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P900: A Putative Novel ERP Component that Indexes Countermeasure Use in the P300-Based Concealed Information Test

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Abstract Countermeasures pose a serious threat to the effectiveness of the Concealed Information Test (CIT). In a CIT experiment, Rosenfeld and Labkovsky in Psychophysiology 47(6):1002–1010, (2010) observed a previously unknown positive ERP component at about 900 ms post-stimulus at Fz and Cz that could potentially serve as an index of countermeasure use. Here, we explored the hypothesis that this component, termed P900, occurs in response to a signal that no further specific response is required in a trial, and could thus appear in countermeasure users that respond differentially depending on the stimulus that appears. In the present experiments, subjects viewed four non-meaningful (irrelevant) dates and one oddball date. In three experiments, we examined P900's antecedent conditions. In the first, the unique item was a personally relevant oddball (the subject's birthdate). In a second, the unique item was a non-personally relevant oddball (an irrelevant date in a unique font color). In a third, all dates were irrelevant. We speculated that the presence of an oddball would not be necessary for P900. All participants made countermeasure-like responses following two specific irrelevant dates. As hypothesized, P900s were seen to *non-responded-to* irrelevant and oddball stimuli in all subjects but not to *responded-to* irrelevant stimuli, and the presence of an oddball was not necessary for elicitation of P900. This finding has potential application in deception settings—the presence of a P300 accompanied by the presence of a P900 in response to non-countered stimuli could provide evidence of incriminating knowledge accompanied by the attempt to use countermeasures to evade detection.

Keywords ERP · P900 · Countermeasures · Readiness potential

Introduction

The detection of deception and concealed information has been the focus of much research over the past 25 years. The most widely used deception detection protocol, the Control Question Test (CQT), consists of two critical item types: relevant questions and control questions. Relevant questions are germane to the subject of the investigation (e.g., did you shoot and kill your roommate on April 1, 2012?), while control questions are deliberately vague questions about past actions that relate to the relevant question (e.g., prior to April 1, 2012, have you ever hurt anyone?). Control questions are broad and are introduced in such a way that the examinee will eventually answer "no" to them, even though the truthful answer is assumed to be "yes" among all examinees, both innocent and guilty of the crime being investigated. However, the innocent subject will remain concerned about them while the guilty subject focuses on the relevant question. Thus, because innocent examinees answer the relevant questions truthfully but feel deceptive about the control questions, they are expected to react more strongly to control questions, while the opposite response pattern is expected in deceptive examinees. The CQT has been surrounded by controversy, specifically with regard to high false-positive rates—instances in which a truthful person is erroneously classified as being deceptive (The National Research Council 2003; Ben-Shakhar 2002). As a result, the control question test is considered inadmissible in nearly all

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courts unless stipulated to by both parties (Iacono and Lykken 2005).

The Concealed Information Test (CIT, Lykken 1959) is a different type of credibility assessment protocol. Instead of attempting to detect actual lying (the goal of the CQT), the goal of the CIT is to determine whether an individual possesses knowledge of specific details of a crime or event. Guilt could then be inferred based on the presence of this knowledge. For example, if a murder was committed at 800 Church Avenue with a 0.38 caliber revolver, the CIT seeks to determine whether a suspect recognizes the address where the crime was committed and the type of weapon used. The CIT presents subjects with various stimuli, one of which is a crime related item (the *probe*; such as the gun used to commit a murder). Other stimuli consist of items from the same *category* as the probe but which are not actually relevant to the crime (*irrelevants*; such as other potentially deadly weapons: a knife, a bat, etc.) such that an innocent person should be unable to discriminate them from the crime related probe item. If the subject's physiological response is greater to the probe item than to irrelevant items, then knowledge of the crime or other event is inferred.

Among the problems with polygraph methods for detecting deception is their potential susceptibility to *countermeasures* (The National Research Council 2003). Honts et al. (1996), p. 84, defined countermeasures as, "anything that an individual might do in an effort to defeat or distort a polygraph test." The National Research Council report went on to state that, ''Countermeasures pose a serious threat to the performance of polygraph testing because all the physiological indicators measured by the polygraph can be altered by conscious efforts through cognitive or physical means'' (The National Research Council 2003, p. 4). More specifically, countermeasures are effective against both the polygraphic CQT (Honts et al. 2001), and the polygraphic CIT, (Honts et al. 1996; Ben-Shakhar and Dolev 1996).

When the P300 ERP component was introduced as the dependent index of recognition in the CIT (Farwell and Donchin 1991; Rosenfeld et al. 1988; Rosenfeld et al. 1991), many expected that this new method would be invulnerable to countermeasures (e.g., Lykken 1998). Unfortunately, Rosenfeld et al. (2004) and Mertens and Allen (2008) showed that the original form of the P300-based CIT was quite vulnerable to countermeasures: subjects simply learned to make secret responses (e.g., toe wiggles) to *irrelevant* items, converting them into covert target items that evoked P300s indistinguishable from the *probe* P300s and thus defeating the test. Both physical and mental countermeasures have been shown to be effective against the P300-based CIT (Rosenfeld et al. 2004; Rosenfeld and Labkovsky 2010). This prompted our lab to develop a novel P300 protocol (the complex trial protocol) which by design has thus far better resisted previously effective countermeasures (Rosenfeld et al. 2004; Mertens and Allen 2008) in three new studies (Rosenfeld et al. 2008; Rosenfeld and Labkovsky 2010; Winograd and Rosenfeld 2011). However, in some cases, as many as 18 % of subjects using countermeasures still beat the new ERP test (Sokolovsky et al. 2011). Reaction Time (RT) helps identify some of these as countermeasure users (Winograd and Rosenfeld 2011), but RT can, to a large extent, be voluntarily controlled (Hu et al. 2012). It would thus be useful to have an *involuntary* index of countermeasure use as a way of identifying uncooperative subjects.

In a recent deception study, Rosenfeld and Labkovsky (2010) reported a previously unknown ERP component (termed P900) that may be such a countermeasure index. In the present study we further explore this novel P900 wave, which to our knowledge, has not been previously reported in waking conditions similar to the ones in which we observed it. In Rosenfeld and Labkovsky (2010), subjects participating in a CIT executed discrete countermeasure responses to two of four non-meaningful dates (termed *irrelevant* dates) by secretly making an extra mental response when those items appeared—for one of the items, the participant was instructed to imagine his own first name immediately upon seeing the stimulus, and for the other he was instructed to imagine his last name. The P900 component, occurring 850-950 ms post stimulus, was seen in response to uncountered irrelevant dates, but was not seen in response to countered irrelevant dates, nor to meaningful dates (*probe* dates) in the ERPs of guilty subjects who were not countering any stimuli. Unlike the Pz-dominant P300, P900 was larger at Cz and Fz than at Pz, where it was usually not seen.

Because P900 was present only on trials in which the subject did not make an additional countermeasure response, we hypothesized that P900 represented the participant's appreciation, upon seeing the probe, that his job for the trial was finished as there was no further response, i.e., a countermeasure, that needed to be made on that trial. Likewise, recognition of one of the two irrelevant stimuli *not* requiring a countermeasure response would also signal the participant that no further response was necessary, and we also saw smaller P900s at Cz in these non-countered irrelevant ERPs, although these were not analyzed.

At least one other experiment has observed a positive peak at 900 ms in an oddball experiment; Hull and Harsh (2001) gave participants an auditory oddball task in which participants were instructed to make a special response (a finger lift) to target items, the probability of which varied according to experimental condition. However, Hull and Harsh did not systematically examine the extent to which P900 was related to response processing; they observed

P900 on both target and nontarget trials equally. There were other large differences between that study and this one—that study was a sleep study, in which participants were instructed to deprive themselves of 3 hours of sleep the night before, and was primarily interested in examining variations in ERP amplitudes based on various different stages of sleep. To our knowledge, no other report has described a P900 similar to the one that we serendipitously observed and formally replicate here.

In the current report, we further explore antecedent conditions which may or may not be necessary for elicitation of our putative new countermeasure-use index, the P900. For example, in Rosenfeld and Labkovsky (2010), there were other antecedent conditions operating that may have been relevant for elicitation of the P900. The italicized phrases that follow indicate these conditions. Specifically, there were four antecedent conditions that were present in Rosenfeld and Labkovsky (2010) but that we do not hypothesize as necessary for elicitation of P900. First, there was the recognition of *personally relevant information*. In Rosenfeld and Labkovsky (2010), participants observed a series of dates, one of which was the participant's birthdate—a personally relevant item. We have no a priori reason to think that the presence of personally relevant information should be necessary for the elicitation of P900, but we did see large P900 peaks to those trials containing personally relevant information (probe trials), so we here test our hypothesis that P900 can still be elicited without the presence of personally relevant information. Second, the personally relevant information in Rosenfeld and Labkovsky served as an *oddball* (low probability) stimulus, but if our hypothesis that P900 represents the participant's cognitive realization that no further response is required, there should be no reason why the presence of an oddball stimulus is necessary for elicitation of P900. Thus, in one experiment in the present study, we attempt to elicit P900 without any oddball stimulus.

Third, Rosenfeld and Labkovsky used our novel *complex trial protocol* for *detection of concealed knowledge*,[1] which involves the presentation of two stimuli per trial and could potentially be necessary for elicitation of P900 (though we hypothesize that it is not). In the present experiments, we use one simple, single stimulus presentation per trial, predicting that use of the CTP is not a necessary antecedent condition for elicitation of P900. Fourth, in this complex trial protocol, the participant must also make a *target versus non-target response*: About 2 s after presentation of the probe or irrelevant stimulus, a second stimulus, one of five number strings, is presented, and the participant must decide if the string is a target stimulus, and if so, must make a unique response. Once again, we do not expect that this target/nontarget stimulus and response should be necessary for elicitation of P900, and so we remove them in this series of experiments.

In the present study, in order to further explore the possibility that P900 represents the participant's realization that the just-presented stimulus does not require a further specific response, we present a series of three experiments in which we systematically remove several of the antecedent conditions (in italics in the two immediately preceding paragraphs) from the Rosenfeld and Labkovsky study that we presently hypothesize as *not* necessary for the elicitation of P900—specifically, the experiments do not use the complex trial protocol, do not contain a target versus nontarget stimulus and response, and sequentially remove personally relevant and oddball stimuli. We predict that as in Rosenfeld and Labkovsky (2010), we will observe larger P900 amplitudes when participants do not have to make a specific response to an item. From an applied perspective, understanding the necessary antecedent conditions required to elicit P900 will be critical in deploying it as an index of countermeasure use, as CIT protocols will not always have the same conditions that were used in Rosenfeld and Labkovsky (2010). A better understanding of what is required to elicit P900 could allow us to design better protocols that will elicit it and may therefore allow the detection of countermeasure use.

Method

Subjects and Stimuli

Participants were 38 students (20 males and 18 females) from the Northwestern University introductory psychology subject pool. All participants gave written consent following a protocol approved by the Northwestern University Institutional Review Board. All had normal or corrected vision and ranged in age from 18 to 23. All participants were right handed and were screened to ensure they did not have any history of head injury, epilepsy, or other neurological conditions. Subsets of these subjects were randomly assigned within each of three sequentially run experiments: (1) A *Probe* experiment (n = 13, 6 males), in which a

[1] For a detailed explanation of the complex trial protocol, see Rosenfeld et al. (2008). The basic difference between the complex trial protocol and the typical older P300-based CIT, sometimes termed the "three-stimulus protocol," is the grouping of stimuli that are presented to the participant. The three-stimulus protocol has a single trial type, on which one of three types of stimuli may be presented, a probe, an irrelevant, or a target (a target is a non-meaningful stimulus, like an irrelevant, that requires a special response from the participant in order to force attention to the task). In contrast, the complex trial protocol divides each trial into two separate stimulus presentation periods: during the first period either a probe or an irrelevant is presented, and during the second period either a target or a nontarget is presented, as described above.

participant saw on each trial one of five date stimuli, one of which, the *probe,* was the participant's birth date, and four other date stimuli which had no personal meaning (*irrelevants*). All stimuli were presented in white font on a black background. As noted in the introduction, the purpose of the probe experiment was to mimic the conditions of Rosenfeld and Labkovsky (2010) by presenting a personally relevant item among other irrelevant items. (2) A participant in the *Color* experiment (n = 12, 7 males) saw on each trial one of five irrelevants, all in white font on a black background, except for one *oddball* stimulus which was an irrelevant presented in *red font* (none of the stimuli in this experiment had personal relevance for the participant). The purpose of the color experiment was to retain the presence of an oddball item, but remove the presence of personally relevant information, allowing us to determine whether presentation of personally relevant information is necessary for the elicitation of P900. (3) A participant in the *Innocent* experiment (n = 13, 7 males) saw one of five dates on each trial where all five date stimuli were in white font on a black background and were irrelevant to subjects. One of these was designated as an *oddball* for comparative purposes, in that its elicited ERP was separately averaged (as in the innocent control participants of many P300-based deception experiments). However, the stimulus designated as a oddball was simply another irrelevant item with no special meaning to the participant. The purpose of the innocent experiment was to eliminate the presence of an oddball item, allowing us to determine whether presentation of an oddball is necessary for the elicitation of P900. However, all three experiments had in common that the subject must make an additional button response on some items but not on others, and we anticipated that trials where such a response was not necessary would elicit a P900.

All stimuli were 1 cm tall and were presented for 300 ms, once every 4 s on a display screen located 1 m from the participants' eyes. Dates were presented in the form of the three letter abbreviated month followed by the date (e.g., MAR 9, AUG 4, APR 23, etc.). Each of the five randomly presented dates was presented in a random order an equal number of times such that each date had $p = .2$. Each subject was asked before the running block—one block per experiment—to verify that irrelevant dates had no personal meaning to the subject, and inadvertent exceptions (e.g., a parent's or friend's birth date) were replaced by confirmed irrelevant dates.

Procedure

After entering the lab, and having electrodes applied, participants were informed that they were about to have brain waves recorded while they performed a response task. After screening irrelevant stimuli (described above), participants were told that they would be seeing a series of dates one at a time every few seconds. For each participant, two randomly selected irrelevant dates were designated as "responded to" stimuli, requiring them to make right hand button responses. For one date, participants were told to immediately press the left button on a two-finger response box under the right hand. For the other date, participants were told to immediately press the right button on a two-finger response box under the right hand (none of the remaining three stimuli were to be followed by a right hand press). These were considered to be analogous to countermeasure responses to designated irrelevant stimuli in deception experiments (such as Rosenfeld et al. 2004; 2008, Rosenfeld and Labkovsky 2010).[2]

Participants were further instructed that on *all* trials they should acknowledge having seen the stimulus (regardless of which stimulus was presented) by pressing one randomly selected button on a five-button response box under their *left* hands. They were advised to keep these selections random and that we would be monitoring the randomness of their selections. During the recording we verified that subjects were randomizing the choices, avoiding pressing the same button repeatedly, and not developing any other pattern of button presses. On those trials where responded-to stimuli appeared and a right hand button response was also required, participants were instructed to make the right hand response first, followed by the randomly selected button with the left hand. These random responses were regarded as analogous to the stimulus acknowledgements in our previous complex trial protocol for P300-based deception detection (Rosenfeld and Labkovsky 2010) in which we first observed P900, and we therefore retained them here, while removing other (hypothetically unnecessary) features of the complex trial protocol. To summarize, each trial proceeded as follows: (1) a stimulus appeared, (2) if that stimulus was a responded-to item, the participant pressed the appropriate button with his right hand (a "countermeasure-like" response), and (3) for all stimuli, the participant pressed a random button using his left hand (see Fig. 1). All stimuli were shown in white font 0.7 cm high on a monitor approximately 70 cm in front of the subject.

As in all of our recent studies (e.g., Rosenfeld and Labkovsky 2010), we forced attention to the stimuli by

[2] While some recent P300-based CIT research has used mental countermeasures, as those used in Rosenfeld and Labkovsky (2010), CIT countermeasures have traditionally been physical movements, such as a wiggling of the finger or toe. For example, Rosenfeld et al. (2004) instructed each participant to press a finger imperceptibly against his leg; highly similar to the overt button presses used here. We chose to use explicit movements like this because they allow the experimenter to monitor that participants are actually making responses, and they also allow for the measurement of reaction time to the button presses.

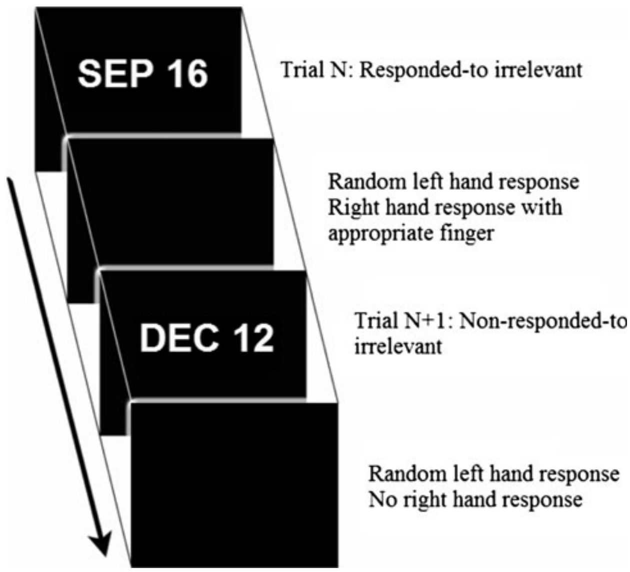

Fig. 1 Structure of two example trials, featuring one responded-to stimulus and one non-responded-to stimulus

interrupting the run unpredictably every 20–40 trials and requiring the subject to identify the presented stimulus by speaking it aloud. Prior to the run we told each participant that he would be asked at various times throughout the experiment which date last appeared. Subjects failing to correctly name the stimulus on more than two such tests were to be removed from the sample, but no such cases occurred.

Data Acquisition

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 located laterally above and medially 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 40uV. 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 Contact Precision Instruments amplifiers with a 30 Hz low pass filter setting, and high pass filters set (3db) at 0.3 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 up to pass frequencies from 0 to 6 Hz using a "Kaiser" filtering algorithm.

P900 was measured at Cz, as our previous study (Rosenfeld and Labkovsky 2010) found it to be most prominent at that site. While the use of three electrode sites allowed us to ensure that the P300 scalp distribution was parieto-central, we chose to report P900 data only from Cz for three reasons. First, our initial goal was to simply replicate our results from Rosenfeld and Labkovsky (2010), so we focused our analyses there. Second, we wanted to maintain simplicity, given that our purpose here was to test a very basic hypothesis regarding the cognitive processes associated with P900. Though this may limit the strength of the conclusions we may draw, we prioritize a simple interpretation in a preliminary study like this one. Third, from an applied perspective, the most effective way to use P900 to detect countermeasures in a CIT would be to measure it where it is the largest, and thus provides the greatest distinction between countered and non-countered stimuli. We measured P900 (baseline-to-peak) as the difference between the 100 ms pre-stimulus baseline average voltage and the maximum positive average 100 ms voltage between 800 and 1,000 ms post-stimulus.

P300 was measured at Pz (where it is typically largest) using the Peak–Peak (p–p) method, which, as repeatedly confirmed in our previous studies of oddball recognition, is the most sensitive in P300-based deception investigations (e.g., Soskins et al. 2001): The algorithm searches from 300 to 650 ms for the maximally positive 100 ms segment average. The midpoint of the segment defines P300 latency. The algorithm then searches from this P300 latency to 1,300 ms for the maximum 100 ms negativity. The difference between the maximum positivity and negativity defines the p–p P300 measure.

Analyses

Our hypothesis was that P900 represents a participant's realization that no specific response is required for that stimulus, regardless of its possible oddball or non-oddball nature, the presence or the absence of a deception situation, or the presence or absence of secondary target discrimination. This hypothesis predicts that *oddball* and *non-responded-to* irrelevant stimuli in each of the three experiments will elicit equivalent Cz P900s that will be greater than P900-absent ERPs to *responded-to* irrelevants. This prediction was tested with two planned orthogonal contrast expectations in each experiment: (1) There will be no difference between P900 amplitudes of *oddball* and *non-responded-to* irrelevant stimuli; and (2) There will be a difference between mean combined P900s of *oddball* and *non-responded-to* versus *responded-to* irrelevants in each experiment, with the former amplitude set larger than the latter.

Second, regarding possible Pz P300 responses: in the Probe and Color experiments, but not in the Innocent experiment, there should be a larger P300 to salient *oddball* than to *non-responded-to* irrelevant stimuli. Oddballs are salient because of relative rareness ($p = .2$) and personal significance (birthdates) or unique color. There should also be P300s to *responded-to* irrelevant stimuli (compared to *non-responded-to* irrelevants) because of task relevance (button responses) and moderate rareness ($p = .4$). It is noted that the P300s are not expected to be large in the Probe and Color experiments since probabilities of all P300-eliciting stimuli in these experiments sum to 0.6.

Results

Qualitative results are described first, followed by statistical confirmation. Cohen's *d* values are provided as a measure of effect size. Grand average ERP waveforms are shown in Fig. 2, plotted separately by experiment in the three columns and with the stimulus types indicated in colors. P900s are indicated with vertical lines (drawn at exactly 900 ms) in the top row, showing Cz data, where P900 has been more prominently observed. P300s are indicated in the bottom row, showing Pz data, where P300 is usually largest. In the *oddball* stimulus waveforms (solid line), the P900s are at about 850 ms for the Probe and Innocent experiments, and at about 925 ms in the Color experiment. The *non-responded* stimulus waveforms (dashed line) also show small P900s. It is evident that both *oddball* and *non-responded* waveforms are clearly more positive than the *responded-to* waveforms (dotted line) in all participants in the time region around 900 ms, as expected.

The P300s are most evident in the *responded-to* waveforms at about 500–550 ms. The *oddball* stimulus in the Color experiment also shows a clear P300 at a similar latency. In the Probe experiment, the grand average *oddball* waveform suggests a P300 via an inflection at the 500–550 ms latency. There was considerable between-subject latency jitter for P300 in this experiment, perhaps accounting for the relatively small P300 in this grand average. In the Innocent experiment, the clearest peak–peak P300 is seen in the *responded-to* waveform, as expected.

Figures 3 and 4 show bar graphs based on computer calculated P900 and P300 amplitudes, respectively. As described above, our algorithm searches within a pre-defined search window to find maximum positivities for each individual, and it is clear in Fig. 4 that despite what was seen in the grand averages of Fig. 2, for the *oddball* stimulus, computed P300s are numerically largest in Probe and Color experiments, with no P300 evident for the *non-responded-to* stimuli. The *responded-to* stimulus evoked the largest P300s in all participants, as expected. Figure 3 shows that within each experiment, the P900s are numerically largest for *oddball* stimuli, next largest for *non-responded-to* irrelevant stimuli, as expected, and greatly reduced as predicted in response to *responded-to* stimuli. It appears that the relative P900 reduction in the Innocent experiment is greatest, however this is likely related to the large negative rebound from P300 seen in the Innocent experiment. Indeed, as suggested by Figs. 2 and 4, the P300 is numerically largest in the Innocent experiment and in response to the *responded-to* stimulus because in that

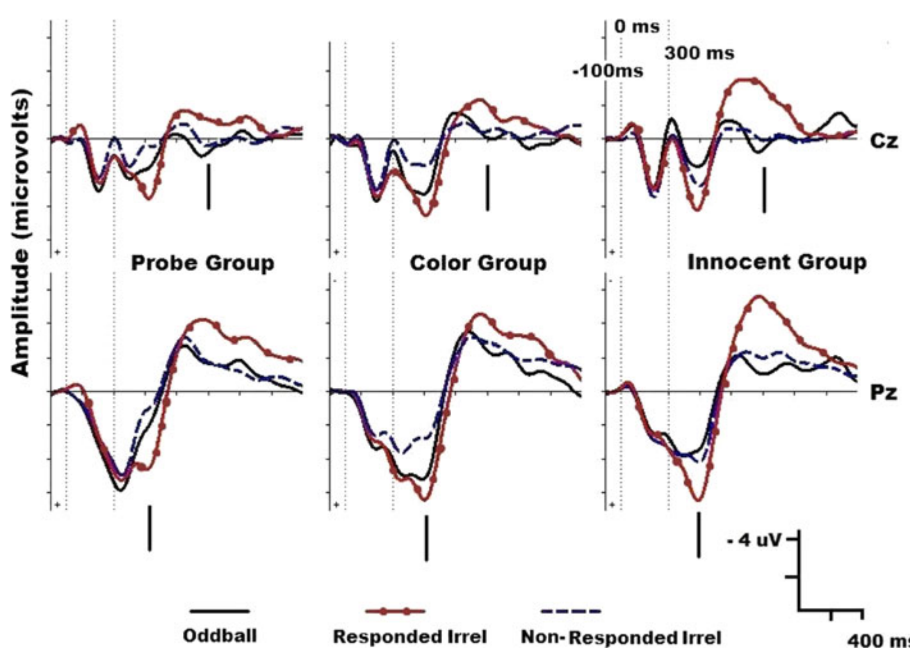

Fig. 2 Grand averages to *Oddball*, *responded-to* (*Responded Irrel*), and *not responded-to* (*Non-Responded Irrel*) irrelevant stimuli in the Probe, *Color*, and Innocent experiments (each called "Group" in the figure) at Cz and Pz. Vertical bars in Cz waveforms indicate 900 ms post-stimulus. P900 at Cz is distributed about these marks in all 3 experiments. *Vertical bars* in Pz waveforms indicate P300 in *responded-to* stimuli at about 400 ms post-stimulus. Y-axis is at −100 ms, as stimulus onset is at 0 ms, offset at 300 ms; the latter 2 time markers indicated with dotted *vertical lines* as shown in upper right panel

experiment, the *responded-to* stimulus is the only salient stimulus, as there is no *oddball* stimulus in terms of personal meaningfulness or physical uniqueness (red color).

This last finding perhaps raises the question of whether or not the P900 is a real positive component, as opposed to the possibility that one cannot observe P900 if the negative-going P300 recovery is so large as to overwhelm and obscure the positive-going P900. Figure 5 was composed to partially address this issue. It shows data similar to the top (Cz) row of Fig. 2 except it shows three representative *individual* average *oddball* and *responded-to* waveform sets from three single subjects in each of the three experiments (a *non-responded-to* waveform is also shown only for the Innocent experiment subject at right for purposes of clarity). It is evident in Fig. 5 that for each subject the *oddball* P300 recovery is as great as or greater than the negative recovery from P300 of the other waveforms, yet this *oddball* waveform shifts immediately positive to the P900 peak for each subject.

For P900 analysis, we specified two planned orthogonal contrasts to be done within each experiment, with specific predictions. We expected P900 peaks in all three experiments in response to *oddball* and *non-responded-to* stimuli, with no differences between these two stimulus types. We expected no P900 to the *responded-to* stimuli in each experiment, such that the comparison of the mean P900s to combined *non-responded-to* and *oddball* stimuli versus the P900 to the *responded-to* stimuli would be significant. In confirmation and as suggested by the figures, there were no significant differences between P900s to *oddball* and *non-responded-to* stimuli in all experiments: For the Probe experiment, $t(12) = 0.81, p = .43, d = 0.12$. For the Color experiment, $t(12) = 0.79$, $p = .45$, $d = 0.29$. For the Innocent experiment, $t(11) = 0.90$, $p = .39$, $d = 0.29$. On the other hand, the combined *oddball* and *non-responded-to* P900s were significantly larger than the *responded-to* P900s in all three experiments: For the Probe experiment, $t(12) = 3.85$, $p < .003$, $d = 0.92$. For the Color experiment, $t(12) = 3.12$, $p < .01$, $d = 0.89$. For the Innocent experiment, $t(11) = 3.98$, $p < .003$, $d = 0.95$. The expected and confirmed directions of all differences may be seen in Figs. 3 and 4 as well as Tables 1 and 2. Though our sample size is fairly small (though not atypical for studies in our field), with only 11 or 12 subjects per experiment, we note that the effect sizes are small (<0.3) for those tests that do not achieve significance, and large (>0.8) for tests that do achieve significance, implying that a lack of power is not the cause of nonsignificant tests. We address this issue further in the discussion section.

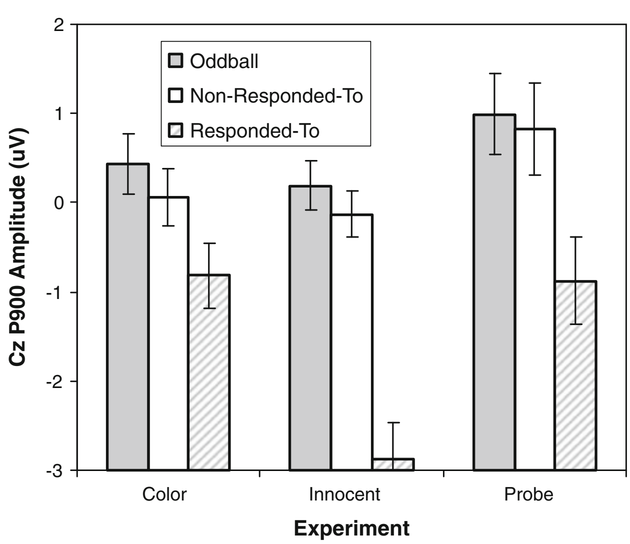

Fig. 3 Computer calculated P900 amplitudes at Cz as a function of stimulus type in the three experiments

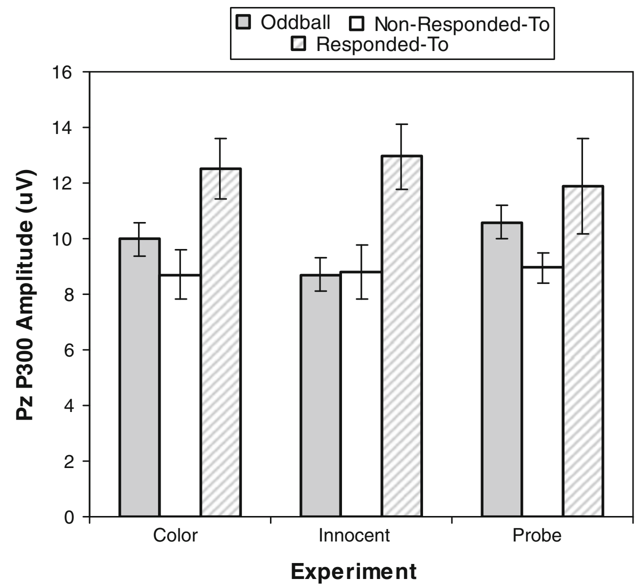

Fig. 4 Computer calculated P300 amplitudes at Pz as a function of stimulus type in the three experiments

Regarding our lesser interest in P300, we expected responses to *oddball* stimuli in the Probe and Color experiments, which had true oddballs, but not in the Innocent experiment where the designated probe stimulus was just another irrelevant. On the other hand, we expected P300s to *responded-to* stimuli in all three experiments, and no P300s in all experiments in response to *non-responded-to*, irrelevant stimuli. Thus, we separately compared *oddball* stimuli and *responded-to* stimuli to *non-responded-to* stimuli in each experiment. *Oddball* stimuli evoked larger P300s than *non-responded-to* stimuli in both the Probe experiment, $t(12) = 2.88$, $p < .02$, $d = 0.79$, and the Color experiment, $t(12) = 2.27, p < .05, d = 0.63$. As expected, the difference was not significant in the Innocent experiment, $t(11) = 0.11$, $p = .92$, $d = 0.03$. Additionally, *responded-to* stimuli evoked larger P300s than *non-responded-to* stimuli in the

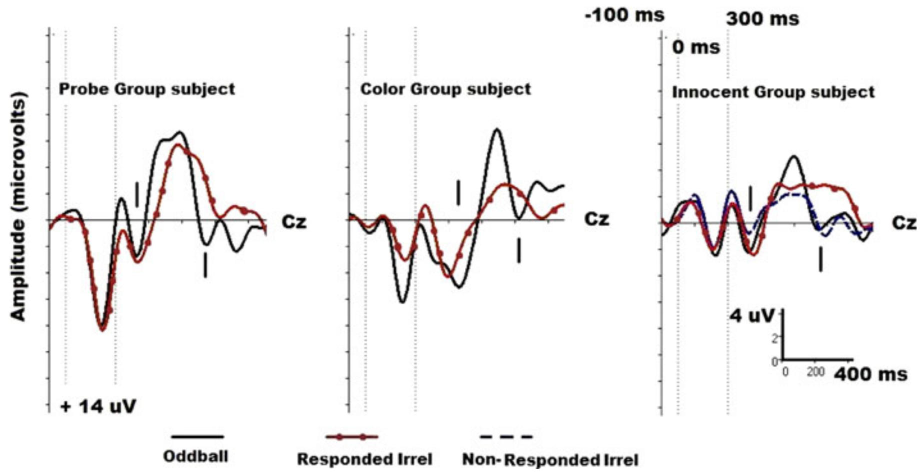

Fig. 5 Representative *individual* averages to *Oddball*, *responded-to* (*Responded*), and *not responded-to* (*Non-Responded*) irrelevant stimuli from the Probe, *Color*, and innocent experiments at Cz. Y-axis is at −100 ms, as stimulus onset is at 0 ms, offset at 300 ms; the latter 2 time markers indicated with *dotted vertical lines* as shown in the *right panel*. *Vertical bars* under x-axes indicate Cz P900s in all 3 subjects' *oddball* waveforms, and additionally in *non-responded-to* irrelevant stimulus for the innocent subject at right. *Vertical bars* above x-axes indicate modest Cz P300s in Probe and *Color* experiment subjects, and in the innocent subject having smallest P300. All 3 subjects show that despite the large P300 (*negative*) recovery component in *oddball* waveforms, the waveforms then go immediately positive to the P900, as the *responded-to* irrelevant component remains *negative*

Table 1 P900 mean amplitude, standard deviation, and *n* for all three experiments, from recording site Cz

	Color experiment			Innocent experiment			Probe experiment		
	n	Mean	SD	*n*	Mean	SD	*n*	Mean	SD
Oddball	12	0.44	1.40	13	0.19	1.03	13	0.99	1.46
Non-responded-to	12	0.06	1.23	13	−0.13	0.99	13	0.83	1.32
Responded-to	12	−0.82	1.32	13	−2.88	1.43	13	−0.88	1.53

Table 2 P300 mean amplitude, standard deviation, and *n* for all three experiments, from recording site Pz

	Color experiment			Innocent experiment			Probe experiment		
	n	Mean	SD	*n*	Mean	SD	*n*	Mean	SD
Oddball	12	9.98	1.93	13	8.71	2.13	13	10.59	2.07
Non-responded-to	12	8.71	2.07	13	8.78	1.87	13	8.95	2.03
Responded-to	12	12.51	2.16	13	12.95	3.02	13	11.87	4.27

Probe experiment, $t(12) = 3.12, p < .01, d = 0.87$, the Color experiment, $t(12) = 6.49$, $p < .001$, $d = 1.80$, and the Innocent experiment, $t(11) = 5.75, p < .001, d = 1.66$.

Discussion

We have shown, within the limited conditions of the present experiments, that a stimulus will elicit a P900 if it signals to a subject on a given trial that no specific response is required in a trial block in which other presented stimuli on other trials do require a specific response. Such a stimulus may have special salience as a personally meaningful item (the Probe experiment) or as a physically unique item (the Color experiment), but it may also have no unique significance at all (the Innocent experiment). Importantly, this study makes three key contributions: (1) it replicates the initial serendipitous observation of the P900 (Rosenfeld and Labkovsky 2010),[3] providing data that

[3] We have since replicated the P900 again in a deception context, in a recent paper (in this journal) examining the effects of various numbers of countermeasures against the P300-based CIT (Labkovsky and Rosenfeld 2011). In that study, P900 was observed again in probe and noncountered stimuli but not in countered stimuli, as would be expected under our working hypothesis of the cognitive processes that lead to P900.

support the hypothesis that P900 is elicited only in response to stimuli that signal to subjects that no further responses is necessary, (2) it demonstrates that P900 can be elicited outside of deception detection paradigms, and (3) it observes the P900 peak over a broader range of antecedent conditions, therefore indicating that it has strong potential as an index of countermeasure use in the CTP version of the CIT.

It is recalled that *all* stimuli in the present experiment required a stimulus acknowledgement response via a randomly selected, left hand button press. Thus P900 does not simply represent the participant's having been signaled by the current stimulus that the trial is concluded, with no further activity to be expected. The P900-eliciting stimulus instead appears to signal the participant that no response *specific to the just presented stimulus* is required. Thus, stimuli requiring a specific additional response, such as a left or right button press on the right hand response box in this study, do *not* alone evoke P900. This is consistent with the Rosenfeld and Labkovsky (2010) finding that only stimuli requiring a countermeasure response failed to elicit P900 in trial blocks in which other non-countered stimuli did elicit P900. As noted above, we retained the random acknowledgement response because it was used in Rosenfeld and Labkovsky (2010) in which P900 was first seen. This random response may also not be necessary for P900 generation, although it may interact with other P900 antecedents, and this interaction may have causal properties regarding P900. More research on this possibility is in order.

We also note, as briefly mentioned in the results above, that while we did not find significant differences between P900 amplitudes of *oddball* and *non-responded-to* stimuli in any of the three experiments, we did find small effect sizes ($d < 0.3$; Cohen 1988) in the color and innocent experiments. While these effect sizes may cause some concern that there is an actual difference between the groups that may not have been captured due to a lack of power, we do not find this likely for two reasons. First, the p values of those two tests were not even close to significant (0.45, and 0.39 for the color and innocent groups, respectively). If the p values indicated near-significance, we would have some concern that our power was insufficient, but given the grossly nonsignificant p values, we would have to increase our sample size several orders of magnitude to reach a significant p value with the same effect size. This combined with the fact that the effects we do find are highly significant with a sample size of only 12–13 subjects in each experiment leads us to believe that our power was sufficient. Second, we typically use 12 subjects per group in P300-based CIT studies (e.g., Rosenfeld et al. 2004, 2008), and we have always found this sample to be more than sufficient to demonstrate group effects.

The present data do show that certain protocol-specific features that were present in the Rosenfeld and Labkovsky (2010) deception study are not necessary for P900 elicitation: (1) The nature of the information in the P900-eliciting stimulus need not be self-referring or an oddball in any way, (2) No secondary target discrimination task need follow the first stimulus, and (3) The participant need not be in a situation in which he is aware that experimenters are trying to extract information which he resists disclosing. The unusual stimulus acknowledgement method (random button selection) of our previous protocols and used also here is probably not a key antecedent for P900 elicitation since, as noted above, this acknowledgement follows all stimuli, P900-eliciting and otherwise, but as just noted, it may interact with other antecedents of P900.

On the other hand, it would be premature to suggest that we presently have a complete understanding of all the antecedent psychological conditions for P900 production. One reason we state this is because the probe Cz P900s for the countermeasure group (in which two of four irrelevants were countered) in Rosenfeld and Labkovsky (2010) were larger than the comparable values in the present data set as seen in Table 3 (see also Figs. 2, 5, 6, the last from Rosenfeld and Labkovsky 2010). We are not certain about the reason for this difference. One possibility is that removing the target/non-target discrimination, which was included in the Rosenfeld and Labkovsky (2010) protocol, from the present trial structure may be important in producing *larger* P900s, even though its removal did not eliminate *smaller* P900s from appearing here. This possibility could be tested by repeating one or more of the present studies both with and without the later target discrimination task.

It is also unclear from the current data whether the P900 is related to a cognitive process associated with conscious awareness of no longer having to make a response, or whether the component does not require awareness of the decision making process. P300 has long been associated with context updating (Donchin and Coles 1988), and the action associated with generating a P300 to a stimulus (such as a required response to an oddball stimulus, or the

Table 3 Comparisons of computed mean Cz *oddball* P900 values (uV) from Rosenfeld and Labkovsky (2010) and present experiments

Experiment comparison				
R&L	Probe	Color	Innocent	3 present studies combined
3.64	0.97, $p < .02$	0.46, $p < .003$	0.22, $p < .004$	0.56, $p < .002$

p values are provided from t tests comparing Rosenfeld and Labkovsky values to each of the three present experiences, as well as all three present studies combined

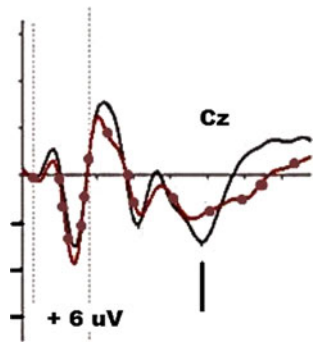

Fig. 6 The prominent grand average Cz P900, indicated with the vertical bar under the x-axis, from the Rosenfeld and Labkovsky (2010) Countermeasure group (like the present Probe experiment). Times −100, 0, 300 ms with respect to stimulus on and offset as in Fig. 1. Amplitude tic marks are 2 uV apart, positive down, and time tic marks are every 200 ms as in Fig. 1

execution of a countermeasure in a P300-based concealed information test) is not itself what generates the P300 peak; rather it is the recognition of the stimulus as meaningful that generates the P300. Likewise, P900 may be elicited by a similar recognition of an item as not requiring a further response; it is entirely possible that the response itself is not even necessary for elicitation of the component, but instead recognition of the stimulus as one that requires further responses generates the peak (much like a physical countermeasure is not what produces a P300 peak, but rather the recognition of the stimulus as meaningful, because it has to be countered, generates the P300; Winograd and Rosenfeld 2012). To be sure, we observe P900 only on trials in which no further response is required (while no P900 is observed where an additional response must be made), so there can be no argument that the actual response itself is critical in eliciting P900 since there is no response (this is unlike the required special response frequently made to target or oddball stimuli in P300 paradigms). However, our current data cannot parse whether generation of the P900 is related to conscious awareness that no further response is necessary. This is an interesting area for future work, and further understanding of what elicits P900 could yield important applied benefits when attempting to use the component to index countermeasures.

Finally, it may be worth considering whether or not this P900 component—which we are suggesting is a novel ERP, related to a specific kind of information—may in fact be a previously described later positive wave, particularly one that is associated with a *go/no go* type protocol. We mention the *go/no-go* paradigm because it contains some trials requiring no response and other trials that require a response, and it thus has some resemblance to the protocol used here. However, past research on the go/no-go paradigm has frequently found that no-go trials result in an N2 component; a frontocentral negative peak between 250 and 350 ms post-stimulus (Kok 1986). Also relevant would be a cued reaction time protocol used in connection with the Lateralized Readiness Potential (LRP; Coles 1989). While these tasks are of interest because of their similarity to the task used in the present report, we know of no prior publication reporting a component with the same morphology, latency, and scalp distribution that we observe in this putative P900 component.

There are other late positive responses that have been reported in the literature. One such response is the late positive component (LPC; Rugg and Curran 2007). In fact, however, this component, though positive and reported to occur as late as 800 ms, tends to be largest centro-parietally, unlike the P900 reported here, and is usually linked functionally to recognition memory. P600 (Osterhout and Holcomb 1992) also has been reported to endure until 800 ms post-stimulus, but is usually associated with syntactical anomalies which are not present here. There are also ERPs referred to as late positive slow waves (Ruchkin et al. 2003). These are positive potentials that endure until well beyond 900 ms, but are also centro-parietal and functionally associated with increased perceptual difficulty. Additionally, as the name implies, these ERPs tend be of much greater wavelength (>500 ms) than P900 whose wavelength is 300 ms at most (see Fig. 6).

The well known readiness potential (RP) (Trevena and Miller 2002) and its derivative LRP would seem the previously studied ERP to be the most likely candidate to have some relationship to P900. The RP in its typically elicited form—a cued reaction time paradigm—is, however, clearly not identical to P900: For one thing it is a long-enduring (>500 ms) *negative* potential, though sometimes reported to be positive frontally (Trevena and Miller 2002), whereas the P900s we have seen now and in Rosenfeld and Labkovsky (2010) are uniformly positive at Fz and Cz. Moreover, Papa et al. (1991) reported that although RPs precede voluntary movements, there was no RP seen in response to a stimulus in a cued reaction time paradigm. On the other hand, Coles (1989) and colleagues report robust LRPs in cued reaction time studies, following warning stimuli. Still, these LRPs are exclusively negative at C3 and C4, and they endure from 500 ms post warning stimulus, extending well after the imperative stimulus occurring at 1,200 ms. Thus the latency onset range overlaps that of P900, but the wavelength is far greater, even allowing for differences in filtering parameters between our experiment and LRP experiments. Moreover, whether the LRP precedes a left or a right hand movement, the ERP is slow and negative, the polarity lateralization being a matter of *degree* of negativity (see Coles 1989, Fig. 5). Thus, as briefly noted in the results section, P900s are not positive-going, truncated negative RPs or LRPs, but seem to be positive true ERP components with a different functional significance.

While none of these previously documented components appear to be the P900 that we observe here, the similar nature of the tasks that elicit them, particularly the go/no-go paradigm, means that these earlier studies may provide some insight as to the neural generator associated with P900. The use of only three electrodes in this present study prevents us from being able to make conclusions regarding the localization of P900 aside from its central or fronto-central scalp distribution. However, one possible generator that would be consistent with our task and scalp distribution is the anterior cingulate cortex (ACC). ACC is typically associated with cognitive control and monitoring of conflict during response selection, which are highly implicated in the current task, and the go/no-go literature has identified the ACC as a possible generator of the N2 component associated with that task (Nieuwenhuis et al. 2003). Other structures implicated in the go/no-go task include the ventral prefrontal cortex (VLPFC) and dorsolateral prefrontal cortex (DLPFC) (Lavric et al. 2004). While further research is necessary to provide evidence that these areas are associated with P900, they provide a good starting point for examination.

From an applied perspective, it may be worth considering that countered items lacking a P900 component could potentially be difficult to interpret, as many factors can contribute to the absence of an ERP component. Here, it is important to keep in mind that the diagnosis of countermeasure use could be made based on the presence of the P900 in the non-countered stimuli of a P300-based CIT. In a number of prior publications on the P300-based CIT, using both the complex trial protocol and the traditional three-stimulus protocol (for review, see Rosenfeld 2011), we have never observed a P900 component in the ERPs of participants not performing countermeasures, nor have others in the field reported one. Thus, the actual presence of the P900 in the ERP of any of the stimuli may be indicative of countermeasure use—P900 should not appear at all if countermeasures are not being performed (as in Rosenfeld and Labkovsky (2010) and Labkovsky and Rosenfeld (2012)). While diagnosing the reasons for the absence of the P900 may make it difficult to determine which stimuli were countered, the actual diagnosis of countermeasure use on the individual-subject level would be done by detecting the presence of the P900 in addition to some P300 to irrelevant items.

One other avenue for future research is the potential for a countermeasure to P900—a sort of "countermeasure to the countermeasure-detector." We have not examined this possibility here, as we have tried to catalogue and focus on the antecedent conditions necessary for the elicitation of P900 under the simplest possible conditions, but future applied research should examine whether such countermeasures are possible, and further test P900 as a detector of countermeasures when participants are motivated to beat the test. While one possible such countermeasure might be to perform countermeasures to *all* irrelevant items to reduce the P900 observed in response to those items, we know that such a countermeasure actually makes the probe item more unique, thus reducing the effectiveness of the countermeasure (Meixner and Rosenfeld 2010). We also note that while the present study is introductory and thus can only make minimal conclusions regarding the cognitive processes associated with P900, even if our conclusions about those cognitive processes are later revealed to be incomplete or even incorrect, P900 is likely to continue to be useful as a countermeasure-detection tool because we only observe it when countermeasure-like additional responses are made.

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