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Deception awareness improves P300-based deception detection in concealed information tests

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ABSTRACT

We asked if increased awareness of deception enhanced P300-based detection of concealed information with two groups: 1) *Control* subjects saw a randomized series of either rare probes (subject home towns), frequent irrelevants (other towns), and rare targets, which are irrelevant stimuli but requiring Button 1 responses. Probes and non-target irrelevants required Button 2 responses. Controls were told to be sure they performed target/non-target discrimination correctly, and were so reminded throughout the run. 2) *Deception* subjects received an identical stimulus series and response instructions, but were also alerted about their deception (pressing a non-recognition button to probes) before and throughout the run. The deception group had significantly greater differences between probe and irrelevant P300s than controls, as well as significantly greater individual detections (10/10) than did controls (5/10), suggesting that the deception awareness manipulation enhances test sensitivity.

1. Introduction

The concealed information test (CIT) is a protocol that is often used with physiological measures (e.g. skin conductance responses, heart rate, event-related potentials, etc.) to detect intentionally concealed information, e.g. autobiographical information or crime-related information (Hu et al., 2012; Peth et al., 2012; Nahari and Ben-Shakhar, 2011; for a review, see Verschuere et al., 2011). During the test, a suspect is presented with multiple-choice questions referring to the crime. Only one of the answer choices for each question will be crime-relevant (*probe*), other answers are crime-irrelevant (*irrelevant*) and cannot be discriminated from the relevant item by an innocent person (Lykken, 1959). Due to the probe's special significance for guilty subjects, this item will elicit a complex of physiological and behavioral responses in such subjects, which can be differentiated from responses elicited by irrelevant items (Verschuere and Ben-Shakhar, 2011). The theoretical basis for this pattern of response is known as the orienting reflex (OR; Sokolov, 1963). Specifically, the crime-relevant information will elicit a stronger OR than irrelevant information because of the former's personal significance and added signal value (Lykken, 1974; Verschuere, et al., 2004). In the CIT studies, participants' recognition of the meaningful probe among meaningless irrelevants is conceptualized as the most important factor to elicit the OR.

Previous studies consistently find that stimulus salience (which affects stimulus memory strength) in the CIT moderates the sensitivity of the test (Carmel et al., 2003; Peth et al., 2012; Nahari and Ben-Shakhar;, 2011). For instance, for peripheral information that was not directly related to the crime (e.g. the picture on the wall of the crime scene) and cannot be recalled after a certain time delay, the CIT's detection efficiency was decreased (e.g. Carmel et al., 2003; Gamer et al., 2010; Peth et al., 2012).

In addition to stimulus salience and memory strength, other factors may also influence the CIT's detection efficiency (see Verschuere and Ben-Shakhar, 2011). One known factor is the motivation to defeat the test and avoid detection. Gustafson and Orne (1963) initially reported that when motivational instructions (e.g. try to avoid detection and beat the test) were given to participants, those participants showed larger probe-irrelevant skin-conductance response differences than participants who lacked the motivation to avoid detection (Gustafson and Orne, 1963; see also Elaad and Ben-Shakhar, 1989). However, some other, later studies found no effects on probe-irrelevant differences between high motivated participants and low motivated participants, where motivation was manipulated by promising versus withholding monetary rewards (Davidson, 1968; Furedy and Ben-Shakhar, 1991).

Compared to the relatively inconclusive results obtained regarding the role of motivation, it has been more consistently found that forcing participants to give explicitly deceptive responses during the CIT will improve its detection efficiency. For instance, when participants were required to verbally deny the concealed information, the CIT's detection efficiency was improved compared to participants who remained silent

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(Gustafson and Orne, 1963; Elaad and Ben-Shakhar, 1989; Furedy and Ben-Shakhar, 1991; but see Kugelmass et al., 1967).

Recently, Verschuere et al. (2009) re-examined the role of deceptive response awareness in the P300-based CIT. In previous standard P300-based CIT studies, including Verschuere et al. (2009), a so-called "3-stimulus protocol" was employed (Rosenfeld et al., 1988; Farwell and Donchin, 1991; Allen et al., 1992; see Rosenfeld, 2011, for review). In this protocol, one of three types of stimuli is presented in random order on each trial: The rarely ($p=.125$) presented item of to-be-concealed, meaningful knowledge is called the *probe*; it might be a crime-relevant item like a pistol used in a murder. Frequently ($p=.75$) presented items in the same category as the probe but not relevant for the crime are called the *irrelevant* items, e.g., a rifle that is not used in the murder under investigation. Another rarely ($p=.125$) presented item is the *target*; it is inherently irrelevant also, but the subject is directed to make a unique response to it, e.g., a right button press, making it task-relevant so that like the probe, it too evokes P300 because it is both rare and meaningful. Probes and non-target irrelevants both require an identical other response, e.g., a left button press. Since on any trial, any one of the three stimuli might be presented, the subject is forced to attend to stimuli on all trials, and therefore the guilty/knowledgeable but not innocent/ignorant subject should recognize the rare and meaningful probe, thereby producing a P300. Irrelevant items do not elicit P300, so that the probe P300 amplitude exceeds the irrelevant P300 in guilty subjects.

Rosenfeld et al. (1988) and Farwell and Donchin (1991) have used two versions of the protocol that differed in several ways (see Rosenfeld, 2005), particularly with regard to how subjects might have been alerted to their need to lie during the tests. Farwell and Donchin (1991) simply instructed subjects to discriminate targets and non-targets, and refrained in any way from explicitly alerting subjects that they would be seeing and needing to deceptively conceal recognition of probes. In contrast, Rosenfeld and colleagues consistently warn subjects that they will be seeing personally relevant or crime-related probe items, recognition of which they must deceptively deny (Rosenfeld et al., 1988; Rosenfeld, 2011). The aim of this manipulation is to heighten awareness of probe items and enhance their meaningfulness relative to irrelevant items, presumably leading to larger probe P300 amplitude and thus improved detection of concealed information. Accuracies of both approaches have been comparable at 85–90% (Rosenfeld, 2011).

Verschuere et al. (2009), for the first time, systematically compared the two protocol versions in terms of whether or not the subject's awareness of deception would influence the sensitivity of a P300-based concealed information test. In that study, two groups were run, one (*control group*) in the manner of Farwell and Donchin (1991), and the other (*deception group*) as in Rosenfeld et al. (1988). The probes in both conditions were subjects' first names. The deception group was instructed as were the controls but additionally were told once prior to the ERP recording run that they would have to lie when pressing the "no" button (since it meant, "I don't recognize the name") when their first names were presented. The P300 results, however, did not confirm that the deception group had larger probe and irrelevant P300s than the control group as there was no significant main effect of instructions on amplitude overall, nor was there a significant interaction; i.e., there was no difference between the probe-minus-irrelevant P300 differences between groups. However, there was a suggestive difference between the individually diagnosed detections (based on bootstrapping) between the control (8/18) and deception (12/16) groups, (Chi Square = 3.26, $p=.07$).

We hypothesize here that two factors should be re-considered before concluding that enhanced deception awareness does not improve P300-CIT detection efficiencies. First, Verschuere et al. (2009) used an extremely over-learned probe, one's first name, whose special meaningfulness may have overshadowed the deception manipulation, so that even in a control group not alerted about the need to deceive, the oddball effect may have produced P300 amplitudes at levels already too high to be further enhanced by the deception manipulation. 2) Subjects were given the deception manipulation only once prior to the P300 recording block. In contrast, we expect here that by maintaining awareness of deception via ongoing feedback throughout the testing run, and by using a less well-rehearsed probe, the home town name, we can demonstrate the enhanced effect of awareness of deception on probe-minus-irrelevant P300 differences and detection rates. We expect that the deception manipulation will produce increased probe-minus-irrelevant differences in information-knowledgeable subjects because it will direct such subjects' attention to the discrimination between probes and irrelevants more so than instructions which direct subjects' attention only to a need to press correct buttons to appropriate stimuli, which should force attention more to the target–nontarget discrimination aspect of the task.

Finally, it should be noted that the deception awareness manipulation may also have implications for increasing the CIT's sensitivity in applications. Previous studies either employed multiple tests or recorded multiple physiological activities so as to increase the CIT's sensitivities (e.g. Matsuda et al., 2011; Nahari and Ben-Shakhar, 2011; Hu and Rosenfeld, 2012). Here, if deception awareness can improve the CIT's detection efficiency, it may be preferred because it simply requires instruction modification rather than the use of multiple tests or combined indicators.

2. Methods

2.1. Participants

Twelve members of an advanced laboratory course in cognitive psychophysiology at Northwestern University each recruited two Northwestern students as subjects (so total n = 24), one for a *Deception* group and one for a *Control* (non-deception) group. Assignment to groups was random. All subjects had normal or corrected to normal vision and were between the ages of 17 and 23. There were six males in the deception group and seven in the control group.

2.2. Procedures

Upon entering the laboratory, each subject supplied a previously completed card with his/her name, home address (including town/city,), and phone number. Probe stimuli were home towns. For all subjects, the target was the town name "Norfolk" and the six irrelevants were selected from a list (available on request from authors) of other moderate to large U.S. city names so as to exclude cities in which subjects lived or that had other special meaning for the subject (e.g., a relative's city). Then, after reading and signing an IRB-approved consent form, as electrodes were applied, subjects read a set of instructions also read aloud by an experimenter as follows:

Control subjects read, "You are going to see a series of words on the display screen. These words are town names. You are to press the right hand button which means, "I recognize the target" when you see the target name which is *Norfolk*. You press the left hand button to all other names. We can tell from your brain waves we record on each trial—with 80–90% accuracy—if you mistakenly press the wrong button. We will give you feedback to this effect every few minutes."

Deception subjects read, "You are going to see a series of words on the display screen. These words are town names. You are to press the right button which means, "I recognize it", when you see the target name which is *Norfolk*. You will therefore be telling the truth since you DO recognize it as your target name. You press the left button which means "I don't recognize it" to all other names which are not targets. But one of these non-target names you will see is your home town name. When you press the "I don't recognize it" button for this name you will be lying. You don't recognize it as your target, but you DO recognize it as your home town. We can tell from your brain waves we record on each trial—with 80–90% accuracy—when you deceptively deny recognizing your personal information. We will give you feedback to this effect every few minutes."

Each subject was then led to an EEG recording chair, and the three types of stimuli were presented, one at a time in random order for 300 ms each, on a video display about 1 m from the subject's eyes. Eight different stimuli, each repeated 50 times resulted in total 400 trials. Using a 4 second interval for the 3-stimulus protocol (with 8 stimuli) yields 400 trials × 4 s = 1600 s = 27 min. Subjects were expected to experience about 50 probes, 50 targets and 300 irrelevants. About every 40 trials (about every 4 min) allowing for artifact trials, data collection and stimulus presentation were halted and one of six *non-veridical* feedback messages was presented to deception group subjects that essentially stated that experimenters believed subjects were lying. (Actual sentences in Appendix A.) In contrast, control group subjects also saw six *bogus* messages (see Appendix A) in which we stated our belief that they were occasionally making incorrect button responses. The non-veridical feedback message remained on the screen for 10 s for both groups. It was expected and confirmed in de-briefing that subjects (both groups) did not know that the feedback was not real, but programmed.

It should be appreciated that these key manipulations do not constitute a formal comparison between the methods of Rosenfeld et al. (1988, 1991) and of Farwell and Donchin (1991), neither of which utilized the extensive feedback used here. The primary intent here was to note the effect of enhanced deception instruction and manipulation in comparison with a *comparable* control group. We believed that it was necessary to give the control subjects the same *amount* of feedback as the deception group in order to avoid the confounded interpretation that any observed control-deception differences were attributable to differences in visual stimulation during the data collection run.

2.3. ERP recording

EEG was recorded with Ag/AgCl electrodes attached to sites Fz, Cz, and Pz. The scalp electrodes were referenced to linked mastoids. EOG was recorded with Ag/AgCl electrodes placed above and below the right eye. The diagonal placement of the eye electrodes ensured that both vertical and horizontal eye movements would be picked up, as verified in pilot study and in Rosenfeld et al. (2004, 2008). The artifact rejection criterion was determined off line so as to allow at least 20 probe trials per subject while rejecting all trials with eye movement artifacts as verified with visual inspection. We started with 24 participants: for 16 subjects, 50 μV was the rejection criterion. For four subjects, the criterion varied from 80 to 130 μV. Two subjects were excluded because of excessive behavioral errors. For two remaining subjects, the eye movements were so excessive that it was impossible to average 20 or more probe trials. These subjects were dropped. The EEG electrodes were referentially recorded but the EOG electrodes were differentially amplified. The forehead was connected to the chassis of the isolated side of the amplifier system ("ground"). Signals were passed through Grass P511K amplifiers with a 30 Hz low pass filter setting, and high pass filter set (3 dB) at .3 Hz. Amplifier output was passed to a 16-bit National Instruments A/D converter sampling at 500 Hz. For all analyses and displays, single sweeps and averages were digitally filtered off-line to remove higher frequencies: the digital filter was set to pass frequencies from 0 to 6 Hz using a *Kaiser* filtering algorithm.

P300 at Pz was measured using the Peak–Peak (p–p) method, which, as repeatedly confirmed in our previous studies, is the most sensitive in P300-based deception investigations (e.g., Soskins et al., 2001): The algorithm searches from 350 to 850 ms [1] for the maximally positive 100 ms segment average. The midpoint of the segment defined P300 latency. Then it searches from this P300 latency to 1300 ms for the maximum 100 ms negativity. The difference between the maximum positivity and negativity defines the p–p measure.

[1] Verschuere et al. (2009) used a time window of 350–900 ms post-stimulus for P300 amplitude measurement. Results with the present data set, but based on this 350–900 ms time window were the same as those reported below with our present 350–850 ms time window.

2.4. Analyses, error handling

To determine group effects ANOVAs were run. All data from all artifact-containing trials were discarded so that analyses were done on artifact free trials.

2.5. Within individual analysis: bootstrapped amplitude difference method

To determine whether or not the P300 evoked by one stimulus is greater than that evoked by another *within an individual*, the bootstrap method (Wasserman and Bockenholt, 1989) was used on the Pz site where P300 is typically the largest. This will be illustrated with an example of a probe response being compared with an irrelevant response. The type of question answered by the bootstrap method is: "Is the probability more than 90 in 100 that the true difference between the average probe P300 and the average irrelevant P300 is greater than zero?" For each subject, however, one has available only one average probe P300 and one average irrelevant P300. Answering the statistical question requires distributions of average P300 waves, and these actual distributions are not available. One thus bootstraps these distributions, in the bootstrap variation used here, as follows: A computer program goes through the probe set (all single sweeps) and draws at random, with replacement, a set of n1 waveforms. It averages these and calculates probe P300 amplitude from this single average using the maximum segment selection method as described above for the p–p index. Then a set of n2 waveforms is drawn randomly with replacement from the irrelevant set, from which an average P300 amplitude is calculated. The number n1 is the actual number of accepted probe sweeps for that subject, and n2 is the actual number of accepted irrelevant sweeps for that subject multiplied by a fraction (about .16 on average across subjects in the present report) which reduces the number of irrelevant trials to within one trial of the number of probe trials. The calculated irrelevant mean P300 is then subtracted from the comparable probe value, and one thus obtains a difference value to place in a distribution which will contain 100 values after 100 iterations of the process just described. Multiple iterations will yield differing (variable) means and mean differences due to the sampling-with-replacement process.

In order to state with 90% confidence (the criterion used in previous studies, e.g., Farwell and Donchin, 1991; Soskins et al., 2001; Rosenfeld et al., 1991, 2004) that probe and irrelevant evoked ERPs are indeed different, we require that the value of zero difference or less (a negative difference) not be > -1.29 SDs below the mean of the distribution of differences. In other words, the lower boundary of the 90% confidence interval for the difference would be greater than 0. It is further noted that a one-tailed 1.29 criterion yields a $p < .1$ confidence level within the block because the hypothesis that the probe evoked P300 is greater than the irrelevant evoked P300 is rejected either if the two are not found significantly different or if the irrelevant P300 is found larger.

3. Results

One subject in each group was dropped for behavioral error rates in excess of our formal cutoff of 10% (failing to press unique buttons to targets). Another subject in each group was dropped due to excessive eye movement artifacts. Data from 10 subjects in each group were analyzed. Effect size was estimated by the partial eta squared value, η_p^2.

Table 1
Mean reaction times (in ms) for target, probe and irrelevant stimuli in deception group and control group; standard deviations in ms are given in parentheses. (We do not present comparison Verschuere et al. (2009) RT data with our RT data here as the older study used a different response apparatus than we did in the present study.)

	Target	Probe	Irrelevant
Control group	640.30 (69.66)	561.90 (76.86)	542.00 (82.84)
Deception group	735.30 (88.70)	667.60 (75.93)	611.60 (91.89)

3.1. Behavioral data

All 20 data sets retained for analysis were from subjects whose error rates were less than 8%. There were no differences in error rates between control and deception groups. Neither were there significant differences between total numbers of trials for averaging (probe, target, and irrelevant combined) between groups, although the deception group averaged fewer trials (211.1) than the control group (264.6).

Regarding RTs (for descriptive purposes, see Table 1), a 2 (groups: deception vs. control) × 3 (stimulus types: target vs. probe vs. irrelevant) mixed-model ANOVA revealed a main effect of group; F (1, 18) = 7.86, p<.02, η_p^2 = .304, suggesting that participants in the deception group took a longer time to respond than participants in the control group for all stimuli since no interaction was found between group and stimulus (F (2,36) < 1, p > .4, η_p^2 < .1). There was also a main effect of stimulus type; F (2,36) = 29.25, p < .001, η_p^2 = .619, as is typically reported by Seymour et al. (2000). These findings were similar to those of Verschuere et al. (2009) who did a 2 × 2 stimulus type by group ANOVA, omitting target RT.[2]

3.2. ERPs

Fig. 1 shows the grand average ERPs for the three stimulus types in the two experimental groups studied. The positive P300 proper peaks are indicated with the asterisks under the target P300s which were comparable in both groups (t(18) = .7, p > .05) and of minimal interest otherwise in the present study. The p–p probe P300 (measured here from the positive P300 peak to the subsequent prominent negative peak) appears barely larger in the deception group than in the control group, whereas the irrelevant P300 shows the reverse relation and in larger amount. There appears to be not much difference (about 2 μV) between probe and irrelevant P300s in control subjects, in comparison to the appreciable difference (about 5 μV) in deception subjects. Latency jitter across subjects may distort amplitudes in grand averages, and so Fig. 2, based on averages of computer calculated P300 maxima in each subject, is shown. The actual values of the computer calculated P300 amplitudes are given in Table 2 along with those from Verschuere et al. (2009) for comparison as the present study was run in the same room with same equipment and settings as was the Verschuere et al. (2009) study. The table shows that the P300s in all conditions and in response to all stimulus types in the Verschuere et al. (2009) study were larger than the comparable waveforms reported here.

To confirm these visual impressions, a 2 (groups) × 2 (stimulus types) ANOVA was performed. There was the expected and typical main effect of stimulus type F (1,18) = 72.05, p < .001, η_p^2 = .802. No effect of groups was found: F (1, 18) = .29, p > .5. However, unlike Verschuere et al. (2009), we did find a significant groups × stimulus type (crossover) interaction, F (1,18) = 7.58, p < .02, η_p^2 = .289, indicating that the present deception manipulations led to a greater probe-irrelevant difference in the deception group than in the control group.

These group findings are supported by individual diagnostic data: At the .9 bootstrap criterion, 10 of 10 (all) deception subjects were correctly diagnosed as having probe P300 > irrelevant P300, i.e., guilty, but only 5 of 10 control subjects were detected. Using the two-tailed, Chi-square test, we found our independent proportions (5/10 vs. 10/10) to differ at p < .002 (Chi-square = 6.67, df = 1). Using the more conservative Fisher exact test, we still obtained significance at p < .04. If we counted as guilty one control subject whose probe P300 exceeded the irrelevant 87 (vs the criterion 90) times in 100, the control proportion detected would be 6 of 10, but the new Chi-square value (5.0, df = 1) would remain significant at p < .03.

Another individual diagnostic comparison of interest lending itself to a parametric significance test is the comparison between groups of actual numbers of probe-greater-than-irrelevant iterations out of 100. The means were: control group, 83.5; deception group 97.9; t (9.5) = 2.28, p < .05. We used the separate variance df (see Fig. 3a which will also be noted in the discussion): The variances of the two groups differed with F = 39.55, p < .001.

There were no hypotheses offered about P300 latencies, but for completeness we report that in the control group, probe and irrelevant P300 latencies were 496.0 ms and 434.2 ms, respectively, and 495.6 ms and 451.4 ms, respectively, in the deception group. A groups × stimulus types ANOVA revealed a significant effect only of stimulus types, F (1, 18) = 11.3, p < .004, η_p^2 = .386.

4. Discussion

Consistent with many previous studies (e.g. Elaad and Ben-Shakhar, 1989; Furedy and Ben-Shakhar, 1991; Ben-Shahkar and Elaad, 2003; Kubo and Nittono, 2009), we extended our previous study (Verschuere et al., 2009) regarding the role of deception awareness in the P300-CIT by showing that increasing participants' awareness of being deceptive did increase the CIT's detection efficiency. We believe that our present manipulations succeeded in eliciting a large effect of deception awareness on probe-minus-irrelevant P300 amplitude difference for two reasons: First, we used here a less meaningful probe stimulus, the subject's home town, than the subject's first name, a highly rehearsed item of meaningful information. The more meaningful the probe, the larger the P300 is expected to be (Fabiani et al., 1987; Johnson, 1986), and Rosenfeld et al. (1995) showed that different types of autobiographical probes, differing in salience, produced different sized P300s. If the P300 becomes too large, it probably approaches a limit such that deception awareness manipulations may not appear effective. That this could have happened in Verschuere et al. (2009) is consistent with Table 2 having showed that the P300s in the Verschuere et al. (2009) study were larger across the board than the comparable waveforms reported here. Moreover, the values seen in Table 2 may actually *underestimate* the comparison because Verschuere had only a 1:6 probe probability with four irrelevants, whereas we here had a 1:8 probe probability with six irrelevants. Thus, inasmuch as Fabiani et al. (1987) and Johnson (1986), reviewed the well known inverse relationship between probe probability and P300 amplitude, our rarer probes should have evoked the *larger* probe P300s rather than the actually smaller ones compared to those reported by Verschuere et al. (2009). That deception awareness helps the detection of less rehearsed information may also help in field situations in which one investigates for recall of incidentally learned crime details that are not as well rehearsed as one's home town that we used here.

Secondly, and perhaps more important, the continuous (though bogus) feedback about deception received by the deception group but not the control group in the present study probably helped maintain subjects' awareness of their deception such that each probe presentation, and behaviorally denied recognition, had its original salience reinforced. By contrast, the control instructions imparted no awareness of deception whatever. The feedback received by the control group, with its emphasis on correct button responding, was more likely to focus subjects' attention to the explicit target/non-target discrimination task, such that less attention was paid to noticing probe occurrences. Indeed the emphasis on correct target detection could have distracted control subjects' attention away from probe recognition. One might

[2] We do not compare Verschuere et al. (2009) RT data with our RT data here as the former study used a different response apparatus than we did in the present study.

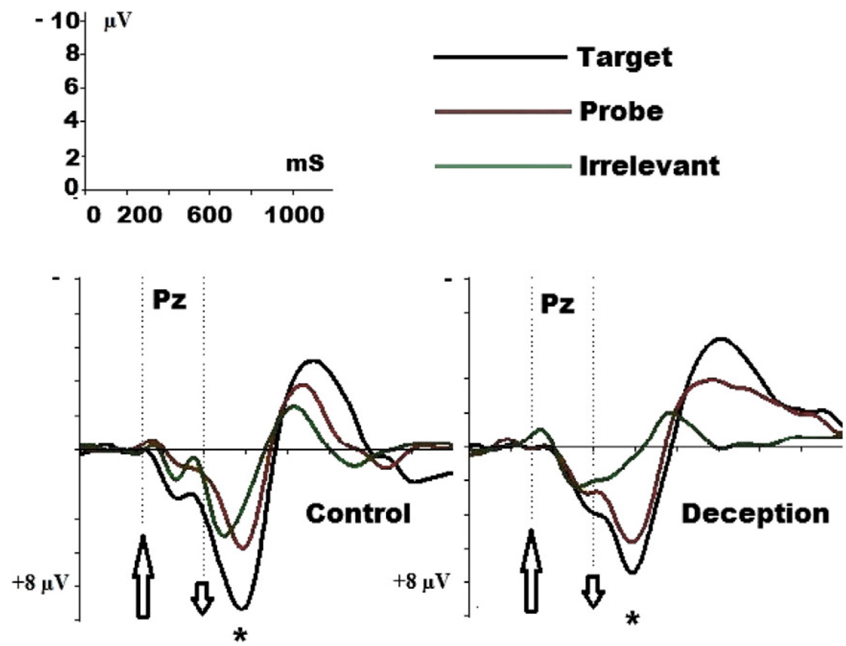

Fig. 1. Grand averaged Pz ERPs from control (left) and deception (right) groups. Asterisks under target waves indicate P300 positive peaks. Up arrows indicate stimulus onset, down arrows indicate offset 300 ms later.

then have expected larger target P300s in control subjects than in deception subjects. However, the major group difference between groups' P300s is in the irrelevant waveforms, not in the target waveforms. Clearly, however, the significant difference in CIT effect (probe-minus-irrelevant P300 differences) found between groups is consistent with the notion that probes and irrelevants were experienced more similarly in the control group subjects than in the deception group. This finding is also consistent with those of Kubo and Nittono (2009) who found that having an intention to conceal information elicited larger probe-irrelevant P300 differences than having no intention to conceal information among participants.

The RT data were also consistent with the view that participants in the deception group paid more attention to stimuli and/or devoted more resources to processing them than the control group, as the RTs in the deception group were notably greater than those in the control group, as also found by Verschuere et al. (2009).

Fig. 3, however, suggests that although the deception group seemed homogeneous, with all subjects well detected, the control group members did not all respond in the same manner. Fig. 3a in particular shows that the five detected control subjects have iteration number values that fall perfectly within the comparable distribution of the deception group, but that the five undetected control subjects (significant iterations<90/100) may indeed represent a different population. (This trend is reflected to some extent by the probe-irrelevant amplitude difference distributions of Fig. 3b.) This sub-population would be one so evidently distracted by control instructions and thus focused on the target task that they behaved more like innocent subjects showing very little probe-irrelevant difference, whereas the detected subjects were more focused on probe familiarity. Fig. 4 was constructed to preliminarily examine these hypotheses. It shows partial grand averages of detected control subjects at right and non-detected control subjects at left (statistical tests seemed inappropriate in groups with only five subjects each). As expected, the probe-irrelevant differences are greater in the detected subjects; in fact the irrelevant P300s are even slightly larger in undetected subjects. Consistent with the preceding hypotheses, the probes and targets appear to be equally attended in the detected subjects as their P300s have similar amplitudes, both greater than irrelevant P300s. In contrast, in the undetected subjects, the target P300s tower over those of similarly smaller probe and irrelevant P300s, and also seem appreciably larger than the target P300s in the detected group, suggesting as hypothesized above, that the targets received most of the subjects' attention in this sub-population of the control group.

Although the above speculations need confirmation in larger groups, for applied purposes, the present experiment illustrates that instructions designed to raise deception awareness will probably lead to more effective detection of concealed information than will deception-neutral instructions designed to emphasize the target discrimination task in the 3-stimulus protocol. However, we noted in the methods section that

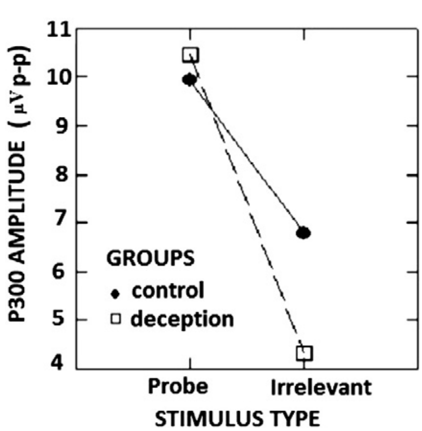

Fig. 2. Average of computer calculated P300 values (µV, p–p) as a function of groups and stimulus types.

Table 2
Computed mean p–p P300 amplitudes, µV (sd); 2 studies.

	Deception group	Control group
Present study		
Probe	10.48 (3.68)	9.93 (5.15)
Irrelevant	4.30 (3.18)	6.78 (4.41)
Verschuere et al. (2009) study		
Probe	14.72 (9.73)	12.64 (5.24)
Irrelevant	8.64 (4.43)	9.44 (5.07)

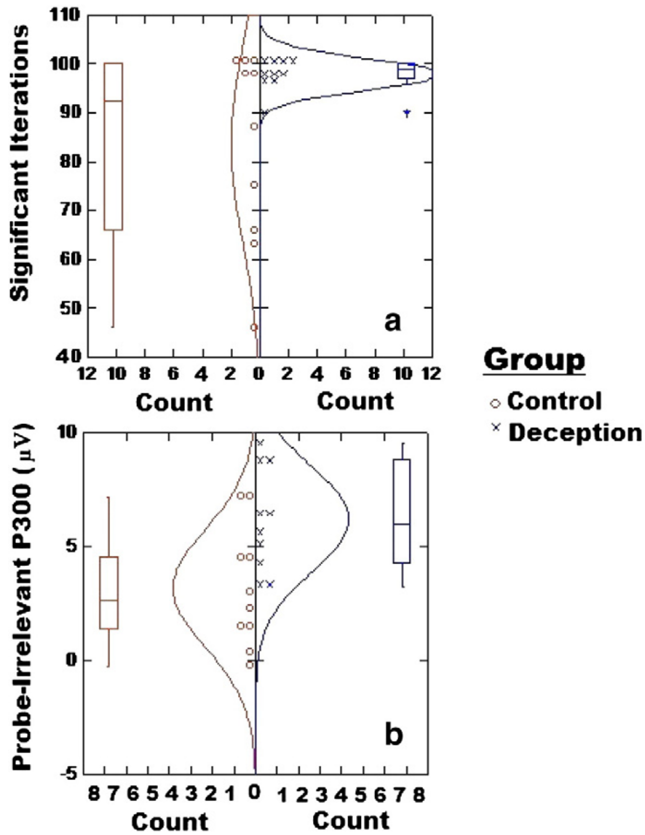

Fig. 3. Top (a) shows frequency distributions of numbers of subjects (x-axis) with indicated numbers of bootstrapped iterations (y-axis) in the two groups. 100 is the maximum on the y-axis, and 90 out of 100 was required for a guilty decision. Bottom (b) shows frequency distributions of numbers of subjects (x-axis) with indicated values of (Probe P300 — Irrelevant P300) voltage differences (y-axis) in the two groups.

the present manipulations were not intended to constitute a formal comparison between the specific methods of Rosenfeld et al. (1988, 1991) and those of Farwell and Donchin (1991). The primary intent was to compare the effect on concealed information detection of *enhanced* deception awareness manipulations with those of manipulations designed to keep subjects focused on the target discrimination task. In other words, we attempted to exaggerate deception awareness manipulations and compare these effects with those of exaggerating target discrimination manipulations as used by Farwell and Donchin (1991). It remains quite possible that using more neutral instructional methods in the present controls—like those of Farwell and Donchin (1991)—may have produced better detection rates than those actually seen in the present controls. Indeed Farwell and Donchin (1991) reported 87% classification accuracy overall.

It is acknowledged that the present results do not allow a conclusion about whether it was the change in stimulus type (first name vs. home town) or the continuous feedback used here or both which produced the stronger detection effect in the present deception group. It is also possible that the stimulus salience moderates the enhanced detection efficiency induced by deception awareness: for well-rehearsed stimuli such as one's first name, deception awareness may not be that helpful; yet for less-rehearsed stimuli such as hometown or incidentally acquired crime-relevant information, deception awareness may be more effective, as shown here.

It is also acknowledged that although we have used the phrase "deception awareness manipulation" throughout this report, since the actual operations used in the deception group involved direction of subjects' attention to their deceptive behaviors, we cannot know from this study what the actual cognitive psychophysiological source or mediator of the effect is. As noted above, we believe that the deception manipulation tended to force subjects' attention to the probe-irrelevant dimension in the deception group, but not in the control group, whose attention was directed to the target–nontarget dimension,[3] and that this would tend to enhance P300 effects in the former group because P300 amplitude depends in large part on attention to the probe dimension (Donchin et al., 1986; Fabiani et al., 1987). It is possible that some other cognitive consequence of the deceptive responses could have been the true mediator of the reported effects (e.g. response monitoring, Hu et al., 2011; Johnson et al., 2004). It is also possible that since we provided feedbacks regarding participants' deceptive responses, these feedbacks therefore heightened participants' motivation to defeat the test, which in turn improves the CIT's sensitivities (Stern et al., 1981; Gustafson and Orne, 1963).

The present study of course did not need nor use an innocent control group since the aim was to compare two guilty groups treated differentially. This may raise the apparent concern that the present deception manipulation that enhances probe-irrelevant differences might have such effect in an innocent subject, and thereby tend to produce false positives, which would reduce the manipulation's field utility. Under closer scrutiny, this is not a logically justifiable concern in that the manipulation is non-selective, meaning that there is no reason to expect that enhancing deception awareness in an innocent person (i.e., ignorant of the correct probe identity) should specifically select any one of the irrelevant stimuli for enhancement of salience. In any case, the present question concerned the effect of deception awareness in a guilty group. The effect on innocents could be investigated in the future. One could also raise an ethical concern about giving false feedback to subjects, especially innocents. Although this is not a present scientific concern, and it is possible to debrief an innocent suspect in a field CIT after clearing him/her of suspicion, this is a legitimate concern regarding the appropriateness of lying in the field to innocent subjects by giving bogus feedback.

This last point begs the question of whether or not and how to use such deception awareness manipulations in the more recently utilized *complex trial protocol* (Rosenfeld et al., 2008). In this relatively more countermeasure-resistant protocol (Rosenfeld, 2011), subjects have the target discrimination task separated from the presentation of probe or irrelevant at trial onset, and subjects respond with the same button press regardless of which stimulus (probe or irrelevant) is first presented. There is no explicit deception required with such a button press that simply indicates stimulus perception. Thus, in this protocol one cannot logically give feedback about deception. On the other hand, it is certainly possible to alert subjects, prior to their run, and to reinforce via feedback during the run that they may be seeing some relevant and familiar information on occasional trials, and that it is to their advantage to conceal its recognition (if for example it is a crime relevant detail). This kind of consciousness-raising could likely have the same effect as the present bogus deception feedback manipulation, but this will remain a hypothesis until future testing. It is also clear that the planned future use of the complex trial protocol also solves to a large extent the problems raised by accusing possibly innocent subjects of deception in the present 3-stimulus protocol. This is precisely because the feedback in the complex trial protocol cannot be about deception, but merely recognition. Moreover, the feedback need not be fake; it can be given following a subject's single probe trials that are computer-observed to contain a large P300.

As mentioned above, the current ERP findings correspond with the ANS-based CIT studies reporting that deceptive responses enhance the test's sensitivity in memory detection (Furedy and Ben-Shakhar, 1991; Ben-Shahkar and Elaad, 2003). Moreover, for the recently developed

[3] We thank Emanuel Donchin for reminding us of this interpretation in personal communications.

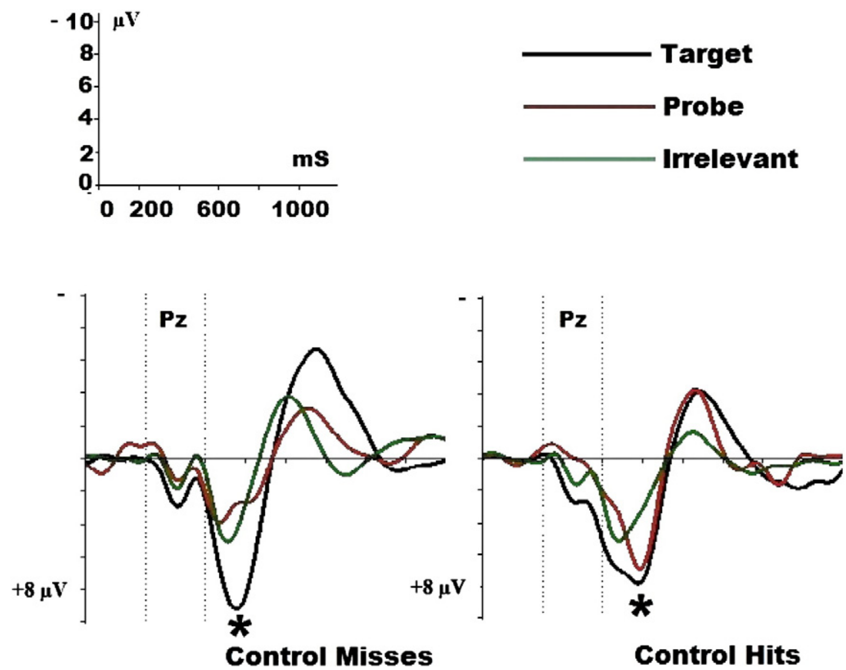

Fig. 4. Grand averaged Pz ERPs from undetected control subjects (left) and detected control subjects (right) groups. Asterisks under target waves indicate P300 positive peaks. Up arrows indicate stimulus onset, down arrows indicate offset 300 ms later.

fMRI-based memory detection methods, although it has been found that it is memory-retrieval process driving probe-irrelevant differences (Gamer et al., 2012), whether increased deception awareness could similarly improve the test's sensitivity remains to be addressed.

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Appendix A

Deception group false feedbacks:

1) "Based on your brain waves in the past several minutes, we see you are lying on certain trials, but mostly following button press instructions very well."
2) "Based on your brain waves in the past few minutes, we see you are still lying on a few trials, but following button press instructions well."
3) "Based on your recent brain waves you are lying on certain trials, but mostly following other instructions."
4) "Based on your brain waves in the past several minutes, we see you are lying on certain trials, but mostly following button press instructions very well."
5) "Based on your brain waves in the past few minutes, we see you are still lying on a few trials, but following button press instructions very well."
6) "Based on your recent brain waves you are lying on certain trials, but mostly following other instructions very well."

Control group false feedbacks:

1) "Based on your brain waves in the past few minutes, we see you are making mistaken button presses on certain trials, but mostly following button press instructions very well."
2) "Based on your brain waves in the past several minutes, we see you are still making a few mistaken button presses on a few trials, but following button press instructions well."
3) "Based on your recent brain waves, we see you are making some mistaken button presses on certain trials, but mostly following other instructions very well."
4) "Based on your brain waves in the past few minutes, we see you are still making occasional mistaken button presses on certain trials, but mostly following button press instructions very well."
5) "Based on your brain waves in the past several minutes, we see you are still making mistaken button presses on a few trials, but following button press instructions well."
6) "Based on your recent brain waves, we see you are still making a few mistaken button presses on certain trials, but mostly following other instructions very well."

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