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# A concealment-specific frontal negative slow wave is generated from the right prefrontal cortex in the Concealed Information Test

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ABSTRACT

Recent studies have shown that a memorized item in the Concealed Information Test elicits a frontal negative slow wave (500–1000 ms) of the event-related potential, the cortical source of which involves the right prefrontal cortex. To examine whether this negative slow wave reflects a process that is specific to concealment rather than a more general cognitive control process, we compared the event-related potentials of 24 participants in four conditions involving the presence or absence of memory and the intention to conceal. Results showed that right prefrontal activation during the frontal negative slow wave (estimated by Standardized Low Resolution Brain Electromagnetic Tomography) was only observed when participants attempted to conceal the memorized item, but not when they were motivated to reveal it or had no intention to conceal. These findings suggest that the right prefrontal cortex is involved in a concealment-specific process in the Concealed Information Test.

## 1. Introduction

The Concealed Information Test (CIT) (Lykken, 1959; Verschuere, Ben-Shakhar, & Meijer, 2011) has been used in criminal investigations to examine whether a suspect knows crime-relevant information that only people involved in the crime should know (Matsuda, Nittono, & Allen, 2012; Osugi, 2011). In the CIT, an examiner presents a crime-relevant item and several crime-irrelevant items. While ignorant people naturally cannot distinguish the relevant and irrelevant items from each other, those with involvement in the crime will try to pretend that they do not recognize the relevant items. However, an examiner can infer that the suspect recognizes the crime-relevant items if physiological responses differ between the crime-relevant and irrelevant items.

Autonomic responses have been traditionally measured in the CIT. When a participant recognizes a relevant item, this typically elicits an increase in skin conductance, reduction in heart rate, and suppression of respiration when compared with irrelevant items (Gamer, 2011a; Matsuda & Nittono, 2018). These autonomic responses are thought to reflect orienting responses elicited by the rareness and significance of the relevant item (Gamer, 2011a).

CIT studies have also measured event-related potentials (ERPs). ERPs in response to the relevant item exhibit a larger P3 (also known as P300) component than that elicited by the irrelevant items (Rosenfeld, 2011; Rosenfeld, Hu, Labkovsky, Meixner, & Winograd, 2013). The P3 has a parietal-dominant scalp topography and a positive peak at approximately 400–500 ms after stimulus onset. The P3 is associated with a stimulus evaluation process, and is elicited by rare or significant stimuli (Donchin & Coles, 1988). Recent studies also indicate that the P3 elicited by relevant items is preceded by a larger N2, and is followed by a larger slow wave. The N2 has a frontocentral-dominant scalp topography and a negative peak at approximately 200–300 ms after item onset. The N2 in the CIT is related to response monitoring (Gamer & Berti, 2010) or attention (Matsuda, Nittono, Hirota, Ogawa, & Takasawa, 2009). The slow wave occurs at approximately 500–1000 ms after onset of the memorized item, and has an anteriorly negative and posteriorly positive scalp distribution (Matsuda & Nittono, 2015b; Matsuda et al., 2009; Matsuda, Nittono, & Ogawa, 2011). This ERP component is often termed the *late positive potential* (Matsuda & Nittono, 2015b; Matsuda, Nittono, & Ogawa, 2013). However, in the present study, we termed it the *slow wave* or *frontal negative slow wave* for two reasons. First, it exhibits a different scalp distribution compared with the classical late positive potential elicited by affective stimuli (Weinberg, Ferri, & Hajcak, 2013). Second, the polarity of this potential is negative at the frontal site, and its cortical source is estimated in the frontal cortex (Matsuda & Nittono, 2015a). Considering the significance of the frontal part of this ERP component, it is misleading to term it a 'positive' potential. The frontal negative slow wave has been shown to increase with cognitive load (Birbaumer, Elbert, Canavan, & Rockstroh,

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1990; Rösler, Heil, & Roder, 1997). The occurrence of this component in the CIT suggests that the participants engage in an additional cognitive task after they detect the memorized item (Matsuda & Nittono, 2015b).

Although the physiological responses in the CIT have been considered to be orienting responses, several studies recently proposed that the physiological responses can be decomposed into at least two processes. For example, klein Selle et al. decomposed autonomic responses into orienting responses and arousal inhibition (i.e., the process of inhibiting experienced physiological arousal) by comparing the responses between a Conceal condition and a Reveal condition (klein Selle, Verschuere, Kindt, Meijer, & Ben-Shakhar, 2016). In the Conceal condition, participants concealed memorized information as well as the usual CIT, while in the Reveal condition, participants were asked to covertly communicate the identity of the memorized item to the experimenter. The main findings were a greater increase in skin conductance for the relevant item compared with the irrelevant items in both the Conceal and Reveal conditions. By contrast, both heart rate and respiration were suppressed only in the Conceal condition. The authors argued that skin conductance reflects orienting responses, while heart rate and respiration reflect arousal inhibition. Rosenfeld et al. (2017) also compared ERPs between the Conceal and Reveal conditions, and found that the P3 was associated with the orienting responses, while delay of the N2/N3 latency was associated with arousal inhibition (Rosenfeld, Ozsan, & Ward, 2017).

Matsuda, Nittono, and Ogawa (2013) decomposed autonomic responses and ERPs into recognition-related and concealment-related responses by comparing between the Conceal condition and a condition in which the memorized information was exposed to an experimenter before the test; thus, the participants did not need to conceal it (No-secret condition). A greater skin conductance response, N2, and P3, and a slower heart rate, were observed for the relevant item compared with the irrelevant items in both conditions. However, suppressed respiration and an increased slow wave were observed only in the Conceal condition. Thus, the increase in skin conductance, N2, and P3, and the slower heart rate represent recognition-related responses, whereas the suppressed respiration and increased slow wave represent the concealment-related responses.

Using Standardized Low Resolution Brain Electromagnetic Tomography (sLORETA) (Pascual-Marqui, 2002), Matsuda and Nittono (2015a) estimated the source of the slow wave in the CIT to be primarily in the right middle frontal gyrus, with a supplemental source in the right inferior frontal gyrus. This finding is consistent with the idea that the activation of cortical cell assemblies close to the scalp recording site manifests itself as a negative slow wave (Birbaumer et al., 1990; Rösler et al., 1997). Activation of the right middle frontal gyrus during the CIT has also been reported in a meta-analysis of functional magnetic resonance imaging (fMRI) studies (Gamer, 2011b).

However, it remains unclear whether the right prefrontal activation underlying the frontal negative slow wave is specific to the concealment. Alternatively, the frontal negative slow wave might reflect a more general cognitive control process, regardless of concealment. The right middle frontal activation in the CIT is considered to be associated with a general cognitive control process that requires attention and working memory (Christ, Van Essen, Watson, Brubaker, & McDermott, 2009; Gamer, 2011b). In fact, the right middle frontal gyrus is activated by a spatial working memory task (Sakai, Rowe, & Passingham, 2002) and the increase of memory load (Rypma & D'Esposito, 1999).

The present study investigated whether the right prefrontal activation underlying the frontal negative slow wave in the CIT is specific to concealment. For this purpose, we attempted to replicate and extend a previous study (Matsuda & Nittono, 2015a). Four experimental conditions were made by manipulating the presence or absence of memory and the intention to conceal. In the Conceal condition, participants were asked to conceal the memorized item by inhibiting its physiological responses. As opposed to this standard condition, the Reveal condition required participants to let the experimenter know the memorized item, and thus enhance its physiological responses (i.e., the participants did not have the intention to conceal in the Reveal condition). The third condition was the Exposed condition, in which participants were asked to tell the experimenter the memorized item before receiving a test (by definition there was no intention to conceal). Although this condition was previously termed the No-secret condition (Matsuda & Nittono, 2015a; Matsuda, Nittono, & Ogawa, 2013), herein we call it the Exposed condition to avoid confusion with other conditions without a secret. The Innocent condition was added as the fourth condition, in which participants did not know which item was critical.

Based on the finding of Matsuda and Nittono (2015a), the right prefrontal cortex should be activated when the participant intends to conceal the relevant item, and will be reflected as a greater right than left frontal negative slow wave and source estimation with sLORETA. A key question in the present study is whether this right hemisphere predominance is only observed in the Conceal condition. If the right prefrontal activation is not specific to concealment, but related to a more general cognitive control process, the right prefrontal activation signature will be also observed in the Reveal condition, which requires an additional cognitive effort. By contrast, if the intention to conceal specifically recruits the right prefrontal cortex, a greater right than left frontal negative slow wave will be observed, and its source will be estimated in the right prefrontal cortex only in the Conceal condition. The amplitude difference of the frontal negative slow wave between the relevant and irrelevant items should not appear in the Exposed and Innocent conditions (Matsuda, Nittono, & Ogawa, 2013). We also analyzed the N2 and P3, in addition to the frontal negative slow wave, as these components are often reported in CIT studies. We hypothesized that the relevant item would elicit a greater N2 and P3 in the Conceal, Reveal, and Exposed conditions, as these two components are associated with orienting responses.

## 2. Method

### 2.1. Participants

Twenty-five healthy volunteers (9 men and 16 women; mean age: 33.3 ± 5.8 years, range: 20–40 years) participated in the experiment. All participants had normal or corrected-to-normal vision. They were right handed according to the Edinburgh Inventory (Oldfield, 1971). The study was approved by the research ethics committee of the National Research Institute of Police Science, and all participants gave their informed consent before participation. Participants were paid 7000 yen (equivalent to approximately US $70) after completing their participation.

### 2.2. Stimuli

Four stimulus sets were prepared. Each stimulus set consisted of five neutral pictures selected from the International Affective Picture System (IAPS; Lang, Bradley, and Cuthbert, 2005).[1] All 20 pictures (4 sets × 5 pictures) depicted non-affective images (Valence: mean = 5.00 ± 0.26; Arousal: mean = 2.79 ± 0.53) to prevent affective-related components being elicited. Images were presented on a 22-in. cathode ray tube display with a resolution of 640 × 480 pixels at a distance of 100 cm.

### 2.3. Procedure

All participants completed each of the four conditions. For each

[1] The IAPS pictures used in the experiment were: Stimulus Set 1: 7003, 7004, 7009, 7010, and 7190; Stimulus Set 2: 7000, 7030, 7038, 7060, and 7100; Stimulus Set 3: 7002, 7020, 7080, 7090, and 7233; Stimulus Set 4: 7034, 7040, 7042, 7050, and 7150.