The P300 is sensitive to concealed face recognition


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Abstract

In two experiments, we investigated whether a P300 based Concealed Information Test (CIT) can be used to detect concealed face recognition. The results show that detection of concealed face recognition is highly successful when stimuli depict persons who are personally highly familiar, and instructions to conceal recognition are given. When pictures depict recognized, but personally less familiar faces, and no specific instructions to conceal recognition are given, detection is unsuccessful. These findings indicate that pictures of faces can be used in a P300 based CIT, and that mere recognition is not sufficient for successful detection of concealed information.

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1. Introduction

The P300 component of the Event Related Potential (ERP) has been used for the detection of concealed information for almost two decades (Farwell and Donchin, 1991; Rosenfeld et al., 1988). Although the practical use of P300 based Concealed Information Tests (CITs) has been limited so far (e.g., Harrington v. Iowa, 2000; Miyake et al., 1993), many researchers in the field emphasize the method’s strengths (Ben et al., 2002; Elaad, 1998; Iacono, 2007). Accordingly, in its 2003 report, the authoritative National Research Council recommended further investigation of measurement of event-related potentials as an alternative or supplement to the polygraph (National Research Council, 2003).

The rationale underlying the P300 based CIT is that rare, meaningful stimuli elicit a P300 (Donchin and Coles, 1988; Rosenfeld, 2002). Stimuli that are meaningful to the individual, like autobiographical information, have been shown to elicit a P300 waveform when presented infrequently in a series, intermixed with irrelevant stimuli (Berlad and Pratt, 1995; Gray et al., 2004). Consequently, the P300 can be used to detect simulated amnesia for autobiographical facts (Rosenfeld et al., 1995). When a crime has been committed, crime-related details are thought to be meaningful to the perpetrator, but not to an innocent suspect. Therefore, if crime-relevant details are presented infrequently in a series of equally plausible, but crime-unrelated details, the crime-related details are expected to elicit a P300, but only so in guilty suspects.

The majority of studies investigating P300 based CITs used words or short phrases as stimuli. These words or phrases generally refer to either autobiographical information (e.g., Rosenfeld et al., 1995), mock crime-related information (e.g., Farwell and Donchin, 1991; Rosenfeld et al., 1988), or incidentally rehearsed information (e.g., Allen et al., 1992; Ellwanger et al., 1996). In a typical P300 based CIT, these words of phrases belong to one of three types, namely targets, probes and irrelevants (e.g., Farwell and Donchin, 1991). The probe is the stimulus of interest, of which the participant denies knowledge. The target is a stimulus that has been made task relevant through instructions, and serves to ensure participant cooperation. The irrelevant stimuli are equally plausible, but unrelated to the crime. The participant is instructed to acknowledge recognition of the target by pressing one button, and press another button with any other stimulus (probe and irrelevants). For an innocent participant, probe and irrelevants

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1 Although the defendant in this case underwent a P300 based CIT, the outcome of this test was never accepted into court. See Rosenfeld (2005) for a review.

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are indistinguishable, and thus no difference in P300 is expected. For a guilty participant, on the other hand, the probe should stand out and elicit a P300.

As noted, the majority of studies investigating P300 based CITs used words or short phrases as stimuli. Photographic stimuli have seldom been used, whereas especially the use of pictures of faces might be relevant. In this study, we investigated whether pictures of faces can be used in a P300 based CIT.

Many studies have investigated the cognitive processes underlying face perception and recognition. Associated ERP components include an occipito-temporal N170, thought to reflect face perception (Bentin et al., 1996), the inferior temporal N250r found in repetition priming paradigms (Negri et al., 1995; Schweinberger et al., 2002), the centro-parietal N400 component that is thought to reflect the facilitation in accessing perceptual or semantic memory codes for people (Schweinberger and Burton, 2003) and a centro-parietally distributed late positive component (P300/LPC). Especially the latter has been found to be sensitive to the recognition of familiar faces, whether famous (Henson et al., 2003), learned during a study phase (Joyce and Kutas, 2005; Paller et al., 1999, 2000, 2003), or the participant’s own face (Ninomiya et al., 1998). Moreover, a later positive ERP component in response to familiar faces has even been observed in prosopagnosia patients, regardless of their incapability of familiar face recognition (Bobes et al., 2004; Renault et al., 1989). However, paradigms used in the studies cited above vary greatly and in each case deviate from a typical P300 based CIT. Still, the finding that familiar faces elicit a distinct late positive ERP component supports the idea that ERPs may serve as indicators of concealed face recognition. With these considerations in mind, the aim of our first experiment was to explore whether the P300 could be used to infer concealed face recognition.

In a second experiment, we tested whether mere recognition was sufficient to detect face recognition. In a typical CIT experiment, participants are instructed to conceal recognition of the probe. But several studies have shown that a P300 can also be elicited under passive conditions, i.e., without specific task instructions (Polich, 1987, 1989; but see Bennington and Polich, 1999), indicating that, at least to some extent, the P300 indexes automatic processing (Sommer et al., 1998). In the second experiment we tested whether a P300 to familiar faces is also present in the absence of specific instructions to conceal recognition of the probe.

2. Experiment 1

2.1. Methods

2.1.1. Participants

Participants were 24 undergraduate students (4 men) at Maastricht University (average age 23.1 years; range 18–35).

2.1.2. Stimuli

Every participant was asked to bring two passport photos: one of a sibling and one of a good friend. The persons on the two photos had to be of the same sex. These photos were scanned and converted to grayscale. Stimulus size was 49 mm by 66 mm and viewing distance was 1 m.

2.1.3. Experimental design and procedure

Participants were allocated to groups of three. For each member of a group, stimulus material consisted of the two pictures they brought (target and probe) plus the four pictures the other two participants brought (irrelevants). For half the participants, the picture of their sibling served as target and the picture of their friend as probe, while for the other half the picture of their friend served as target and the picture of their sibling as probe. This way, a design was created in which every stimulus served equally often as target, probe and irrelevant, thus minimizing physical stimulus confounds (Luck, 2005).

Participants were instructed to acknowledge recognition of the target by pressing one of two buttons placed under their left and right index fingers, respectively, and pressing the other button for all unfamiliar pictures. They were explicitly instructed to deny recognition of the probe, by classifying it as unfamiliar. The assignment of the target to the left and right button was balanced over participants.

Each trial started with the presentation of a picture, which was shown until the response button was pressed, with a maximum of 2500 ms. Feedback was given if no response was given after 2500 ms (‘too slow!’) or if the response was incorrect (‘wrong!’). The intertrial interval was 2100 ms. The task consisted of 12 practice trials that served to familiarize the participants with the procedure, and 432 trials that were presented in three blocks of 144, with a break in between blocks that could be terminated by the participant. Thus, probe, target and each of the four irrelevants were each presented on 72 trials.

2.1.4. Data acquisition, reduction and analysis

EEG data were recorded from 4 midline sites (Fz, Cz, Pz, Oz) and the right mastoid (M2), using Ag/AgCl electrodes, glued to the scalp with 10–20 conductive gel. All leads were online referenced to the left mastoid (M1). Horizontal and vertical electrooculograms (EOGs) were recorded using electrodes placed laterally to both eyes as well as below and above the left eye. EEG and EOG electrode impedances were below 5 kΩ and 10 kΩ, respectively. All signals were amplified using Contact Precision Instruments amplifiers. EEG was amplified 20,000 times, EOG 4000 times. The signal was filtered online (0.1 to 30 Hz bandpass), and digitized at 200 Hz. All leads were offline re-referenced to an average of M1 and M2. Eye blink artifacts were reduced using a regression based method (Semlitsch et al., 1986) performed on the continuous data.
Suppose that, after discarding artifacts and incorrect behavioral type within each individual, allowing for statistical testing. This approach generates a distribution for each stimulus bootstrapping approach (see e.g., Wasserman and Bockenholt, 1989). This approach allows the success of detecting concealed face recognition generally largest at Pz, we limited our analysis to this site.

2.2. Results and discussion

2.2.1. Behavioral data

Participants made, on average, 8.4% errors (incorrect or no button press) on target trials, 1.2% errors on probe trials, and 0.12% errors on irrelevant trials. A 2 × 2 ANOVA on these error rates with stimulus type (probe, irrelevant) as repeated measure and probe type (sibling, friend) as between-subjects factor revealed no significant interaction [F(1, 22) = 1.76, p = .20], indicating that the probe–irrelevant difference did not depend on probe type. The factor probe type was therefore dropped from the analysis. The subsequent ANOVA showed that participant indeed made more errors on probe than on irrelevant trials [F(1, 23) = 9.8, p < .01]. Table 1 shows the RTs for the different stimulus types. A 2 × 2 ANOVA on these RTs with stimulus type and probe type as factors again revealed no significant interaction [F(1, 22) = 2.27, p = .15], and the factor probe type was therefore dropped from the analysis. The subsequent ANOVA yielded a significant effect [F(1, 23) = 45.2, p < .001], showing that reactions to probes were slower than those to irrelevants. Bootstrapping of the reaction times resulted in a hit rate of 79%, i.e., for 19 out of 24 participants concealed face recognition was detectable through their slower responses on probe stimuli.

2.2.2. P300 data

Fig. 1 (left panel) shows the grand average ERP waveforms at all electrode sites. A 2 × 2 ANOVA on peak–peak P300 amplitude at Pz with stimulus type and probe type as factors revealed no significant interaction [F(1, 22) < 1], and the factor probe type was therefore dropped from the analysis. The subsequent ANOVA revealed a main effect for stimulus type [F (1, 23) = 54.4, p < .001], indicating that the P300 elicited by probes was larger than the P300 elicited by irrelevants.3 Table 1

<table>
<thead>
<tr>
<th>Experiment 1</th>
<th>Experiment 2</th>
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<td>P300</td>
<td>RT</td>
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<tr>
<td>Target</td>
<td>23.1 (6.6)</td>
</tr>
<tr>
<td>Probe</td>
<td>16.7 (6.5)</td>
</tr>
<tr>
<td>Irrelevant</td>
<td>9.6 (5.8)</td>
</tr>
<tr>
<td>Hits</td>
<td>22/24 (92%)</td>
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</tbody>
</table>

Standard deviations are given between parentheses.

To state with 95% confidence that probe P300 is larger than irrelevant P300, and thus that the detection of concealed information was successful, we checked whether the mean difference score minus 1.65 * the standard deviation was greater than zero. If so, the probe was classified as recognized. In order to compute the hit rate based on RTs, an identical procedure was applied to the behavioral data.

3 Analysis of the base–peak P300 measure yielded similar results (main effect for stimulus type [F(1, 23) = 45.0, p < .001]).
presents mean P300 amplitude and individual classification. The hit rate for the peak–peak P300 measurement was 92%, i.e., 22 out of 24 participants displayed a P300 for probes that sufficiently deviated from that for irrellevants to be of diagnostic value. The peak–peak measure outperformed a base–peak measure, which achieved a hit rate of 71% (17 out of 24 participants). These results show that, whether based on RTs or P300, our face recognition based CIT was highly successful.

To test whether this P300 associated with concealed face recognition can be explained by mere recognition processes, we conducted a second experiment. To isolate recognition processes, no instructions to conceal recognition of the probe were given. Furthermore, we addressed a point of concern, namely that the stimuli were photographs acquired through the participants themselves. As a consequence, targets and probes may have been recognized as familiar faces, but also as their self-brought pictures. If so, the P300 found might represent photo recognition instead of face recognition per se. In the second experiment we used as stimuli pictures of university professors that had lectured in courses that were attended or unattended (in two groups) by the participants.

3. Experiment 2

3.1. Methods

3.1.1. Participants

Participants were 29 first-year students at Maastricht University. Five of them were dropped from the analysis because they could not correctly identify the critical photos after the experiment (see Experimental design and procedure section). Thus, the remaining sample consisted of 24 participants (average age 19.7 years; range 18–24, 2 men). Twelve of them were first-year psychology students, whereas the other 12 were first-year health sciences students. They read and signed an informed consent, and received course credits for their participation. The experiment was approved by the ethical committee of the Faculty of Psychology, Maastricht University.
3.1.2. Stimuli

Photos of the faces of six university professors served as stimuli. Two of these professors taught at the Faculty of Psychology, two at the Faculty of Health Sciences, and two at the Faculty of Law. All six professors had taught a first-year course that year that had already been completed. As a consequence, two faces were familiar to each participant, while four were not. Twelve pictures were taken of each professor, four from a slight angle from the left, four from en face, and four from a slight right angle. This was done to reduce the chance that any physical property of the picture would lead to an easy classification. Size and resolution of the pictures were identical to those in Experiment 1.

3.1.3. Experimental design and procedure

For each participant, one of the two familiar faces was denoted as the target. Participants were instructed to rapidly press one button upon presentation of the face of the professor teaching course X, and the other button upon presentation of any other face. In contrast to Experiment 1, no specific reference was made to the fact that, besides the target, another familiar face would be presented, nor to concealing recognition of this face. Participants were then shown a picture of the professor teaching course X. Which of the two familiar faces served as the target was balanced over participants. The other familiar face served as probe. The remainder of the procedure was identical to Experiment 1, with one exception: stimuli were presented in six blocks containing 72 stimuli each (i.e., all 12 pictures of each of the 6 professors presented once), preceded by a practice block that also contained 72 stimuli. After the ERP recording, all participants were given a pencil-and-paper forced-choice recognition test. This test consisted of a form on which participants had to link the pictures to a specific course, or check the ‘unknown’ option if they had not seen the person prior to the experiment. This test served, to make sure both the target and the probe, but not the irrelevants, were indeed recognized.

3.1.4. Data acquisition, reduction and analysis

Data acquisition and analysis were identical to Experiment 1, with the exception that, due to technical problems, electrodes were re-referenced to M2. Only the trials with pictures of professors who taught at the psychology or health sciences faculty were analyzed. This was done because only psychology and health sciences students participated, and in this way all pictures that were included in the averages served as targets, probes and irrelevants.

3.2. Results

3.2.1. Behavioral data

Participants made on average 5.8% errors to targets, 0.12% errors to probes, and 0.20% errors to the irrelevant stimuli. A $2 \times 2$ ANOVA on these error rates with stimulus type (probe, irrelevant) and study (psychology, health sciences) as factors revealed no interaction $[F(1,22)<1]$. The factor study was therefore dropped from the analysis. The subsequent ANOVA showed that the difference between the number of errors to probes and irrelevants was not significant $[F(1,23)=1.56, p=.22]$. Table 1 shows the RTs to the different stimulus types. A $2 \times 2$ ANOVA on these RTs with stimulus type and study as factors revealed no interaction $[F(1,22)<1]$, and the factor study was therefore dropped from the analysis. The subsequent ANOVA did not reveal an effect for stimulus type $[F(1,23)=2.23, p=.15]$. Bootstrapping of the reaction times resulted in successful detection of recognition in only one participant (hit rate 4%).

3.2.2. P300 data

Fig. 1 (right panel) presents grand average waveforms of Experiment 2. A $2 \times 2$ ANOVA on peak–peak P300 amplitude at Pz with stimulus type and study as factors revealed no interaction $[F(1,22)=1.47, p=.24]$, and the factor study was therefore dropped from the analysis. The subsequent ANOVA did not reveal an effect of stimulus type $[F(1,23)<1.0]$.

Table 1 gives the mean P300 amplitude and hit rate. Both the peak–peak and the base–peak methods correctly classified 17% of all participants, which means that in 4 participants the P300 amplitude for probes deviated sufficiently from that for irrelevants to be of diagnostic value.

3.2.3. Comparison of experiments

Including the data from both experiments in one $2 \times 2$ ANOVA with experiment (Experiment 1, Experiment 2) and stimulus type (probe, irrelevant) as factors indeed showed a strong interaction $[F(1,46)=42.1, p<.001]$, confirming the difference in the P300’s sensitivity to probes between the two experiments. Similarly, the RT data showed a strong interaction between experiment and stimulus type $[F(1,46)=43.7, p<.001]$.4 Table 1

4 Analysis of the base–peak P300 measure yielded a non-significant main effect for stimulus type ($[F(1,23)=4.0, p=.06]$).

4. General discussion

The aim of this study was two-fold. Firstly, we investigated whether a typical P300 based CIT can be used to detect concealed face recognition. Secondly, we investigated whether this effect could be explained by mere recognition processes. The CIT in Experiment 1 was successful, both in terms of statistical significance at the group level as well as in terms of individual classification. Experiment 2 showed that this effect could not be explained by mere recognition.

The results from Experiment 1 support the use of pictures of faces in a P300 based CIT. This may help to identify someone as a member of a terrorist network or a criminal organization, or may help to identify a rapist by presenting the face of the victim. The latter may be especially useful when the rapist does not know the name of the victim. If this pattern generalizes to other pictures, the range of items available for forensic CITs may be increased, thereby helping to overcome a practical problem often raised for the CIT, namely that in real crimes insufficient numbers of items are available (Podlesney, 1993, 2003).
At the same time, the results from Experiment 2 show that mere recognition is insufficient for a successful CIT. Most likely, because of the instructions to deny recognition of the probe in Experiment 1, probe and irrelevants were processed differently. In Experiment 2, the absence of specific instructions may have resulted in similar processing of probe and irrelevants, and thus similar P300s. This is consistent with a view that P300 in response to the probe in Experiment 1 was due to intentional rather than to automatic processing, and concurs with previous studies showing an increased P300 with specific task instructions (Castro and Diaz, 2001; Rosenfeld et al., 2004). Furthermore, the large P300 to the target stimulus in Experiment 2 corroborates the P300 eliciting effect of task instructions, as this stimulus was equally familiar as the probe, but was made task relevant through instructions.

Another difference between the two experiments was that the pictures of professors used in Experiment 2 were personally less familiar than the pictures of siblings and good friends used in Experiment 1. Emotionally significant stimuli have been shown to elicit a P300 (Ito and Cacioppo, 2000; Schupp et al., 2000) and this may be (partly) responsible for the P300 in Experiment 1. This explanation would be in line with recent studies by Rosenfeld et al. (2006, 2007), who found that detection of well-rehearsed, but personally non-significant word stimuli (the name of the experimenter) was inferior to that of personally significant stimuli (participants’ own name), and would also be consistent with recent models of face recognition (Breen et al., 2000; Ellis and Lewis, 2001). According to these models, brain systems responsible for the processing of faces include a cognitive route providing access to semantic and biographical information about the faces. Additionally, a second, separate route is responsible for the generation of an affective response to familiar faces. Face recognition units are activated when a familiar face is recognized, and subsequently, one or both of these routes can be triggered. Given the relationship between the participants and the persons on the pictures, the faces in Experiment 1 may have triggered the affective route, whereas the faces in Experiment 2 have not. A larger P300 to faces that triggers the affective route would, in turn, be in line with models of P300 that emphasize the importance of stimulus meaning (Johnson, 1993).

Two limitations of the current experiments deserve some comments. Firstly, as mentioned, the stimuli used in Experiment 1 were photographs acquired through the participants themselves. As a consequence, targets and probes may have been recognized as familiar faces, but also as their self-brought pictures. If so, the P300 found in Experiment 1 might represent photo recognition instead of face recognition per se. Secondly, two factors were modified between Experiment 1 and Experiment 2. In Experiment 2, task instructions did not make any specific reference to presentation of the probe, nor to concealing its recognition, and stimuli depicted someone personally less familiar to the participants. Either of these factors may have affected P300 amplitude. Whether one of these factors alone is sufficient for a successful P300 based CIT should be clarified by future studies.

In sum, the present results demonstrate that pictures of faces can be used effectively in a P300 based CIT, and that mere recognition is not sufficient for successful detection of concealed information.

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References


