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Limitations of Brain-based Lie Detection [1]

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Abstract
Brain-based lie testing methods are still very much in the experimental phase, and it is not yet proven whether there is any method that directly examines the human brain that is suitable for lie testing. Even if a method works, it is necessary to clarify the concerns and doubts that it raises. What would be the procedural and forensic limitations of such a method, and at what stage of criminal proceedings would it be appropriate? There are many questions and doubts, yet there are criminal cases overseas in which some methods considered suitable for lie detection, such as brain fingerprinting, have been used. These attempts were premature, and the method should have been validated before it was tried in a criminal case.

Keywords: lie detection, brain fingerprinting, brain, fMRI, fNIRS

Introduction

Brain fingerprinting, fMRI (functional magnetic resonance imaging), and fNIRS (functional near-infrared spectroscopy) are the three methods used for lie detection. The expectation of these methods is that they have greater validity than other lie detection methods (e.g. polygraph, grafomether, e layered voice analysis, thermal camera), because they directly examine the human brain. The polygraph channels are also related to the human brain, but only indirectly. Experts measure with the polygraph:

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- changes in respiration (abdominal wall deflections and the characteristics of the flow of expired and inspired air);
- changes in the electrical resistance or conductivity of the skin (with electrodes placed on the fingers or palms);
- changes in blood pressure/pulse rate (using a blood pressure cuff on the upper arm).
- it is also possible to measure the following parameters:
- the volume of blood flow through the periphery (plethysmography) is recorded with a photoelectric sensor attached to the fingers;
- the activity of the subject's movements is detected using sensors placed under the legs, on the armrest, or the cushion of the test chair. (Budaházi, 2015)

The physiological changes are related to brain processes, but only indirectly because the polygraph does not directly examine the human head or the brain activity.

Brain-based lie detection techniques are primarily carried out in the United States, but some methods are becoming more widely known in Europe and Asia. Brain fingerprinting and fMRI has also been used in criminal cases, but their use is infrequent, only in a few cases. We will discuss the reasons for this and the concerns and limitations of each method in this paper.

Brain fingerprinting

In the 1980s the American neuroscientist Larry Farwell has developed a lie-detecting technique that directly examines the brain. The brain fingerprinting detects whether specific information is stored in the human brain or not (Moenssens, 2002). The examinee is shown photographs flashed on a computer screen, amongst which some critical crime-related visual images appear. Should the brain react to the picture or word relevant to a crime, giving a so-called 'ah' signal (Farwell, 2012), the examiners consequently indicate that they are testing the perpetrator. In fact, the 'ah' or 'yeah' signal is 'MERMER' response, namely, Farwell has discovered a 'MERMER' signal in the brain, and the larger brain frequency component of that is known as P300 (Póczos, 2006). EEG (electroencephalogram) sensors are used in the analysis to detect the electric brain functions of the subject generated by various external stimuli. In case of a MERMER response the examiner concludes that the information connected to the effect is stored in the subject's memory. On the contrary, the irrelevant stimulus does not result in a MERMER response (Stoller & Wolpe, 2007).

Rosenfeld and colleagues (Rosenfeld, Nasman, Whalen, Cantwell & Mazzeri ,1987; Rosenfeld, Hu, Labkovsky, Meixner & Winograd, 2013) concluded that the P300 brainwave might be suitable for revealing concealed information stored in memory. Even the subject denies that this information (e.g., a particular object, environment, person) is known. However, the appearance of the P300 potential alone does not indicate a lie, only the recognition of information. Verbal denial of this may mean direct misrepresentation. The technique measurably shows whether the concealed information is present in the subject's consciousness (Littlefield, 2009). The detection of 'concealed' memory traces in the brain, the possibility provided by the P300, was recognized by another research group in the United States (Farwell & Donchin, 1986) contemporaneously with Rosenfeld and colleagues.

In their study, similar to Rosenfeld and colleagues, the CIT (Concealed Information Test) paradigm was applied. Farwell and his team tested the P300 brainwave-based technique both under laboratory conditions and on actual perpetrators. About detection of concealed information during the P300-based procedure Farwell's team reported good results in this early study and subsequent studies. Specificity and sensitivity values generally exceeded 90% (Farwell & Donchin, 1991). The name 'brain fingerprinting' is also due to this working group. Brain fingerprinting was used in several criminal cases in the United States in the early 2000s. The techniques were considered suitable to orient the investigation. According to some researchers, the expert can use the method to answer whether the subject's brain responds to a photo or text related to the crime. If he does not respond, it is presumed that he did not commit the crime. The expert shows photos, such as the gun with which the perpetrator committed the crime. The expert shows him several guns and watch which gun the P300 brainwave triggers. Brain fingerprinting is a non-invasive yet safe and painless technique. (Fox, 2008) Although it has already been used in three criminal cases in the United States, there are doubts as to its suitability for a lie detection.

P300 MERMER response

The basis of the operation of the technique is the P300 MERMER response. If the photo is familiar, the brain gives a P300 MERMER response. The P300 brain wave is a group of cerebral bioelectrical signals. It can be examined by electroencephalography (EEG) methods used in medical practice, among others. The EEG signal – i.e., the electroencephalogram – is a continuously changing voltage fluctuation over time, which is the sum of the electrical activities from billions of brain neurons. The EEG signal can be measured by the potential difference between a sensing electrode placed on the scalp ('scalp') and an electrically neutral point on the head (such as the earlobe). EEG is no longer registered from the scalp in case of scientific research and clinical trials using not one, but usually many, possibly hundreds, sensors so that the activity of each brain area can be monitored with high spatial accuracy. The P300 brain wave, which is important for brain fingerprinting, is an essential class of event-related evoked potentials. Sutton and colleagues first described the P300 brainwave in 1965 (Sutton, Braren, Zubin & John, 1965). In their experiment, subjects were presented with high and low tones in a ratio of 8: 2 in random order. Participants had to count the infrequent sounds. As a result of their study, they found that the P300 brain wave was always 'triggered' by rare sounds, regardless of whether the high or low sound was the rare stimulus. In which stimuli different in some respects from the series are used, this test situation is called the 'oddball' paradigm. The name P300 comes from the fact that after the stimulus is presented, it appears with a delay of about 300 milliseconds (hence 300) (typically lasts for hundreds of milliseconds), and the brainwave has a positive amplitude (therefore P) (Budaházi, Fantoly, Kakuszi, Bitter & Czobor, 2021). As a result of further studies, they described that the amplitude of the P300 wave is most significant in the midline parietal, central, and frontal brain areas. It grows in proportion to the 'rarity' of the stimulus and the subjective meaning and 'meaning' of the stimulus. 'Meaning in itself' can be certain stimuli, such as information about ourselves, name, birthday, phone number, or information about the crime. In other cases, a particular stimulus can be made 'meaningful' to the subject by augmenting it with a task (e.g., in a study to detect concealed information, pressing the appropriate response button after a particular image flashes) (Budaházi et al., 2021).

The study by Fabiani and his colleagues was an important milestone in exploring P300 brainwave memory (Fabiani, 1979). In their study, a list of words was taught to the participants. The P300 brain waves generated by the presentation of the 'familiar' words thus learned were studied. Specifically, the study involved presenting the subjects one by one with a long list of words, mainly consisting of 'new' words (not memorized words). However, one or two of the memorized 'meaningful' words were randomly and infrequently inserted into the new words, and the amplitude of the resulting P300 brain potential was analyzed. They found that the memorized, familiar words elicited a P300 potential, whereas the new words did not trigger a P300 brain wave.

Rosenfeld et al. (Rosenfeld et al., 1987; Rosenfeld et al., 2013) recognized that the appearance of the P300 potential might help to reveal confidential information about the crime. The authors hypothesized that the P300 brain wave might reveal information stored in memory even when the subject denies that this information (e.g., a particular object, environment, person) is known to him or her.

In this situation, the appearance of the P300 potential does not indicate in itself lying but only recognition of the information; its verbal denial may indicate direct misleading. The authors initially used the term 'guilty knowledge' (which is not precise enough and involves value judgments, so the use of the terms 'concealed' information is more justifiable).

The laboratory study conducted by Rosenfeld et al. involved participants in a simulated crime. Subjects were 'pretended' to have stolen one of 10 objects in a box. The names of the objects were then shown to the subjects one by one on a screen.

Based on the analysis of P300 potentials, the objects that the subjects 'stole' (pretended to steal) – known as probes – triggered a P300 potential in 9 out of 10 subjects.

The other 'irrelevant' objects did not produce a P300 potential. In this study, another special stimulus (target) was also used, presented at random.

For each specific randomly presented stimulus, subjects had to respond by saying the word 'yes'. The authors used this method to confirm that the subjects were actually focused on the task during the testing and thus attended to the test stimulus's presentation (probe).

When presented with all stimuli other than the target ringers, the subjects had to give a negative response ('no'), i.e., they had to lie about the items that were 'stolen' in the task situation.

The P300 potential was also elicited by specific target stimuli (objects), as these stimuli were infrequent and meaningful to the subjects.

It should be noted that the task used by Rosenfeld and his colleagues was very similar in many respects to the Guilty Knowledge Test (GKT) paradigm developed by Lykken (Lykken, 1959), which was later called the Concealed Information Test (CIT), mentioned above.

The possibility of detecting 'hidden' memory traces in the brain, a possibility offered by the P300, was recognized by another group of researchers in the United States (Farwell, 1986) at the same time as Rosenfeld and his colleagues were investigating it. In their study, like Rosenfeld's, they used the CIT testing paradigm. Farwell and his team tested the P300 brainwave-based method in laboratory conditions ('mock crime scenario') and on actual offenders.

Farwell's team reported good results for the P300-based method in this early study and subsequent studies (specificity and sensitivity values generally exceeded 90%) (Farwell & Donchin, 1991; Farwell, Richardson & Richardson, 2014). The name 'brain fingerprinting' was coined by this working group.

Recent meta-analytical studies suggest that the P300 brain wave provides a higher power of detection in CIT tests to reveal hidden information compared to psychophysiological parameters (e.g. skin resistance, respiration, heart rate) (Budaházi et al., 2021).

Brain fingerprinting in criminal cases

In 1977, Terry Harrington, who was 17 at the time, was accused of the murder of John Schweer, a retired police captain. The victim worked as a security guard at a car dealership, where the offense took place (Hurd, 2012). In the criminal procedure, Harrington had alleged that he had been at a rock concert with friends in another town on the evening of the crime. Several witnesses corroborated the defendant's alibi. However, Kevin Hughes, a primary prosecution witness who was 16 at the time, testified in contradiction to the defendant's plea, upon which Harrington was found guilty and sentenced to life without parole. In 1997, Harrington petitioned the Iowa District Court for post-conviction relief for a new trial, and in March 2000, he amended his petition to include the results of Farwell's brain fingerprinting testing. The applicant alleged that the brain fingerprinting results enhance new evidence unknown to the first decree court and upon which the defendant should have been acquitted. Farwell concluded that Harrington's brain did not store critical details of the crime subject to his conviction; for example, his brain did not recognize the crime scene.

On the other hand, with regards to critical details on the alibi (he had been at a concert on the evening of the crime) Farwell concluded, that Harrington's brain stored such information. When confronted with the brain fingerprinting test results, Kevin Hughes, the key prosecution witness, recanted his testimony and admitted that he had lied in the original trial, falsely accusing Harrington. Hughes explained that he had lied, fearing that he might have been charged with murder himself if he was telling the truth (URL3).

In November 2000, the Iowa District Court held a hearing on the petition for post-conviction relief. Farwell has testified as an expert on the new method. Furthermore, two acknowledged professors, William Iacono of the University of Minnesota and Emanuel Donchin of the University of Illinois, have confirmed the efficiency of the Farwell research and stated that brain fingerprinting – as a scientific method – can recall any information stored in the human brain with a 99.9% accuracy. It enhances the technique to meet the legal standards for admissibility for the authorities proceeding in criminal cases as reliable evidence (URL3).

After an eight-hour session, the court ruled that brain fingerprinting testing met the legal standards for admissibility in court as unquestionable scientific evidence. It constituted new evidence in the case that could be the ground of a new trial opened upon the post-conviction petition. However, the court also ruled that along with other newly discovered evidence in the case would probably not have resulted in the jury arriving at a different verdict than at the original trial, and therefore it denied the petition for a new trial. In August 2001, Harrington filed an appeal on the Iowa District Court's decision to deny a new trial, resulting in the Iowa Supreme Court ordered a new trial (Harrington v. State, 659. N.W.2nd 509 (Iowa 2003, No.96-1232.). Although the Iowa Supreme Court has undoubtedly acknowledged Farwell's expert opinion on brain fingerprinting testing, the good closure of the case to Harrington was based on the injury of the Brady rule. Thus, the defendant was not confronted with the key prosecution witness since he recanted his testimony when confronted with the brain fingerprinting test results. In the light of the new evidence and the fact that the key prosecution witness of the original case recanted his testimony, the base of the conviction, in 2003 Harrington was released and his conviction was reversed. He has received USD 12 Million compensation for the years he had spent in jail (URL3). In connection with the Harrington case, Rosenfeld criticizes the fact that the concealed information was not found in the convict's mind more than twenty years after the crime was committed, so he believes the naive conclusion that Harrington did not commit the crime was not there (Rosenfeld, 2005). The suggestion is valid, and it is also questionable when the image of the concert serving as an alibi may have entered his brain. On the day the crime happened or at another time? Also, what photo did Farwell have of the concert? When was it made? Did it trigger a P300 brainwave because Harrington was actually there at the concert seen in the picture on July 22, 1977, or was it just his brain that responded to a photo taken of a concert?

The James B. Grinder case

James B. Grinder has been the prime suspect of the murder of 25-year-old Julie Helton, despite the defense's conviction that the evidence was insufficient to indict him and convict him in first-degree murder. In January 1984, the abduction of Julie Helton was reported in Macon, Missouri. The victim's body was found three days after near a railroad track outside Macon. The coroner discovered signs of rape and physical abuse on the body and also found a stabbed wound on the neck. During the 15-year long criminal procedure, Grinder gave several different testimonies. He soon recanted his first testimony confessing his involvement and denied the offense. Some of his testimonies referred to other perpetrators of the crime. However, the testimonies were invariably contradictory to the available material evidence and to the testimony of an alleged witness of the defense. Even DNA tests did not bring favorable results since the blood samples taken at the crime scene were rather old. In 1999, Macon County Sheriff Robert Dawson – after approximately 10.000 man-hours of unsuccessful investigation – turned to brain fingerprinting testing to decide whether Grinder had committed the crime or not. Grinder, who had spent several years in prison before, agreed to the test. The Sherriff gave all significant information gathered during the investigation to Farwell, and Farwell completed the test with the cooperation of an FBI agent. He completed the examination at the correction institute where Grinder was held. During the analysis, he showed Grinder the murder weapon, specific methods of killing the victim, the object the perpetrator used to bind the victim's hands, the crime scene, and the victim's belongings found not far from the location of the offense after discovering the criminal act. Farwell concluded that all the critical information was stored and present in Grinder's brain. Following the principles of the method, the conclusion was that Grinder did commit the offense. Otherwise, his brain would not have enhanced MERMER responses to relevant information.

However, Grinder concluded a plea deal, pled guilty to rape and murder of the victim, and in exchange – instead of the death penalty – he agreed to a life sentence without parole. Uniquely, in this case, Grinder did not only confess to murdering victim Julie Helton, but after the brain fingerprinting examination, he gave a detailed confession to the murder of three more young girls. He first raped and then stabbed or beat his victims to death (URL4). As for now, there are two final and binding orders in a conviction of Grinder. Another procedure is still pending. Brain fingerprinting was essential both for confession and for the fact that Grinder committed 15 years before. The method could be used to detect that critical information was in Grinder's brain. The Grinder case dampens Rosenfeld's criticism of the Harrington case that years passed could remove concealed information from the brain.

The Jimmy Ray Slaughter case

In 2004, Jimmy Ray Slaughter, a death row inmate, had pleaded for a new trial referring to negative test results of brain fingerprinting (information not stored in the brain) and other evidence at the Court (of Criminal Appeals) of Oklahoma.

The appealer referred to the favorable results of brain fingerprinting and referred to the exempting results of DNS analysis and further evidence proving his innocence (Farwell, 2012).

Slaughter was condemned to death for the July 2, 1991 murder of his former girlfriend, the 29-year-old Melody Wuertz, and their child, the 11-month-old Jessica Rae Wuertz (URL5). He committed the killing actions in the victims' Edmond home. According to the ruling, Slaughter has shot both his victims in the head. In addition, he has hit his exgirlfriend in the neck. Moreover, he has stabbed the victim several times and then mutilated her body (URL2). Slaughter has claimed innocent of the crime all along, although investigation proved that he had a somewhat stormy relationship with his exgirlfriend, and they had numerous fights and furious quarrels over unpaid child support. In the end, Slaughter was executed. Denying the petition for a new trial, the court has also referred to brain fingerprinting. He stated the court did not recognize the results because the court did not receive a comprehensive and detailed method – neither on nature nor the application or the results of the technique. The brain fingerprinting 'evidence' would not have changed the balance of the scales before the jury – ruled the court. (Slaughter v. State, Oklahoma 2005, No. PCD-2005-77.) The Slaughter case also exemplifies that the result of brain fingerprinting alone is not sufficient to order a retrial because it is not the weight of evidence that would affect the judgment of the retrial court. Although the court justified disregarding the result of brain fingerprinting by not receiving information about the method, in our view, if Farwell had provided sufficient information about brain fingerprinting, the court would probably not have made any decision other than to dismiss the renewal request.

If the method works

While in two out of three cases in the United States, brain fingerprinting was performed on the accused to order a retrial, in Hungary, the legal regulations allow for the instrumental confession check during the investigation. According to the Hungarian Criminal Code (Act XC of 2017 on criminal procedures) '*During the investigation, the prosecution or the investigating authority may examine the testimony of the witness and the suspect using an instrumental examination of the testimony. The consent of the witness or the suspect is required for the examination.'* If brain fingerprinting were to become a validated method of examination and thus suitable for use in criminal cases, the Hungarian Criminal Code would not allow brain fingerprinting to be carried out either in court proceedings or during extraordinary legal remedies, but only during the investigation phase of criminal proceedings.

If the method works, brain fingerprinting could be a screening tool similar to a polygraph examination. In the case of a witness, the test result should rule out the possibility that the person tested is the perpetrator of the crime, or on the contrary, the test result is another argument in favor of suspicion. In the case of a witness, the method could be used both at the investigation and inquiry stages. During the detection phase, it would be most helpful to identify the perpetrator in the witness's position or show that the witness under investigation could not have committed the crime because there is no concealed information in his brain relating to the case. In a case that has reached the investigative stage, the use of brain fingerprinting may also be justified when checking the witness's testimony to see whether he or she saw everything as he or she said in the testimony, because the witness may not be telling the truth, but his or her brain activity may be exposed by the testing method (Farwell, 2012). Brain fingerprinting can be used to test confessions more widely than polygraphs because it can test the part of the confession where the witness honestly denies having committed the crime or know who the perpetrator is and to test other parts of the confession. As there is usually no identification of the perpetrator at the investigation stage because the suspected perpetrator is already known, it may be more appropriate to carry out a brain fingerprinting of the witness to verify the confession. Confession checking may also be necessary during the detection phase, so the detection phase is the most appropriate time to apply the method to the fullest extent.

Since only the suspect is interrogated during the investigation phase, all other evidentiary acts concerning the suspect occur in the investigation phase. Therefore the place for brain fingerprinting of the suspect is in the investigation phase when it is possible to examine whether the suspect committed the crime, whether the information about the commission of the crime is present in his brain. It can also be used to test a suspect who has confessed to the crime, but the authorities assume that he/she did not commit the crime but only took the blame. Brain fingerprinting may have the advantage over polygraphs in that it does not require fear of exposure and possible consequences and sanctions. This fear is not necessarily inherent in the accused in such a situation.

Concerns and limitations

The main problem with brain fingerprinting is that experiments are being conducted to test how the method works, but these experiments are far from being validated. In criminal cases, only Farwell provides validation figures. It is problematic because it does not necessarily meet the requirements of objectivity that not an independent organization carries out the testing. Further validation experiments are needed to verify the reliability of the technique.

The limitations of brain fingerpring include the need to have a photo available. If there is no photo of the scene of the crime, the means of committing the crime, the method of committing the crime, the victim, the case will not be suitable for brain fingerprinting. The availability of photos presupposes that the authority is beyond a practical inspection or research where, for example, a knife, a corpse, etc., used to commit a crime have been found. Photos can already be taken, but the possibility of applying the method is reduced if neither a picture of the victim, nor a knife is available, or it is not possible to know exactly where the crime was committed. For example, the polygraph may yield results, but the use of brain fingerprinting seems to be ruled out. Proper timing also plays an important role in the use of the method. On the one hand, this can be done when suitable photos are already available, and on the other hand, the photos should be taken as soon as possible to avoid, for example, a change in the crime scene (not the same picture in winter or summer, etc.).

It is essential whether the brain responds to the image seen on the monitor with the P300 because the person committed the crime or saw only the pistol in the photo on TV. Recent EEG research to eliminate the contrast used in the concealed information test promises a significant turnaround. In one study, Japanese researchers convincingly demonstrated that not only the display of information intended to be concealed could be linked to a specific brain response (the P300 brainwave), but also the process of concealment itself. They concluded that the relevant stimuli elicited a higher amplitude P300 potential than the irrelevant stimuli. They analyzed how the amplitude of the slow frontal wave varies depending on whether the memory content sought is 'absent' or 'present' in the subject's brain; and, if present, if the subject intends to conceal or reveal it. The results showed that selective correct hemisphere activation during the slow frontal wave was specifically observed when subjects tried to hide the recognition of the critical relevant stimulus (Matsuda & Nittono, 2018). These experimental results suggest that it is possible to determine from the activity of the hemispheres whether P300 can be detected because the subject committed the crime. However, this was only one experiment, and more experiments are needed.

Another problem is related to the photo. For the investigation to be effective, photographs must be presented to the person under investigation that capture circumstances of the commission of the crime that the person under investigation did not obtain information about in the criminal proceedings. In a case where the suspect knows everything that the investigators know because he has been exposed to all available information in a previous trial, there is no available information with which to construct probe stimuli, so a test cannot be conducted. Even in a case where the suspect knows many of the details about the crime, however, it is sometimes possible to discover salient information that the perpetrator must have encountered in the course of committing the crime, but the suspect claims not to know and would not know if he was innocent. This was the case with Terry Harrington. By examining reports, interviewing witnesses, and visiting the crime scene and surrounding areas, Farwell was able to discover salient features of the crime that Harrington had never been exposed to at his previous trials. The brain fingerprinting test showed that the record in Harrington's brain did not contain these salient features of the crime, but only the details about the crime that he had learned after the fact (Kumar, 2011).

A major, often unacknowledged, problem with brain fingerprinting is the suspect's possible lack of memory for details due to the passage of time since the crime and/or to drug and alcohol use. Additionally, an investigator needs to determine what the suspect will remember (Wilcoxson, Brooks, Duckett & Browne, 2020).

Brain fingerprinting detects information-processing brain responses that reveal what information is stored in the subject's brain. It does not notice how that information got there, be it a witness or a perpetrator. Brain fingerprinting does not detect lies. It simply detects information. No questions are asked or answered during a brain fingerprinting test. The subject neither lies nor tells the truth during a brain fingerprinting test, and the outcome of the test is unaffected by whether he has lied or told the truth at any other time. The outcome of 'information present' or 'information absent' depends on whether the relevant information is stored in the brain, and not on what the subject says about it (Ahuja & Singh, 2012).

Another problem is what information is stored in the subject's brain. It does not detect how that information got there. This fact has implications for how and when the technique can be applied. In a case where a suspect claims not to have been at the crime scene and has no legitimate reason for knowing the details of the crime and investigators have information that has not been released to the public, brain fingerprinting can determine objectively whether or not the subject possesses that information. In such a case, brain fingerprinting could provide useful evidence. If, however, the suspect knows everything that the investigators know about the crime for some legitimate reason, then the test cannot be applied. There are several circumstances in which this may be the case. If a suspect acknowledges being at the scene of the crime, but claims to be a witness and not a perpetrator, then the fact that he knows details about the crime would not be incriminating. There would be no reason to conduct a test, because the resulting 'information present' response would simply show that the suspect knew the details about the crime – knowledge which he already admits and which he gained at the crime scene whether he was a witness or a perpetrator (Kumar, 2011).

fMRI

The fMRI method looks at which brain parts are active when the subject sees a photo on the monitor or hears a word. Within the human brain, it can isolate a resolution of 1.5mm x 1.5mm x 4mm, an area the size of a grain of rice (pepper) out of a total volume of 150,000 such grains of rice. According to Csaba Fenyvesi, '*by detecting the oxygen consumption of the brain, the amount of blood flowing (the magnetic resonance of the hemoglobin molecules or hydrogen atom nuclei in the blood), fMRI can monitor a person's decision-making processes, thinking, emotions, and thus truthfulness or dishonesty*.' (Fenyvesi, 2007). Several studies have investigated how the BOLD (blood oxygenation level-dependent), an fMRI method based on blood oxygen content to visualise active brain areas (URL1), fMRI signal in different brain areas of subjects shows up in different forms of forced lying, spontaneous lying, memorized lying, feigned memory impairment, and the GTK (guilty knowledge test). The results show more significant activity in certain prefrontal and anterior cingulate regions in the case of lying (Simonyi, 2017). Birbaumer and Rosler, and co-authors, in their paper, based on a meta-analysis of data from a study using this method, confirmed activation of the right medial frontal cortex during testing (Birbaumer, Elbert, Canavan & Rockstroh, 1990).

While PET (positron emission tomography) imaging allows a view of average regional brain metabolism with radioactive-labeled glucose over fractions of an hour, fMRI more directly reflects regional metabolism by imaging the changes of oxygenation of hemoglobin in a more immediate fashion, as the blood passes through the circulation of the brain. SPECT (single-photon emission computed tomography) imaging also maps brain blood flow, but it uses radiotracers and an epoch of time too great to approach the speed of thought. The advantages of fMRI, therefore, include the absence of radioactivity and a time scale measured in seconds rather than minutes. Perhaps the chief threat to the validity of the use of fMRI to detect deception is the overinterpretation of its ability to map pathways underlying brain processes. No function has discrete localization except for the simplest lesion resulting in paralysis or pain. Brain functions, however, are distributed with many interconnections. The images generated by PET or fMRI are blurry compared with those obtained by microscope, or even a dissection for the demonstration of brain lesions. But how small is a thought? This facetious question unfortunately is the heart of the problem. Even if we were able to map the activity of each and every neuron in a time-lapse motion picture, we would still be up against Chaos Theory and the Heisenberg Uncertainty Principle in our attempt at understanding thinking and consciousness. Fortunately, the idea behind fMRI lie detection is much simpler than imaging a thought. The experimental finding that there is more activation (measured by oxygen use) in the prefrontal and anterior cingulate regions in the lie condition relative to the truth condition in an experimental setting is the basis of fMRI lie detection (Merikangas, 2008).

One of the experiments involved 23 participants from the University of Pennsylvania. They were offered $20 if they could conceal which card they had drawn. The experiment found that parts of the subjects' brains were more active when lying than telling the truth. They concluded that fMRI could detect these changes in brain activity (Langleben at al., 2002).

The fMRI has also been used in criminal cases in the United States, with at least four requests for it to be admitted as evidence in court - write Farah and colleagues (Fara, Hutchinson, Phelps & Wagner, 2014). It would not be a problem; in a polygraph examination in Hungary, the court practice does not accept the test result as evidence either, but it can still be considered as a recognized method to orient the investigation with good efficiency. The problem with the fMRI is that it is still very much in the testing phase, and it has not yet been proven beyond doubt that it is suitable for lie detection. It is also in need of validation by an independent institute. Further empirical research is needed (Spence, 2008). These circumstances are limitations of fMRI, which in themselves raise doubts as to whether it should be used in criminal cases where the stakes are high, and the case could end with imprisonment for the accused. We think it is not correctly ascertained yet that the method works and has sufficient validity.

Similar to brain fingerprinting, another limitation of the method is the projection of a photo or word for the person under investigation, which may include photos or words linked to the commission of the crime. The brain activity triggered by the relevant photos or words is examined. The main limitation is the image since the authority must have images that can be presented to the subject and linked to the crime. If there are no photos or insufficient photos, an fMRI scan is not possible.

Another problem is that fMRI is an expensive test. Another limitation of the method is that it requires the subject to remain still. It is necessary to ensure that the images of the brain can be taken properly. Cooperation is also required for polygraphy, so this limitation is not significant for fMRI, but there is also the issue of the subject's consent to the scan, which guarantees voluntariness. The use of fMRI is neither invasive nor painful.

fNIRS

All biological tissues transmit electromagnetic radiation of different frequencies and intensities to different degrees. It is the basis of all electromagnetic radiation imaging techniques, including fNIRS and fMRI. Near-infrared rays penetrate body tissues without any particular obstruction, providing a few centimeters of illumination. The method uses light absorption to determine tissue oxygen saturation, indirectly infers neural activity in the observed brain area (Simonyi, 2017). In a lie detection test, the near-infrared emitter and receiver are fixed to the subject's forehead (Simonyi, 2017). As in fMRI, photos are projected onto the subject in fNIRS. The limitations listed for fMRI are also a problem for fNIRS.

In one fNIRS experiment, subjects had to steal two banknotes of different denominations in a room. They then tried to determine which subject stole which banknote. In addition to fNIRS, the experiment also used polygraphs on the subjects. The averaged classification accuracies of individual fNIRS and polygraph were 71.6 and 74.5%, respectively; but that of the combined fNIRS-polygraph system, remarkably, was 86.5%. These results prove emphatically that the combined system is more efficient in discriminating between true and lie responses (Bhutta, Hong, Kim & Hong, 2015).

On the other hand, polygraph testing requires a real stake in the test, a fear of exposure by the subject and its consequences. If this fear is absent, the test will not be practical. The present experiment was not conducted in a real case, so there was no real stake in a possible detection, which is why the polygraph test could have resulted in a validity value of only 74.5%.

In another experiment, subjects had to say whether the coin would appear on the right or left side of the screen. They had to move their right or left hand under the tabletop secretly, but they did not know they had been videotaped. After the coin appeared on the screen, they had to declare whether they had hit the coin's position. They were awarded a point for a successful guess and a point deduction for an unsuccessful one. At the end of the experiment, a cash prize was offered for reaching a specific point limit. They were not told that this could only be achieved by cheating. As a result of the experiment, it was found that an fNIRS system could be built to study lying (Ding, G. X. Fu, G. Fu, G. Fu & Lee, 2013). As the phrase 'a lie can be studied' indicates, the method still needs time and further testing before it can be considered a lie testing method.

Conclusions

The brain fingerprinting technique, which is also considered suitable for lying, is characterized by the fact that its operation and validity are uncertain, although it has been used in criminal cases. In our view, the method should not have been used before proper validation. They have a high stake in criminal cases, and human destinies may depend on the endless, unvalidated technique that should not be used, even if it 'only' served the orientation of the investigation and was not taken into account by the court as evidence. Even the misorientation of the investigation no longer led a criminal case astray, which could even result in a judicial murder. Brain fingerprinting needs further testing, experimentation, and development. It is primarily due to the lack of validation and scientific validation related to the operation of the method that is rarely used. Even if brain fingerprinting were a validated method, it should help to orient the investigation. We think so, although it has been used in the United States in retrial proceedings. There is no longer any place for instrumental lie detectors in court proceedings. In the investigation, it may be of some help to know whether the person under investigation may be the perpetrator of the crime. If the person's brain reacts to the information sought, this does not mean that he or she committed the crime. It is necessary to investigate what might be the reason for the information being in the brain.

The fMRI has all the same problems as brain fingerprinting. Although there is a fair amount of testing, the method is still far from being validated. The fMRI has been used in criminal cases, but we agree that the court did not consider it evidence. The fMRI is not yet ready to be considered as a method to be used in criminal cases. The disadvantage of fMRI compared to brain fingerprinting is that it is costly. It does not help its future use as a lie detection method. The fNIRS method works similarly to fMRI and is expected to become more widely used because of its cost-effectiveness. Nor is fNIRS validated. It has not yet been used in criminal cases and is not yet well enough known to be a serious option. The limitation of both brain fingerprinting, fMRI, and fNIRS is that they work with photos. If there are insufficient or inadequate photos, this may make the case unsuitable for the use of the method. Even if one of the brain-based lie detection methods were to be validated and used in criminal cases, mass use is not expected, just like the polygraph has a narrower range of applications.

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