

Invoking the Feigner in us; Methodological Approaches for Investigating Deception in fMRI Setting

Maral Yeganehdoost¹, Morteza Pishnamazi^{1,2}, Mohammad Ali Oghabian¹

1. Neuroimaging and Analysis Group (NIAG), research Center for Molecular and Cellular imaging (RCMCI), Tehran University of Medical Sciences, Tehran, Iran.

2. Student's Scientific Research Center, Tehran University of Medical Sciences, Tehran, Iran.

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ABSTRACT

The attempt to find out if someone is telling a lie has been of human's interest. One of the techniques which is believed to be efficient in future is fMRI (functional Magnetic Resonance Imaging), using which the changes of regional blood flow during the designed paradigm can be recorded. This method has been considered as a better technique for studying lie and deception. For investigating the neural network associated with lying and deception, a task needs to be designed in which participants are instructed to participate in a lie-like situation. In this article, frequently used tasks have been reviewed with their merits and demerits. In addition, a summary of involved neural networks related to lie and deception, according to previous studies, is provided. The goal in future studies is to allocate brain regions associated with lie and deception that are independent of features related to the chosen task.

1. Introduction

Intentional false responses and hiding the truth is a common issue in the real world and distinguishing whether a lie or a truth is being told has been of human interest for a long time. To approach this goal, various ways have been examined. One of the frequently used devices is polygraph. A polygraph is a measuring device which simultaneously records series of physiological indices that are believed to be critical when a lie is being told (Saxe, Dougherty, & Cross, 1985). These factors include the person's blood pressure, pulse and skin conductivity. The reason of its high application is that it is assumed when a lie is being told; the liar feels anxious this is why his physiological responses change. An important defect of this application is that on one hand: there is no proof for making sure that these physiological indices necessarily change through the process of ly-

ing and deceiving. For example, people who have more control while lying will not be detected, or people who have psychopathic personality disorder might not have considerable changes in their physiological responses (Verschuere, Crombez, De Clercq, & Koster, 2005).

On the other hand, anxiety and fear can be due to many other factors and not necessarily lying or deceiving. There is also another device called electrodermal response (EDR), also known as Galvanic skin response (GSR), which measures electrical conductance of the skin. This device has the same problem as polygraph, as its working principle is measuring changes in one's physiological response (skin conductance) originated from anxiety and fear.

Based on what have been mentioned, these devices are not completely reliable and accurate for investigating if a person is telling a lie or not.

*** Corresponding Author:**

Mohammad Ali Oghabian, PhD,

Address: Medical Physics group, Faculty of Medicine, Tehran University of Medical Sciences, Tehran, Iran

Phone: +98 21 66907518-9 Fax: +98 21 66438630

E-mail: oghabian@sina.tums.ac.ir

The perfect way for detecting lie and deception is through a measurement over which the target cannot control the factors affecting responses. One of the ways that during recent decades is getting more into consideration is functional neuroimaging methods and more specifically: fMRI. In this paper, with the body of experiences suggesting fMRI as a promising way for detecting lie and deception, we tried to review the studies using fMRI for investigating lie and deception and classify their methods and results.

1.1. fMRI (Functional Magnetic Resonance Imaging)

fMRI is an MRI procedure that detects brain activity by measuring changes in blood oxygenation level across brain tissue (Logothetis, Pauls, Augath, Trinath, & Oeltermann, 2001). Since 1980s, it has been known that changes in blood flow and the level of blood's oxygen in the brain are closely linked to brain activity. When the neurons of a special region in the brain become active, the blood flow of that part increases, leading to higher level of oxygen compared to other parts of the brain. This difference is mapped in fMRI procedure and is an indicator of areas that are active at a time.

Employing fMRI in the field of deception studies comes with numerous benefits. First of all, unlike other indirect physiological methods, fMRI enables us to directly investigate the organ responsible for lying which is the brain tissue and gives us quantitative measures of activity. Also it helps us decipher the neural circuitry of lie related networks which in turn leads to better understanding of neuroscientific and cognitive mechanism of lie.

Furthermore fMRI is also the preferred choice among other functional neuroimaging methods such as PET and SPECT. Some of the remarkable practical merits of this technique are listed below:

- It is noninvasive with no need of injection or radioactive isotopes
- Images' spatial resolution can be less than 3mm
- Scan time duration; depending on the paradigm; is considerably short

1.2. Article's Aim

In the laboratory settings developed for investigating lie; the paradigm by which participant are compelled to lie plays an important role, real life situation do not fit

into conservative structure of experimental studies and as more restricted and narrowed design are employed, practical validity of the results becomes questionable. The aim of this article is to review the lie paradigm deployed by recent neuroimaging studies and scrutinize their characteristics with aim to help develop new improved designs and help with interpretation of future neuroimaging results in a way that is independent of specific task effects.

2. Cognitive Dimensions of Lie & Deception

The spectrum of human intelligent acts considered as deception is broad and diverse. From white lie with benevolence in mind to systematic fraud with malicious consequences, all are categorized as lie and deception. Being diverse both in case of intentionality and methodology, it is hard to describe lying as a distinct cognitive phenomenon. But confining our discussion to the classic lie situation used in deception studies, which is answering falsely to a question which the participant is aware of its true answer, we can state that lying invariably consists of the following steps (Mohamed, et al., 2006):

1. Perception
2. Comprehension
3. Memory recollection
4. Judgment, planning, decision making
5. Response inhibition
6. Fallacious response delivery

Perception of visual or auditory stimuli containing the question and comprehension of their content occurs rather passively and regardless of the participant's intention to lie or response truthfully. Afterwards, information regarding the question is recollected from memory; having neuroimaging studies in mind; in this stage, major confounders can be introduced into the results. Emotional saliency of data retrieved can lead to parallel activation of areas dealing with emotion and might invoke other physiological consequences (e.g. sympathetic activation). Extent of these activations can vary from case to case both by the content of questions and the situation in which they are presented and also based on inter-individual differences in personality traits (Fullam, McKie, & Dolan, 2009).

The decision to lie is usually a consequence of benefit assessment and part of a broader planning scheme (Ekhtiari, & Behzadi, 2001), but many neuroimaging studies manipulate this stage by providing obligatory lie/truth cues in each trial and how this affects the decision making and executive aspects of lying process is a matter of substantial question. Disorders of this stage have known clinical consequences. In some clinical conditions such as Münchhausen syndrome and Pseudologiafantastica; trend of system leans toward more lying (Abe, Suzuki, Mori, Itoh, & Fujii, 2007), while in conditions such as Parkinson disease, patients become more honest (Abe, et al., 2009).

The inclusion of a response inhibition step in the process of lying implies the belief that a truthful response is automatically generated and should be actively inhibited in order to provide a deceitful response. While this is mostly the case, in certain situations this step might be skipped. For instance when a person is asked by the same question for multiple times and the process of providing a specific lie occurs repeatedly, it can be conditioned in a way that the question itself automatically activates the lie response hence skipping the response inhibition step.

Finally is the step of response delivery which can be verbal or in case of most fMRI studies using predefined key presses.

The degree to which each of these cognitive processes plays part in a deceptive act, varies extensively based on the type of questions and the paradigm in which lies are asserted, that is why designing an appropriate task for neuroimaging studies is of great importance and any aspect of the experimental paradigms can influence the anatomical results prominently.

What comes next is a review of commonly used paradigms in deception studies.

3. Applied Tasks for Investigation of Deception using fMRI:

3.1. GKT (Guilty Knowledge Test)

GKT is a questioning paradigm which was first used in lie detection using polygraph. In that paradigm a group of questions were asked from a person who was engaged to specific crime. The asked questions were the ones that just a person involved in the crime would know the answers of. The suspect was asked to answer to some of the questions with “No”. While he was asked, his physi-

ological responses, including breathing rate, blood pressure and skin conductivity were being recorded. GKT also has been used in modeling deception and monitoring its effects using fMRI technique (Gamer, Bauermann, Stoeter, & Vossel, 2007; Ganis, Kosslyn, Stose, Thompson, & Yurgelun-Todd, 2003; Karim, Schneider, & Lotze, 2009; Langleben, et al., 2005; Nose, Murai, & Taira, 2009). Giving a general definition, GKT is a questioning method in which the person is asked to answer to specific questions with “No” while the participant and the investigator both know some of those given answers are: “Yes”. However, in some of these paradigms, the participants are not aware of experimenter’s knowledge about the answers. The arguable difference between lab GKT and forensic one is that in the first one the participant does not feel guilty while answering to some questions incorrectly, whereas in forensic one anxiety and guilt are invoked (Langleben, et al., 2002)

GKT method used in fMRI technique has various kinds, all of which follow the same explained paradigm. As an example, in a study, (Gamer, et al., 2007) five playing cards were shown to participants. They were asked to memorize which of those cards are the ones that they are going to lie about their possession. Before going for MR scan, they were given an envelope containing some cards and were instructed to memorize their cards. Consequently, they were taken to MR scan in which they lied about possession of mentioned cards.

In another study (Hakun, et al., 2008), participants are asked to choose a number between 3 and 8, then in the MR scan, they are asked about their chosen number and are supposed to lie about it. This way, they answer to all questions correctly except for the chosen number.

Another way for pursuing GKT paradigm is answering “autobiographical questions” (Fullam, et al., 2009; Kaylor-Hughes, et al.; Nunez, Casey, Egner, Hare, & Hirsch, 2005; Spence, et al., 2001). The questions in which participants are asked about their daily routines (for examples: Today, have you made your bed? Have you drunk a cup of tea?) Or about their possessions (for example: Do you own a laptop computer? Have you ever told a lie?). It is believed that asking these kinds of questions makes a more similar situation to real lie situations because they are really attached to a person’s life. In an example of autobiographical- question study, (Nunez, et al., 2005), some autobiographical questions were asked including: Can you ride a bicycle? Then they were followed by non- autobiographical questions like: Does a bicycle have six wheels? Then the results were compared. In answering to autobiographical ques-

tions, participants are instructed to once answer to all of the questions correctly and once incorrectly. The way subjects are asked can vary. It can be auditory or visual (Spence, et al., 2001).

The important issue that should be taken into consideration is that GKT is not necessarily an easy scenario. It can be more complicated while keeping the basic mentioned structure of answering to questions with predefined answers. For example, in a study (Andrew Kozel, et al., 2009) a scenario was designed. Participants were asked to go to a specific room in order to find a CD. They were told that the CD contains information of a robbery. After finding the CD, they were supposed to watch the CD to make sure it is the one they are looking for. But the real reason of watching the CD was using it as stress stimulation for participants. After watching, they were supposed to destroy the CD using a shredder located in the room. While trying to use the shredder, they encountered an unexpected difficulty: the shredder was not working, the examiners were aware of that, though. Using this trick, real anxiety might be involved in the experiment. Another factor which was used in this study to approach a more real situation of lying was while the task was being performed by participants, someone knocked on the door, so the feeling of possibility for getting arrested was induced. After performing all of these actions, a piece of destroyed CD was brought by participants as evidence and they were taken to the MR scan during which they were supposed to deny their presence in that specific room. As it has been mentioned once, this task might seem much more complicated but still, it can be considered as GKT, because the answers are all predetermined and participants do not have the free choice of lying or telling the truth while answering.

To sum up, using GKT, participants do not have free choice for the time of lying or to answer a specific question correctly (truth) or incorrectly (lie). Being oversimplified, the method is far from real situations that is why it is considered as a demerit. The important merit of this task that makes it more common compared to others is that the examiners have the control on all situations, thus an unexpected factor will not interrupt the results.

3.2. Modified GKT

Modified GKT paradigms represent other tasks for approaching lie like or deceptive situations. Modified GKT is similar to GKT paradigm except for the fact that in modified ones free choice, the factor that GKT lacks, exist. Having free choice, participants have the authority to pick the questions they are going to lie about. To

get to this approach, for instance in the context of studies using playing cards, a specific card is shown to participants and it is their decision whether to tell the truth or lie about possessing it (Monteleone, et al., 2009).

Another example for modified GKT is a study in which money hiding was used (Kozel, Padgett, & George, 2004). In this study, participants were escorted to a room in which there were six different objects. Under the two of them, a fifty-dollar note had been hidden. The participants' duty was to go to that room and find the two objects under which money was hidden. After finding them, they were instructed to memorize them and leave them there. They had the free choice of choosing one object, and telling the truth about that one while in MR scan. During scanning, picture of six objects were shown and the participants were asked to answer to this question: Is there a fifty-dollar note under this object? Then they had to answer to one of the objects correctly (the one that they had picked before), and answer about the other ones incorrectly (lie). Also, to study deception as well, they had been instructed to pick one of the objects without money under it and tell that it was the one under which money was hidden. Since the participants could choose which item they pick for misleading examiners, this study can be located in the modified GKT classification.

In this method, the participants choose whether to tell the truth or to lie so they have the option of free choice that is an advantage because, it is closer to real-life situations. On the other hand, presence of multiple unknown items may lead in limiting our ability to contrast lie and truth.

3.3. Games

The most complicated tasks are games. For a real deception, a plan is needed to inhibit responses, and to follow the opponent's believes all of which are possible through a real game. As it can be predicted, games are the most similar tasks to real world's lies and deceptive situations. Using various games, participants are able to decide when to deceive which is an important advantage.

As an example, in an experiment (Sip, et al., 2010), the game "Meyer" was used as a deceptive task. In this game, two players are supposed to roll two dice and without showing them, they call a 2-digit number. The other person either refuses his opponent's call and asks him to reveal them or accept his call and call a 2-digit number (the same number or bigger than that). The sec-

ond call can be with rolling the dice or without it. As it can be seen, in this game, "bluffing" has an important role. Moreover, in these games a reward is promised to the participants, as reward anticipation is a motivation

for them to lie better and again it makes it closer to real deceptive situations. The most important demerit of this method is loss of control over the number of deceptive events.

Table 1. A list of various tasks used in different fMRI studies for production of a lie-like or deceptive situation with their merits and pitfalls. A task will be considered successful if it creates a realistic situation of lying and simultaneously provide experimenter enough control. GKT, Guilty knowledge test.

Table 1. Merits and demerits of different task designs		
Task	Merit	Demerit
1/. GKT	<ul style="list-style-type: none"> •examiner's full control over experimental situations •easy to implement as block-design fMRI task 	<ul style="list-style-type: none"> •subjects get no direct gain from lying •far from real lie situations
2/. Modified GKT	<ul style="list-style-type: none"> •subject's free choice for lying •easy to implement as block-design fMRI task •subjects might get rewards 	<ul style="list-style-type: none"> •uncontrollable factors
3/. Games	<ul style="list-style-type: none"> •Subjects have real reward •most similar to real-world situations 	<ul style="list-style-type: none"> •lots of uncontrollable factors •must be an event-related design •unequal lie/truth trials

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4. Items to Consider when Designing an fMRI Deception Paradigm:

In this section we discuss items which play important role in the outcome of a deceptive paradigm and also suggest feasible methods to apply them based on our developed design.

1. Block/Event Design

In a block design, a similar neural function shall be repeated in several tandem trials. In the context of deception paradigms, this means that subjects should change their responses from truthful to deceptive based on predetermined structured trial orders (e.g. truth response to first 10 trial, lie response to next 10 trials and so on). Also a block design would yield more statistically powerful results but the constriction it imposes to the paradigm design is too costly. First of all it limits the experimenter only to GKT designs, also it will restrain participant's freedom in deciding whether to lie or not, and this means no free choice. The sequence of truthful/deceptive trials shall be inducted to subjects (usually using color cues) and how this affects neural correlates of lying is yet to be determined. On the other hand, event related designs gives space to more lenient designs where participants' will can be implemented into the study. The less statistical power of event designs can be overcome by gathering more data and using hypothesis driven analysis methodologies.

2. External Validity

Given the prospect applications of deception paradigms it is preferred to make designs as close as possible to real world scenarios. As mentioned before Game tasks provide most similarity to real world situations. In case of GKT and modified GKT different methods have been applied to create more valid experimental paradigm. Mock crimes are experiment where before imaging session subjects are enrolled in a real crime-lock scenario and will subjectively feel the emotions and experience the events that they will be asked about during the imaging. Albeit mock crime works well in increasing the external validity of designs but their implementation comes costly and time consuming hence many small labs lack the facilities for proper implementation of these tasks. Another common approach is using studies based on subject's real world experiences. In this approach usually a set of autobiographical questions are prepared, imaging paradigms can be individualized or a uniform design can be applied to all participants. This approach is easy to implement and works well by involving personal experience and emotion as a means of increasing external validity.

3. Freedom of Choice and Gain

In real world scenarios in each situation subjects decide whether to lie or not and this decision is usually based on their prospect gains. Many of recently employed de-

signs ignore these aspects. Many designs impose lie/truth responses using external cues (color patches) and subject gain are either absent or indirect. A prevalent way to introduce gain into the GKT studies is conditioning the amount of participation initiative based on the subject's performance. Usually subjects are deceitfully instructed that an experimenter is trying to determine trials when they're lying and if they succeed to deceive them they'll gain more reward. This methodology is not a direct gain of lying because subjects receive gain based on their theatrical performance rather than a programmed plan to deceive. Introducing direct gain and free choice into design necessitates more flexible paradigms and event related design and analysis of data.

4. Length of the Study and Trial Repetition

Flexible event related designs demand higher number of trials and more trials means lengthier designs. Fatigue related diminution of performance can substantially affect data quality and even render them useless. Limiting imaging length to about 20 minutes and dividing lengthier designs into two or more sessions is recommended. Another important aspect is how many times each question is repeated during an imaging session, for instance a 200 trial design may either have 100 unique questions with one truth one lie condition for each one or may consist of many repetitions of scanty unique questions. Unique trials introduce more confounders and make valid analysis of data more difficult. On the other hand in designs with many repeated trials neural shortcuts may develop, by neural shortcut we mean that a classic deception neural process which involves executive function and response inhibition mechanisms can be reduced to pure recollection. It means when subjects face a repeated question they only need to remember the response that they provided last time instead of a complete executive judgment and executive control.

5. Training

Last but not least is the importance of subject training. A research environment specially one that involves frustrating procedures such as MRI is stressful by itself. And when it comes to lie detection and autobiographical questions this becomes more demanding. It is important to familiarize participants with the experiment's procedure and equipment. A special case in lie studies is that many subjects assume that their level of honesty is being tested or in the case of autobiographical questions they might feel like being interrogated. It is necessary to explain aims of the study and stress the confidentiality of their personal data and specify exactly what aspects

of lie and deception they shall pay attention to during the experiment. Substandard training procedure leads to biased subjects and depending on the aim of study this might make the collected data useless.

Here we provide a brief description of an event related modification of Spence et al 2001, autobiographical task. We suggest using this paradigm because of its feasibility, acceptable external validity and subject's free choice. In our suggested paradigm subjects first complete a questionnaire of autobiographical questions truthfully based on their recent personal experience then we instruct them to choose a subset of questions and lie about them whenever asked from this point onwards. Then they enroll in a computer simulation of the imaging task in order to familiarize them with the procedure and also assess their performance before running main imaging session. The main task is an event related design with 2 second question presentation and jittered interstimulus intervals (3.5-11.5 seconds, 7.5 seconds on average). Fig. 1 provides an overview of experiment procedure.

5. Regional Brain Activity during Lie and Deception

When reviewing results that these studies yielded for main effect of lie, there is inconsistency even among studies within each group of task paradigms. As we mentioned before both personal and task related items can influence result to much extent.

What is highly consistent in all studies is the higher level of brain activation comparing lie situation comparing with truth. Virtually no brain area has showed consistent higher activation during truth than during lie.

The involvement of prefrontal cortices has also been consistent, implying the involvement of executive function areas in the mechanism of lie. In a recent meta-analysis (Christ, Van Essen, Watson, Brubaker, & McDermott, 2009) of brain areas activated during lie the area consistently activated among all studies were as follows: Left and Right insula, Left and Right IFG, Right middle frontal gyrus, Right inferior parietal lobule/supramarginal gyrus, Right internal capsule/thalamus, Right anterior cingulate, Left inferior parietal lobule, Left internal capsule, Left precentral gyrus/middle frontal gyrus.

These areas are mostly part of frontal executive control and decision making system. In further analysis in the same study these areas were compared by areas re-

sponsible for distinct subset of executive function. The areas showed significant overlap with areas responsible for working memory, inhibitory control and task switching while working memory showed the most extensive

overlap with the other two having sparse overlaps. It can be said that also lying and executive control share a large amount of circuitry but they shall be regarded as two distinctive networks working side by side(Abe, 2011).

Table 1. A list of various tasks used in different fMRI studies for production of a lie-like or deceptive situation with their merits and pitfalls. A task will be considered successful if it creates a realistic situation of lying and simultaneously provide experimenter enough control. GKT, Guilty knowledge test.

Table 1. Summary of areas showing higher activation in lie condition among various studies		
Article, Year	Task	Brain Regions
(Spence, et al., 2001)	GKT, autobiographical	bilateral VLPFC
		dorsolateral PFC
		medial PFC
		left inferior parietal cortex
(Langleben, et al., 2002)	GKT, Playing cards	DLPFC
		medial frontal gyrus extending to ACC
(Lee, et al., 2002)	GKT, memory task	Anterior frontal regions
		bilateral parietal& temporal cortex
		sub-cortical regions including
		Caudate
(Phan, et al., 2005)	GKT, Playing cards	mPFC
		bilateral DLPFC & VLPFC
		bilateral superior temporal sulci (STS)
(Nunez, et al., 2005)	GKT, Autobiographical	mPFC
		DLPFC
		VLPFC
		ACC
		BA 9/10
		Caudate
(Hakun, et al., 2008)	Modified GKT, number memory	IFG
		ACC
		IPL/SMG
(Kozel, et al., 2009)	Modified GKT, mock crime	Lateral PFC
		mPFC
(Sip, et al., 2010)	Game (Meyer)	Left Premotor
		BA 6

BA, Broadman Area; VLPFC, Ventrolateral Prefrontal Cortex; DLPFC, Dorsolateral Prefrontal Cortex; ACC, Anterior Cingulate Cortex; IFG, Inferior Frontal Gyrus; IPL, Inferior Parietal Lobule; SMG, Supramarginal Gyrus.

6. Future Horizon

Lie detection using fMRI comes as a big enterprise, but as it is with every novel research methodology; caution should be taken with trials of implementing the results into real world scenarios. The forensic and civil applications of lie detection methodologies and their major consequences necessitates high amount of attention to

be paid to prevent premature application of the method outside of research environment. Issues of test validity and reliability as well as privacy and ethical aspects of lie testing are still to be answered and have been focus of much recent discussion (Wolpe, Foster, & Langleben).

Based on what has been discussed, the prospective paces can be towards finding different factors affecting

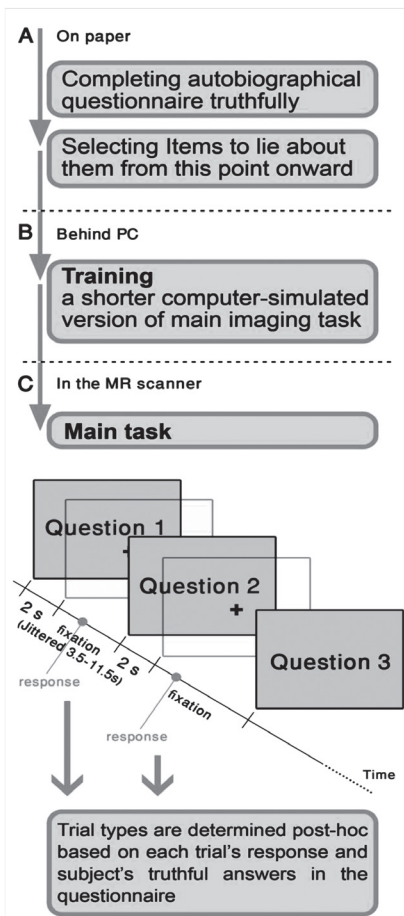


Figure 1. Sequence of an applicable task NEURSCIENCE

brain regions that are related to lie. These factors include gender, ethnicity and culture. One of the approaches for examining these factors is replicating other studies for different groups. We can do the exact experiment for making sure whether culture plays a role in lie-related brain regions or not (Ekhtiari, Behzadi, Dehghani, Jan-nati, & Mokri, 2009). Alternatively, we can replicate some studies for making sure whether we will reach another conclusion if we examine women. The other step we can make in this field is to change the coordinator of asking questions in some special studies to find the relationship between activated brain regions with coordination (Hakun, et al., 2008).

The other consideration we can take into account is using TMS (Transcranial Magnetic Stimulation). This is a noninvasive method that causes depolarization or hyper polarization in the neurons of the brain. Using a rapidly changing magnetic field, TMS induces weak electric currents into the brain. Its pulse generally reaches no more than five centimeters into the brain. This weak electric current temporarily changes the function of pre-cise regions of the brain. In a large number of studies,

they have successfully modified the process of working memory, planning and response inhibition (Luber, et al., 2007). They also have disrupted processing of self / other distinction (Lou, et al., 2004).

Using TMS, we might be able to change a person's ability to deceive and lie. The last but not the least, we can design new tasks through which we can make a real life situation and have the control of deceptive factors at the same time or someone's deceptive ability might be changed using TMS.

Conclusion

To sum up, considering the importance of lie detection, fMRI studies can play a crucial role for studying activated brain regions during a deceptive procedure; we need a lie-like situation. To achieve this, some tasks need to be designed. There are three groups of tasks. Each of them has its advantages and disadvantages. The ideal result we can get is finding brain regions that are related to lie and deception in all individuals irrespective of their age, gender or ethnicity. To reach this goal, we try to design a task whose activated brain regions are as independent as possible from its task, so that the results can be generalized for all individuals. This way, in near future, fMRI can be used as a reliable method of lie detection.

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