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Deceptive communication: the effects of transcranial magnetic stimulation and the signatures of electroencephalography

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CONTENTS

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This dissertation is based on the following original publications; further referred to by respective Roman numerals:

I **Karton, I**., Bachmann, T. (2011). Effect of prefrontal transcranial magnetic stimulation on spontaneous truth-telling. Behavioural Brain Research, 225, 209–214.

II **Karton, I**., Rinne, J.-M., Bachmann, T. (2014). Facilitating the right but not left DLPFC by TMS decreases truthfulness of object-naming responses. Behavioural Brain Research, 271, 89–93.

III **Karton, I**., Palu, A., Jõks, K., Bachmann, T. (2014). 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. Neuroscience Letters, 583, 21–25.

IV **Karton, I**., Kitt, A.-B., Rutiku, R., Bachmann, T. (*submitted*). Does the critical stimulus in a psychophysiological concealed information test have a unique status in terms of the revealing ERP components? It depends. Applied Cognitive Psychology.

The author of the present dissertation contributed to these publications as follows:

- In Studies **I** and **II**: participated in developing the study concept and data collection, carried out data analyses and participated in writing the manuscript.
- In Study **III**: participated in developing the study concept, conducting the experiments, in data collection and analyses and wrote the manuscript as the primary author.
- In Study **IV**: participated in developing the study concept, data collection, data analyses and participated in writing the manuscript.

Principal aims of the studies:

- Study I: to test whether spontaneous propensity to lie can be changed by the disruptive (inhibiting) brain stimulation by repetitive transcranial magnetic stimulation (rTMS) targeted at the dorsolateral prefrontal cortex (DLPFC).
- Study II: to test whether changing the rTMS protocol from the disruptive (inhibiting) to facilitatory (exciting) type will lead to opposite results.
- Study III: to re-test previous studies and to examine the role of the disruptive and facilitatory rTMS as applied to the DLPFC in behavioural conditions where participants were motivated to lie.
- Study IV: to investigate how more or less significant crime-related items in the concealed information test are associated with the amplitude of the event-related potential (ERP) P300 component and how rTMS targeted at DLPFC affects P300 amplitude depending on item significance.

INTRODUCTION

Lying and deceiving, as well as efforts to establish the truth or to detect a lie, are as old as Mankind and have a long and versatile history, both in jurisprudence and popular lore. Recent scientific research has focused on both the evolutionary aspects of lying and the search for observable signs – identifiable verbal and non-verbal cues to deception and lying. Several methods have been proposed to detect lying: observation of people's non-verbal behaviour; analysis of verbal content, structure and style of what somebody says; measurement of physiological responses. Still no perfect lie detection tests exist and lie detection experts are wrong on a regular basis.

Many behavioural scientists have studied the phenomena involved in lying and concealment, and their identification. For example, Vrij (2000) took an interest in the search for specific signs that would indicate, on a verbal and non-verbal level, the presence of deception. Ekman (2001) studied in his work expressive signals of insincerity, focusing his attention on the evolutionary aspects of this behaviour. According to Ekman (2001), lying can be defined as a deliberate attempt to mislead, without the implicit or explicit prior consent or notification of the target (the other person). In Vrij (2000) a definition of deception is as follows: "a successful or unsuccessful deliberate attempt, without forewarning, to create in another a belief which the communicator considers to be untrue". Therefore, according to Vrij (2000): (1) lying is an intentional act; (2) people are lying only when they do not inform others in advance about their intentions to lie; (3) the lie has been defined solely from the perspective of the deceiver; (4) people sometimes fool themselves, a process which is called self-deception – the current definition excludes such self-deception.

Historically, the technology based experimental works on deception have typically concentrated on: (i) the "lie detector" (instrumental diagnostics of emotional stress, polygraph testing); (ii) the reaction time based method; (iii) the event-related potential (ERP) method. As the most up-to-date methods the recording of bioelectrical potential fluctuations of the brain by electroencephalography (EEG), registration of the brain local metabolism by functional magnetic resonance imaging (fMRI), or recording and measuring electromagnetic signatures of brain processes by magnetoencephalography (MEG) have also been used. Contemporary methods in the procedures of identifying lying are based on registering the activation level of the brain regions that are hypothetically associated with deceptive information processing.

Nowadays, the area of deception research is developing rapidly. According to Ganis and Keenan (2009) the respective future directions need to concentrate on: (i) identifying specificity or generality of deception processes; (ii) integration of different methods and measures; (iii) determining key variables of deception such as the dependence on the context; (iv) testing more real-life like

situations. This doctoral dissertation was designed to contribute to further development of this area. Importantly, the approach taken in this thesis purports to capitalise on moving from the prevailing correlational approach, which typically examines correlations between brain activity patterns and deceptive behaviour, to the less developed causal approach, whereby the effects of targeted manipulations of the brain processes on deception are studied. For this purpose the method of transcranial magnetic stimulation (TMS) is employed. The main focus was on the putative involvement of the brain mechanisms of cognitive-behavioural control in lying and the combined use of different methodologies such as behavioural experimental protocols, TMS, and EEG/ERP. The work behind this dissertation can be subsumed under basic research, however it has clear implications for the possible applications and their constraints thereof, in a legal and forensic context. In what follows we present the methodological and theoretical background of the current approach and describe the original research results – the most essential part of this work – where it fits in this context. Thereafter, the published work is collected so the reader can have a more detailed view of the topic and the specifics of the conducted studies.

One aim of the present work is to study the susceptibility of lying behaviour and bioelectrical brain-process signatures indicative of deceptive communication to targeted perturbation of brain regions implicated in deception, specifically the dorsolateral prefrontal cortex (DLPFC). The other, related aim is to explore the dependence of the expression of the above-mentioned bioelectrical signatures on the type of concealed information test and level of participants' motivation to lie. We planned to: (1) test whether there are reliably verifiable effects of perturbation of DLPFC by TMS on the behavioural expression of deception; (2) examine the effects of exhausting vs. exciting the brain by TMS on deception; (3) measure the EEG/ERP signal fluctuations as a dependent variable indicative of the criticality of stimuli in the deceptive behaviour contexts. More specifically, the responses of the perturbed brain were measured in the circumstances where the participant's cognitive processes were expected to distinguish automatically between the critical and neutral stimuli (a version of the "guilty knowledge test"). We set the following statements as the hypotheses: (1) there are cortex areas for which it is true that when their functionality is manipulated by TMS, a change in deceptive behaviour occurs; (2) this kind of TMS manipulation leads to a change in the degree of expression of the EEG signatures of deceptive communication and (3) the bioelectrical fluctuations of the EEG/ERP P300 potential in responses to critical stimuli differ from the responses to noncritical stimuli, with the extent of this effect depending on the particular experimental protocol and level of motivation of the participants.

1. Non-invasive brain stimulation and its effects on deception

1.1. Deception-related brain regions: the dorsolateral prefrontal cortex

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 (Sip, Roepstorff, McGregor, & Frith, 2008), this is because deception is based on several different cognitive processes that are linked to the same region (Sip et al., 2010). In several studies the DLPFC has been found to be involved in deceptive behaviour (e.g., Langleben et al., 2002; Priori et al., 2008; Christ, Van Essen, Watson, Brubaker, & McDermott, 2009; Mameli et al., 2010; Karim et al., 2010; Abe, 2011; Ito et al., 2012). More precisely, Kozel and colleagues (2009) found that a fMRI blood-oxygen-level dependent (BOLD) signal could detect past event-related deception with 100% sensitivity, but with only 33% specificity. In their study, the mock-crime participants group showed a lateral and prefrontal pattern of activation, while the no-crime group showed activation of the medial prefrontal area. In an earlier work (2005) Kozel and colleagues observed increased activation of the anterior cingulate cortex, the motor areas of the frontal lobe, the insular cortex, orbitofrontal cortex, right medial frontal cortex, right superior area of the temporal lobe and in the left medial parietal lobe; this was found in a situation where the participants were denying a theft they actually committed. Other fMRI studies (Langleben et al., 2002; Spence et al., 2004) have shown that lying is associated with increased activity in the frontal cingulate cortex and parietal lobe. Lying, as well as the processes that accompany truthfulness are mediated by similar frontoparietal networks (Langleben et al., 2002). However, in the case of lying increased working memory-intensive activity is observed, characterised by increased activity in the inferolateral cortex, an area implicated in response selection, inhibition and response generation. In that study lying was discriminated from truth on a single-event level with an accuracy of 78%. In other studies lying was associated with activation of the frontal lobe's lower lateral region, while making up new versions of a lie required activation of the posterior lateral frontal lobe (Spence et al., 2004). Well-rehearsed lies that fit into a coherent story elicit more activation in the right anterior frontal cortices than do spontaneous lies that do not fit into a story (Ganis, Kosslyn, Stose, Thompson, & Yurgelun-Todd, 2003). The opposite pattern (decreased activation) occurs in the anterior cingulate and posterior visual cortex. According to this same study both types of lies were accompanied by excitation of the anterior prefrontal cortices (bilaterally), the parahippocampal gyrus (bilaterally), the right precuneus, and the left cerebellum when compared to the pattern of activity observed in the condition of behavioural truthfulness (Ganis et al., 2003).

True memory, false memory and outright deception were studied by Abe and colleagues (2008): intentional manipulation of response in deception was

characterised by increased prefrontal activity. They reasoned that the intentional cognitive process necessary for response manipulation required activation of the left middle frontal gyrus, also known as DLPFC. In their opinion, this structure can be seen as a reliable indicator of pretending to know and thus prefrontal activity seems to separate not only deception from truthfulness, but also deception from false memory. The experimental design used by Abe and colleagues (2008) allowed a differentiation between true recall and false recall of auditory presented words, with each eliciting a different brain activation pattern where the former was associated with activation of the lateral temporal and parietal cortices in a process of sensory reactivation. Their most important finding was confirmation of the central role the left prefrontal cortex played in the pretending-to-know cognitive task, whereas the right hippocampal area was involved in false recognition without a concomitant activation of sensory (auditory) areas (Abe et al., 2008).

Lying is a type of mental activity presuming high demands on cognitive control. Consequently, brain structures involved in cognitive control must be a natural target for brain imaging analyses and intervention methods in research on deception. Even though the studies of the brain mechanisms of cognitive control often do not directly investigate deception as such, their results are also important to consider in deception research. For example, it has been noted that right and left DLPFC can be characterised as bearing different functionality: right DLPFC is involved in cognitive control, avoidance and behavioural inhibition (Knoch & Fehr, 2007; Shackman, McMenamin, Maxwell, Greischar, & Davidson, 2009; Vartaniana, Kwantesa, & Mandela, 2012); while left DLPFC participates in reality monitoring, approach motivation, strategic behaviour, naming and execution (Berkman & Lieberman, 2010; Abe, 2011; Steinbeis, Bernhardt, & Singer, 2012; Ito et al., 2012). As the prefrontal cortex is asymmetrical in its function, it is possible to assume that purposeful experimental manipulation (e.g., carried out by the rTMS) applied to the left and right DLPFC also brings about varying changes in behaviour with cognitive and executive control involved (Knoch et al., 2006). Therefore, the data from this mentioned research is relevant for our purposes, as we will see later on.

Neuroimaging studies in which specific cortical areas are shown to become activated during lying cannot be taken literally or interpreted simplistically to indicate a cortical "locus" for lying. As pointed out by Luber and colleagues (2009) and Karim and colleagues (2010) such studies only provide evidence of a correlation between the activation of certain brain regions and the occurrence of a specific behaviour. However, the same cortical areas – together or separately – are involved in a variety of cognitive tasks when no deception is taking place. For example, the prefrontal, parietal, and anterior cingulate regions commonly activated in deception studies are also generally activated when executive processing is studied with no deception involved. Therefore, the activation of a cortical area during lying does not prove a directly causal relationship between it and the occurrence of lying (Luber et al., 2009). For this

reason we chose to investigate the causal effects of manipulation of DLPFC on deception related behaviour, which was carried out in **Study I, II, III**, and **IV** (Experiment 1). DLPFC as the locus of interest was selected primarily for three reasons: first, it is implied in many earlier studies as the cortical area somehow involved in deception; second, the precise role of DLPFC is not clear and controversial results have been obtained so far; third, this area can be relatively comfortably accessed by TMS.

Studies of brain area activation through neuroimaging techniques (see Christ et al., 2009) can be said to fall broadly into two categories: studies that attempt to elicit evidence of deception through the presence of a specific pattern of cortical activation and studies that aim at the unraveling of the neurocognitive processes underlying deception. In the former, the aim is to correlate the activation of a set of brain regions with the occurrence of lying behaviour or instances of truthfulness. In this type of research, no attempt is made to infer what types of psychological processes are involved in lying and in correlating the activation of specific brain areas with such processes. This approach is relatively closer to some of the (possible) practical applications in the detection of deception. The other type of study views lying as a complex, high-level cognitive task and attempts to create a model for the underlying neurocognitive processes, using different experimental setups. This approach is more theoretical in its nature and is more strongly related to basic cognitive, affective, and social neuroscience.

1.2. Methods of non-invasive brain stimulation: tDCS and TMS

Non-invasive brain stimulation in the form of TMS or transcranial direct current stimulation (tDCS) have been used to test the validity of brain imaging findings (Luber et al., 2009) or in order to establish a causal relevance between the state of a cortical region and deceptive behaviour through the transient inhibition of cortical excitability (Karim et al., 2010). TMS can alter brain activity in a specific cortical region through the use of targeted magnetic fields temporarily disrupting or otherwise perturbing neural processing in the focal area (Luber et al., 2009). TMS is brought about by a brief and strong electrical current sent through a coil, which in turn produces a magnetic field that can be directed to the brain tissue (Hallett, 2007; Wagner, Valero-Cabre, & Pascua-Leone, 2007). The directed magnetic field has an effect on the neural processes, with the strongest effect taking place in the brain areas close to the source of the field. Thus TMS can be used to study the functioning of a certain area of the brain in relation to an existing behaviour through the disruption of neural processing in that area and the measurement of small but significant alterations in behaviour (Ilmoniemi & Karhu, 2008; Ridding & Rothwell, 2007). In this manner TMS and tDCS attempt to overcome "brain states versus behaviour" correlational issues and to demonstrate a causal relationship between the activation/inhibition of a specific brain region and changes in the performance of a complex cognitive task.

Neural processes can be either facilitated or inhibited depending on the intensity or timing of the TMS pulses. TMS uses the principle of electro-magnetic induction, in order to induce a temporary and rather narrowly localised bioelectrical noise in the brain and to temporarily switch off or inhibit or even facilitate the functions in a particular region. In case of rTMS it could alter the excitability of the cortex, either increasing or decreasing it, depending on the parameters of stimulation (Hallett, 2007; Wagner et al., 2007). Inhibition typically emerges with stimulation at about 1 Hz frequency and excitation with stimulation at about 5 Hz frequency and higher (Hallett, 2007; Luber et al., 2009). As for the tDCS, it can either excite cortical areas or decrease their activation capitalising on the passage of a DC current between anodal and cathodal scalp electrodes (Luber et al., 2009). (Obviously, the parameters of current are harmless for the participant's health.) Anodal tDCS seems to increase excitability in the areas of interest, whereas cathodal stimulation appears to have an inhibitory effect (Luber et al., 2009).

1.3. The effects of dorsolateral prefrontal cortex stimulation on deception

Repetitive transcranial magnetic stimulation (rTMS) of the DLPFC causes a transient disruption of functioning in this area. Stimulating DLPFC by rTMS optimised for the disruptive effect has been reported to result in altered decision-making strategies compared with sham stimulation. Knoch and colleagues (2006) inhibited the right DLPFC with low frequency rTMS and observed significant increases in risky decision making in their participants, compared to participants in which inhibitory stimulation was received on the left DLPFC or sham stimulation was applied to either side. Similarly, Fecteau and colleagues (2007) used tDCS to impact anodal stimulation to the right DLPFC while applying a cathodal tDCS to the left DLPFC and found that their participants more often made the safer choice, while taking less time to evaluate and choose between low risk and high risk possibilities, compared with sham stimulation. Inversion of the experimental parameters with anodal tDCS stimulation of the left DLPFC and cathodal inhibition of the right DLPFC did not induce a difference in riskiness of choices but did result in a longer time interval in making a choice. Experimental manipulation of the human ability to produce deceptive responses through interference with the neural processes at specific sites (DLPFC, bilaterally) was described by Priori and colleagues in a 2008 study involving the stimulation of the right and left DLPFC through anodal and cathodal direct currents applied separately to these areas. Their results showed no influence on the frequency of deceptive responses, but a demonstrable increase in the time delay (RT) involved in making deceitful responses. Mameli and colleagues (2010) found that the neural networks underlying personal knowledge related deception vs. deception regarding general knowledge are separate and distinct. They showed this by an

experimental design involving anodal tDCS stimulation of DLPFC bilaterally and demonstrated a speeding up of reaction times in the production of general knowledge related deceptive responses. Karim and colleagues (2010) found that inhibition of the anterior prefrontal cortex (aPFC) by cathodal tDCS led to significant within-participant increase of deceptive behaviour.

When we started with rTMS experiments there were – up to our knowledge – no TMS studies which would have tried to modulate deception performance and no research to date has addressed the issue of whether the technique has any potential for reliably disrupting deception in a single participant (Ganis, 2014). There were two studies that used single pulse TMS to probe motor cortex excitability during deception (Duzel et al., 2003; Kelly et al., 2009). So in our first experiments (**Study I and II**) the more specific exploratory aims of those studies were to ascertain whether the propensity to lie can be artificially changed and if yes, what specific brain locations are involved in this effect. In **Study I,** we tested whether spontaneous propensity to lying can be changed by brain stimulation and found that stimulating the DLPFC with rTMS affects the rate of spontaneous lying in simple behavioural tasks. Where participants (16 subjects divided into two stimulation groups) 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 6.31 minute long 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. The main shortcoming of **Study I** consisted in the lack of the sham condition. Because experimental TMS related manipulation for obtaining a true sham condition indiscriminable from real TMS does not exist (especially when DLPFC as a region close to face is stimulated), we used a control area (parietal cortex) which is not known to be directly associated with lying. However, in order to check for the different type of possible shortcomings stemming from the absence of sham condition such as differences in the general non-localised effects of TMS we used in our next studies the sham condition for finding the baseline lying rate to be compared with this rate in main experimental conditions.

With **Study II**, we wanted to test whether changing the rTMS protocol from the disrupting to facilitatory type can lead to results showing opposite effects. In **Study II** the participants (20 subjects divided into two stimulation groups) 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 (16 trains of 10-Hz rTMS pulses; each train lasted 1 s, followed by 10 s stimulation free period between trains) were delivered to the right DLPFC, the propensity to lie increased while similar left-hemisphere DLPFC stimulation did not change the rate of untruthful responses. Hence, compared to the results of **Study I**, the opposite effect was revealed in **Study II**: propensity to produce non-truthful naming responses increased when we stimulated the right DLPFC. At the same

time left DLPFC stimulation did not lead to the expected decrease in non-truthful responding. This result supports the possibility that the earlier results were not caused by contralateral hemispherically localized effects of TMS, but were hemisphere dependent in other ways. The opposite effect compared to the one found with right DLPFC stimulation in **Study II** and the lack of the expected opposite effect with left DLPFC stimulation as taken together and as supported by an experimental design where sham control was used suggest that levels of bias to lie were manipulated primarily by right DLPFC stimulation. Either the former left DLPFC effect can be obtained only with the disrupting type of rTMS and not with the facilitatory type or it was obtained as a result of contralateral homotopic TMS-induced excitation of the right DLPFC by left DLPFC stimulation.

In order to retest those earlier findings and develop this subject further, we conducted **Study III** in which we examined all four conditions (the excitation and inhibition of the left and right DLPFC with rTMS) together in the same participants and used a larger sample (16 subjects for each condition). However, in order to develop a 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. Notwithstanding this, we preserved the participants' free will in regard to whether, how much and when to lie. We found that the excitation of the left DLPFC decreased lying compared to excitation of the right DLPFC, but contrary to the expectation, inhibition had no different effects. The reason that no difference of the effect was found between left- and right-hemisphere stimulation in the rTMS inhibitory condition may be predominantly methodological: that is to say 1-Hz rTMS has a lingering effect which reduces the comparative laterality effects between DLPFCs especially when cognitive control is involved (Torii, 2012; Hansenne, 2004). The duration of the rTMS effect is mainly dependent on the duration and the strength of the magnetic stimulation. Thus, the one reason why in our first experiment (**Study I**) the behavioural differences occurred may be related to the length of the behavioural task: in our first experiment the task performance lasted several times less (2-3 min) than in this experiment (5-8 min) whereas the duration of stimulation was even half a minute shorter (6 min vs. 6.31 min). Therefore, in the present case (**Study III**) the rTMS application was not sufficient to induce a statistically significant change in behaviour.

Taking the results of **Studies I, II,** and **III** all together it is possible to formulate that the propensity to lie can be manipulated by non-invasive brain stimulation by TMS targeted at DLPFC. The effects depend on (i) stimulated hemisphere, (ii) type of stimulation, and (iii) possibly on task demands. It seems that the excitation protocol is more systematic compared with the inhibition protocol. It also appears that whether right-hemisphere effects or left-hemisphere effects are more or less robust depends on the type of task and the duration of stimulation as well as on the aftereffects – all this being evidenced by the differences between the results of different studies.

2. EEG signatures of deception and what does combining the TMS with EEG show

2.1. Electroencephalogram and concealed information test

The traditional psychophysiological lie detection measures used to be obtained with polygraph. These measures typically include respiration, galvanic skin reaction (GSR) or electrodermal response (EDR), cardiovascular measures such as pulse and blood pressure (e.g., Lykken, 1959; Ben-Shakhar & Elaad, 2003; Carmel, Dayan, Naveh, Raveh, & Ben-Shakhar, 2003). Today's studies are based also more on electroencephalographic psychophysiology and brain imaging other than EEG. A widespread behavioural task, which is used together with these methods is the Guilty Knowledge Test (GKT), recently known also as the Concealed Information Test (CIT; Lykken, 1959, 1979; Rosenfeld, 2011). CIT is a modern method of polygraph interrogation that advances psychophysiological detection of prior knowledge of crime details that would be known only by the perpetrator (Verschuere, Ben-Shakhar, & Meijer, 2011). It is developed to detect whether or not a person (e.g. suspect) recognises the importance of information, which could be known only by the guilty perpetrator. In the CIT psychophysiological responses to critical (i.e., potentially accusation allowing or incriminating) items are compared to the responses to neutral (i.e., contextually not significant) items with participants trying to hide or deny that they have specific contextualised knowledge of the critical items. If critical items lead to enhanced responses compared to the responses to neutral items, concealed information knowledge is said to be detected.

When combined with EEG recording, CIT has produced quite reliable ERP signatures of deception such as P300 (Farwell & Donchin, 1986; Ambach, Bursch, Stark, & Vaitl, 2010; Rosenfeld & Labkovsky, 2010; Verschuere, Ben-Shakhar, & Meijer, 2011; Farwell, 2012). CIT studies have used both the two- and three-item protocols; a three item protocol includes an additional stimulus – a target (Farwell & Donchin, 1991; Rosenfeld, Soskins, Bosh, & Ryan, 2004; Mertens & Allen, 2008; Rosenfeld, Hu, & Pederson, 2012). The target is basically an irrelevant item in what concerns concealment behaviour, but the participant is assigned to make a unique button response which would be different from the responses to irrelevant and critical ("probe") items. The target is meant to be used to keep the participant's attention on randomly presented unpredictable items. However, there is no clear consistency in the ERPs associated with targets as the responses to targets may be sometimes significantly less accurate than responses to true irrelevants (Seymour, Seifert, Shafto, & Mosmann, 2000; Gamer & Berti, 2010). In some studies, the probes and targets have produced similar ERPs (Farwell & Smith, 2001) but in some cases targets have produced larger P300 amplitudes than probes (Mertens & Allen, 2008).

The significance of a crime-related knowledge is one source we have to consider in creating more real-life like experiments. Ambach, Dummel, Lüer, & Vaitl (2011) compared two different questioning formats ("did you see?" vs. "did you steal?") with two different encodings of items of interest (only seen vs. seen and stolen items). Thus, the level of significance was different for these two types of items and, depending on the item type, only one question required deception. They found that both types, irrespective of the question, elicited different physiological responses compared to entirely new items. However, only for the stealing question, responses to actually stolen objects were also different from merely seen objects. It is important to elaborate on the work of Ambach and colleagues (2011) to further understand how levels of information significance influence the sensitivity of deception detection with a CIT. The combination of CIT with EEG should be particularly well suited for pursuing this task due to the superior temporal resolution of the evoked neural processes in response to a crime related item (and its significance). Thus, for **Study IV**, we decided not to include targets in our CIT protocol and modeled our approach more closely on the classical CIT protocol. In **Study IV**, two experiments (Experiment 1 and Experiment 2) were carried out to examine the effect of stimulus significance on ERP-based detection of deception. Differently from previous studies which used a CIT protocol with the mock crime scenario, we distinguish between three types of stimuli: the critical stimulus (stolen by the participant), familiar stimuli (present during the enactment of the crime) and neutral stimuli (no prior exposure). Also, it was examined how rTMS to DLPFC affects P300 as a function of stimulus significance. The respective results will be summarised in part 2.3.

2.2. Electroencephalographic signatures of deception

Electroencephalogram and event-related potentials based methods are designed for registering the changes in the bioelectrical potentials of the brain. EEG measures electrical activity of the brain with sensors (electrodes) picking up bioelectrical signals of the brain communicated through the skull and scalp. ERP consists in a series of time-related changes in bioelectrical potentials resulting from the activity of billions of nerve cells involved in sensory, cognitive and motor processes as specific neural events in response to external and internal perturbations. To obtain ERP numerous event-related epochs of EEG are taken, being timed to the same specific event and the potential of the epochs is averaged. By the means of measuring the level of synchronisation of the power changes and/or the phases of the oscillatory processes recorded in EEG, information on the neural correlates of different cognitive processes can be obtained (Luck, 2005; Sauseng & Klimesch, 2008). Although spatially inaccurate, EEG has some advantages compared, for example, to fMRI and PET (positron emission tomography) as the latter are methods with low temporal resolution. While cognitive processes are dynamic, EEG/ERP enable to describe

the course of the phenomenon in the range of short intervals (millisecond-range) in real time (Ward, 2003; Sauseng & Klimesch, 2008); this enables one to analyse the oscillating activity of the brain. Each oscillation can be described through its frequency value, amplitude, and the phase. The oscillatory brain activity can be divided into the following typically used frequency bands: Delta (0–4 Hz), Theta (3.5–7 Hz), Alpha (8–13 Hz), Beta (18–30 Hz) and Gamma (30–100 Hz). The EEG phase synchrony can be characterised by several important features such as its cross-cortical manifestation, cross-frequency coupling and relatedness to external events (Sauseng & Klimesch, 2008).

The ERP waves consist of positive and negative deviations, the typical peaks of which in response to a visual stimulus are marked P1, P2, P3 and N1, N2 N3. The P3 wave that is strongly dependent on the performed task is sensitive to cognitive demands during task processing, working memory operations, response preparation, and evaluation of the significance of the perceived stimulus (Luck, 2005; Polich, 2007). The EEG-assisted recording of the P300 (P3) amplitude and topography of the critical ERP components have been used for various purposes in fundamental and applied research. When the stimulus-evoked activity is significant and highly meaningful for the person, enhancement of this positive potential component is registered, beginning approximately 300–400 milliseconds after the stimulus (Mertens & Allen, 2008). If a stimulus signifying or depicting an object related to a crime or personally significant to a participant is presented, P300 in response to this stimulus is enhanced (Ambach et al., 2010; Farwell, 2012). Typically, persons involved in actions allowing incrimination or having knowledge that would allow relate this person to some suspicious connection, try to conceal knowledge of the critical stimuli. However, based on P300 the range of correctly identified deceptions in different studies has been 89–95% (Rosenfeld, Angell, Johnson, & Qian, 1991; Farwell & Donchin, 1991; Allen et al., 1992). At the same time, more modest results have been also obtained: e.g., Gamer and Berti (2010) did not find an increase in P300 for critical items. In the study by Mertens and Allen (2008) the range of correctly identified "guilty" respondents was 27–47%, depending on the form of the analysis; this range decreased even more when respondents were instructed on how to use the countermeasures. However, the respondents who were "not guilty" were correctly identified in almost all cases. (It should be noted here that from the applied legal point of view, it should be useful not only to reliably detect lies, but also to provide evidence pointing towards innocence of the participant so as to avoid mistaken accusations or even convictions.)

2.3. Deception detection research: design components

The ultimate purpose of research in detecting deception is to develop valid and reliable objective signatures of deception in the applied context. This purpose necessitates making the experiments more similar to real life situations, which

leads to using the mock-crime type experimental protocols. Ben-Shakhar and Elaad (2003) also concluded in their meta-analytic work that various card-test procedures have relatively low validity, while mock-crime procedures have the highest level of validity (compared to the card-test and personal-item paradigms). They also suggested that motivation is likely to be much higher under realistic simulated conditions. One possibility to make the experiment more similar to real life is to use objects as means of experiment, supported by cues indicative of these objects. Cutmore and colleagues (2009) have compared faces, pictures of objects and words in ERP based deception detection, partly because of practical reasons (as photographs are usually used in crime investigations) and partly because they are more effective in eliciting the oddball P300. Their results confirmed that a picture of a stolen object was a more efficient cue than the word of the stolen object. Therefore, to make the test more realistic, it would be useful for deception detection to photograph the objects in the context where the mock-crime took place. McBride and Dosher (2002) also showed that pictures are better recalled than words (free recall) and better recollected when cued with only a fragment. Ambach and colleagues (2010) demonstrated a more pronounced P300 to probe (critical) stimuli when pictures were used. Stronger ERP responses to pictorial rather than verbal stimuli in concealed information detection were also found by Cutmore and colleagues (2009). They compared the effects of faces, pictures of objects and words in ERP based deception detection, their results also confirmed that a picture of a stolen object was a more effective cue than the word specifying the stolen object. Ally and Budson (2007) found that compared to words, when familiarity is enhanced, pictures enhance recollection; therefore, less post-retrieval processes are needed.

In addition to the cognitive components of mental activity involved in deception, motivation of the participant also plays an important part. There are different ways to motivate a participant. Ben-Shakhar and Elaad (2003) reported that highly motivated deceptive guilty participants were more easily detected in the CIT than less motivated deceptive guilty participants. Motivation to defeat the test and thus avoid detection is also an important factor, as shown by Rosenfeld and colleagues (2012). These researchers showed that deception awareness makes it easier to detect the less rehearsed information. Furthermore, feedback about deception proves to be important in this respect: continuous feedback about deception received by the deception group but not in the control group helped maintain participants` awareness of their deception and therefore also attention to the probe-irrelevant dimension (Rosenfeld et al., 2012). The feedback would enhance P300 effects in the deception group, but not in the control group (where the attention was directed to target-nontarget dimension). Motivation and attention can also be better engaged by asking the participant to respond by providing a verbal answer. This was found for example by Ben-Shakhar and Elaad (2003), who suggested that although producing deceptive responses verbally may not be absolutely necessary for producing differential

responsiveness to the relevant items, they may contribute to the enhancement of the signatures of deception. It is also important to bear in mind here that the amplitude of the P300 is also affected by the number of items. Hu and colleagues (2012) showed that increasing the number of irrelevant items would increase the task demands of executing countermeasures. In that case, the participants would need to hold more irrelevant stimuli in their working memory, which is cognitively more demanding for participants aspiring to use countermeasures; additionally adding more irrelevant items will also increase probe P300.

In conclusion, it is possible to summarise that the amplitude of P300 may depend on stimulus type (word or picture) (Cutmore et al., 2009; Ambach et al., 2010) or familiarity with the object (accessibility to recall) (Ally & Budson, 2007), participants' attention and motivation to lie and awareness of their deception (Rosenfeld et al., 2012) as well as on memory load (Hu et al., 2012) etc. Also, it may depend on the type of response (pressing the button or verbal) (Ben-Shakhar & Elaad, 2003). Even though it is a well-known fact that P300 amplitude is enhanced along with the more meaningful the stimuli are, and the less frequently they appear (see for example Rosenfeld et al., 2012), it is not the easiest thing to achieve in a precisely measurable way. One possibility to overcome this problem is to add more irrelevant stimuli, which will increase the probe P300 amplitude by making the task cognitively more demanding and more complicated if one wants to use countermeasures (Hu et al., 2012). It does mean, however, that more stimuli, more time for measurements. As indicated by Huffmeijer and colleagues (2014), at least up to about 30 trials are needed in order to have more or less reliable ERP's per stimuli type for analysis (for P300 it is suggested to have even up to 60 trials). When we planned our EEG-CIT experiment (**Study IV**), we tried to take into account and control as much of the above-mentioned considerations as possible. By means of the two experiments, we vary the number of conditions. Besides the modification of the relevance of the stimuli the frequency effect and the word versus picture effect was tested, a more realistic crime scenario paradigm compared to the former more artificial paradigm was used, and the level of motivation to lie was enhanced. In Experiment I of **Study IV** we adopted a behavioural task where sheets of paper with words indicating goods to steal were presented to participants. They were instructed to imagine stealing one of these items from the store. Words were used as stimuli during the CIT as well. The goal of the Experiment II of **Study IV** was to further investigate the effect of stimulus significance on the P300 response. We hypothesised that any potential differences between critical and familiar stimuli might depend on how life-like, including how engaging, the experiment is. We know from previous CIT studies that the P300 response is indeed stronger for more realistic stimuli (Cutmore et al., 2009; Ambach et al., 2010). It is also positively influenced by the participants' attention and motivation to lie and their awareness of the deception (Rosenfeld et al., 2012; Sip et al., 2013). Last but not least, the P300 response to the critical stimulus

depends on the number of irrelevant stimuli included in the experiment (Johnson & Rosenfeld, 1992; Hu et al., 2012). Thus, in Experiment 2 participants had to steal real objects from a room nearby the laboratory. Furthermore, pictures of these objects were used as stimuli during the CIT. The second experiment also involved more familiar and neutral stimuli than the first experiment, and some of the participants were observed by an eyewitness during the crime episode (to increase deception awareness).

Based on the aforementioned published findings we expected to observe differences between our first, more low-key and artificial, experiment and our second, more realistic and engaging, experiment. We hypothesised that the effect of the critical stimulus on the P300 response is more pronounced in Experiment 2 compared to the effect of familiar and neutral stimuli in Experiment 1. Consistent with the hypothesis, in Experiment 1 and 2 (**Study IV**) we found that the P300 component exhibited systematic amplitude differences in response to critical items compared to neutral items. Importantly, with the more realistic and deception awareness enhancing conditions of Experiment 2 as compared to Experiment 1 the effects were much more robust. P300 was more reliable as a marker of deception on the single participant level in Experiment 2 compared to Experiment 1. Deception could be detected reliably using P300 amplitude for only 22% of the participants in experiment 1. In Experiment 2, this was true for 71% of the participants.

While ERP/P300 is the best known brain-potential signature of deception in the concealed information detection test, it would be important to know whether rTMS has any effect on the extent of expression of P300 and if yes, are there any hemispheric differences analogous to what was found in the behavioural spontaneous lying study where rTMS was used. This is important both for theoretical analysis of the brain mechanisms behind the participants' behaviour in the CIT-like tasks and for practical purposes where purposeful manipulation with participants' sensitivity to critical stimuli operationalised by deception-related ERPs might be desirable.

2.4. EEG signatures in combination with TMS effects

If we look only at the response of the brain to the stimuli, we get the results that are merely correlational in nature. A different tradition of neurobiological research on deception combines brain imaging with non-invasive brain stimulation (Thut & Pascual-Leone, 2010; Miniussi & Thut, 2010; Shafi, Westover, Fox, & Pascual-Leone, 2012; Rogasch & Fitzgerald, 2013). This approach is capable of examining also causal effects and therefore increases the methodological rigour of the studies of brain mechanisms of deception as we did in our **Studies I, II, III** (Priori et al., 2008; Luber et al. 2009; Mameli et al., 2010). Despite this potential, there were no studies of brain stimulation effects on deception-related P300 ERP responses when we began our survey (**Study IV**, Experiment 1). It is reasonable to assume that the location one would like to

choose for non-invasive brain stimulation in order to see the effect on ERP/P300 should be meaningful from the point of view of earlier results from the brain imaging studies of deception. At the same time, this type of brain locus should be accessible for manipulation by non-invasive stimulation methods. The TMS is a convenient method to influence cortical processes in the locus of interest. So, the combined use of EEG and TMS gives better possibilities to study the activity of neural networks and the brain functions and to understand the connections between the brain and behaviour as the stimulation of different brain regions evokes different patterns in EEG (Ilmoniemi & Karhu, 2008; Komssi & Kähkönen, 2006; Ridding & Rothwell, 2007; Wagner et al., 2007; Hallett, 2007). In order to study the temporal-causal connections of the active areas with the functional MRI we also need the models of neural networks, where one of the possibilities to map the cortex is provided by the combination of TMS and EEG (Komssi & Kähkönen, 2006).

To state the working hypothesis in **Study IV**, Experiment 1 we also needed to consider specific information related to DLPFC-targeted rTMS effects on deceptive behaviour. On the one hand, it appears that specifically right-hemisphere rTMS targeted at DLPFC influences deceptive behaviour (the joint results of **Study I** and **II**) and thus is expected to have a significant effect on P300. On the other hand, clear disruptive rTMS effects on P300 have been found specifically with left-hemisphere rTMS of DLPFC (Torii et al., 2012). Thus, in order to have a clearer picture of the putative rTMS effects on P300, DLPFC of both hemispheres had to be stimulated. We hypothesised that right but not left DLPFC rTMS will have an effect on the P300 difference between the conditions of neutral and critical stimulus presentation whereas left DLPFC rTMS will change P300 parameters uniformly regardless of the stimulus type.

Therefore, our **Study IV**, specifically Experiment 1 turned to be an exploratory study by nature, where P300 as an ERP signature known to be sensitive to critical stimuli in CIT is measured in the conditions where a CIT like task is combined with brain stimulation. As P300 has been found to be susceptible to rTMS effects in the context of cognitive control (Hansenne et al., 2004; Torii et al., 2012), it was in our interest to test whether P300 is susceptible to rTMS effects in the CIT context as well. We examined whether the extent to which this expressed signature can be manipulated by non-invasive brain stimulation depends on CIT type experimental variables. Our aim was not to validate or cross-validate more or less standardised CIT tasks and methods against EEG and/or brain stimulation procedures, but just to explore whether an ERP signature having been implicated in deception detection research earlier is in principle subject to manipulation in the context similar to CIT where brain responses to critical and neutral stimuli are compared. Our results (**Study IV**, Experiment 1) showed that the P300 response to critical stimuli had higher amplitude if compared with the P300 response to neutral stimuli. However, this effect was suppressed if DLPFC was inhibited with rTMS prior to stimulus presentation. This result supported our assumptions that DLPFC is involved in

CIT type deceptive behaviour, and P300 is a sensitive signature of this. As TMS provided a means to exert a causal effect on the respective brain systems, the arguments in favour of DLPFC and P300 as the factors in CIT type deceptive behaviour were strengthened. If participants lie less about what they see as a result of suppression of the functionality of a cortical locus by rTMS (e.g., as happened with the right DLPFC suppression also in **Study I**), this means that this locus must be instrumental in establishing the cognitive control necessary to produce untruthful responses. When a participant sees a critical stimulus in a concealed information task, a highly meaningful representation of the stimulus is formed in the working memory and the participant has to exert strong control in order to avoid reporting or otherwise indicating that this stimulus is what he/she stole. Consequently, the amplitude of the P300 in response to the critical stimulus must be larger than the P300 amplitude in response to a neutral stimulus. If rTMS subdues this locus – e.g., the right hemisphere DLPFC –, P300 amplitude should also relatively decrease when the participant sees a critical stimulus.

The unexpected result was that we did not find any difference between left- and right-hemisphere stimulation, which did not support our specific TMS-related hypothesis. First, because contralateral homologous brain areas are strongly and reliably influenced by ipsilateral TMS, there may be a carryover effect, so that right and left hemisphere manipulations become equivalent in certain specific conditions. Second, because in our other studies (**Studies I** and **II** looked at in combination) especially the right DLPFC involvement in deception was indicated and a different task compared to the CIT type of task used here was employed, this difference may be a consequence of the different task demands and cognitive processes associated with these tasks. Further studies are needed to understand this discrepancy.

Taken all together the deception studies of this thesis which were based on ERP registration allow to state the following: (i) P300 can be used as the informative and perhaps the main signature of deception, (ii) P300 as the marker of deception can be manipulated by TMS, (iii) realistic scenarios and specific depiction of critical items (photographs) gives better interpretability of the results, (iv) task performance should be sufficiently motivated in order to lead to noticeable effects, (v) a considerable inter-individual variability of the susceptibility to the ERP based CIT should be acknowledged.

CONCLUSIONS

This doctoral thesis is founded on the effects of transcranial magnetic stimulation on deceptive communication and electroencephalography of the signatures of this kind of communication. More broadly speaking, the thesis investigates lying behaviour in its relation to the brain processes. We hypothesised that certain cortex areas exist, for which it is true that when their functionally is manipulated by TMS changes in deceptive behaviour follow and this will also lead to the change in the degree of expression of the EEG signatures of deception. To test the hypotheses, we studied the effects of exhausting and exciting the selected brain areas (left and right DLPFC) by TMS and tested whether there are corresponding effects on the behavioural expression of deception. We also measured the EEG/ERP signal fluctuations in response to the criticality of stimuli in the deceptive behaviour contexts. Our results showed that the frontal cortex plays a crucial role in deceptive behaviour, particularly as related to the propensity to lie, and that the brain-process signatures of lying can in principle be manipulated by non-invasive brain stimulation targeted at the dorsolateral prefrontal areas. It is also apparent that sensitivity of the electrophysiological brain-process signatures of deception to critical stimuli considerably varies between subjects.

Main results of the empirical part of the dissertation consisted of the following:

1) The propensity to lie can be manipulated by non-invasive brain stimulation by TMS targeted at DLPFC. The effects depend on the stimulated hemisphere and type of stimulation. (**Studies I, II,** and **III**)
2) The spontaneous choice to lie more or less in a naming task can be influenced by brain stimulation. 1-Hz offline rTMS can be used for changing participants' situational disposition to lie more or to lie less; right hemisphere DLPFC stimulation in the specific conditions of our setup and design decreased lying while homologous left hemisphere stimulation increased lying. (**Study I**)
3) The way how right DLPFC and other areas functionally associated with it are involved in producing truthful or deliberately deceptive statements about perceived objects considerably depends on what are the parameters of stimulation by which functionality of the system involving DLPFC is manipulated. 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. (**Study II**)
4) In an informed and motivated lying situation the left DLPFC excitation protocol tends to decrease lying contrary to right DLPFC excitation, but the inhibition did not make any significant differences (**Study III**). Based on our studies it seems that the excitation protocol is more systematic compared with the inhibition protocol when manipulation of the propensity to lie is at stake in a more motivated and realistic lying context. It appears that whether

right-hemisphere or left-hemisphere excitatory or inhibitory effects are more or less robust depends on the type of task in conjunction with the duration of stimulation as evidenced by the differences between the results of different studies (**Studies I, II,** and **III**).

5) Pre-CIT inhibitory rTMS could decrease the sensitivity of the participant's brain to the test: rTMS to DLPFC attenuated P300 amplitude in response to the more significant items (**Study IV**, Experiment 1).
6) P300 can be used as the main signature of deception (**Study IV**). P300 exhibits systematic amplitude differences in response to the more as well as, the less significant items compared to neutral items (**Study IV**, Experiment 1). More realistic scenarios and specific depiction of critical items (photographs) help emphasise the enhancement of the P300 component only in response to the more significant items (**Study IV**, Experiment 2).
7) P300 may be quite an unreliable marker of deception on the single participant level – it depends on CIT experiment paradigm and participants' individual differences: only 22% of the participants could be detected reliably using P300 amplitude in Experiment 1 and 71% of the participants in Experiment 2 (**Study IV**).

Based on the results of the present thesis one can conclude that TMS can be used to manipulate the relative level of propensity to deceive and that P300 is a reliable marker of deception in a CIT type of test only in a sub-sample of participants. P300 as a marker of deception if observed in a suitable behavioural test can be manipulated by TMS. However, our present level of knowledge informed by the studies reported here cannot allow to state reliably whether the TMS effects in principle are limited only to a quite modest range of modification of deceptive behaviour – as was the case in our experimental data – and nothing more, or is there a potential for some more robust modification of the willingness and capability to lie.

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SUMMARY IN ESTONIAN

Petukäitumine: transkraniaalse magnetstimulatsiooni efektid ja elektroentsefalograafia signatuurid

Käesolev doktoriväitekiri keskendub ebaausa suhtlemise alusmehhanismide uurimisele. Eesmärgiks on välja selgitada, kas ja kuidas muutub isiku poolt antud tajuhinnangu tõelevastavus, kui mõjutada aju transkraniaalse magnetstimulatsiooniga (TMS) ning millised on aju tööd kajastavad bioelektrilised signatuurid valetamise ja petukäitumise puhul. Eeldati järgmist: (i) on olemas ajukoore piirkonnad, mille funktsioonide häirimine TMS abil muudab petukäitumist ning nende muutuste iseloom sõltub TMS rakendamise kohast ning stimulatsioonirežiimist (**Uurimused I, II ja III**); (ii) aju bioelektrilised vastused kriitilistele stiimulitele erinevad vastustest neutraalsetele stiimulitele (**Uurimus IV, Eksperiment I ja II**); (iii) aju TMS-ga mõjutamine muudab elektroentsefalograafia (EEG) abil registreeritud sündmuspotentsiaalide väljendumise määra (**Uurimus IV, Eksperiment I**).

Kokkuvõtvalt on antud väitekirja peamised tulemused järgmised:

1) Ajustimulatsiooni abil on võimalik manipuleerida inimeste valetamise määra. See, kas inimesed hakkavad TMS-i mõjul vähem või rohkem valetama, sõltub sellest, millist ajupoolkera ja millisel moel (mõjurežiimil) on mõjutatud. (**Uurimused I, II ja III**)
2) Korduvimpulssidega transkraniaalse magnetstimulatsiooni (rTMS-i) nn väsitava ehk pärssiva režiimi mõju (1-Hz sagedusega *offline* režiimis mõjutamine) rakendamisega on võimalik esile kutsuda muutust inimeste petukäitumises. Olukorras, kus katseisikutel oli vabalt valida, millal ja kui palju nad tõeselt või mittetõeselt nimetavad nähtud objekte, kutsus parema poolkera dorsolateraalse prefrontaalse ajukoore funktsionaalse seisundi pärssimine esile valetamise suhtelise vähenemise, samas kui vasaku poolkera vastava piirkonna mõjutamine suurendas valetamist. (**Uurimus I**)
3) rTMS-i ergastava mõju (10-Hz sagedusega *offline* režiimis mõjutamine) rakendamisel on võimalik osaliselt esile kutsuda väsitavale mõjule vastupidist käitumist. Eelmainitud katseülesande täitmisel kutsus ergastavate impulsside suunamine parempoolse ajukoore dorsolateraalsesse prefrontaalsesse piirkonda esile valetamise suurenemise, samas kui analoogiline vasaku poolkera stimulatsioon mõju ei avaldanud. (**Uurimus II**)
4) Suurem teadlikkus koos suurema motiveeritusega valetada võib oluliselt mõjutada eksperimendi tulemust. Olukorras, kus katseisikud olid teadlikud sellest, et peavad valetama ja mil nad ka olid motiveeritud valetama, kaldus vasaku poolkera dorsolateraalse prefrontaalse koore ergastav stimuleerimine valetamist vähendama ning parema poolekra ergastamine valetamist suurendama. Samas pärssiv mõjutamine ei kutsunud esile ühtegi olulist poolkeradevahelist erinevust petukäitumises (**Uurimus III**).

5) rTMS'i ergastav režiim on oma mõjult süstemaatilisem võrreldes pidurdava režiimiga. See, kas ja kuidas erinevate poolkerade mõjutamisel erinevate režiimide (ergastav ja pärssiv) mõju käitumises avaldub, sõltub ülesande tüübist, stimulatsiooni kestusest ning stimulatsiooni tugevusest (**Uurimused I, II ja III).** Valetamise puhul rTMS'i pärssiva režiimi rakendamisel aset leidev teadliku kontrolli tasalülitamine võib vajada oluliselt pikemat ja tugevamat mõjutamist (**Uurimus III**) võrreldes instrueerimata ja spontaanselt toimuva valetamisega (**Uurimus I**).
6) P300 registreerimine ja analüüs on rakendatavad petukäitumise tuvastamisel. Sealjuures tuleb silmas pidada, et see võimalus pole universaalne erinevate katseplaanide ja kõikide katseisikute puhul (**Uurimus IV**). P300 väljendumismäär erineb süstemaatiliselt vastustes kriitilistele ja neutraalsetele stiimulitele (**Uurimus IV**, Eksperiment 1 ja 2). Reaalsemad (elulähedasemad) eksperimendid ja spetsiifilisemad stiimulid (fotod sõnade asemel) aitavad esile kutsuda selgemat ja suurema amplituudiga P300 komponenti vastusena kriitilisele (olulisele) stiimulile (**Uurimus IV**, Eksperiment ja 2).
7) Niinimetatud süülise teadmise eksperimendis avaldab rTMS mõju EEG sündmuspotentsiaalide kui kriitilise stiimuli äratundmise suhtes tundlike signatuuride väljendumisele. Dorsolateraalsesse prefrontaalsesse koorde suunatud pärssiva rTMS'i mõjul vähenes kriitilise stiimuli esitamisele vastusena saadud potentsiaalikomponendi P300 amplituud. (**Uurimus IV**, Eksperiment 1).
8) P300 on üsna ebausaldusväärne valetamise tuvastamisel kasutatav marker, kui silmas pidada vastava protseduuri läbiviimist suvaliselt valitud üksikindiviidiga. Mõne isiku puhul on meetodi tundlikkus suur, mõne teise puhul aga mitte. Selle meetodi (testi) usaldusväärsus sõltub nii eksperimendi ülesehitusest kui ka uuringualuste isikute individuaalsetest erinevustest. Elukaugema ja vähema kriitilisusega stiimuleid kasutava eksperimendiplaani puhul oli käesoleva töö andmetel võimalik kõrgel usaldusväärsuse tasemel korrektselt tuvastada vaid 22% petukäitumisest (**Uurimus IV**, Eksperiment 1). Samas aga elulähedasema eksperimendiplaani puhul oli vastav määr 71%. (**Uurimus IV**, Eksperiment 2).

Käesoleva väitekirja tulemuste põhjal võib öelda, et TMS on kasutatav tõepäraste tajul põhinevate hinnangute suhtelise määra mõjutajana petukäitumisel, ning et P300 on usaldatav marker valetamise tuvastamisel varjatava „süülise" teadmise katsetes. Samuti on lavastatud varguse eksperimendis nn süülise teadmise testi kasutamisel võimalik P300 amplituudi väljendumismäära TMS'iga mõjutada. See annab kinnitust tõdemusele, et P300 on muuhulgas ka valetamisele tundlik EEG sündmuspotentsiaalide signatuur. Küll aga vajavad praegused teadmised olulist lisa selle osas, millised võiksid olla need objektiivselt ajukuva abil registreeritud ajuprotsesside signatuurid, mis kehtiksid enamusel juhtudel ja olukordades. See võimaldaks suurema kindlusega teha oletusi ja anda selgitusi valetamise kontekstis ajus toimuvate protsesside kohta.

PUBLICATIONS

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Sekkumiste tulemuslikkuse hindamine: motiveeriv intervjueerimine ja viha juhtimine

Kuritegevuse ja retsidiivsusega seonduvate tegurite väljaselgitamine ja mudeldamine Eesti korrektsioonisüsteemis

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