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Deception rate in a "lying game": Different effects of excitatory repetitive transcranial magnetic stimulation of right and left dorsolateral prefrontal cortex not found with inhibitory stimulation

Inga Karton [a,b,*], Annegrete Palu [a], Kerli Jõks [a], Talis Bachmann [b]

[a] University of Tartu, Institute of Psychology, Näituse 2, Tartu 50409, Estonia
[b] University of Tartu (Tallinn branch), Institute of Public Law, Kaarli puiestee 3, Tallinn 10119, Estonia

HIGHLIGHTS

- Left-DLPFC excitation by TMS compared to right-DLPFC excitation decreases lying.
- Excitation protocol of TMS is more systematic compared with the inhibition protocol.
- Right hemisphere is more susceptible to opposite effects of stimulation types compared with the left-hemisphere effects.

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ABSTRACT

Knowing the brain processes involved in lying is the key point in today's deception detection studies. We have previously found that stimulating the dorsolateral prefrontal cortex (DLPFC) with repetitive transcranial magnetic stimulation (rTMS) affects the rate of spontaneous lying in simple behavioural tasks. The main idea of this study was to examine the role of rTMS applied to the DLPFC in the behavioural conditions where subjects were better motivated to lie compared to our earlier studies and where all possible conditions (inhibition of left and right DLPFC with 1-Hz and sham; excitation of left and right DLPFC with 10-Hz and sham) were administered to the same subjects. It was expected that excitation of the left DLPFC with rTMS decreases and excitation of the right DLPFC increases the rate of lying and that inhibitory stimulation reverses the effects. As was expected, excitation of the left DLPFC decreased lying compared to excitation of the right DLPFC, but contrary to the expectation, inhibition had no different effects. These findings suggest that propensity to lie can be manipulated by non-invasive excitatory brain stimulation by TMS targeted at DLPFC and the direction of the effect depends on the cortical target locus.

1. Introduction

The importance of studying deceptive behaviour lies primarily in the necessity to be able to detect it. The possibilities of lie detection can be advanced once the brain processes involved in lying are known. Lying is a complex cognitive activity as it requires more effort than speaking the truth [1–3]. This kind of information management entails the implementation and control of the executive functions [3,4], which are essential for deceptive behaviour. Lying does not consist solely of expressing a lie [5]: it is also important to avoid speaking the truth, which may, in some cases, require even more control [1,6]. In recent times, this topic has been studied extensively within the framework of neurosciences targeting the mechanisms of cognitive processes. However, a lot remains unclear in the study of lying and many contradictory research results have been produced, in which correlational relations have been investigated the most while causal relations have been examined significantly less [7].

The aforementioned correlational relations have been studied with the aid of various neuroimaging methods [5,6,8], during which different brain processes are comparatively assessed while subjects respond to stimuli truthfully or by lying. It cannot be claimed without a doubt that certain brain activity is caused by deceptive behaviour or vice versa because lying activates areas of the brain which are involved in many different cognitive processes [2,3,9,10]. The studies capable of observing some causal effects are mostly carried out by implementing either of the two non-invasive

* Corresponding author at: University of Tartu, Institute of Psychology, Näituse 2, Tartu 50409, Estonia. Tel.: +372 737 6611.
E-mail address: inga.karton@ut.ee (I. Karton).

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neurostimulation techniques: transcranial direct current stimulation (tDCS) and transcranial magnetic stimulation (TMS). The principal advantage of TMS is that it helps to investigate causal relations between the activation or inhibition of a certain brain region and monitored behaviour, and thus verify the validity of neuroimaging methods [1,10]. TMS uses the electromagnetic induction principle, which changes certain short-term brain activity in a specific area of the cerebral cortex [11]. When the behaviour of a subject changes after stimulating certain brain regions, it is possible to assume a causal connection between them.

The biggest problem in determining whether lying has its corresponding brain region or specific brain mechanism is the fact that these regions may be and often are active without deception as well [3]; this is because deception is based on several different cognitive processes that are linked to the same region [5]. An increasing number of authors have studied and claimed that processes of lying are associated with the dorsolateral prefrontal cortex (DLPFC) e.g., [2,6,8,9,12]. The functionality of right and left DLPFC is different: right DLPFC is involved in cognitive control, avoidance and behavioural inhibition [13–15] while left DLPFC participates in reality monitoring, approach motivation, strategic behaviour, naming and execution [8,9,16,17]. As the prefrontal cortex is asymmetrical in its function, it is possible to assume that the rTMS applied to the left and right DLPFC also brings about varying changes in behaviour [18]. We have previously [19,20] found that stimulating the DLPFC with rTMS affects the rate of spontaneous lying in simple behavioural tasks. Spontaneous choice to lie more or less can be influenced by brain stimulation. Where subjects had freedom to name presented stimulus-objects (red and blue coloured circles) either veridically or nonveridically the amount of truthful answers can be manipulated by inhibitory off-line 1-Hz repetitive transcranial magnetic stimulation targeted at DLPFC: inhibition of the left DLPFC with rTMS increased the relative rate of lying, but inhibition of the right DLPFC decreased it [19]. In the second study [20] the subjects were allowed to report the name of the shape (circle or square) of the object they actually saw or report the name of the object they did not actually see, therefore producing a non-truthful response. When trains of 10-Hz pulses were delivered to the right DLPFC, propensity to lie increased while similar left-hemisphere DLPFC stimulation did not change the rate of untruthful responses. In order to retest those earlier findings and develop this subject further, we conducted a study reported here in which we examined all four conditions (the excitation and inhibition of the left and right DLPFC with rTMS) together in the same subjects and using a larger sample. But in order to develop the method and test for the generality of the effects, we replaced the task requiring simple spontaneous object-naming responses with lying in a more highly motivated and engaging task context. However, we preserved the subjects' free will in regard to whether, how much and when to lie. In accord with most of our above mentioned earlier results we hypothesise that excitation of the left DLPFC with rTMS decreases the rate of lying and excitation of the right DLPFC increases the rate of lying; also, to the contrary, we expect that inhibition of the left DLPFC with rTMS increases and inhibition of the right DLPFC decreases the rate of lying. (Even though the specific hypothesis about the effect of excitation of left DLPFC was not confirmed in the earlier study, there is no reason for the contrary assumption.)

2. Method

2.1. Subjects

Seventeen healthy right-handed volunteers participated in the study, sixteen of them (12 females) were included in the data analysis (age of subjects, 20–47 years, M = 25.6, SD = 7.85). One subject was excluded due to problems with following the instructions. Subjects visited the lab altogether on five days: four experiment days and one a pre-experiment day when his/her motor threshold (MT) was estimated, and a written informed consent document introduced and signed. The study was approved by the Research Ethics Committee of the University of Tartu and was conducted according to the principles set in the Declaration of Helsinki. The subjects each time received 5-8 EUR in compensation for participation; the precise amount of money depended on the collected points, which was another element in the attempt to increase the motivation to lie.

2.2. Experiment

The experimental task consisted in playing a so-called 'circle game', which was created in our lab and was a further development of our previous experimental protocol [19]. During the game, red and blue circles appeared in quasi-random order on the computer monitor for 100 ms per each appearance. The time between appearance of the circles and possibility to respond was set at 400 ms. Each trial started with a fixation interval with a variable length of 1000/1500 ms (Fig. 1A)

The subjects' behavioural task was to name the colour of the circle. In each trial, a circle (diameter 13 cm) was presented on a SUN CM751U monitor (1024 × 768 pixels; 100 Hz refresh rate) from the viewing distance of approximately one metre. The slight variability in viewing distance appeared due to the precondition that participants were allowed to choose a distance that was comfortable for them to look at the screen and perceive the stimuli as they liked. During the entire game, a total of 240 circles were presented, either of the colours was used 120 times. Participants were instructed that the purpose of the game is to collect as many points as possible and that seeing and naming the red circles will give one point per each red circle. However, they were additionally told that there is also possibility to lie and name the blue circles as red. Thus, one point was earned when the subject answered "red", no points were earned for answering "blue". The subjects were free to choose whether to lie or not. Importantly, during the game there were also occasional checks. For every untrue answer detected by the experiment program, the subject lost 5 points. 40 control trials were divided equally between trials with red and trials with blue circles. To answer, the subjects' used two fingers on their right hand: they pressed the right arrow key to answer red and the left arrow key to answer blue. The score and number of trials executed were visible during the entire experiment. Also, feedback from control trials was shown after each control trial.

2.3. Transcranial magnetic stimulation

The experimental task was accompanied by "off-line" 1-Hz and 10-Hz rTMS to inhibit or excite the left or right DLPFC (BA 9, see Fig. 1B). Each subject participated in four experimental sessions, carried out on different days. All subjects received all stimulation conditions (left and right 1-Hz and sham; left and right 10-Hz and sham) and the conditions were counterbalanced between subjects.

In the part of the experiment with inhibitory stimulation (in two separate days) the subjects received – prior to each experimental block – a train of 1-Hz rTMS (360 pulses over the course of 6 min) or sham stimulation to the left or to the right DLPFC followed by the experimental task which contained the naming of 120 circles. Each block was carried out twice. In the part of the experiment consisting of excitatory stimulation (spanning over two days) the subjects received 24 one-second trains of 10-Hz or sham stimulation to the left or to the right DLPFC, followed by the 10 s long time 'window' without rTMS. During this 'window' subjects performed the experimental tasks naming five circles per 'window'.