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Emerging neurotechnologies for lie-detection: promises and perils

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Abstract
Detection of deception and confirmation of truth telling with conventional polygraphy raised a host of technical and ethical issues. Recently, newer methods of recording electromagnetic signals from the brain show promise in permitting the detection of deception or truth telling. Some are even being promoted as more accurate than conventional polygraphy. While the new technologies raise issues of personal privacy, acceptable forensic application, and other social issues, the focus of this paper is the technical limitations of the developing technology. Those limitations include the measurement validity of the new technologies, which remains largely unknown. Another set of questions pertains to the psychological paradigms used to model or constrain the target behavior. Finally, there is little standardization in the field, and the vulnerability of the techniques to countermeasures is unknown. Premature application of these technologies outside of research settings should be resisted, and the social conversation about the appropriate parameters of its civil, forensic, and security use should begin.

Keywords
Brain Imaging, Lie Detection, neuroethics, Privacy, confidentiality

Disciplines
Bioethics and Medical Ethics

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INTRODUCTION

Rapid advances in diagnostic medical imaging over the past decade have revolutionized neuroscience. Scientists are gaining a new understanding of brain function and structure, and uncovering exciting and challenging insights into the nature of human behavior. Advances in magnetic resonance imaging, electroencephalography (EEG), and other modern techniques, can, for the first time, reliably measure changes in brain activity associated with thoughts, feelings and behaviors, in principle allowing researchers to link brain activity patterns directly to the cognitive or affective processes or states they produce (e.g., Canli and Amin 2002; Fischer et al. 1997; Sugiura et al. 2000).

While most of this work is still in the basic research stage, its potential social, legal, and ethical implications are significant (see, e.g., Farah 2002; Foster et al. 2003; Illes et al. 2003; Wolpe 2002, 2004). For the first time, using modern neuroscience techniques, a third party can, in principle, bypass the peripheral nervous system—the usual way in which we communicate information—and gain direct access to the seat of a person's thoughts, feelings, intention, or knowledge (Berns et al. 1997). Given the current state of the art in neuroscience research, speculations about any impending ability to "read thoughts" of unsuspecting citizens are not realistic, and free-form mind-reading in the style described in recent films such as "Minority Report" remains science fiction (see Ross 2003). Nevertheless, there has been real, if limited, progress in finding brain correlates of certain simple memories, emotions, and behaviors, and potential applications in the social arena are foreseeable (Donaldson 2004).

One application of these techniques has been the attempt to develop reliable brain-imaging lie-detection technology. In the United States, defence-related agencies have dedicated significant funds to the development of new lie-detection strategies for eventual use in criminal and terrorist investigations. A number of universities and private companies are trying to develop lie-detection technologies, using fMRI, EEG, near infrared light, and other strategies to directly access brain function.

The ethical issues that would arise from a reliable (or thought-to-be-reliable) brain-imaging deception technology are complex. Using these technologies in courtrooms and for security screening purposes, for example, raises many of the same difficult ethical and legal issues already present in the debate over conventional polygraphy. However, some of the ethical issues that such technologies would present are novel. For the first time, we would need to define the parameters of a person's right to "cognitive liberty," 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. Clearly, a comprehensive and probing debate concerning the limits and proper use of brain-imaging technologies is needed and timely. Our goal in this essay is to inform that debate through a description of the technical limitations in neuroscience research on detecting deception, and to raise concerns about their premature and inappropriate use.

NEW METHODS, OLD PARADIGMS

A lie-detection system such as the polygraph, or any system aimed at determining physiological correlates of behavior, consists of two components. One is the set of physiological parameters being measured, and the other (no less important but often overlooked) is the paradigm or model used to produce the target behavior (such as deception) in a standardized fashion. Conventional polygraphy measures the subject's physiological responses by monitoring chest expansion, pulse, blood pressure, and electrical conductance of the skin. The physiological data measured in polygraphy signify the activity of the autonomic nervous system, and so may reflect not only arousal during deception but anxiety in general, no matter the cause.

To overcome this limitation, a number of recent studies have attempted to employ more direct measurements of brain activity to indicate deception and the presence of concealed information. Some of these studies, for example recent applications of functional Magnetic Resonance Imaging (fMRI) for lie detection, have attracted attention because of the novelty of the physiological parameters being measured (see Spence et al. 2004). What is less recognized, however, is that many of these studies have used, sometimes unknowingly, variants of decades-old paradigms to produce the target behavior.

In order to test any means of lie detection, a standardized protocol to generate the behavior must be developed. There are two prototype paradigms that have been used to generate instances of truth-telling and deception to be subjected to measurement. The first is the comparison question test (known in the polygraph literature as the control question test, CQT), which forms the basis of conventional polygraphy. The CQT requires a subject to respond to a series of yes–no questions of one of three kinds. “Relevants” are intended to produce a presumed lie and would, in a standard polygraph test, be related to the matter under investigation (e.g., “Did you kill your wife?”). Comparison or control questions are designed to induce a strong response in all subjects (e.g., “Did you ever steal something?”). Finally there are irrelevant questions to establish a baseline (“Are you sitting in a chair?”). A consistently stronger physiological response in a subject to the relevants than to the control questions is taken as evidence of deception.

In contrast, the second paradigm, the guilty knowledge test (GKT), seeks to determine the salience (“attentional value”) of information to a subject by comparing his or her responses to “relevant” and “neutral” questions. For example, in a crime investigation involving a stolen red car, a sequence of questions could be: “Was the car yellow? Was the car red? Was the car green?” The questions are chosen so that subjects with knowledge of the crime (but not other individuals) would have an amplified physiological response to the relevant question—that the car was red—which is dubbed “guilty knowledge” (Ben-Shakhar and Elaad 2003; Lykken 1991).

Whereas the CQT involves measurement of physiological or psychophysical responses to classify a response as a lie, the GKT uses such responses to indicate the presence of concealed knowledge. The tester then uses this information to make inferences about the truth. Thus, the GKT does not detect deception directly and indeed, in the polygraphic literature, the term ‘lie-detector’ is reserved for the CQT-based applications (Lykken 1991). In fact, the GKT need not rely on verbal responses from the subject at all; physiological responses to simply hearing the relevant question can suffice. This has given rise to the claims that GKT “directly” probes the information stored in a person’s brain (Farwell and Smith 2001).

The debate about the relative advantages of the CQT versus GKT as research and applied paradigms has been raging for decades. The main criticism against the CQT has been the inability to standardize the selection of the control questions (though the choice of the neutral items in the GKT could also affect the results). From a neuropsychological perspective, both the CQT and GKT are “forced-choice” protocols that seek to detect differences in psychological salience between question by examining the physiologic responses of the subject to target and baseline conditions. Though investigators generally agree that the GKT is methodologically more robust than the CQT (Rosenfeld et al. 1988; Stern 2002), it has been less popular with forensic practitioners in the field because the test requires reliable and specific crime-related information known only to the investigators and the perpetrator, which is often difficult to obtain.

In recent years, investigators have used the GKT (or variants) to explore the usefulness of a variety of neuroscience techniques for detecting deception. One group, for example, has used infrared photography to detect changes in temperature patterns (and thus blood flow) near the eye, and proposed it for “deception detection on the fly” such as screening airline passengers (Pavlidis and Levine 2002; Pavlidis et al. 2002). Another group has applied the GKT using scattering of near infrared light (NIR) using sensors placed in contact with the scalp that detect infrared light shone through the skull and relected off the blood vessels of the cortex (Chance and Kang 2002). Another set of studies has employed a variety of GKT-like forced-choice paradigms with fMRI (e.g., Langleben et al. 2002, 2004; Spence 2001). All of these examples, however, are laboratory based and are in early stages of research.

One technique, however, has been applied in an actual forensic situation and has drawn considerable media attention. Dubbed "brain fingerprinting" by its developer, Lawrence Farwell (Farwell and Donchin 1991; Farwell and Smith 2001), it involves application of the GKT while using EEG as a measurement tool. The signals picked up by the EEG, known as event related potentials (ERPs), can be measured on the scalp 300–500 ms after the subject is exposed to a stimulus; their precise origin is unknown, but they are associated with novelty and salience of incoming stimuli. Through this technique, Farwell claims to be able to tell whether a stimulus is familiar or unfamiliar to the subject (e.g., whether or not a suspect's response indicates familiarity with a picture of a crime scene). "Brain fingerprinting" is thus not really a deception- or lie-detection technology. It is also not new; the use of the GKT coupled with ERP was reported as long ago as 1988 (Rosenfeld et al. 1988). Farwell's "brain fingerprinting," in fact, is a proprietary version of the technology that has been developed commercially by Farwell and is being actively promoted by his firm Brain Fingerprinting Laboratories, Inc. (http://www.brainwavescience.com) for forensic, medical, advertising, and security applications.

RELIABILITY CONCERNS

Polygraph testing in civil and judicial settings have been subject to ongoing concerns about accuracy of measurement, reliability of the questioning paradigm used, and the relevance of the test to the field situations in which it is used (Stern 2002). Neurotechnological means of lie detection suffer from many of the same weaknesses as conventional polygraphy. While monitoring brain activity directly, rather than monitoring peripheral responses such as skin conductance, may improve the measurement component of a lie-detection system, there is no assurance that changing the measurement component alone will result in improved overall performance for any particular application.

A simple example, using concepts familiar in medical testing, shows the difficulty of the problem. In a meta-analysis of a number of GKT studies used with polygraph, Ben-Shakhar and Elaad found an effect size (the ratio of the difference in the mean responses in "knowledge present" vs. "knowledge absent" subjects to the standard deviations in responses) ranging from 1.1–1.3 to 2.09standard deviations, with the higher effect size being found in studies involving mock crime tests (Ben-Shakhar and Elaad 2003). In terms used to characterize medical tests, this corresponds to a sensitivity and specificity ranging from 0.7 to 0.85. A similar sensitivity and specificity of 0.8–0.82 was found in a separate review of the GKT in laboratory experiments (MacLaren 2001). Ben-Shakhar and Elaad conclude: "when properly administered, the GKT may turn out to be one of the most valid applications of psychological principles. … This raises a question regarding the limited usage of the GKT in criminal investigations in North America" (Ben-Shakhar and Elaad 2003).

Measures of accuracy determined under laboratory conditions, however, may not be relevant to the performance of a test under field conditions. Moreover, what counts as high accuracy by the standards of a laboratory scientist may not be adequate when used to characterize test performance in forensic and civil populations. The probability of a true positive test result depends not only on the specificity and the sensitivity of the test but also on the frequency of occurrence of the condition being tested for in the population (known, in statistical terms, as the base rate). If the condition is rare, then a specificity of 85% corresponds to 15% false positive responses.

Table 1 illustrates a simple example of this important principle. Imagine using the GKT/polygraph test with two hypothetical populations. The first is a population consisting of criminal suspects with the "base rate" of prevaricators of 50%; the second is a group of Department of Energy employees with the base rate of prevaricators of 0.1%.

Table 1 Effect Size in GKT Test and Estimated Sensitivity and Specificity of Test (based on Ben-Shakhar and Elaad 2003).

				Base Rate of Prevarication 50%		***Base Rate of Prevarication 0.1%***	
Test Condition	***EffectSize (Standard Deviations between "Truth" and "not Truth")***	***Sensitivity***	***Specificity***	***Probability of False Positive****	***Positive Predictive Value*****	***Probability of False Positive****	***Positive Predictive Value*****
Card tests (57 studies)	1.1 to 1.3	0.70–0.75	0.70–0.75	0.125–0.15	0.70–0.75	0.25–0.30	0.002–0.003
Personal items (eg. Birth date) (24 studies)	1.58	0.8	0.8	0.1	0.8	0.2	0.004
Mock crime test (42 studies)	2.09	0.85	0.85	0.075	0.85	0.15	0.005

*The probability that an individual who is not prevaricating tests positive.

**The probability that an individual who tests positive is actually prevaricating.

In Table 1, we calculate the probability of false-positive and false-negative results of the test when applied to these two hypothetical populations, which differ only in the base rate of prevaricators.

The implications of Table 1 are profound. If the prevalence of "prevaricators" in the group being examined is low, the test will yield far more false-positive than true-positive results; about one person in five will be incorrectly identified by the test.

Another measure of the accuracy of the test is its positive predictive value, namely, the probability that a person who tests positive really is a prevaricator. The test has a higher predictive value when used with the hypothetical population of criminal suspects, but even there, the performance of the test is quite poor. This dismal result certainly brings into question any reasonable use of the test in a civil setting. A similar point was made in the recent National Research Council assessment of polygraphy for screening for security risks in national laboratories (Stern 2002). New technologies may—or may not—improve the situation, but clearly a very large improvement in the specificity of the test would be needed for its performance to be acceptable for most forensic or security purposes.

Further difficulties with these methods are apparent, beyond the simple statistical problems discussed in this example. The classic paradigms (i.e., CQT, GKT) remain poorly defined and investigated, and their accuracy when combined with the new methods of measuring brain activity has not been determined in properly designed experimental trials. Indeed, nearly all of these methods come out of basic research or from preliminary development work, and few if any large-scale investigations of the test performance have been attempted.

Conceptual issues related to the validity of studies to determine the accuracy of a test can be considered at several levels, specifically, those related to external and internal validity.

External Validity

External validity refers to the ability of a test to yield information about the things it claims to test. For example, many laboratory studies of deception employ protocols in which participants are instructed by the investigators to lie and are then monitored by the same investigators. Since, by definition, deception is an interactive process that requires an unknowing target (victim), such a study, though scientifically useful, could not be considered a valid indication of the ability of the test to detect deception in a situation when only the test subject knows when, or even whether, he will be lying. In short, lying can be a complex, situation-dependant activity, with a variety of degrees and levels of prevarication, and the ability to detect simple deceptions in laboratory settings may not translate into a usable technology in less controlled situations.

Another issue is the relevance of a study to predict the performance of a test with a specific population or individual: For example, the first three studies on lie detection with fMRI were performed in young healthy controls (Langleben et al. 2002; Lee et al. 2002; Spence et al. 2001). The baseline brain activity, and thus fMRI signals, of subjects varies with age, health status and multitude of other variables (including the use of prescription or illicit drugs, depression, or the presence of a personality disorder). Clearly the results of these studies cannot be generalized to the "real world" populations of criminal and terrorist suspects.

Internal Validity

The internal validity of a test (also called 'reproducibility') depends on the success of a method in controlling possible confounding variables. Factors relevant to internal validity include both how the test is designed, and how data is collected and analyzed.

Test Design

The reproducibility of a test can be affected by a number of factors, including: the scenario used in the test (e.g., what is the test about: a crime, espionage or hidden playing cards?), the level of risk that the test carries to the subject (e.g., whether the test is being applied to real-life crime suspects or to college students role-playing in a simulated crime scenario or asked to lie about playing cards), the paradigm used by the test (e.g., GKT or CQT), or to specific design features of the test (e.g., frequency of presentation, order, duration, semantic significance and graphic properties of the stimuli).

To give a concrete example of such concerns, the State of Iowa objected to Lawrence Farwell's use of "brain fingerprinting" on Terry Harrington, in *Harrington v. State of Iowa* (a post-conviction relief action undertaken 23 years after the crime). In his testing, Farwell claimed to show that Harrington had no memory of the crime scene, using Harrington's familiarity response to probes that included: "across street," "parked cars," "weeds and grass," "drainage ditch," "by trees," and "straight ahead." The state argued, however, that familiarity or lack of familiarity with probes of such a general nature was neither a robust nor specific enough measure to prove his innocence, particularly given the long period since the crime had occurred.

This case has been cited by Farwell and others as setting a precedent for use of "brain fingerprinting" in court. However, while the district judge in the post-conviction relief hearing (a non-jury proceeding) heard Farwell's evidence, he denied Harrington's petition on other grounds and indicated that Farwell's evidence would not have affected the results of the proceedings. An appeal to a higher court reversed the district court's decision, on grounds unrelated to Farwell's testing (the recantation of a witness), and ordered a new trial for Harrington; the local prosecutors declined to pursue the case and Harrington was freed. Thus, despite the claims in the media and on Farwell's website implying its success in the Harrington case, "brain fingerprinting" in fact had been heard by a judge only in a non-jury proceeding, and was judged irrelevant to the outcome of the case. To our knowledge the technology has not been admitted to any court proceedings since that case.

To create a test that truly measures verisimilitude or salience, the relation between the measured signal and the physiological chain of events coupling a behavior with the signal must be fully characterized. In studies using functional MRI (specifically, using a technique called Blood Oxygenated Level Dependent, or BOLD fMRI), the local change in the concentration of oxygenated hemoglobin in the brain is used as an indicator of neuronal activity. Although local blood flow in the brain is related to neural activity, the relationship remains incompletely understood (Heeger et al. 2000; Miezin et al. 2000; Mintun et al. 2001; Vafaee and Gjedde 2004). "Brain fingerprinting" suffers from an even more basic problem: Though EEG has been around for quite a while, the specific techniques used in brain fingerprinting rely on a proprietary (and nondisclosed) method of analysis, and therefore cannot be validated independently.

New truth-detecting technologies should not be used for socially important applications until their capabilities and limitations are adequately understood—not that neuroscience cannot yield reliable technologies for determining truth-telling for legal or security applications. There are fundamental differences between deception and truth-telling at the neurological level, and neuroscience may provide the tools to detect these differences with sufficient reliability—or they may not. The requirements for "sufficient reliability" will clearly depend on the social purposes for which the technologies will be applied, and an adequate evaluation of new truth telling technologies has not even begun. Whatever its other problems, considerable effort has been spent over the years to standardize polygraph testing (Kleiner 2002). Similar work would have to be done before any new technique is ready for routine use for real-world applications.

COUNTERMEASURES

Effective measures to thwart conventional (CQT) polygraphy have long been known. Most attempt to increase the response of a subject to the comparison (control) questions using physical (e.g., biting the tongue or pressing the toes to the floor) or mental (e.g., counting backward by 7) techniques (Honts et al. 1994).

Countermeasures against the GKT when used with polygraphy have also been demonstrated. There is no reason to doubt that countermeasures against the GKT could be used with other brain-measurement techniques as well. Additionally, Rosenfeld et al. (2004) have reported that "tests of deception detection based on P300 amplitude as a recognition index may be readily defeated with simple countermeasures that can be easily learned." Since brain fingerprinting is based on the P300, this suggests that countermeasures against brain fingerprinting are also available. Recently, Langleben et al. (2004) provided preliminary data suggesting that similar countermeasures could reduce the robustness of the GKT-fMRI technology as well. Thus, until conclusively proven otherwise, brain imaging should be expected to be no less sensitive to countermeasures than the polygraph.

THE HYPE

Despite the caveats that many investigators themselves have raised about the various methods, there is an obvious attraction of new techniques for detection of deception in a society that is newly concerned with internal security and foreign threats. It is not surprising, therefore, that the media have spread an overly optimistic perception that these methods will soon become useful for practical application. “Truth and Justice, by the Blip of a Brain Wave” was the headline in one *New York Times* article (Feder 2001), while the San Francisco Chronicle simply announced “Fib Detector” (Hall 2001).

A television news broadcast in October 2003 on the “cognoscope,” a helmet-mounted instrument using near infrared light (NIR) scattering to detect changes in brain blood flow, showed an enthusiastic student saying that the technique “works,” followed by a fictional scenario showing airline passengers being screened by beams of light. Such scenarios go far beyond the claims of the investigators themselves; indeed, neither the accuracy of the method for lie detection nor the ability of fNIR to measure changes in brain blood flow without direct skin contact have been conclusively demonstrated. Press coverage of the studies by the University of Pennsylvania group investigating use of fMRI using the GKT (Langleben et al. 2002), often include speculation about the imminent usefulness of the technology in civil or forensic settings, a claim not made by the investigators and not justified by the state of current research.

Farwell’s brain fingerprinting technique has been the most aggressively promoted of all neurotechnology for detecting deception. On his company’s website (http://www.brainwavescience.com), Farwell is shown in a white lab coat, surrounded by testimonials from a U.S. Senator, media clips, and praise of the technique for applications including forensic investigation, counterterrorism efforts, early detection of Alzheimer’s disease, studies of efficiency of advertising campaigns, and security testing. Indeed, brain fingerprinting is on the verge of more widespread use. Several countries have purchased equipment for ‘brain fingerprinting,’ and India is beginning to use the method for forensic investigations (The Statesman 2003). In May 2004, the DaVinci Institute, a Colorado “futurist think tank” (http://www.davinciinstitute.com) announced funding for a task force to develop a curriculum to train 1000 “brain fingerprinting” technicians by September 2005.

Media reports have been bolstered by excessive claims made for these methods. Farwell has been quoted as claiming “100% accuracy” for “brain fingerprinting” and the ability to detect “scientifically” if certain information is “stored” in the brain (BBC 2004). In his testimony in *Harrington v. State of Iowa*, Farwell compared the P300 phenomenon to the sound made by a computer when it replaces a computer file with an updated version of the same file (*Harrington v. State of Iowa*). Our understanding of the workings of human memory is insufficient to support the implications of such an analogy (Squire et al. 2004), which suggests an erroneous model of both human memory and the P300 wave generation (Bledowski et al. 2004). Moreover, the proprietary “brain fingerprinting” technology has been the subject of few peer-reviewed publications, and those that exist are by Dr. Farwell and his colleagues, covering less than 50 subjects altogether and raising obvious concerns about conflict of interest. (On his website, Farwell claims that “nearly 200 scientific tests” prove the accuracy of “brain fingerprinting.” This appears to refer to tests conducted over time on 200 individual subjects, not to 200 independent studies. Most of the data is not published in peer-reviewed literature.) Thus, the true accuracy, validity, and relevance of this method to any real-world applications must be deemed unknown by any modern scientific standard.

Polygraphy, despite its considerable limitations, is commonly used not only for testing criminal suspects, but also for civil purposes such as screening employees or applicants to sensitive positions. The widespread use of polygraphy, even in the face of critical reports such the one by the National Academy of Sciences (Stern 2002) and an earlier report by the U.S. Office of Technology Assessment (1990), shows how strongly lie detection technologies are desired. Alternatives are welcomed and implemented even though they suffer from the same, or new, limitations.

ETHICAL CONCERNS

Traditional polygraphy has long been the topic of ethical debate. Questions have been raised concerning its validity, reliability, misuse of results, testing biases, coercion of examinees, and even possible harm due to comparison questions in the CQT (Furedy 1993; Kokish 2003). Many of these concerns are also relevant to brain-imaging technologies.

In addition, the current state of development of brain imaging and the existence of societal and political demand for improvements in the methods of lie-detection raise some other ethical concerns worthy of consideration, specifically 1) premature adoption; 2) misapplication through misunderstanding of the technology; 3) privacy concerns; 4) collateral information; and 5) forensic use.

Premature Adoption

Much of the funding for development of new methods to detect deception and concealed information comes from federal (U.S.) defence-related security agencies, who are looking for practical products from the research in the shortest time possible. The competition over funding and the need to attract new sources of investment have led researchers to promote the technology in the media as well as to federal agencies. Clearly there are benefits to being an early player in the marketplace. However, such competition to win potentially lucrative government contracts for these productscan lead to premature translation of new technologies into practice before they are established scientifically.

Conventional polygraphy was introduced when the standards of scientific research and publications were significantly less rigorous than today. In fact, polygraph testing was shielded for many years from independent scrutiny, as were many other forensic technologies (Risinger and Sacks 2003), due in part to lack of interest by the mainstream scientific community. Current standards of practice in conventional polygraphy are therefore strikingly behind those used in commercial psychological testing, in evaluating medical devices and therapies, or in research that is acceptable to most peer-reviewed science journals. This regrettable situation should not be allowed to develop with new technologies coming into existence.

Some investigators have promoted these technologies with claims that can be taken out of context. Pavlidis and Levine (2002), for example, suggest the use of their thermographic technique in airports or borders and comment: “The machine’s recommendation will serve as an additional data point to the traveler’s on-line record.” Given the reaction of US security agencies to even weak evidence of terrorist activity in specific individuals, one wonders whether agencies will pay heed to the second part of Pavlidis and Levine’s recommendation: to give such evidence a weight that is “commensurate with how well the machine proves itself in actual practice” (Pavlidis and Levine 2002).

Misapplication Through Misunderstanding of the Technology

None of the new imaging technologies actually detect “lies.” Techniques such as fMRI, P300 electrophysiology, or “brain fingerprinting” detect physiological changes, such as blood flow or increased electrical activity in the regions of the brain that might be activated by the act of deception per se, or by the visual or psychological salience of a particular test item to the individual being tested. Separation of a deception-related signal from the host of potentially confounding signals is a complicated matter, and depends on the careful construction of the deception task rather than the measurement technology. Sophisticated application of the technology and interpretation of results will therefore be crucial to the successful translation of these technologies to settings outside the laboratory. The technical limitations can be easily overlooked in civil settings. If employers, for example, started screening employees using these methods, they might find it easier to simply eliminate individuals with ambiguous results rather than understand the confounding factors that can lead to ambiguous results even in an innocent person.

Presently, compiling and interpreting brain-imaging data requires highly specialized skills in neuropsychology, physics, and statistics. Unlike polygraphy, which yields an irregular multichannel tracing that is uninterpretable by the uninitiated, the graphic appearance of processed functional brain images may give a false sense of security to anyone lacking relevant experience. Yet, those images are not the raw data itself, but pictorial renderings of statistical maps of brain activity that have been thresholded for display at an arbitrary level of significance and projected over a brain template that may not even belong to the person being imaged. Individuals with experience in generating, processing, analyzing, and interpreting functional brain imaging data are currently available only at major research institutions, and there are currently no training or professional standards for their skills.

Who will be allowed to use the technology and in what settings? Will private firms begin offering deception detection to banks looking for honest employees, parents trying to determine whether their children are really using drugs, and boy scout troops looking to weed out child molesters? The potential for misuse might require a careful system of licensing practitioners, should the technology develop to the point where it is used widely for consumer applications (Rosen and Gur 2002). However, this will require a more open process than licensing practitioners by the company that produces the equipment, as is presently the case with “brain fingerprinting.” The safest approach may be to continue applying the privacy and safety standards of medical information use to any data acquired using medical technology regardless of indication.

Privacy Concerns

Does a person have an alienable right to keep his or her subjective thoughts private? If technology develops to the point where, for example, remote fNIR could be used covertly to monitor a person’s frontal lobe patterns during questioning, would it be mandatory in all cases to reveal that one is being probed? Would a reliable lie detector, if one can be developed, find its way into airports and courtrooms, stores and offices, the Olympics, the schools? Reliable, safe lie detectors (and other potential uses of imaging not discussed in this paper) would force a reexamination of the very idea of privacy, which up until now could not reliably penetrate the individual’s cranium. A number of organizations have already begun to advocate for the right to cognitive freedom.

Collateral Information

Brain imaging data that has been acquired for research purposes in the U.S. is subject to strict ethical and legal standards provided by the Declaration of Helsinki and the federal regulations, however, there is no guarantee that similar standards could be maintained in civil, forensic, or security settings. MRI images usually cover more of the brain than the discreet area of concern.

Therefore, imaging for a non-medical indication could reveal medically relevant information. It is easy to foresee a lawsuit by a person who was given a brain scan in the course of pre-employment screening in which an early-stage brain tumor was clearly visible on the scan, yet the candidate was not informed (see, e.g., Illes et al. 2004; Katzman et al. 1999). In addition, researchers are discovering that brain scans may reveal a great deal of information about us. Data indicates that brain scans could potentially reveal rudimentary information about personality traits, mental illness, sexual preferences or predisposition to drug addiction (Andreasen 1997; Hamann et al. 2004; Kiehl et al. 2001; Lindsey et al. 2003). If disclosed without proper consent, such information could lead to unanticipated insurance, employment, or legal problems for the individual being tested. Most of this research, so far, has been conducted by comparing groups, not individuals, and consequently its potential for identifying such information in individuals is unknown (Farah 2002). Still, some traits are distinguishable on an individual level, and as research continues, more such traits are likely to be discovered. The ability to store brain-scan images indefinitely suggests a scenario that we are already facing in genetics: Genetic information that was inconsequential when originally stored in tissue samples becomes increasingly revealing as our knowledge of genetics grows more sophisticated.

Forensic Use

Results of polygraph examinations are not admissible in most U.S. courts (or in courts in most other countries) because of well-justified concerns about the reliability of the results. Is “brain fingerprinting” a more reliable technology? Nobody really knows, and the appropriate studies have not been done. As the State of Iowa complained in its brief against brain fingerprinting in *Harrington*, the most critical problem with admission of “brain fingerprinting” evidence is the lack of any track record establishing its reliability.

High technology tools such as brain scans can give a persuasive scientific gloss to what in reality are subjective interpretations of the data. The implied certainty and authority of science can be prejudicial to juries, and when it is accompanied by images to reinforce expert testimony it can be particularly persuasive. This concern has been raised about the use of computer-generated visual displays in the courtroom in general (Borelli 1996). Brain scan images might influence juries even when the images add no reliable or additional information to the case. In addition, if such scans gain currency in judicial settings, subjects may face intense pressures to undergo such testing to “prove” guilt or innocence, and their refusal to undergo such testing might be used against them in subsequent proceedings.

CONCLUSION

Neuroscience research has begun to establish brain correlates of specific cognitive processes. In a real though very limited sense, we have begun to probe the subjective contents of the mind. Brain-imaging technology has created the potential for powerful new ways to understand the workings of the human brain, as well as concerns about misusing that potential. Limitations of the existing methods to detect lies and verify truth and changing priorities of the federal defense agencies have led to attempts to apply these research advances for forensic and defense purposes. Though promising, it remains unknown whether those early research findings will ever lead to a better lie detection methodology. While media and research attention has been focused on the impressive images medical-imaging technology can produce, the limitations of the existing forms of questioning formats and deception paradigms (CQT, GKT, etc.) that include sensitivity to countermeasures and the choice of appropriate questions remain unchanged.

Premature commercialization will bias and stifle the extensive basic research that still remains to be done, damage the long-term applied potential of these powerful techniques, and lead to their misuse before they are ready to serve the needs of society. Society must be ready to come to a decision about the value of cognitive privacy before these technologies become widespread. Scientists, ethicists, and other advocates must take an active role in the discussion of the threat to civil liberties that their research might make possible. The discussion about the implications of reliable, as well as involuntary, lie-detection technologies should begin in scientific, legal, and civil forums in anticipation of the further development of these promising and challenging technologies.▪

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