology in government and in the other limited circumstances in which nongovernmental employers are allowed to administer polygraph examinations. Although there are several unresolved questions regarding the ethics of this type of application, it is not clear that the concerns are qualitatively different, with fMRI lie detection in this context, from those raised by the polygraph, or from concerns about the use of brain imaging in other contexts such as research or diagnostics. As previously mentioned, absolute reliability is not necessarily required in employment applications.

Like polygraph evidence, which is generally inadmissible, fMRI lie detection may still find a role in civil suits and in criminal investigations. No claims would be made that the results definitively determine the truth as do those of the more traditional forensic tests, but the findings could be used in settlement negotiations. Police could employ the technique in criminal investigations as a means to rule out suspects, as they already do with the polygraph.[63]

A variety of practical, legal, and ethics-related concerns surround the potential use of functional MRI for the purpose of lie detection. Given the current state of the field and the unresolved practical matters mentioned herein, the forensic role of the technique is likely to be limited to the civil arena, with both sides agreeing to have one or more parties consent to undergo the test. Use in the workplace is also possible, but if FEPPA applies, then the use of fMRI lie detection in employment will be as limited as the use of the polygraph. Although the ethics-related dangers are perhaps not as grave in employment applications or civil suits as they would be in a criminal case, an ongoing scientific, legal, and bioethics dialogue about the appropriate uses of fMRI lie detection is certainly prudent and timely.

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