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# Review of Research on Detecting Deception Through Functional Magnetic Resonance Imaging (fMRI)

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New imaging techniques have given us a great opportunity to recognise the processes that take place in the human brain, and the interest of forensic sciences in this area of knowledge should come as no surprise. The key is to understand the processes that take place in the brain when telling a lie, which – in a broader perspective – can lead to the development of a technique allowing error-free detection of deception.

Imaging through functional magnetic resonance imaging (fMRI) is one of the neuroimaging techniques that is hoped to provide a failsafe lie detector. To this

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day, a sizeable number of experiments using the technique have been conducted all over the world, while forensic scientists have been keen on following its development (see e.g.: J. Widacki 2007). The goal behind the article is to present a review of the most important current studies related to the problem.

Technological progress makes it possible to become increasingly familiar with the lie related processes taking place in the human brain. In the first studies of these processes, the potential evoked by a particular stimulus (Event Related Potential) was used, yet due to the low spatial resolution, the method is being slowly abandoned (Abe 2009). A more advanced technique of neuroimaging is Positron Emission Tomography (PET), yet the cost of its use is very high, which is why functional magnetic resonance imaging (fMRI), a technique cheaper than PET and more precise than ERP, is commonly used.

One of the first experiments conducted with the use of fMRI was the one conducted by Spence and collaborators (2001) less than twelve years ago. Participating in the experiment were 40 subjects, who had earlier expressed their consent in writing. However, not all the people were placed in the scanner. Connected to the machine were only 10 (individually entering) participants, while the remaining group of 30 people were tested outside the scanner. The subjects were asked specific questions, and in answering all of them they had to answer by telling both the truth and by lying. In the experiment conducted, the scientists noticed that when the participants tried to lie the reaction time increased insignificantly, and specific regions of the brain (ventrolateral prefrontal cortex) became activated (Spence 2001). The experiment conducted by Spence and collaborators (2001) initiated a large volume of research that aimed at finding what is responsible for a lie at the neuronal level (Abe 2009).

Research on seeking the areas of the human brain related to lying has gained momentum. Less than a year after the experiment described by Spence and collaborators (2001), the results of an experiment conducted by Lee et al. (2002) were announced. Natives of China were selected for this experiment, all strongly right-handed, and all having successfully passed health tests. The subjects were asked to simulate problems with memory, which was to lead to an intentionally mistaken solution of two memory tasks. The first task was a test composed of two stimuli, each being a three digit number. The participant was presented with the numbers in certain time intervals (2.25 sec). Once both the numbers had been displayed, the subject was to state whether the two numbers presented (stimuli) were the same. The second question included autobiographical questions related to the subject. The participants were asked questions of the "Where were you born?" type. The authors of the experiment observed activity in various areas of the brain in the subjects. Increased reaction time and increased activity of the brain were registered in the prefrontal cortex, temporal cortex, parietal cortex, posterior cingulate gyrus, and the caudate nucleus.

Published in the same year was another, equally interesting, experiment using the fMRI. The experiment was conducted by Langleben and collaborators (2002). It is worth mentioning as it combined the guilty knowledge test (GKT) and the aforementioned functional magnetic resonance imaging. Initially, the test involved the participation of 23 right-handed subjects (12 women and 11 men), aged from 22 to 50, with an average age of 32. However, five subjects had to be excluded due to artefacts. Regular playing cards were used for the experiment, and the participants had to – simplifying the matter greatly – answer (by lying or telling the truth) questions concerning the cards shown. Increased activity and reaction time were also observed in this study, among others, in the area of the superior frontal gyrus, interior cingulate cortex, and interior parietal cortex. A number of significant conclusions were drawn from this experiment: an attempt at limiting or withholding the true answer by the subject can be considered an intended lie, and the superior frontal gyrus (SFG) and the anterior cingulate cortex (ACC) can be considered the areas of the brain responsible for lying. Moreover, the use of the fMRI technique for distinguishing between true and false answers was corroborated.

Three years after Langleben et al.(2002), the same group conducted another experiment. In 2005, they used a slightly modified guilty knowledge test. The experiment was conducted again with cards, but this time the experience included a remuneration of $20, which was to make the test in a way closer to the conditions present in the natural environment. Participating in the experiment were 26 right-handed people. The experiment conducted by Langleben et al.(2005) was the first attempt at a quantitative estimation of the precision of lie detection with the use of the fMRI technique. The precision in discerning lie from truth was 78%. The first experiment that was to define patterns of neuronal activity for lying, and true and false memories, was the experiment conducted by Abe and collaborators (2008). Participating in the experiment were 28 right-handed native Japanese, who had all successfully passed medical tests. The experiment used a list of words that were used to trigger errors in the memory of the participants. In the experiment conducted in this way, the supervisors of the examination determined that providing false answers results in increased activity in the prefrontal cortex area.

Most experiments using fMRI conducted to detect lie took place in premises designed for conducting such studies in isolation from the natural environment. Which is why, besides the introduction of gratification motivating the participants, interest began to focus on the moral aspects of such tests.

A good example is the experiment published by Green and Paxton (2009). To bring the conditions as close as possible to natural, they introduced monetary remuneration. The subjects were given money for the correct naming of the side of the coin displayed on the computer monitor (special application was used for dropping it). The participants had to write down their predictions or immediately provide oral answers. It must be mentioned that the subjects could try to cheat the researchers to obtain remuneration. Green and Paxton observed an increased activity of the prefrontal cortex area accompanying deception. Moreover, this form of activity also appeared in cases when participants tried to refrain from lying. In turn, in people who were sincere and honest, no increased activity in the aforementioned area was registered. The experimenters put forward a thesis that sincerity is related to the absence of temptation rather than to an attempt at countering it. Nevertheless, the experiment was the first attempt at finding a link between lie and an attempt to infringe on moral norms, and defined new directions of research.

Trying to bring experiments closer to the conditions present in the natural environment, Kozel and collaborators (2009) used a sabotage related design. In the experiment, participants were divided into two groups. The task of one was to take into possession and destroy CDs with incriminating evidence, while the other did not perform such an action. Going further, the respondents from the first group had to collect an envelope from an experimenter, while the other group did not perform the task. Both the groups were later to claim that they collected the envelope and did not attempt to destroy the CDs. Later, another task, called the Ring – Watch Test, was conducted; in this case, the participants were to take a watch or a ring. The subjects were asked to lie about this. Out of the group of 36 people participating in the Ring – Watch Test, lie was detected in the case of 25 participants. The Ring – Watch Test made it possible to select a specific number of people who were subjected to a single fMRI scan, this time concerning the test with envelopes and CDs. In the selected group of 25 people, nine out of nine participants of the CD and envelope trial, and five out of 16 of the Ring – Watch Test were correctly identified (Kozel 2009).

One of the new directions of research was examining not only healthy people but also ones who were unwell, or had traumas of neurological origin. A good case of such an experiment is the one conducted on patients with Parkinson's disease. The experiment was described and conducted by Abe and collaborators (2009). As is known from medical literature, Parkinson patients are more truthful than healthy people. Abe et al.(2009) tried to prove or deny that. Participating in the experiment were quite a large number of subjects, who were divided into two groups. The first consisted of 32 people affected with Parkinson's and 20 healthy individuals. The second group, in turn, was composed of 14 healthy people (seven women and seven men). Participants in the experiment were shown photographs, and later were asked questions concerning the illustrations. As can be guessed, the subjects were asked to lie or to tell the truth. In this study, Abe and collaborators (2009) used the PET technique. The researchers corroborated the hypotheses that people affected with Parkinson's are more likely to tell the truth than healthy ones. This is probably caused by a dysfunction of the prefrontal cortex. Moreover, the experiment showed that there is a powerful link between the prefrontal cortex (or to be more precise: left dorsolateral prefrontal cortex) with the processes that constitute a lie, and that the unique truthfulness of Parkinson patients has neurological grounds (Abe 2009).

Another good example of this type of experience comes from the experiment described by Kikuchi and collaborators (2010). Participating in the study were people who suffered from psychogenic (dissociative) amnesia. The experimenters observed activity of the right dorsolateral prefrontal cortex, probably related to the unconscious suppression of memory.

The experiment aimed at recognising the reactions of people observing attempts at deception was conducted by Grezes and collaborators (2004). The experiment consisted in watching videos and the subjects being later asked to answer whether the weight of the box lifted was actually as big as the expression of the actors suggested, or whether the actors were trying to deceive the viewers. The experimenters observed a major increase of activity in the rostral part of the anterior cingulate cortex area and in the amygdala in people who believed that the actor was trying to deceive them. Moreover, similar experiments conducted two years later by Grezes et al.(2006) revealed an increase of activity in the area of the amygdala when the subjects realised that the actor had deceived them.

In a somewhat different experiment by Harad and collaborators (2009) concerning moral assessment and lying, a significant increase of activity was recorded in the caudate nucleus, medial prefrontal cortex, lateral orbitofrontal cortex, the left temporal lobe, and the left temporoparietal junction (TPJ).

Worth noting is the test whose results were published by Etcoff (2000), who stated that participants of the test suffering from aphasia, probably caused by a left middle cerebral artery stroke, which made them lose linguistic abilities had much better capacity in lie detection than healthy individuals. Etcoff's discovery (2000) resulted in putting forward a hypotheses that the regions of the left hemisphere of the human brain play a small role in the process of human lie detection. Varied activity of the many areas in the brain during experiments with functional magnetic resonance imaging concerning lie detection poses a major problem. A number of studies to corroborate the claim have been conducted.

An experiment undertaken to define the existence of a specific area in the human brain that would show activity during the process of lying in every subject was conducted by Montelone and collaborators (2009). Unfortunately, the results of the study were not in line with expectations. The experimenters ascertained that so far it is impossible to define a specific area of the human brain, identical for every person, that would be responsible for lying. However, as was noticed in the earlier studies, the area of the medial prefrontal cortex (mPFC) showed certain activity. As Montelone and collaborators (2009) remarked, the technique of functional magnetic resonance imaging does not seem to discriminate processes that would be unique for deception.

In another experiment, Lee and collaborators (2010) tested neuronal correlates of lie related to affective information. Besides fMRI, the experiment also used the International Affective Picture System (IAPS), a collection of illustrations subjected to the process of standardisation. Thanks to such composition of the set, the experimenters can choose photographs providing particular stimuli causing various emotions. Lee et al.(2010) assumed that activation of the human brain while uttering a true statement should significantly differ from activation while lying. Participating in the experiment were 14 right-handed males from the age group of 25–39, with the median at 29.44 years. Every participant was tested for psychological and neurological conditions. The study did not cover the results obtained from one of the subjects, as the person was unable to complete the experiment. The IAPS was slightly modified for potential cultural differences. The stimuli were provided by IAPS illustrations; 96 photographs were used in all, with 48 of them aimed at causing positive emotions, and 48 – negative. Simplifying assumptions, the experiment had the subjects answer (falsely or truthfully) the question of the type “What sensations does this photograph cause in you? Positive or negative?” The respondent was provided with information whether he or she was to use the button that attested that the subject was telling the truth, or whether his or her task was to deceive the asker of the question. For example, when the message “lie” was displayed with a photograph causing negative emotions, the respondent was to convince the psychologist that in his or her case the photograph shown evoked positive emotions (Lee and collaborators, 2010). The experiment conducted by Lee and collaborators (2010) used event related design. Eighty trials were conducted, each composed of two parts, with one half containing negative stimuli, and the other – positive, in random order. The supervisors observed increased activity among others in parts of the brain including the left superior medial frontal, left middle frontal, and left inferior frontal when the participant lied, yet if the subject told the truth, the increase of activity was present among others in the left superior frontal, right calcarine, and right postcentral. The people deceptive about the illustrations that were to trigger positive emotions showed greater activity in areas including the right middle frontal gyrus, and left middle cingulum gyrus; moreover, greater activity in the visual perceptual system and the area responsible for emotions was discovered (Lee and collaborators, 2010). When the subjects were deceptive about illustrations that pointed to negative emotions, increased activity was observed in the left inferior orbital frontal gyrus, and left lingua. The experiment conducted by Lee et al.(2010) shows a certain type of interaction between cognitive processes accompanying lying and emotions. Increased reaction time and increase of activity in the frontal-parietal area is present, independent of the affective stimulus. Yet, one may hypothesise that the increase of activity in the remaining areas may be caused by the emotional stimulus. It must be noted that the neuronal correlates of lying do not depend only and solely on the type of deception, but also on the emotional value. Such an approach to research may allow acquiring information concerning lying for profit, and deception in fear of punishment (Lee and collaborators, 2010).

It is worth remembering that the problem of the stability of lie detection is not limited only and solely to the functional magnetic resonance imaging. Other methods of neuroimaging are used with greater or lesser success. Interestingly, to achieve better, and hence more precise, results the fMRI is combined with other methods of neuroimaging (Positron Emission Tomography (PET), Nuclear Magnetic Resonance (NMR), magneto-electroencephalography (MEG), and electroencephalography (EEG)), and with deception detection techniques developed earlier.

The experiment conducted by Seth and collaborators (2006) proved that magneto-electroencephalography can be helpful in defining areas responsible for lying.

Positron Emission Tomography (PET) is one of the neuroimaging techniques that was also used in experiments on detecting deception. In an experiment described by Abe and collaborators (2006), it was proved that prefrontal cortex activity can be linked to deception. Participating in the study were 14 males who had no history of psychological or neurological conditions. All the participants in the study were right-handed, with the average age of 20.4 years. Before the planned brain scanning, the subjects had to participate in tests, in which they coloured pictures, played instruments, and solved puzzles. Every task was designed so as to be different than the others, which means that every picture coloured presented something else, and the instruments played were of different type. Later, during a PET scan, the subjects were presented with photographs of the instruments they played and objects and figures they had coloured. The photographs also included new pictures and objects that they had not encountered during the experiment. One of the tasks of the participants was to tell the truth or lie about the illustrations shown. The experimenters observed greatest activity during attempts at deception in the area of the prefrontal cortex (Abe and collaborators, 2006).

The large number of experiments using the fMRI helped beyond doubt to expand our knowledge of the processes taking place in the human brain. In most experiments, an increase of activity in the prefrontal cortex was observed, which can prove that this region plays the main role in the process of deception. Nevertheless, it must not be forgotten that in some experiments the region was not the main area of increased activity. This is why focusing studies solely on this area still seems to be highly problematic (Abe 2009). As rightly noted by Sip and collaborators (2007), functional magnetic resonance imaging replicates the problems present in the polygraph. One can quote here, for example, the case with the manipulation of the BOLD signal by the subjects (Bles and Haynes, 2008). Nevertheless, there are hopes for detection of the aforementioned attempts of manipulation (Sip and collaborators, 2007).

These are not the only problems with fMRI. As is generally known, the experiments are conducted on a well selected group of participants, in most cases right-handed, of the same gender. Testing with the use of fMRI was conducted with individuals in isolation. It must be taken into account that people who have committed a crime and will be examined later will strongly differ from such a rigid selection (Sip and collaborators, 2007).

In turn, the factors determining the decision that the given person should lie are not constant or permanent, and depend on beliefs and convictions. Hence these factors will change in every subject, and must be taken into account during an fMRI study. A good though extreme case that can illustrate the problem is psychopathy (Sip and collaborators, 2007).

As J. Widacki (2007) rightly remarked, the use of neuroimaging methods also brings various new problems of an ethical and legal nature. The use of neuroimaging methods may lead to an excessive encroachment on human privacy, which is why a set of principles that will be able to fill in the gap should these new methods be used, whether in lie detection or for other reasons, should be developed.

The last problem that fMRI causes is of a technical nature. First, fMRI scanners are bulky devices that cannot be moved as simply as a polygraph, which can prove a difficulty. A phenomenon encountered during the fMRI is the so-called scanner drift. The device requires plenty of energy to be able to work for an extended period, which makes the image of the scanner "hover" due to heating. Nevertheless, it seems that – thanks to rapid technological progress – this problem will be the first to be solved.

The use of a guilty knowledge test in experiments with fMRI seems a good solution when it comes to lie detection, which is why experts should use it more frequently (Sip and collaborators, 2007).

It is difficult to define clearly the diagnostic value in the case of experiments conducted with the use of the functional magnetic resonance imaging to discover deception. Bles and Haynes (2008) claim that in *certain* experiments, the precision of the method exceeds 90%. Reaching this value is declared also by NoLieMRI, a company offering fMRI lie detection and quoting similar information on its website (noliemri.com/products/overview.htm; see also: Davatzikos C. *et al*, 2005; Wolpe P.R. *et al*, 2005).

Despite numerous experiments conducted with fMRI, plenty of doubts concerning the precision of the method remain, and the path to the development of a tool allowing lie detection based on fMRI seems long and uncertain. It must be stated clearly that, with the current advancement of development, implementation of the fMRI method in forensic sciences practice is definitely premature. This status quo will not change until the new method has met APA and ASTM standards.

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