Brain and Cognition 90 (2014) 142–150

Contents lists available at ScienceDirect

Brain and Cognition

journal homepage: www.elsevier.com/locate/b&c

Detecting concealed information using feedback related event-related brain potentials

Liyang Sai [a,b,1], Xiaohong Lin [a,d,1], Xiaoqing Hu [c,*], Genyue Fu [a,*]

[a] Department of Psychology, Zhejiang Normal University, Jinhua, China
[b] School of Psychology & Cognitive Science, East China Normal University, Shanghai, China
[c] Department of Psychology, Northwestern University, Evanston, USA
[d] Bioimaging Core, Faculty of Health Sciences, University of Macau, Taipa, Macau, Macau SAR, China

ARTICLE INFO

Article history:
Accepted 20 June 2014
Available online 21 July 2014

Keywords:
Conceal information test
Feedback processing
Deception detection
Event-related potentials

ABSTRACT

Employing an event-related potential (ERP)-based concealed information test (CIT), the present study investigated (1) the neurocognitive processes when people received feedbacks regarding their deceptive/truthful responses and (2) whether such feedback-related ERP activities can be used to detect concealed information above and beyond the recognition-related P300. During the CIT, participants were presented with rare, meaningful probes (their own names) embedded within a series of frequent yet meaningless irrelevants (others' names). Participants were instructed to deny their recognition of the probes. Critically, following participants' responses, they were provided with feedbacks regarding whether they succeeded or failed in the CIT. Replicating previous ERP-based CITs, we found a larger P300 elicited by probe compared to irrelevant. Regarding feedback-related ERPs, a temporospatial Principle Component Analyses found two ERP components that were not only sensitive to feedback manipulations but also can discriminate probe from irrelevant: an earlier, central-distributed positivity that was elicited by "success" feedbacks peaked around 219 ms; and a later, right central-distributed positivity that was also elicited by "success" feedbacks, peaked around 400 ms. Importantly, the feedback ERPs were not correlated with P300 that was elicited by probe/irrelevant, suggesting that these two ERPs reflect independent processes underlying memory concealment. These findings illustrate the feasibility and promise of using feedback-related ERPs to detect concealed memory and thus deception.

1. Introduction

Researchers have devoted great efforts to the development of event-related potential (ERP)-based concealed information tests (CITs). A majority of these studies focused on the P300, a large, positive deflection of brainwaves that occurs between 300 and 800 ms after stimulus onset. P300 is sensitive to a range of factors such as subjective probability, task-relevance and available cognitive resources (Donchin & Coles, 1988; Johnson, 1988). These characteristics of P300 have been employed in P300-based CITs that aim to identify whether the examinee recognizes the concealed information or not, regardless of his or her verbal report (Rosenfeld, 2011; Rosenfeld, Hu, Labkovsky, Meixner, & Winograd, 2013). Specifically, examiners compare the P300s elicited by two types of information in the CIT: a rarely presented, crime-related information item (e.g. the weapon used in a murder, also referred to as a "probe" item) and a series of crime-irrelevant alternatives (e.g. other weapons that were not used in the murder, also referred to as irrelevant items). If the probe is associated with significantly larger P300 than the irrelevant, then a recognition diagnosis is made. If, however, no systematic difference is found between the probe and irrelevants, then a non-recognition diagnosis is made. Indeed, it has been found that considerable P300s can be elicited by a range of stimuli, including incidentally acquired crime-related information as well as well-rehearsed personal information (e.g. one's hometown or first name probe items) (Hu, Hegeman, Landry, & Rosenfeld, 2012; Hu, Pornpattananangkul, & Rosenfeld, 2013; Rosenfeld et al., 2008). The fundamental mechanism underlying P300-based CITs is detection of the memory status of the information of interest (i.e. old vs. new; recognized vs. not recognized).

* Corresponding authors. Address: Department of Psychology, Northwestern University, 2029 Sheridan Rd., Evanston, IL 60208, USA (X. Hu). Address: Department of Psychology, Zhejiang Normal University, Yingbin Rd., Jinhua 321004, China (G. Fu).

E-mail addresses: xhu@u.northwestern.edu (X. Hu), fugy@zjnu.cn (G. Fu).

[1] These authors contributed equally to this work

http://dx.doi.org/10.1016/j.bandc.2014.06.012
0278-2626/

In addition to the memory mechanism underlying the P300-based CIT, the influence of intentional concealment on ERPs (e.g. P300) in a CIT has also been investigated. The central aim of these studies is two-fold: (1) from a theoretical view, to explore whether the concealment intention or deceptive response involve mechanisms that are independent of the memory/recognition account underlying CIT; and (2) from an applied view, to determine whether an intention to conceal information and deceptive responses can influence the detection efficiency of ERP-based CIT (Kubo & Nittono, 2009; Rosenfeld, Hu, & Pederson, 2012; Verschuere, Rosenfeld, Winograd, Labkovsky, & Wiersema, 2009). For instance, in Verschuere et al. (2009) and Rosenfeld et al. (2012), researchers examined two groups: a deception group and a control group. Participants in the deceptive group were instructed to conceal probe items while participants in the control group were told to perform a target/no target discrimination task: thus in this group, no deception or concealment was mentioned (Rosenfeld et al.,2012; Verschuere et al., 2009). However, results are inconsistent across studies: whereas Verschuere et al. (2009) and Rosenfeld et al. (2012) found that deception did improve individual detection efficiency of the CIT, results from other studies suggest that an intention to conceal does not modulate the P300s in the CIT (Kubo & Nittono, 2009). Recently, Rosenfeld et al. (2012) added a novel manipulation to investigate the role of deception in the P300-based CIT. Specifically, in addition to the instruction that explicitly required participants to respond deceptively to probe items, the study also included periodic feedbacks to maintain participants' awareness that they were giving deceptive responses to probes. Results showed that when deceptive participants received periodic feedback regarding their deception, they showed larger P300 amplitudes than participants in the control group who had no intention to conceal the information (see also, Hu et al., 2013). Because a previous study that manipulated only instruction failed to find enhanced P300s among the deceptive participants, the enlarged P300 responses observed in Rosenfeld et al. (2012) was ascribed specifically to the use of periodic feedback that reminded participants of their deceptive responses. This feedback manipulation was recently applied in the complex trial protocol (Rosenfeld et al., 2008) and replicated the effect that such feedback can enhance the detection efficiency based on P300 (Hu et al., 2013). Moreover, receiving feedback regarding information concealment elicited higher frontal–central negativities between 200 and 400 ms, suggesting the involvement of performance monitoring processes during information concealment or deception (Gamer & Berti, 2010; Hu et al., 2013). Thus, from an applied view, it seems that an intention to conceal, especially when feedbacks are used to emphasize one's deceptive responses throughout the test, can improve the detection efficiency of ERP-based CIT (Hu et al., 2013; Matsuda et al., 2013; Rosenfeld et al., 2012). However, the neurocognitive processes associated with feedback processing among those who intentionally conceal information are still unclear, and it remains to be explored that whether ERP activities during feedback can discriminate probe information from irrelevant information. These will be the major questions we aim to explore in the present study.

Here, we aim to examine ERPs that are directly elicited by feedbacks during a CIT to investigate the neurocognitive processes underlying feedback processing. Previous studies in feedback processing consistently find a negative deflection of ERPs between the 200 and 300 ms time window that is sensitive to negative feedbacks in comparison with positive feedbacks, which is termed the Feedback-negativity (FN, also known as feedback-related negativity FRN, or feedback error-related negativity fERN (e.g. Holroyd, Larsen, & Cohen, 2004). Such negative feedbacks are usually contingent upon participants' performance or choices, such as incorrect motor responses (Miltner, Braun, & Coles, 1997), monetary loss (Gehring & Willoughby, 2002) and unexpected outcomes (Ferdinand, Mecklinger, Kray, & Gehring, 2012; Holroyd, Nieuwenhuis, Yeung, & Cohen, 2003). The amplitude of the FN is suggested to reflect the difference between actual and expected outcomes (Holroyd & Coles, 2002; Nieuwenhuis, Holroyd, Mol, & Coles, 2004), or participants' evaluation of the motivational impact of ongoing events (Gehring & Willoughby, 2002; Yeung, Holroyd, & Cohen, 2005).

Here we adapted to a CIT that gave feedbacks following each test item (e.g. probe and irrelevant). As in previous CIT studies, participants were presented with a rare probe item and a series of irrelevant items. Moreover, they were instructed to deny the knowledge of probe items via button pressing (e.g. Rosenfeld et al., 2012; Verschuere et al., 2009). Critically, after participants made a button press to the CIT stimulus, we provided them with feedbacks regarding whether they had successfully deceived the brainwave-based lie detector. Here, the feedbacks were given randomly and were not contingent upon their behavior. Because of the great motivational significance of probe to participants, e.g. they need to try to conceal the probe and avoid being detected; we predicted that feedbacks following probes would elicit larger feedback-related potentials than irrelevant (Luo, Sun, Mai, Gu, & Zhang, 2011; Yeung et al., 2005).

To fully explore the feedback-related ERPs, we used a temporo-spatial Principle Component Analysis (PCA) to quantify the feedback-related ERPs. As a data-driven approach, PCA has been widely used in ERP research to decompose raw ERPs components along temporal and spatial domain (Donchin & Heffley, 1979; Spencer, Dien, & Donchin, 2001). An advantage of PCA is that it allows researchers to separate ERPs activities that may overlap with each other in time/space. In particular, PCA has been used to quantify feedback-related ERPs in monetary feedback processing (Foti, Weinberg, Dien, & Hajcak, 2011), as well as memory-related ERPs in the P300-based CITs (Lui & Rosenfeld, 2009). Because the present study aims to explore the feedback processing during information concealment, the PCA will be particularly useful to isolate ERP-of-interest that is sensitive to our independent variables: feedback valence and stimulus type.

Finally, we predict that as the feedback-related ERPs reflect participants' motivational process to evaluate whether their behavior/responses is success or not, this ERP pattern should be independent of the P300 that mainly reflects memory processes such as item recognition. Such independence information would be valuable from an applied perspective, as this suggests that the feedback-related ERPs can identify concealed information above and beyond the P300.

2. Methods

2.1. Participants

Twenty participants were recruited (all males, M_{age} = 21.6 years, SD = 2.7 years), three of which were excluded from ERP analyses due to excessive artifacts. All participants had normal or corrected to normal vision, and were right-handed. None had a history of any neurological or psychiatric disorders. The study was approved by ethics committee of Zhejiang Normal University.

2.2. Procedures

Upon entering the laboratory, each participant signed an informed consent form. For all participants, the target was a Chinese celebrity's name "Liu Dehua," and the probe was their own name. Four irrelevants were selected from a list of ordinary Chinese names. Before experiment, a questionnaire was conducted