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Characteristics of alpha power event-related desynchronization in the discrimination of spontaneous deceptive responses

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ABSTRACT

Event-related desynchronization (ERD) occurs in the alpha frequency band when individuals are mentally active, and reflects increasing task demands. Lying involves a relatively greater cognitive load, and should be indicated by an increase of alpha power ERD. This study aimed to examine whether ERD discriminates deceptive responses from truthful responses. In the deception task, subjects made their own decision or were instructed either to type the presented numbers on the dice or input different numbers. Based on a subject's response and rule of the task, the type of response was determined. There were four types of responses: spontaneous deceptive, spontaneous truth, instructed deceptive, instructed truth. The findings of this study suggest that spontaneous deceptions produced significantly greater ERD than spontaneous truths, whereas ERD did not distinguish instructed deception from instructed truth. Different patterns between spontaneous and instructed deceptions may be due to different levels of cognitive load. Spontaneous lies require a greater cognitive load than other types of deceptions. The results of this study suggest that ERD has the potential to detect spontaneous deceptive responses. That is, ERD can detect deceptions that require cognitive effort in natural situations.

1. Introduction

Social and economic harm is the consequence of deception, which is highly prevalent in modern society. Although the exact amount of damage caused by deception is difficult to determine, the costs of applicant dishonesty and employee misconduct have been estimated to range between six and two hundred billion dollars per year in the United States alone (Berry, 2002). Not only does deception result in financial loss, but in social disapproval as well. For example, committing perjury in court may lead to the misuse of investigatory resources, or the innocent may be labeled as criminals while the criminals go free. Thus, detecting deception is an important issue in society, as deception is a potential harm to oneself and others.

Currently, the polygraph test is the most common method of deception detection. However, the validity of this type of test remains controversial as it relies on measures of autonomic system responses (Saxe et al., 1985). In particular, the autonomic measures (e.g., skin conductance, respiration) do not necessarily reflect the corresponding psychological and cognitive processes involved in deception (Happer, 2005). Researchers have begun to seek alternative measurement tools and methods that represent the biophysical processes underlying decision making due to the lack of a clear causal link between a psychological decision to deceive and the autonomic measures.

A number of neurophysiologic signals have been studied for their possible application to deception detection. These studies hypothesized that monitoring the brain function directly, rather than monitoring peripheral responses, may improve the understanding and measurement component of a lie-detection system (Farwell and Donchin, 1991; Rosenfeld et al., 1995). They include the event-related potentials (ERP) (Farwell and Donchin, 1991; Rosenfeld et al., 2004) and Functional Magnetic Resonance Imaging (fMRI) (Langleben et al., 2005; Kozel et al., 2005; Nuñez et al., 2005; Spence et al., 2004).

An attempt to distinguish the cognitive subcomponents involved in the act of telling lies has also become an interesting topic in cognitive neuroscience (Abe et al., 2008). Deceptive behavior is known to be involved in various aspects of cognitive activations, such as conflict control, response inhibition, and higher levels of cognitive control (Nuñez et al., 2005). Liars have to inhibit the truth and construct the contents of their lies. The present study focused on the cognitive features of deception as they relate to changes in brain activity during deception. The act of lying has been associated with certain cognitive features. Specifically, when individuals lie, they expect to be seen as if they are telling the truth, which leads these individuals to make more of an effort to seem credible (DePaulo et al., 1991). Zuckerman et al. (1981) have suggested factors that could help to find deception: generalized arousal, the specific

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aspects for deception, and attempts to control behavior in order to maintain the deception.

The activation-decision construction model explains how people make the deception (Walczyk et al., 2003). Liars' cognitive processes control their behavior by using the following method: the truth is transferred to working memory that points to an orchard of semantic and episodic nodes for lie construction (Malone et al., 1997). Further, decisions require a decision-making process and inhibition of details related to truth information. Finally the construction of deception needs attention. Zuckerman's (1981) four-factor model – the activation-decision construction model (Walczyk et al., 2005) – has conceptualized lying as a cognitively complex task. Based on these concepts, the present study attempted to target specific elements of deceptive behaviors, including conflict resolution, response inhibition, and higher level cognitive control using a game involving financial risks and rewards.

We created an experimental task “Jack's beanstalk” to induce lying which requires cognitive effort. We believed that our task is associated with cognitive load for the following reasons. With the goal of the task in mind, participants have to decide which number from a simulated dice roll to enter into a computer. If they decide on a deceptive response, they have to inhibit their responses in order not to enter the presented number. They also have to attend to controlling their facial expressions or gestures in order to prevent another participant detecting their deception. These processes require cognitive effort. The task was also designed to increase the feeling of being immersed in the task and to provoke the natural desire for deception. This design also included an interpersonal factor to account for the fact that many forms of deceptions occur during interpersonal communication.

It is assumed that deceptive and truthful responses would show different patterns of cortical activation due to different levels of cognitive demands associated with lying and telling the truth. To examine these differences, cortical activity was assessed using event-related desynchronization (ERD) in the alpha frequency band. Desynchronization of the alpha band occurs by activation of the cortex and alpha synchronization (ERS) indicates alpha activity increase (Pfurtscheller and Aranibar, 1977; Pfurtscheller, 1989). ERD and ERS occur when alpha desynchronization or synchronization is associated with a paced event (Pfurtscheller, 1992), respectively. The alpha power displays a pattern of desynchronization when individuals are engaged in mental activity (Fink, 2005). ERD patterns are influenced by the level of complexity or difficulty associated with information processing (Krause et al., 2000; Fink et al., 2005). An increase in task complexity or attention has been reported to lead to a decrease in alpha power (Klimesch, 1999; Stipacek et al., 2003; Grabner et al., 2004).

One goal of this study was to examine whether ERD discriminated deceptive responses from truthful responses. Lying requires relatively more cognitive complexity than telling the truth, and we proposed that this phenomenon would be reflected in the alpha power ERD. A second goal was to explore the differences in various types of deceptions. Cognitive activity experienced during deceptive behavior can be different based on the type of deceptive responses. Therefore, the design of our study differentiated between spontaneous deceptions or truth and those for which participants were instructed to respond. While it has been demonstrated that instructed responding requires an individual to simply retrieve information from memory (Ganis et al., 2003), a spontaneous response requires a more complex decision-making process than does an instructed response, as well as executive functioning to select a response from various alternatives (Stipacek et al., 2003). Additionally, to compare the ERD values between time periods, we divided the time course into two: Activation 1 period (between stimulus onset and response) and Activation 2 period (between response and feedback onset). The two intervals may reflect different processes in this paradigm. People have to make a decision (whether they respond falsely or truthfully) and select a response in the Activation 1 interval, while the Activation 2 interval is associated with an attempt to avoid a judge's lie detection.

2. Method

2.1. Participants

Twenty-seven male undergraduates participated in this study. They were recruited from announcements posted on a university internet bulletin board. The bulletin board announcement stated that participants were being recruited for a psychology experiment to measure brain waves while playing a game, and they would be paid \$10 for their participation. On arrival at the psychology laboratory, all participants read and signed a written consent form. Due to extensive EEG artifacts, one participant had to be excluded from further analyses. The remaining sample consisted of 26 participants whose age ranged from 20 to 27 years ($M = 24.32$, $SD = 2.11$).

2.2. Experimental task

Participants performed the “Jack's beanstalk” task, a computer program we developed where a dice roll is displayed on a computer monitor, and the game's character climbs a number of steps based on the rolled dice. Based on a subject's response and rules of the task, the type of response was determined. There were four types of responses: spontaneous deceptive, spontaneous truth, instructed deceptive, instructed truth.

Subjects had to decide whether to enter the actual rolled number (truth response) or a different number (deceptive response) by typing the corresponding number on a keyboard. There were five numbers and one letter on the dice: 0, 1, 2, 3, 4, and X.

Based on the presented number, spontaneous–instructed responses were determined. When the numbers “0,” “4,” or “X” were presented, the responses were fixed (instructed response). The instructed truth response occurred when a “0” or a “4” was rolled on the dice at which point participants were instructed to type in the presented number. The instructed deceptive response was when an “X” was rolled on the dice and participants were instructed to enter any number they desired between 1 and 4. When number “1,” “2,” or “3” was presented (spontaneous response), on the other hand, participants could choose their response — whether to enter an actual number or another number. If participants entered the presented number, it was a spontaneous truth response. If not, the response was a spontaneous deceptive response.

There were thirty occurrences of number 1, ten of number 3, and twenty each of number 0, 2, 4 and X. Each participant was provided with a randomized sequence of dice roll values. Thus, there were 60 trials each for the spontaneous and instructed responses. At the end of all trials, subjects who had responded as the numbers were presented could move up 180 of the 200 stairs when all responses had passed. Thus, they would not be able to achieve the goal of the task. In order to reach the top of the steps, subjects needed to make as many spontaneous deceptive responses as possible.

Each trial started with a fixation cross. This was followed by an image of a rolling dice presented for 1 s, and the presentation of dice roll result followed for 5 s. Then a rectangle was presented under the stimulus. The participant had to enter the presented number or a deceptive number within 5 s in the rectangle. A sign stating “pass” or “doubt” was presented on the monitor for the participant as the observer's judgment. This sign stating “pass” or “doubt” was suggested randomly, 60 times for each (so frequency of detection was 50% of the trials). Following another two-second delay, visual feedback was displayed on the monitor regarding the amount of money remaining and the stair that they had reached (Fig. 1). Each trial lasted up to 20 s, with 120 trials in total.

The goal of the task was to climb up 200 stairs. If they reached 200 stairs, they would receive the participant's fee and extra money, and if not, subjects received only the participant's fee. Based on their responses, they could go up the stairs; however, if the “doubt” was