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Target Article

Neuroimaging Techniques for Memory Detection: Scientific, Ethical, and Legal Issues

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There is considerable interest in the use of neuroimaging techniques for forensic purposes. Memory detection techniques, including the well-publicized Brain Fingerprinting technique (Brain Fingerprinting Laboratories, Inc., Seattle WA), exploit the fact that the brain responds differently to sensory stimuli to which it has been exposed before. When a stimulus is specifically associated with a crime, the resulting brain activity should differentiate between someone who was present at the crime and someone who was not. This article reviews the scientific literature on three such techniques: priming, old/new, and P300 effects. The forensic potential of these techniques is evaluated based on four criteria: specificity, automaticity, encoding flexibility, and longevity. This article concludes that none of the techniques are devoid of forensic potential, although much research is yet to be done. Ethical issues, including rights to privacy and against self-incrimination, are discussed. A discussion of legal issues concludes that current memory detection techniques do not yet meet United States standards of legal admissibility.

Keywords: neuroethics, neuroimaging, memory, Brain Fingerprinting, lie detection, Daubert

In the 2004 film *Eternal Sunshine of the Spotless Mind*, a neuroscientist invented a technique whereby specific memories can be erased from one's brain. Although the ethical issues about the use and abuse of such technology were explored in the film, the film was not warning viewers of the imminent development of such technology. Indeed there are two characteristics of memory storage that make specific erasure difficult, if not impossible. First, memories are stored in a distributed fashion, and second, a memory network in one locus contains many memories. The first is a problem for erasure because to erase a memory trace in one locus leaves traces at other loci. The second is a problem for erasure because erasing a network erases more than just the desired memories.[1] Specific memory erasure can be viewed as a two-stage process: in the first stage, the neural basis of the memory is identified, and in the second stage, the memory is erased. Although the second stage is science fiction, neuroimaging techniques that could accomplish something resembling the first stage are currently in development, and, in one case, actually being used. Thus it is not too early to begin discussing the ethical and legal ramifications of such techniques.

Criminal investigation is the most obvious application of a technique that can identify the existence of a memory in the brain. If an individual is being investigated for the commission of a crime, then such a technique, it has been claimed, could identify them as guilty or innocent based on the presence or absence of a memory for the crime. Note that such a *memory detection* technique is different than lie detection because, in theory, the existence of a memory could be detected regardless of whether the examinee is lying. The development of neuroimaging techniques has made memory detection possible because existing behavioral techniques for the detection of memories rely on participant cooperation, which cannot be expected of the guilty person claiming innocence.

Imagine a neuroimaging test that can detect the presence of a crime memory. A positive result on such a test would support the conclusion that the examinee was guilty, and a negative result would support the conclusion that the examinee was innocent. The test has neither perfect specificity nor perfect sensitivity, however. A positive test result for an innocent examinee is called a *false positive*, and a negative result for a guilty examinee is a *false negative*.

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[1] Memory *dampening* techniques, which are pharmaceutical in nature (Brunet et al. 2007; Doyère et al. 2007; Pitman et al. 2002), are different than erasure techniques in that they are designed to reduce the emotional intensity of memories (e.g., for the treatment of post-traumatic stress disorder). Such techniques are not hindered by the distribution and network characteristics of memory storage because the emotional component of memories is handled by localized processes that specifically act on those memories that are currently active (i.e., new or reactivated).

The validity of the test for guilt detection relies on a low false-positive rate, and the validity of the test for innocence detection relies on a low false-negative rate. The next section reviews three memory detection techniques with an emphasis on their vulnerabilities to false positives and false negatives.

NEUROIMAGING TECHNIQUES FOR MEMORY DETECTION

The two most obvious neuroimaging methods for memory detection are event-related variants of electroencephalography (EEG) and functional magnetic resonance imaging (fMRI). EEG measures brain electrical activity that reaches scalp electrodes, and fMRI measures regional blood oxygenation in the brain, which is correlated with brain activity. *Event-related* refers to a specific sensory stimulus event rather than an entire event, such as a crime, that would have a multitude of sensory stimuli associated with it. Event-related neuroimaging presents an event to a participant, and then measures the resulting activity. Memory research using event-related EEG (called the *event-related potential*, or *ERP, technique*) or event-related fMRI has sought to identify characteristic activity that occurs when an event has been presented to the brain prior to the test, as is the case with crime-relevant events and the criminal's brain. For all the effects described later in text, the activity resulting from *old* events (i.e., presented earlier) is quantitatively distinguishable from that resulting from *new* events (i.e., not presented earlier). Note that the utility of these effects are not compromised by the aforementioned characteristics of distributed memory networks. Even if a memory trace is distributed, a test need only find it in one place to demonstrate its existence; moreover, some of the effects described later in text indeed find distinguishable activity in multiple regions. The fact that many memories are stored in a single network is not a problem either, as long as the network is differentially active for old and new events.

Each of the effects reviewed will be evaluated on the following four attributes that characterize the ideal memory detection test for criminal investigations:

1) *Specificity*: Everyone has seen knives before, but only the guilty examinee has seen the specific knife that was used in the crime. If an effect occurs for new events that merely resemble old events, then there is a real risk of false positives. On the other hand, if an effect is very specific, then false negatives could result if the event is an inaccurate portrayal of the crime stimulus.
2) *Retrieval automaticity*: One of the problems that limits the validity of the polygraph is its vulnerability to countermeasures (National Research Council 2003). The neuroimaging effects described here distinguish between old and new activity, and an effective countermeasure would use mental control to make old and new activity indistinguishable. Old/new differences can be eliminated by making old events look new or by making new events look old. A memory effect that has automaticity is resistant to the former type of countermeasure. In other words, there is nothing that an examinee can do to make an automatic memory effect produce new-like activity for old events. A non-automatic effect, on the other hand, is susceptible to countermeasures and thus prone to false negatives. The second type of countermeasure, in which new events are made to look old, is also a very real possibility, especially for tests that lack specificity. For example, if the new (crime-irrelevant) events include a tree, then the guilty examinee can attempt to recall a tree from the past, thereby producing old-like brain activity from which the brain activity produced by crime-relevant events will be indistinguishable.
3) *Encoding flexibility*: Encoding refers to the initial presentation of a stimulus. In the criminal investigation scenario, encoding occurred at the crime. All memory and neuroimaging research uses a prospective memory approach in which the encoding conditions are both known and controlled. This research has shown that the encoding conditions can have a profound impact on how a stimulus event is responded to on subsequent presentations. A criminal investigation necessitates a retrospective memory approach in which the encoding conditions are neither known nor controlled. For this reason, it must be assumed that the encoding conditions could have been poor. If a memory detection test is to ensure a low false-negative rate, then the effects must be robust in a variety of encoding conditions.
4) *Longevity*: Because considerable time might pass between the crime and the memory detection test, an ideal effect would remain measurable for long retention intervals. If an effect is known to decay to the point of immeasurability after a certain retention interval, then it should not be used for longer retention intervals. Otherwise the likelihood of false negatives is too high.

Priming Effects

The first effects I will describe are usually referred to as neural *priming* effects (Schacter et al. 2004) or *repetition suppression* effects (Grill-Spector et al. 2006). Just like priming a surface affects the way it receives paint, priming the brain with a stimulus affects the way it responds to the stimulus on subsequent presentations. Neuroimaging studies of priming have generally shown a reduction in activity for primed (old) events compared with unprimed (new) events, and the most consistent reductions are found in regions of the brain involved in the perceptual processing of sensory stimuli (Grill-Spector et al. 2006; Schacter et al. 2004).

Specificity

Priming effects are most robust when the event is perceptually identical to the prime stimulus (Koutstaal et al. 2001; Schacter et al. 2004). This has obvious implications for how priming effects might best be employed in criminal investigations. For example, if a knife was used in a crime, then a photograph of the actual knife would be more likely to elicit a priming effect than a pictorial representation of the knife, a photograph of another knife, or the word *knife*. Priming effects can also be attenuated when the prime and event, although the same object, are shown from different viewpoints (Vuilleumier et al. 2002). If priming effects are to be used in criminal investigation, then the selection of events should thus consider the most likely viewpoint of the perpetrator. In summary, priming effects are very specific, and thus there seems a greater risk of false negatives than false positives.

Retrieval Automaticity

Priming effects are thought to occur automatically (Wiggs and Martin 1998). Most priming research has used experimental tasks, often called *indirect memory tasks*, in which participants are not told that they are participating in a memory experiment, and they are given a task to do that is not explicitly mnemonic. Researchers generally assume that participants are not aware that they have seen an old event earlier. It is easy to envision a criminal investigation scenario, however, in which a guilty examinee is aware that they have seen a particular crime-relevant event earlier. Thus it is useful to consider research that has examined whether priming effects occur for *direct* memory tasks in which participants are explicitly told that some events are old. Although some studies have shown similar priming effects for direct and indirect tasks, other studies have shown differences (Henson 2003; Henson et al. 2002). More research is clearly necessary to understand the test conditions under which automatic priming effects can be reliably measured.

Encoding Flexibility

The priming literature has examined the impact of attending to the prime stimulus at encoding. Attending to an object is not the same as looking directly at it; one can look at one object but attend to another. Several fMRI studies have found that visible but unattended primes produce smaller priming effects than attended primes (Eger et al. 2004; Vuilleumier et al. 2005; Yi and Chun 2005; Yi et al. 2006; although see Bentley et al. 2003). In criminal investigations, even if it can be assumed that the perpetrator viewed an object, it might be unsafe to assume that they attended to it. Imagine a murder investigation in which the shirt worn by the victim might seem an obvious choice for a prime because the perpetrator must have seen it. However, the shirt was likely irrelevant to the task at hand, and thus could have gone unattended. The selection of events for a memory detection test should thus consider the likelihood that an object received the attention of the perpetrator.

Longevity

Behavioral priming effects can last an impressively long time (Cave 1997; Mitchell 2006). The question remains, however, whether neural priming effects last as long as their behavioral correlates. The first studies to confirm the longevity of neural priming used modest retention intervals of days (van Turennout et al. 2000, 2003), but a more recent study (Meister et al. 2005) found lasting, albeit less distributed, priming effects after a six-week retention interval.

Old/New Effects

Old/new effects are similar to priming effects in that they are differences in neural activity for old and new events. The primary difference is that old/new effects are thought to reflect memory retrieval processing rather than perceptual processing. When an old event is presented, there are two distinct types of retrieval processes that might be initiated (Yonelinas 2002). One type, called *familiarity*, is relatively fast and automatic and results in knowing that an event is old without remembering the context in which it was seen. The other type, called *recollection*, is relatively slow and effortful and results in remembering the context in which an old event was seen. ERP research has led the way in identifying distinct old/new effects associated with familiarity and recollection (Friedman and Johnson 2000; Rugg and Yonelinas 2003). The *mid-frontal* old/new effect, associated with familiarity, is a negative potential occurring between 300 and 500 milliseconds after event onset that is less negative for old than new events at mid-frontal electrode sites. The *parietal* old/new effect, associated with recollection, is a positive potential occurring between 400 and 800 milliseconds after event onset that is more positive for old than new events at parietal electrode sites.[2] More recently, fMRI research has also been successful at identifying brain activity uniquely associated with familiarity and recollection (e.g., Daselaar et al. 2006; Henson et al. 1999; Yonelinas et al. 2005).

Specificity

New events that are similar to old events are sometimes falsely recognized as old. Such false recognition is associated with the experience of familiarity (Yonelinas 2002), and mid-frontal old/new effects have shown old-like activity for similar-new events (Mecklinger 2006). Although this suggests a risk of false positives, there is reason to think that this problem is not as great as it may seem. False feelings of familiarity are a relatively rare occurrence in everyday life—it is not as if objects we encounter commonly elicit feelings of familiarity simply because of their resemblance to old objects. Scientists who wish to study familiarity in the laboratory thus create artificial situations in which participants are much more likely to experience familiarity and false recognition (e.g., Curran and Cleary 2003). Other research suggests that the mid-frontal old/new effect might be appropriately specific. For example, it is sensitive to study-to-test changes

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[2] Two hypotheses stated here are not without controversy among memory scientists. Namely that: 1) familiarity and recollection are supported by distinct retrieval processes, and 2) the mid-frontal and parietal old/new effects represent familiarity and recollection, respectively. Nevertheless, the application to memory detection is unaffected by these scientific controversies. In other words, as long as an old/new effect distinguishes old from new events, it does not matter whether that effect is uniquely associated with a particular mnemonic process or experience.

in stimulus format (Schloerscheidt and Rugg 2004) and context (Tsivilis et al. 2001).

Retrieval Automaticity

The automaticity of old/new effects has been assessed in studies that have used an *exclusion* methodology (Jacoby 1991). In exclusion tasks there are usually two types of old stimuli, one of which is to be classified as old (i.e., included) and the other as new (i.e., excluded). If brain activity associated with recognizing old events is automatic, then excluded events should show the same activity as included events. Existing studies suggest that this is the case for the mid-frontal old/new effect (Bridson et al. 2006; Czernochowski et al. 2005), but is not always the case for the parietal old/new effect (e.g., Dywan et al. 2002; Herron and Rugg 2003). These results are consistent with the suggestion that familiarity is automatic, but recollection is not (Jacoby 1991). Other results suggest that the parietal old/new effect might be immune to the types of deliberate misclassification that would be used by the guilty examinee trying to conceal his recognition of crime-relevant events (Johnson et al. 2003; Tardif et al. 2000).

Encoding Flexibility

ERP studies have examined two encoding manipulations: 1) *divided attention*, and 2) *levels of processing*. In divided attention studies (Curran 2004), optimal encoding is represented by a *single-task* condition in which items are studied for a later recognition test, and suboptimal encoding by a *dual-task* condition in which studying must be done simultaneously with a second task. In levels of processing studies (Rugg et al. 1998, 2000), optimal encoding is represented by a *deep* encoding condition in which semantic judgments are made about the items, and suboptimal encoding by a *shallow* encoding condition in which perceptual judgments are made. The results suggest that the mid-frontal effect is relatively insensitive to the encoding conditions, and that the parietal effect is relatively sensitive.

Longevity

ERP research has used retention intervals that are far too short to assess the practical longevity of old/new effects. In fact, the studies that have been designed to confirm that the mid-frontal old/new effect has longevity have used retention intervals of only one day (Curran and Friedman 2004; Wolk et al. 2006).

P300 Effects

Although related to the parietal old/new effect (Spencer et al. 2000), P300 effects have been used somewhat differently and thus will be treated separately here. The P300 is a positive ERP occurring between 300 and 1000 milliseconds after event onset that is maximal at mid-parietal electrode sites for events that are both infrequent and meaningful (Polich and Kok 1995). The classic P300 task, called the *oddball task*, requires participants to make one response to infrequent *target* events and another response to all other (*non-target*) events, thus producing a more robust P300 for targets than non-targets. Applications to memory detection were considered following the discovery that old non-targets could produce a target-like P300 (e.g., Allen et al. 1992; Farwell and Donchin 1991; Rosenfeld et al. 1988). In P300 memory detection tests, there are usually three types of events: targets and two types of non-targets. *Irrelevants* are frequent non-targets designed to be meaningless to all participants, and *probes* are infrequent non-targets designed to be meaningless to some participants and meaningful to others. In the crime investigation scenario, probes are crime-relevant events designed to be meaningless to innocent examinees and meaningful to guilty examinees. Studies employing this method have generally shown that probes elicit a target-like P300 for guilty examinees, and an irrelevant-like P300 for innocent examinees (e.g., Farwell and Donchin 1991).

Specificity

Most P300 studies have used words rather than pictures as events. Because words are recognizable stimuli to all literate examinees, it is only in the context of the test that targets, probes, and irrelevants take on their respective roles. Word stimuli thus make specificity a challenge. It is not so much a problem for targets and irrelevants because they are distinguished by frequency and task-relevance, which are known to be important factors in P300 generation. The task-irrelevance of probes, however, creates a risk that they could produce irrelevant-like effects for guilty examinees (i.e., false negatives). The solution to this problem is *context provision*. For example, in a recent PBS special featuring the Brain Fingerprinting test (Brain Fingerprinting Laboratories, Inc., Seattle WA),[3] the examiner read the following statement to examinees: "In this test, you will see an item that one of the suspects was wearing when he was apprehended, an item that was in the possession of the suspects when they were apprehended, the item the suspects were stealing, and where the crime was committed (the kind of place, dwelling or establishment)" (Innovation: Brain Fingerprinting 2004). These statements referred to the probe stimuli; for example, the probe 'flashlight' was referenced by the statement concerning the item in possession of the suspects. This context provision was designed to increase the likelihood that 'flashlight' elicited a target-like P300 for guilty examinees.

The context provision approach is vulnerable to countermeasures. For example, if the guilty examinee simply ignores the contextual information, the meaningfulness of the probe 'flashlight' is likely to be comparable for guilty and innocent examinees, as everyone has had some experience with flashlights. To be fair, some word probes, even without

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[3] The Brain Fingerprinting test is a P300 memory detection test originally developed by Farwell and Donchin (1991) and more recently commercialized by Brain Fingerprinting Laboratories, Inc., Seattle, WA (Rosenfeld 2005). The PBS special was part of the Innovation series, and originally aired in May 2004; available at: http://www.pbs.org/wnet/innovation/episode8.html (accessed December 7, 2007).

context provision, are uniquely meaningful to guilty examinees. Nevertheless, words are inferior to pictures in terms of their potential for meaningfulness, and a photograph of the specific flashlight used in the aforementioned crime would presumably have been less likely to require context provision in order to have elicited a target-like P300 in guilty examinees.

Retrieval Automaticity

The P300 memory detection task described previously is an indirect memory task that does not force guilty examinees to be deceptive concerning their recognition of probes. In other words, when the task requires a target/non-target classification, probes are honestly classified as non-targets. Others, though, have used an old/new classification that forces the guilty examinee to dishonestly classify probes as new. Several studies have shown that the deliberate misclassification of old events as new (Johnson et al. 2003; Miller et al. 2002; Rosenfeld et al. 2003), or the exclusion of old events (van Hooff et al. 1996; van Hooff and Golden 2002), tends to attenuate the P300. The most likely cause of P300 attenuation in these studies is not dishonest responding, per se, but rather the mental effort involved in a difficult classification (Johnson et al. 2003).[4] In other words, it is more difficult to respond dishonestly than honestly. Because the probe P300 can be attenuated by dishonest responding to probe events, it is best to use an easy classification task that does not require examinees to be deceptive concerning their recognition of probes.

There are two countermeasure strategies that could be attempted by the guilty examinee in a P300 memory detection test: 1) to produce an irrelevant-like P300 for probes, and 2) to produce a probe-like P300 for irrelevants. There is no existing evidence to suggest that the former strategy is likely to be successful, as long as the probes are appropriately meaningful (see previous discussion) and the task allows honest classification of probes (see previous discussion). In other words, it is difficult to treat something meaningful as meaningless. The latter strategy, in which events designed to be meaningless are made meaningful, seems more intuitively plausible, and one study has provided evidence supporting this intuition. Rosenfeld et al. (2004) trained guilty participants, who had committed a mock-crime, to employ a countermeasure in which irrelevants were treated as task-relevant events. Although participants were still required to make an overt non-target response to irrelevants, they also made distinct covert responses to different categories of irrelevants, which resulted in a probe-like P300 for irrelevants.

The countermeasure strategy used by Rosenfeld et al. (2004) could be thwarted methodologically, however. The target, probe, and irrelevant events used by Rosenfeld et al. (2004), were organized into distinct categories. Countermeasure training involved informing guilty participants of the categorical nature of the test. They were then trained to make a particular covert response any time they saw an irrelevant from a particular event category. A simple way to prevent such a countermeasure is to eliminate the categorical nature of the test. Consider the following scenario. In preparation for a P300 memory detection test, a guilty suspect is being trained by a P300 countermeasure expert hired by his lawyer. The expert predicts that the weapon used in the crime will be used as a probe. If the test is known to have a categorical structure, then the expert can also predict that the target and irrelevants will be weapons. Thus the expert can train the suspect to use the countermeasure used by Rosenfeld et al. (2004); in other words, the suspect can be trained to make a distinct covert response every time he sees a weapon event. If, on the other hand, the test does not have a categorical structure, then advance training of this nature is impossible, and the only countermeasure available to the guilty examinee is to prepare to make covert responses to irrelevant events that cannot be predicted in advance. It is certainly possible that such a countermeasure strategy will result in a probe-like P300 for irrelevants, but this possibility has not yet been tested.

Encoding Flexibility

Farwell and Donchin (1991) provided a highly optimal encoding environment for probe stimuli. The participants were given detailed instructions before performing a mock act of espionage. The instructions included to-be-memorized details that would later become the probe events in a memory detection test. To ensure that the details were memorized, the participants were repeatedly tested until they had responded correctly at least five times to questions regarding each of the probes. Although this type of memorization might be representative of some types of premeditated crimes, there are many crimes that have far less optimal encoding conditions. Several recent studies have examined the effect of suboptimal encoding on P300 memory detection (Rosenfeld et al. 2006; 2007; van Hooff 2005; van Hooff and Golden 2002). In these studies, suboptimal encoding was represented by an *incidental* encoding condition and optimal encoding by an *intentional* encoding condition. The results have been mixed—incidentally encoded information sometimes does (Rosenfeld et al. 2007) and sometimes does not (van Hooff and Golden 2002) elicit a P300. Given that in many crime situations the perpetrator is not intentionally memorizing crime details, these results suggest that one cannot assume that all crime details will be salient enough to later elicit a measurable P300.

Longevity

In their oft-cited mock espionage experiment, Farwell and Donchin (1991) used a one-day retention interval. In a

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[4] The attenuation of the P300 under high mental effort conditions suggests another possible countermeasure strategy in which the guilty examinee increases task difficulty by covertly performing a second task during the memory detection test (Bashore and Rapp 1993). One limitation of this strategy is that the constant performance of the second task should affect the P300 for all stimuli (i.e., not just probes), and thus the probe P300 should still look target-like.

second experiment, they intended to test the efficacy of their procedure over longer retention intervals by using participants who had committed actual crimes sometime prior to the test. However, because the participants' memories for the crimes were revisited in an effort to determine the appropriate probes for the memory detection test, this experiment should not be considered a longevity test. More research is necessary to assess the longevity of P300 memory detection tests.

SCIENTIFIC ISSUES

Previous research was reviewed in the preceding section and is summarized in Table 1. This section reviews what still needs to be done before these techniques can be put to use in criminal investigations. It also discusses the likelihood that future research will find that the techniques meet the standards required by criminal investigations.

Future Research

All of the research reviewed in the previous discussion was conducted in laboratory environments, and field tests will be an important component of future research. Because the application of P300 effects to memory detection was first considered at least 20 years ago, P300 effects have been tested in situations designed to resemble criminal investigations. By comparison, priming and old/new effects have been tested in situations that lack ecological validity. This is most obvious when considering automaticity, because memory researchers who use priming and old/new effects have not considered situations in which participants are trying to conceal their recognition of old events. Whereas memory research typically reports the combined effects of many participants, criminal investigation requires an assessment of individual examinees. Although priming and old/new effects have occasionally been used at the individual level in cases of amnesia (e.g., Düzel et al. 2001), P300 memory detection tests have been developed with the individual in mind (e.g., Farwell and Donchin 1991). Allen (2002) has provided invaluable information concerning the best way to implement the individual approach in memory detection. Lastly, it would be interesting to see whether variables that influence P300 effects, such as the infrequency of old events, have similar influences on priming and old/new effects.

Longevity and encoding flexibility have not been sufficiently tested for any of the effects reviewed in the previous discussion. Future tests of longevity require a lengthening of the retention interval so that it resembles that which is likely to occur in criminal investigations. As for encoding flexibility, there are many factors likely to affect encoding that have not yet been tested. These factors include the heightened emotional state of the perpetrator (something that cannot easily be reproduced in mock crimes), the possible presence of drugs (e.g., alcohol) in the nervous system of the perpetrator, and the age and health of the perpetrator.

Other issues arise at retrieval (i.e., when the memory detection test is administered) rather than encoding. For example, the emotional state of the examinee at the time of the memory detection test must be considered, because such factors have been shown to affect brain activity (Polich and Kok 1995). Also, an uncooperative examinee could sabotage a test by not following task instructions or by preventing reliable brain measurement (e.g., moving the head during an fMRI scan).

Forensic Potential

The existing research provides no conclusive evidence to suggest that any of the techniques are devoid of forensic potential. Nevertheless, much research is yet to be done. Some of the problems identified in the previous discussion, especially those related to specificity and automaticity, have the potential to be solved with methodological advancements. For problems associated with encoding flexibility and longevity, on the other hand, there is much less reason to be optimistic that methodological advancements will provide solutions. Among the sins of memory categorized by Schacter (2001), the sins of *absent-mindedness* and *transience* respectively describe the encoding flexibility and longevity problems. In other words, methodological advancements can do nothing about the fact that memory has a tendency to fail when the encoding conditions are poor and the retention interval is long. For this reason, it would not be at all surprising if further research using poor encoding conditions and long retention intervals provided evidence that false negatives were a genuine and insurmountable problem for memory detection.

ETHICAL ISSUES

> Nothing was your own except the few cubic centimetres inside your skull.
>
> — George Orwell, *Nineteen Eighty-Four* (1949, 25)

To those who live in free societies, Orwell's Oceania was the ultimate dystopia in which the Thought Police possessed effective means for identifying what was going on inside the minds of individuals based on their overt behavior. As suggested by the quote, the Thought Police did not have neuroscientific techniques for extracting the thoughts out of the brains of individuals. It is not surprising, then, that modern society is extremely wary of the prospect that neuroscience research is attempting to develop, or has developed, such techniques (Sententia 2001). Although one would like to think that free societies could be trusted to use such techniques appropriately, recent events (e.g., the use of torture in interrogations and the increased invasiveness of domestic surveillance by the United States since 9/11) make it clear that such thinking would be naive. It is important to note that EEG- and MRI-based techniques are impractical for surveillance because the former require the attachment of electrodes to the scalp and the latter require that the head remain stationary inside a strong magnetic field.

Table 1.

Technique	Test attribute	Manipulations	False negative risk	False positive risk	References
Priming Effects	Specificity	Stimulus specificity	Manageable	Low	Koutstall et al. 2001
		Viewpoint dependence	Manageable	Low	Vuilleumier et al. 2002
	Automaticity	Direct memory task	Mixed results	—	Henson 2003; Henson et al. 2002
	Encoding flexibility	Attention	Manageable	—	Bentley et al. 2003; Eger et al. 2004; Vuilleumier et al. 2005; Yi & Chun 2005; Yi et al. 2006
	Longevity	3 days	Low	—	van Turennout et al. 2000, 2003
		6 weeks	Low	—	Meister et al. 2005
Mid-Frontal Old/New Effects	Specificity	False recognition	—	Manageable	Curran & Cleary 2003
		Stimulus specificity	Manageable	Low	Schloerscheidt & Rugg 2004
		Contextual specificity	Manageable	Low	Tsivilis et al. 2001
	Automaticity	Exclusion task	Low	—	Bridson et al. 2006; Czernochowski et al. 2005
	Encoding flexibility	Divided attention	Low	—	Curran 2004
		Levels of processing	Mixed results	—	Rugg et al. 1998, 2000
	Longevity	1 day	Low	—	Curran & Friedman 2004; Wolk et al. 2006
Parietal Old/New Effects	Specificity	False recognition	—	Low	Mecklinger 2006
	Automaticity	Exclusion task	Mixed results	—	Dywan et al. 2002; Herron & Rugg 2003; Johnson et al. 2003; Tardif et al. 2000
	Encoding flexibility	Divided attention	High	—	Curran 2004
		Levels of processing	High	—	Rugg et al. 1998, 2000
	Longevity	1 day	Low	—	Curran & Friedman 2004; Wolk et al. 2006
P300 Effects	Specificity	Context provision	High	Manageable	Farwell & Donchin 1991
		Task-irrelevance of 'probes'	Manageable	—	Farwell & Donchin 1991
		Task-irrelevance of 'irrelevants'	—	Low	Farwell & Donchin 1991
	Automaticity	Dishonest classification	High	—	Miller et al. 2002; Rosenfeld et al. 2003; Johnson et al. 2003
		Exclusion task	High	—	van Hooff et al. 1996; van Hooff & Golden 2002
		Countermeasure training	Manageable	—	Rosenfeld et al. 2004
	Encoding flexibility	Incidental encoding	Mixed results	—	Rosenfeld et al. 2006, 2007; van Hooff 2005; van Hooff & Golden 2002
	Longevity	1 day	Low	—	Farwell & Donchin 1991

One might argue that the neuroscientific examination of a criminal suspect is inherently unethical because it violates the suspect's right-to-privacy. If our own thoughts are open to examination, the argument goes, then nothing is private. Although I appreciate this argument, its application to memory detection is dubious, for the following reason: memory detection is not mind reading. All of the techniques reviewed previously measure neural activity associated with the recognition of old events. Recognition is a thoughtless ability possessed by the most primitive of animals. Engineers build machines that perform recognition tasks, and although these machines are far from simple, their complexity is sensory/perceptual, rather than cognitive, in nature. In some cases (e.g., indirect tests of priming) the brain recognizes an event without the mind being consciously aware. So a true positive result on a memory detection test is achieved without reading the examinee's mind. All the test is doing is determining whether the brain has been exposed to crime-relevant information. Is this logically different than judging whether a suspect was present at the crime by using physical evidence found on the suspect's body (e.g., finding a strand of a rape victim's pubic hair amid the pubic hair of a suspect and using the hair as evidence)?

Thoughts aside, it could be argued that one's memories are private. Consider the analogy of the person as a camera, in which the eyes are the lens and the brain is the storage medium (e.g., memory card). It is disturbing to think that an investigator could access one's memory card, and the unethical use of such technology is an oft-explored theme in science fiction. However, the camera analogy breaks down in a way that should alleviate most concerns. First of all, imagine that the memory card is stuck in the camera and cannot be removed. Next imagine that there is no way to transfer the image files to another device. Lastly, imagine that there is no LCD (liquid crystal display) screen on the camera to allow one to view the image files. The only access to the files is to confirm their existence by taking the same picture again, in which case the camera can signal that it has taken the picture before. This is reasonably analogous to the access that a memory detection examiner has to an examinee's memories. It would be difficult to argue that this type of evidence gathering is more invasive to one's privacy than other accepted types of evidence gathering (e.g., tissue samples for DNA testing).

Compare the person-as-camera analogy to a situation in which the perpetrator records the crime on a video or still camera so that he can relive the crime later. Such a recording contains far more information than would be uncovered by a memory detection examination. Who, on ethical grounds, would object to the recording being used as evidence? One who argues that memories are private might also be logically forced to argue that such a recording is private.

Slippery-slope arguments are also invalid when applied to memory detection. For example, one might be concerned that methodological advancements in memory detection techniques might allow an examiner to read out the memory that is currently being retrieved by the examinee. But this is purely science fiction. Recall that multiple memories are stored in a single localized network. ERP and fMRI are only equipped to gauge the level of activation in such a network, and the level of activation provides only rudimentary information about one's memory state. Perhaps someday a completely different technique will be developed that enables memory reading. However, because such a technique would not simply be an improvement of existing techniques, there is no reason to be concerned that the current acceptance of ERP and fMRI techniques as ethical will later be regretted. In other words, ethical issues should be revisited each time a new technique is developed.

The compulsory examination of a suspect's memory for crime-relevant details could be viewed as violating the suspect's right against self-incrimination. On the other hand, if the examination is voluntary, the suspect should rightly be concerned about how the courts will perceive a refusal to be examined. Similar issues arise with uncooperative witnesses—should they be forced to submit to a memory detection test?

There are obvious ethical issues concerning whether memory detection will be used only for its stated purpose. An example of an inappropriate use in a forensic context would be including events that are relevant to a second crime for which there is no probable cause to think that the examinee was involved. Legal systems in free societies have a long history of successfully excluding evidence gathered in such an inappropriate manner. It is important that legal systems remain vigilant about ensuring that memory detection evidence is limited to the crime for which the examinee was knowingly examined.

Neurotechnologies carry considerable weight among those (e.g., jurors, judges, suspects, witnesses) who do not understand them (Wolpe et al. 2005). In the Harrington case (reviewed in following text), a key witness whose testimony contributed to a conviction later recanted his testimony when presented with the results of a post-conviction Brain Fingerprinting test. A guilty suspect who is unaware of the false-negative problem might volunteer a confession because he thinks he has no chance of producing a negative result. The courts have to decide whether such consequences amount to coercion.

LEGAL ISSUES

Legal Admissibility

P300 memory detection test results have already been considered by courts in the United States. In *Harrington v. State of Iowa* (2000), a negative result on a Brain Fingerprinting test (conducted 23 years after the crime) was submitted by the plaintiff as part of a post-conviction petition for a new trial in a murder case. In 2001, an Iowa District Court judge admitted the Brain Fingerprinting evidence based on his judgment that the evidence met the Daubert standard (*Daubert v. Merrell Dow Pharmaceuticals*, 1993), but denied the petition because he determined that the Brain Fingerprinting evidence (and other new evidence) would probably not have changed the outcome of the original trial. Subsequently, a key witness whose testimony contributed to the conviction in the original trial recanted his testimony. According to Brain Fingerprinting Laboratories, the recantation was triggered by the presentation of Harrington's Brain Fingerprinting test results to the witness. The witness's new testimony, along with other new information, was included in an appeal to the Iowa Supreme Court, the District Court's decision was overruled, and a new trial was ordered. When the prosecution decided not to retry the case, Harrington was released.

Let us examine the judge's decision to admit P300 memory detection test evidence based on the Daubert standard. In *Daubert v. Merrell Dow Pharmaceuticals* (1993), the Supreme Court of the United States recommended that judges consider four factors when deciding whether to admit expert scientific testimony: 1) Has the technique been tested? 2) Has it been subjected to peer-review and been published? 3) What is its error rate? and 4) Is it generally accepted in the relevant scientific community? To aid in making his decision, the judge in the Harrington case heard testimony from three P300 experts: Lawrence Farwell (who administered Harrington's Brain Fingerprinting test), William Iacono, and Emanuel Donchin. It became clear to the judge that P300 potentials were more likely to meet the standard than the other potentials used by Farwell's Brain Fingerprinting test, and thus the latter were excluded.[5] Although this exclusion was a wise decision, the judge failed to make the important distinction between P300 effects in general, and the specific use of P300 effects for forensic memory detection. P300 effects in general are very well established in the field of psychophysiology, and this was reflected in the testimony of the P300 experts. However, as should be clear from my earlier review, the use of P300 effects for forensic memory detection is far from established. Consider each of the four factors recommended in *Daubert v. Merrell Dow Pharmaceuticals* (1993). The P300 memory detection technique has not been tested in the field and has not been tested in laboratory or field situations with poor encoding conditions and long retention intervals (factor 1). It has been peer-reviewed and published (factor 2), but not to the point that it is generally accepted by the relevant scientific community (factor 4). Its error rates in relevant situations are unknown, and there is reason to believe that the false negative rate in relevant situations will be high (factor 3).

The decision by the Iowa District Court judge to admit P300 memory detection evidence based on the Daubert standard is not binding on any court in Iowa or elsewhere (Moenssens 2002). Nevertheless it sets a precedent that will surely be considered for future cases in which P300 evidence is submitted. Thus, with all due to respect to the judge, who surely made the appropriate decision given the limited evidence before him, I would like to offer the opinion that his decision was wrong. As of the publication date of this article, P300 memory detection tests do not yet meet at least three of the four criteria recommended in Daubert. The use of priming effects and old/new effects for forensic memory detection are even further away from meeting the Daubert standard.

Some jurisdictions in the United States use the standard recommended in *Frye v. United States* (1923), according to which the admission of scientific evidence should be based on whether the technique has "general acceptance" in the relevant scientific field. Although priming effects, old/new effects, and P300 effects have general acceptance as measures of mnemonic processing, their application to criminal investigations will not have general acceptance until the necessary research (reviewed previously) has been conducted. In other words, the memory detection techniques reviewed here do not yet meet the Frye standard.

The False-Negative Problem

What made the admission of P300 evidence in the Harrington case particularly shocking was that the retention interval was 23 years, and the peer-reviewed publication on which the Brain Fingerprinting test was based (Farwell and Donchin 1991) used a retention interval of one day. A negative result on a memory detection test with a 23-year retention interval is a completely meaningless piece of information for those trying to determine the examinee's innocence or guilt.

Based on the scientific evidence reviewed earlier, it is clear that the forensic application of memory detection is more likely to be limited by false negatives than false positives. Ideally, any forensic technique would have low rates of both false negatives and false positives. Nevertheless, because the criminal justice system is based on the principle that it is worse to convict an innocent person (a false-positive error) than to acquit a guilty person (a false-negative error), and the likelihood of the former might be low, memory detection has forensic potential as a prosecution tool. Assuming that future research using poor encoding conditions and long retention intervals confirms a high false-negative rate, the courts would then have to decide whether to allow evidence from a tool that cannot be used to support the innocence claims of defendants. This hypothetical imbalance would also have interesting implications for the commercialization of memory detection services because such an industry would have only prosecutors (and not defendants) as potential clients. Ethical issues related to rights against self-incrimination have caused some companies developing forensic neurotechnologies to claim that their products will only be used to exonerate the innocent (Pearson 2006). In this context, the false-negative problem creates a real dilemma for companies developing memory detection tools.

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[5] The scientific problems associated with the potentials, other than the P300 potential, used in the Brain Fingerprinting test were reviewed by Rosenfeld (2005). Moenssens (2002), like the Iowa District Court judge, is under the mistaken assumption that the only science yet to be conducted before the Brain Fingerprinting test meets the Daubert standard relates to the these other potentials. I, on the other hand, submit that the use of P300 memory detection does not yet meet the Daubert standard.

A False-Positive Problem?

Some may think that I have underestimated the likelihood of false positives. For example, even when a memory detection technique has the appropriate level of specificity, crime-relevant events are likely to produce old-like activity in some innocent examinees some of the time. There are at least three methodological constraints designed to address this problem. First, crime-relevant events (e.g., probes) should always be compared with crime-irrelevant events (e.g., irrelevants), and the latter are (in theory) just as likely as the former to produce old-like activity in innocent examinees. Second, there should always be multiple crime-relevant events, and when only a subset of these trigger old-like activity, a negative result should be concluded. The appropriate criterion for concluding a positive result based on the level of brain activity produced by crime-relevant events is yet to be determined. This criterion must take into consideration that the criminal justice system abhors false positives, and that reducing false positives by adjusting the threshold used for declaring a test result positive will increase false negatives. A third methodological constraint requires that the memory detection test be given to a control group of known innocent examinees. A positive result for any of the control examinees would suggest that the test is flawed. The use of control subjects is particularly important because of concerns about the subjectivity of event selection (United States General Accounting Office 2001); in other words, if event selection biases a test to a positive result, then the results of the control subjects should identify the bias. Note that, because a memory detection test cannot be given to a control group of known guilty examinees, it is difficult to know whether the test is biased to produce a negative result, thus compounding the false-negative problem.

A second example of a false positive is when an innocent witness to a crime, for whom all crime-relevant events would presumably produce old-like activity, tests positive. Such a witness would not be protected by the aforementioned methodological constraints. It is thus important that memory detection test results are always used in conjunction with other types of evidence that would exonerate the witness. In other words, a positive result should be considered evidence consistent with guilt rather than evidence of guilt (Illes 2004).

Successful memory detection requires that details of the crime are only known to the guilty examinee. If details are made public by the media or during legal proceedings, the selection of crime-relevant events becomes extremely difficult, if not impossible. Despite this problem, Brain Fingerprinting Laboratories has put itself in the ridiculous position of selecting probes in cases that have already been publicized in the media and in the courts. If investigators or defense lawyers plan to put suspects through a memory detection test, it is extremely important that details of the crime are not made publicly available. Once details have been made available, the selection of crime-relevant events becomes futile and a memory detection test becomes useless.

Advantages of Memory Detection Over Lie Detection

Some have erroneously implied or suggested that memory detection tests are actually lie detection tests (e.g., Farwell and Donchin 1991; Garland and Glimcher 2006; Rosenfeld 2005). As should be clear from the previous review, priming effects, old/new effects, and P300 effects measure recognition rather than deception. Moreover, they can (and should) be measured without dishonest responding. Lie detection is fraught with issues concerning what defines lying and truthfulness and whether there is a consistent neural state associated with each (Buller 2005; Illes 2004; Wolpe et al. 2005). These issues do not apply to memory detection, which measures simple brain responses consistently evoked by stimulus events depending on their familiarity. Lie detection is also infamously vulnerable to countermeasures (National Research Council 2003). Although much research is yet to be done, some or all of the memory detection techniques reviewed here may prove to be sufficiently automatic to be relatively invulnerable to countermeasures.

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