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# Detection of concealed information by P3 and frontal EEG asymmetry

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## HIGHLIGHTS

- ► Frontal EEG asymmetry was calculated in the P3-based Concealed Information Test.
- ► Critical items elicited greater relative right frontal activity than non-critical items.
- ► Adding frontal EEG asymmetry to P3 amplitudes improved classification performance.
- ► Frontal EEG asymmetry can serve as a supplementary index in this test.

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## ABSTRACT

Psychophysiological detection of deception has seen increased attention in both research and applied settings. In this field, the most scientifically validated paradigm is the Concealed Information Test (CIT). The CIT does not directly deal with whether a participant is lying, but examines whether a participant recognizes a critical relevant detail, inferred by differences in physiological responses between critical and non-critical items. Although event-related potential (ERP) approaches to the CIT have shown high accuracy, a combination of measures might improve the test's performance. We thus assessed whether a new CIT index, frontal EEG asymmetry that is supposed to reflect differences in approach/withdrawal motivation, would prove useful. Nineteen participants were asked to steal one item in a mock crime, and were then administered two CITs while concealing the stolen item. One CIT included the stolen item (i.e., guilty condition), whereas the other CIT did not (i.e., innocent condition). In the guilty condition, the concealed stolen item elicited greater relative left frontal alpha activity (indicative of relative right frontal cortical activity) as compared to the other items, suggesting that the recognition of the concealed item might have induced withdrawal motivation. Although the discrimination between guilty and innocent conditions by the asymmetry score alone was not as good as that by the ERP P3 index, combining the asymmetry score and P3 improved the detection performance significantly. The results suggest that the frontal EEG asymmetry can be used as a new measure in the CIT that provides additional information beyond that captured by the traditional ERP index.



## 1. Introduction

Psychophysiological detection of deception has garnered increasing attention in both research and applied settings. Deception detection using autonomic responses has been studied for nearly a century [15]. Recently, many studies have reported deception detection approaches that use central nervous system measures, such as functional magnetic resonance imaging (fMRI) (for a review, see [10]). However, no measure specific to deception has yet been found [10]. Hence, to examine the physiological responses related to deception, basic research uses an experimental paradigm that compares responses between an honest condition in which participants are asked to answer questions honestly and a deceptive condition in which participants are asked to answer questions deceptively. However, such a paradigm is difficult to be used in applied settings, for example, criminal investigations.

Therefore, the Concealed Information Test (CIT) has been established as preferable for both research and practice, although its use has not been adopted widely in applied settings other than in Japan [17]. The CIT does not directly deal with whether a participant tells a lie, but examines whether a participant has knowledge of a critical item on the basis of differences in physiological responses between critical and non-critical items [16]. In the CIT for criminal investigation, an examiner presents to a suspect one crime-relevant (critical) item and several crime-irrelevant (non-critical) items, which are

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selected to be indistinguishable from the critical item by an innocent subject. If physiological responses to the critical item differ from those to non-critical items, the examiner infers that the suspect recognizes the critical item.

Among the physiological measures examined in CIT studies, the electroencephalogram (EEG) is often used. Most EEG studies compute the event-related potential (ERP) by averaging the EEG epochs for each item, finding that the P3 amplitude significantly differs between critical and non-critical items when a participant knows the critical item (for a review, see [22]). However, the ERP is just the synchronized portion of the ongoing EEG activity. Analyzing other aspects of the EEG may reveal CIT information not reflected in the ERP.

With that goal, we examined frontal EEG asymmetry as a potential new index for use in the CIT. Asymmetric involvement of prefrontal cortical regions in positive affect (or approach motivation) and negative affect (or withdrawal motivation) can be assessed noninvasively with EEG, and the lateralized role of the prefrontal cortex in affect and motivation has been suggested by lesion, animal, and neuroimaging studies [4,8,14]. This asymmetry is assessed with frontal EEG alpha activity. Because of the inverse relationship between alpha power and cortical activity (cf. [2]), relatively less left-than-right frontal alpha activity is thought to signify greater relative left frontal activity, and may serve as an index of approach motivation or related emotion (e.g., anger and joy). In contrast, relatively less right-than-left frontal alpha activity signifies greater relative right frontal activity, and may serve as an index of withdrawal motivation or related emotion (e.g., disgust, fear, and sadness) [7,13]. In this manuscript, we will refer to asymmetry in terms of the inferred construct of activity, rather than the observed metric of alpha. Frontal EEG asymmetry has been found to relate to individuals' traits (e.g., [5]) but also show state-dependent relationships with motivational/emotional responses (e.g., [6]). In the majority of the previous studies, frontal EEG asymmetry reflected data from a substantial period of time (e.g., several minutes). However, a recent study has shown that the asymmetry score calculated from a shorter period of time (e.g., 2 s or less) correlates with the typical asymmetry score obtained from a longer period of time [1]. In this study, we calculated EEG asymmetry scores using a short, 2-s period after stimulus onset. In the CIT, when confronted with a critical item, participants may be motivated to withdraw or disengage from the testing situation, or attempt to inhibit their responses because they wish to conceal their recognition of that item [24]. If such processes are reflected in asymmetrical frontal brain activity, relatively greater right frontal cortical activity might be observed when participants are presented with the recognized critical item than with the non-critical items.

Therefore, in this study, we measured frontal EEG asymmetry within the standard P3-based CIT. We compared the frontal EEG asymmetry score between critical and non-critical items, and then investigated its performance in detecting concealed knowledge. We also investigated whether the asymmetry score would increase the detection performance of the traditional P3 index.

## 2. Methods

### 2.1. Participants

Twenty healthy volunteers (11 men and 9 women, 20–50 years old, *M* = 36.9, *SD* = 8.06) participated in the experiment. All participants had normal or corrected-to-normal vision and were right handed according to the Edinburgh Handedness Inventory [21]. Volunteers' written informed consent was taken before test administration.

### 2.2. Stimuli

Digitized pictures (640 × 480 pixels) of six accessories (tie pin, necklace, earring, ring, watch, and brooch) and six electric appliances (DVD, video, camera, laptop, game console, and mobile phone) were used. Images were viewed on a 17-in. monitor (refresh rate 75 Hz) at a distance of 100 cm with a visual angle of $12.9^\circ \times 9.68^\circ$.

### 2.3. Procedure

Participants were led to believe that they would be assigned to one of four roles by lottery: stealing an accessory and an appliance, stealing an accessory, stealing an appliance, or stealing nothing. However, by design, half of the participants took the role of stealing an accessory, whereas the remaining participants took the role of stealing an appliance. In the mock theft, participants moved to a different room and secretly stole an item. They know what item to steal as it was written on the instruction sheet. One of the ten items (except for the tie pin and DVD) was assigned to each participant in a counterbalanced order. Then, they went through two CITs: the accessory CIT including the pictures of the six accessories and the appliance CIT including the pictures of the six appliances. Thus one of the CITs included the stolen item (i.e., guilty condition) while the other did not (i.e., innocent condition). Before each CIT, the participants were told to pretend to be innocent even if they had stolen something. To ensure that participants attended to the stimuli, they were asked to press a "yes" button to the target item (i.e., tie pin or DVD) with the left thumb and a "no" button to the other items with the right thumb as quickly and accurately as possible. In each CIT, the six pictures were presented for 600 ms with an inter-stimulus interval of 2 s; each picture was randomly presented 10 times with no identical pictures presented sequentially. This session was repeated twice, so that each item was presented 20 times in total. The order of the accessory and appliance CITs was counterbalanced across participants.

Upon concluding the experiment, the participants were asked to state the item they had stolen. All the participants correctly remembered the stolen item.

### 2.4. Physiological recording

EEG signals were recorded using 128 active Ag/AgCl electrodes with the ActiveTwo system (BioSemi, The Netherlands). Electrodes were embedded equidistantly (5% distance) in a prefabricated cap and were arranged in concentric circles around the vertex and extended to the inferior-posterior regions. An active (common mode sense-CMS) and a passive electrode (driven right leg-DRL) were used to form a feedback loop for amplifier reference. A bandpass filter of 0–100 Hz was used to record all signals, which were digitized with a sample rate of 512 Hz.

### 2.5. Data reduction

In the guilty condition, the item that the participants had stolen was defined as the critical item and the other four items were defined as non-critical items. In the innocent condition, one randomly selected item was defined as the critical item and the other four items were defined as non-critical items.

EEG data were resampled at 128 Hz. EEG and EOG signals were digitally filtered using a 0.1–30 Hz FIR bandpass filter (2320-point Kaiser-windowed Since FIR filter; Kaiser beta = 5.653, max. passband deviation = 0.001, transition band width = 0.2 Hz). They were then segmented in epochs from 200 ms before to 2000 ms after stimulus onset. Epochs containing sensor noise or clearly visible artifacts were discarded. Additionally, epochs were rejected