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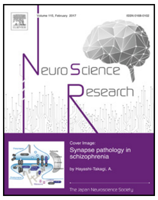

Electric stimulation of the right temporo-parietal junction induces a task-specific effect in deceptive behaviors

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ABSTRACT

How the brain generates a lie is an important and unsolved issue in neuroscience. Previous studies indicated that mentalizing, the ability to understand and manipulate the mental states of others, plays a critical role in successful deception. Accordingly, recent neuroimaging studies reported deception-related activity in the right temporo-parietal junction (rTPJ), a brain region closely related to the mentalizing ability. Detailed functions of rTPJ in deception, however, remain unclear. In the present study, we investigated a causal relationship between rTPJ and deception using transcranial direct-current stimulation (tDCS). Subjects received anodal tDCS to their rTPJ or V1 (control) and then performed three tasks in which they aimed to deceive another participant to get monetary rewards. In one of the three tasks, we found a significant decrease in a rate of successful deception when rTPJ was stimulated, indicating that neural enhancement of rTPJ caused poorer (not better) deceptive performances. Our results suggest that, in some tasks involving selfish (money-motivated) lying, neural processing in rTPJ does *not* contribute to successful deception through the metalizing ability. Rather, it would be related to the self-monitoring of morally-unacceptable behaviors (lying). The neural enhancement of rTPJ therefore increased the psychological resistance to lying, resulting in poorer deceptive performances.

1. Introduction

Deception is generally defined as a psychological process in which one person deliberately intends to mislead another, typically, by distorting truthful information. Because of its importance in legal, moral, and clinical domains (Blandon-Gitlin et al., 2014; Ekman and Osullivan, 1991; Ford et al., 1988; Vrij et al., 2010; Walczyk et al., 2003), the neural processing underlying deceptive behaviors and lying have been extensively investigated (Garrett et al., 2016; Greene and Paxton, 2009; Kireev et al., 2013; Kozel et al., 2005; Langleben et al., 2002; Nunez et al., 2005; Phan et al., 2005; Spence et al., 2004; Sun et al., 2015; Yin et al., 2016). Those studies consistently indicated a close relationship of deception with the prefrontal cortex in the human brain (Abe, 2011; Christ et al., 2009). For example, previous researches using the functional magnetic resonance imaging (fMRI) reported stronger activity in the prefrontal cortex when participants responded falsely to verbal questions (e.g. "where were you born?") than when they answered truthfully (Ganis et al., 2003; Lee et al., 2002). Causal approaches using transcranial magnetic stimulation (TMS) and transcranial direct-current stimulation (tDCS) provided further evidence for an involvement of the prefrontal cortex in deception (Fecteau et al., 2012; Karim et al., 2010; Karton et al., 2014; Mameli et al., 2010; Priori et al., 2008).

Although those studies showed a pivotal role of the prefrontal cortex, deception is a complex cognitive activity and can be classified into many subtypes. Some of them are selfish and anti-social (e.g. financial fraud), while others not (e.g. white lies in social situations). This diversity of deception suggests that different types of lies can arise from different sets of neural systems, therefore implying deception-related brain regions other than the prefrontal cortex. Recent studies indicate that one of such regions lies in the temporo-parietal junction (Abe et al., 2014; Harada et al., 2009; Hayashi et al., 2014; Sowden et al., 2015). In Abe et al. (2014), subjects read scenarios of events that can happen in real-life situations (e.g. You broke a door lock of the restroom in a department by mistake. A cleaning crew asks you if you know something about the broken lock.) and decided whether to tell a lie or not. They found stronger activation in the right temporo-parietal junction (rTPJ) when the subjects made dishonest decisions (anti-social lying) compared with honest ones.

What was a functional role of rTPJ in deception? At least two interpretations are possible. First possibility was that neural activation in this area played a critical role in deception. It is known that TPJ is related to mentalizing (Saxe and Kanwisher, 2003; Vollm et al., 2006), the ability to understand and manipulate the mental

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states of others, especially their intentions and beliefs (Frith and Frith, 2006). Since deception is a cognitively-demanding process (Blandon-Gitlin et al., 2014; Vrij et al., 2008), it requires a variety of high-level functions such as decision making, response monitoring, and mentalizing (Sip et al., 2008; Spence et al., 2004). The deception-related activity in rTPJ (Abe et al., 2014) thus might reflect the process of mentalizing that would be necessary for successful lying in the real world. Another interpretation of the rTPJ activity, however, was that this region was engaged in detection and evaluation of deception. Previous researches showed an involvement of TPJ not only in deception but also in moral judgments (Harada et al., 2009; Hayashi et al., 2014; Parkinson et al., 2011; Sellaro et al., 2015; Young et al., 2010). Hayashi et al. (2014) reported stronger hemodynamic responses in TPJ when subjects read scenarios describing protagonist's anti-social lying than pro-social lying, indicating that TPJ played an important role in monitoring violations of social norms. The significant activity in TPJ when subjects decided to tell a lie (Abe et al., 2014) thus might reflect detection or evaluation of morally-unacceptable behavior produced by themselves.

In the present study, we used tDCS to examine those two possibilities. Anodal tDCS was applied to rTPJ just before subjects (actors) performed deceptive behaviors in social (inter-personal) situations. Those behaviors were videotaped and then presented to another groups of subjects (observers) who judged veracity (truthful/deceptive) of those behaviors. If rTPJ plays a critical role in successful deception, the anodal stimulation would facilitate neural processing in rTPJ, which enables better (more believable and convincing) deceptive performances by actors. This would raise a difficulty of the veracity judgment task by observers, resulting in reduced accuracy of that task. In contrast, if rTPJ is related to moral judgments (lie detection), the anodal tDCS would not improve deceptive performances but would enhance sensitivity of this region to immoral behaviors (lying). This might increase a psychological resistance of subjects to telling a lie, resulting in poorer performances of deception. Our causal approach using tDCS thus would reveal a detailed relationship between rTPJ and deception that has been difficult to be elucidated by neuroimaging methods.

2. Materials and methods

2.1. Subjects

Forty-one subjects participated in the present study (6 as actors and 35 as observers). No statistical method was used to predetermine a sample size. They were undergraduate students (age: 18–22) in Kobe University, Japan. Four additional naïve volunteers (undergraduate students majoring psychology) participated in a tDCS experiment to judge the veracity of the actors' behaviors (inspectors, see below). All had normal or corrected-to-normal vision. Informed consent was received from each subject after the nature of the study had been explained. All experiments were carried out in accordance with guidelines and regulations approved by the ethics committee of Kobe University.

2.2. Basic procedures of a tDCS experiment

Six subjects (3 females) participated in a tDCS experiment as actors. All subjects were healthy and had no contraindication to tDCS. Each subject visited a laboratory on separate two days, approximately a week apart. Three subjects underwent anodal tDCS of rTPJ on the first day, while their mid-occipital region (MO) was stimulated on the second day. An order of the rTPJ and MO sessions was reversed in the remaining three subjects. The MO, corresponding to the primary visual cortex (V1), has been used as a control region in previous tDCS studies on rTPJ (Santiesteban et al., 2015; Sowden et al., 2015). The tDCS was delivered with two saline-soaked surface electrodes (size: $5 \times 7\,\text{cm}^2$) connected to a constant-current stimulator (DC-STIMULATOR Plus, neuroConn GmbH, Germany). In the rTPJ session, an anodal electrode was placed over central parietal 6 (CP6), according to the international EEG 10/20 system (Santiesteban et al., 2012; Sellaro et al., 2015; Sowden et al., 2015; Ye et al., 2015). A cathodal electrode was positioned over the vertex (Cz) of each participant as a reference. In the MO session, anodal and cathodal electrodes were placed over Oz and Cz, respectively. We delivered a weak electrical current of 1 mA for 20 min, which was followed by behavioral tasks involving deception (see below). An effect of this offline (preceding the task) stimulation was reported to be more robust than online stimulation (Pirulli et al., 2013; Santiesteban et al., 2015; Sowden et al., 2015), lasting for 90 min beyond an offset of the stimulation period (Nitsche and Paulus, 2001).

Subjects performed three behavioral tasks after tDCS; Shock, Beverage, and Opinion. The Shock and Beverage tasks had two conditions (Expression and Suppression conditions). An order of the three tasks was counter-balanced across sessions (rTPJ/MO) and subjects. As shown in Fig. 1A, each subject performed those tasks with two persons; an experimenter (second author, R.O.) and an inspector (undergraduate student majoring psychology at Kobe University). We will describe details of the three tasks in the following sections.

2.3. Shock task

In the Shock task, the experimenter delivered an electric shock to the subject through stimulating electrodes attached to right index and middle fingers (Fig. 1B). Each shock was given for 200 ms with a frequency of 50 pulses per second (50 Hz). An intensity of the shock was adjusted (before experiment) by the subject to a level that he/she reported was uncomfortable but not painful. In the Expression condition of Shock task (two trials, upper row in Fig. 1C), the subject was instructed to behave as if he/she received a shock. In one trial, the experimenter gave a shock (real shock) to the subject by pressing a button on a stimulator (SEN-5201, Nihon Kohden, Japan), and the subject honestly reacted to the shock (truthful trial). In the other trial, however, the experimenter turned off the stimulator (unknown to the subject and inspector) and then pressed a button (sham shock). The subject pretended to receive a shock in response to a click sound of the button, producing deceptive behaviors (deceptive trial). An order of the real-shock and sham-shock trials was randomly determined by the experimenter. The inspector, sitting in front of the subject, observed the subject's behaviors in the two trials and indicated a trial in which the subject behaved deceptively (1st or 2nd). If the inspector answered incorrectly, the subjects obtained an extra reward of 100 yen (about 0.88 dollar). This reward for successful deception was to motivate the subject, prompting his/her convincing performances to deceive the inspector. In the Suppression condition of Shock task (two trials, lower row in Fig. 1C), basic procedures were the same as the Expression condition, except for an instruction to the subject. We asked the subject to behave as if he/she received *no* shock. The subject inhibited their reactions to a real shock (deceptive trial) while he/she behaved honestly to a sham shock (truthful trial). The inspector answered a trial in which he thought the subject behaved deceptively (pretending *not* to be stimulated).

2.4. Beverage task

Structures of the Beverage task were similar to the Shock task. Subjects drank a shot glass of apple-cider vinegar (Ringo-Su, Aichi, Japan) diluted with apple juice, instead of receiving an electric