18 Lie Detection: fMRI

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From an evolutionary point of view, greater tactical deception is a feature that belongs to primates closer to humans, which have larger neocortices [1].

Detection indeed is a physiological ability that develops naturally during childhood in humans, and which is impaired among subjects with neurodevelopmental disorders (e.g., autism) or in patients with various psychopathy [1, 2]. Also in case of orbitofrontal lesions, deception seems to be impaired, since most of these individuals show social interaction problems which come from being notoriously tactless that in turn is due to total honesty and frankness [1, 2].

If deception is an absolute normal, although undesirable, condition in everyday life, in forensic practice, it plays a critical role, because of its detrimental implication in the judgement of guilt or innocence.

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Humans are good at lying but very poor at lie detection; in face-to face interaction an average individual's ability to detect deception is slightly over 50%, the same rate that would be expected by chance [3].

That is the reason why over the past centuries, humans have developed many different methods to identify liars and to detect deception [4].

In ancient China, men who underwent an interrogatory were forced to fill their mouth with dry rice and then invited to spit it out. Deceiving was assessed if he/she took longer to spit the rice out of his/her mouth [4].

Even if this anecdotal method could seem old-fashioned and uncivilized, actually it has a scientific fundament, as sympathetic activation that is evoked in stressful conditions such as during deceiving suppresses salivation, and leads to a greater adhesion of the rice grains to liars' mouth, which are barely spitted out [4, 5].

The widely known lie detection machine—the polygraph—is based on the same neurophysiological concept, that is, the tendency for lies to be accompanied by activation of the sympathetic nervous system (SNS) [4]. Working principles of the polygraph machine consist of the measurement and recording of several physiological indices such as pulse, blood pressure, respiration, and skin galvanic conductivity, while the subject is asked and answers a series of questions [4, 6].

Even if polygraph has been widely used in the past, in 2003 American National Academy of

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Science reported high discrepancy on its accuracy, since while it could be up 99% it was often as low as 55%, depending on various conditions, on the setting (experimental vs. forensic), operator, examiner skills and attitude, questioning format, and response classification rules [7]. Thus considering most of the polygraph researches as “unscientific and biased,” and concluding that polygraph testing is largely unreliable in the courtroom, it is outlawed—but widely used—for nongovernmental pre-employment screening [4, 6].

The issue is that the physiological data measured by polygraph reflect only the peripheral effects of SNS activation, and to overcome these limits scientists and forensics have studied other lie detector techniques, in order to identify more direct and impartial data [4, 8].

The appeal of this approach is that, instead of measuring emotional arousal resulting from deception, brain-based method evaluates central brain physiological changes associated directly with a cognitive process—deception or concealing information, for instance [4, 8].

Brain-based lie detection technology was pioneered using scalp-recorded electroencephalography (which is dated back to the 1920s), but fMRI (first applied in humans in 1992) is now the preferred modality, since it is able to localize blood flow in certain areas of the brain [8]. Although fMRI is widely superior to electroencephalography in localizing the source of the signal, it is more expensive and less mobile and it has a lower time resolution [8].

Magnetic resonance imaging (MRI) is a medical imaging technique that provides three-dimensional tomographic images of the body using high magnetic fields without ionizing radiation exposure [9].

The principles of functional MRI (fMRI) of the brain lie on the relationship between blood flow to the brain and brain demand for energy. So it is defined as a “correlational study” since it records brain state in parallel with ongoing mental activity or behavior, in order to define a correlation between these two parameters, but it is not able to establish a causal connection between brain activation and the kind of cognitive processes specifically [9, 10].

The brain needs energy to perform any task (thinking, perceiving, speaking, deceiving, and so on), so when an area of the brain is activated, the blood flow in that region increases, and oxygen level changes—this occurs rapidly (1–2 s) after neuron activation—bursting concentration of oxygenated hemoglobin in this area [9–12].

fMR technique is based on the difference in the magnetic properties of the blood vessel contents and the surrounding brain tissue, and relies on the different magnetic features of oxygenated and deoxygenated hemoglobin [9–12].

fMRI measures this difference, detecting changes in blood flow and oxygenated hemoglobin concentration—that is called blood oxygen level dependent (BOLD) effect—which is indirectly related to brain area activation [9–12].

The vast majority of fMRI in neuroscience relies on BOLD response, although it does not depict absolute regional brain activation, but relative changes in regional activity in a determined timeframe, as aforementioned [9–11].

Changes in BOLD signal are measured in a spatial volume. Every spatial volume, called voxel, reflects a small (300 × 300 μm^2 with a couple of millimeter slice thickness or 500 × 500 × 500 μm^3 isotropic) cube of brain tissue, which represents millions of brain cells. The active “illuminated” part of the brain on fMRI images represents the activation or deactivation of hundreds of clusters of voxel [9].

But, since blood incoming is not static, but flows rapidly, fMRI does not take “instant photo” of brain vascularization, but images come from the evaluation of the blood flow through a defined brain area over a short time (couple of seconds) [9–11].

These changes in blood oxygenation level occur as a part of the physiological brain activity, and since the pulse sequences used in fMRI do not alter neuronal firing or interfere with blood flow, fMRI is considered a noninvasive technique, and reveals how the brain works in real time [10].

In other terms, fMRI study is based on a dependent variable, that is, the brain activation, and an independent one, that is, a defined stimulus or task [9–12].

Once a brain area is activated due to a stimulus, oxygenated hemoglobin concentration in this area increases (relatively to the neutral/control condition) and BOLD signal is obtained [9–12].

Radiologically speaking, the dependent variable—the brain area activation—comes from a subtraction measure of blood paramagnetic behavior between the "rest/control" state and the stimulus/task state, which in turn represents the independent variable, which evokes an increase in blood flow and then in oxygenated hemoglobin [9–13].

At this point, it is essential to mention that even if fMRI is able to define brain state as a consequence of a cognitive process, it is not able to determine whether any specific pattern of brain activation is a necessary determinant of its associated behavior [9–12].

In other terms we can say that defined areas of the brain are activated during lying, but we cannot say that they are activated exclusively because of the cognitive process of lying.

Moreover, evaluating blood flow in specific brain areas is useful only if:

1. We know certain functional subunits of certain areas of the brain
2. We know the main blood flux in nonactivated situation

It has been demonstrated that, although there is not a single region of the brain that seems to be correlated to deception, recent meta-analysis found that certain areas are more active during deception versus truth conditions at a much higher statistical rate than chance: bilateral dorsolateral and ventrolateral prefrontal cortex, inferior parietal lobule, medial superior frontal cortex, and anterior insula [4, 11, 14, 15].

On the opposite, fMRI does not detect any region that is significantly more engaged in truth-telling conditions, suggesting that deception requires a greater effort than responding truthfully [4, 11, 14, 15].

Indeed, lying was demonstrated to come from "higher" cortical centers, such as the prefrontal cortex, that are essential to adaptive behaviors in brand new, difficult, or stressful situations, on the opposite to the posterior and subcortical regions, defined as "slave/lower" systems, which in turn may be sufficient to perform simple, routine, automated tasks [1].

But how does the fMRI work?

In order to define the difference between the active or non-active state, a widely standard maneuver in functional brain imaging is to isolate changes in a certain brain area associated with particular tasks.

This can be done by subtracting images taken in a control state from the images taken during the performance of the task which the researcher is interested in (target): images taken during truth-telling, and images taken during lie-telling [4, 9, 10].

But this implies the use of a standardized protocol that generates these behaviors, and this requires that these behaviors can be measured by fMRI.

These paradigms refer to the methods used to generate deceptive responses and appropriate controls, and the two basic ones are the comparison question test (CQT) and the guilty knowledge task (GKT), also known as the concealed information test (CIT). They are not unique for fMRI studies but they have been developed and used for forensic investigative use by the polygraph and the EEG [6, 8, 11, 13, 16, 17].

In CQT subject is invited to answer three kinds of questions: "relevant," "control," and "irrelevant."

The first one refers to the topic under investigation, and it presumes to evoke a lie: "Did you steal the car?"

The control one is instead used to elicit a strong response, correlated to a sympathetic arousal, but not about the topic of investigation: "Did you ever steal anything?"

The irrelevant one defines the baseline: "Are you sitting on a chair?" [8, 13].

Results come from the difference between the relevant and the control questions: a stronger physiological response (activated areas in fMRI) on the relevant question than on the control one is considered as an evidence of deception [8, 13].

There is a different type of "lie" that does not refer to "lie-telling" but to "not telling the truth, or concealing a part of it."

In GKT, subject is invited to answer a series of questions, created to evoke a fixed uniform response to multiple matters, including an “aspect of knowledge” that a guilty subject would try to conceal. Among these several neutral (control) questions, there is a relevant (target) alternative, for example a feature of a crime under investigation [8, 13].

Questions are chosen in a way that an innocent subject would not be able to discriminate the control ones from the relevant. For example, using the same aforementioned example, if the crime refers to a red stolen car, the question sequence would be “was the car white?” “was the car red?” “was the car blue?”

If the physiological response to the target question—“was the car red”—is widely larger than controls—“was the car white?” and ” was the car blue?”—knowledge about the event is implied, and subject is presumed to be lying [8, 13].

It’s interesting to notice that using GKT, physiological responses to simply hearing the relevant question, not necessary to answering deceptively, can be sufficient to determine whether the subject is concealing information or not [13].

In other terms, the CQT uses the measurement of physiological or psychophysical responses to define an answer as a lie, and the GKT implies such responses to indicate the presence of concealed knowledge.

The literature about fMRI in the lie detection field includes tasks that derive from these tests.

In 2002, in one of the earliest studies about the use of fMRI in deception detection, participants were given two play cards, and were instructed to deny the possession of one of them and confirm the possession of the other one. During fMRI examination patients were showed a series of cards, including the aforementioned ones, and they have to say if they have or do not have the cards they were seeing [18].

Images were acquired and compared between truth and lie states, and indicated the brain activity during deception and during truth-telling [4, 18].

In a similar experiment, the subject mentally picked a number between three and eight, and, under fMRI examination, while a series of numbers were shown on the screen, they have to deny to have picked the critical number (target) and denied having picked the other ones (controls) [19].

A more realistic experiment was conducted by Kozel et al., using a mock scenario, in which participants have to steal a ring or a watch, on their choice, and they have to put the item into a locker. Then, while undergoing fMRI, they have to deny possession of both items (deceive possession of stolen object: deception, TERGET; deceive possession of the other one: truth-telling, CONTROL). Then, in order to define a baseline, that is, the neutral state, they had to answer simple and meaningless questions such as “it is 2004?” or “do you live in US.”

Comparing brain activation while answering different type of questions, researches tried to define the index of neural activity [4, 20].

Although this topic is of great forensic impact, nowadays the use of fMRI in lie detection is not yet widely allowed in the courtroom, because of a series of scientific, ethic, and legal motivations [8].

The main scientific issues of experimental deception-generating models are basically five:

- Endorsement: Subjects in the studies were endorsed to lie; in other terms lying was the target of the experiment, a desirable condition, for which participants were not only allowed, but also instructed, while in the real world deception is considered a despicable action that is usually hidden by the liar [8].
- Emotional impact on lying may modify fMRI findings in a real-world situation, where lying in a legal scenario may have potential impact on guilt or innocence sentences.
- Emotion can influence the neural circuitry of lying, of memory, of inhibition, and of cognitive control, leading to misinterpretation of truth about a highly emotional event, or what would be at stake if the lie were discovered [4, 21–24].
- Moreover, we must mention that anxiety, fear, or heightened emotional status leads to altered BOLD signal, not directly related to deception, in these cases [4].
- Role of memory: BOLD images indicate activation during lying, but it is not determined for sure if this activation occurs BECAUSE

OF the deception or as a consequence of other psychological processes, like memory, which may evoke the same pattern of activity [4, 25].

– Hakun et al. and Gamer et al. have tried to discern the memory issues from the deceiving pattern. In summary, patients were invited to mentally pick a selected number, and while undergoing fMRI they were showed a series of numbers. It has been demonstrated that both when subjects lied about the number they picked and when they simply saw this number, the same pattern of activation occurred, suggesting that it might be due to cognitive processes other than deception per se [4, 19, 25].
– This could be caused by the effort required by lie-telling that implies greater necessity of short-term (and long-term) memory and executive functions than truth-telling. Indeed, liars usually keep in mind two (or more) versions of the event in their working memory, and they force themselves to exhibit a natural behavior, and to inhibit the physiological instinct of answering in accordance with the reality [4].
– Countermeasures/practice: Studies have shown the impact of practice in prefrontal cortex activation, displaying that memorized lies result in a less BOLD activation when compared to unpracticed ones, in all regions (but in the one associated with memory retrieval) [4, 26–28].
– Similar efficacy has been shown in adopting simple countermeasures, like imperceptible finger or toe movements—that can reduce accuracy in detecting lies up to 33% [26]—or mental calculation during control sequences that arises cortical activation while defining the baseline state [4, 26–28].
– Individual neuroanatomy/neurophysiology variances may be the norm rather than the exception, thus leading to an extensive variability in brain area activation, especially in cortical regions which control higher brain functions, and which were subjected to a greater evolutionary development [11, 29].
– The individual variability is particularly important while examining criminals: a study of fMRI-based lie detection in criminal offenders affected by antisocial disorders found that a large majority of these participants did not show the typical prefrontal BOLD activation pattern during instructed deception [4, 30].
– Thus, considering that a relatively high portion of criminals meet the criteria for psychopathy, fMRI lie detection technique in this class of individuals may be unreliable [4, 30].
– Lying moreover can be a complex activity with various degrees and levels of prevarication, of different individuals of different health, age, sex, psychological tracts (for example, high anxiety and extraversion), and instruction, and the ability to detect simple deceptions in experimental setting may not translate into a forensic spendable technology in less controlled situations [4].

In other terms, nowadays fMRI can provide adequate accuracy in detecting deceptive behaviors in particular population and in particular circumstances that are far away from the real world.

Little is known about the accuracy of fMRI as a lie detector in real-world situations or in a legal scenario, in which no studies have yet defined its probative value (how many lies the tool misses and how often it identifies the truth as a lie).

Beyond the social, legal, and ethical issues, which fall outside the purpose of this chapter, it is undeniable that the main scientific shortcoming of the fMRI as a lie detection technology lies upon the sufficient degree of accuracy, specificity, and validity that a worldwide use of this method in such as delicate forensic field requires.

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