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The effects of asymmetric vs. symmetric probability of targets following probe and irrelevant stimuli in the complex trial protocol for detection of concealed information with P300

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ABSTRACT

The complex trial protocol (CTP, [J.P. Rosenfeld, E. Labkovsky, M. Winograd, M.A. Lui, C. Vandenboom & E. Chedid (2008), The complex trial protocol (CTP): a new, countermeasure-resistant, accurate P300-based method for detection of concealed information. Psychophysiology, 45, 906–919.]) is a sensitive, new, countermeasure-resistant, P300-based concealed information protocol in which a first stimulus (Probe or Irrelevant) is followed after about 1.4–1.8 s by a Target or Non-Target second stimulus within one trial. It has been previously run with a potentially confounding asymmetric conditional probability of Targets following Probes vs. Irrelevants. This present study compared asymmetric vs. symmetric conditional probability groups and found no significant differences in detection rates or Probe-minus-Irrelevant P300 differences between groups. Group differences were seen in error rates and reaction times (RT) to second stimuli. These differences were, however, not diagnostic for deception vs. truth-telling, and were attributable to response perseveration.

1. Introduction

There have been many published P300-based tests for detecting concealed information: Allen, Iacono, & Danielson [1], Farwell & Donchin [2], Rosenfeld, Cantwell, Nasman, Wojdac, Ivanov, & Mazzeri [3], Rosenfeld, Angell, Johnson, & Qian [4]. These early protocols were found to be vulnerable to countermeasures, [5,6]. We recently introduced an accurate, countermeasure-resistant, novel protocol for P300-based detection of concealed information called the complex trial protocol (CTP; [7]). It was so called because each trial consisted of two stimuli separated in time. The first stimulus (S1) was either a probe (concealed knowledge item) or an Irrelevant item. It was followed after a random interval (1.4–1.8 s) by either a Target or Non-Target stimulus (S2). Subjects pressed the same response button to the first stimulus, whichever it was, but a specific button to Targets vs. Non-Targets. P300 to S1 indexed Probe recognition (See Fig. 1.). S1 also provided key reaction time data. There were thus four types of repeated trial pairs (S1–S2). The frequencies and probabilities of each trial-pair type are shown in Table 1.

It is noted in this table that there were three types of rare trials. All *Probe* trials were rare as they were meant to evoke P300 if recognized by individuals with concealed knowledge. *Irrelevant* stimuli followed by Targets (Irrelevant–Target trials) were also rarely presented (Table 1), as we wanted to verify (in the first published CTP report, [7]) that these rare Irrelevant-following, Target events would also evoke a second P300 later in the trial. We also expected that rare, Probe-following-Target stimuli would also evoke P300. Seeing this Target-evoked P300 was one way to be certain that unpredictable Target events maintained attention. The rare Irrelevant-followed-by-Target event, however, raised the possibility of a confounded interpretation of P300s evoked by Probe vs. Irrelevant stimuli.

Clearly, the interpretation of a Probe-evoked P300 we wished to make was that the recognized rare presentation of concealed meaningful information caused the P300. However, it is evident from Table 1 that although the conditional probabilities of Probes followed by Targets vs. Non-Targets are equal (both 50%), such is not the case with Irrelevant stimuli, which are 89% of the time followed by Non-Targets. Subjects could thereby come to notice that a Probe, but not an Irrelevant was especially likely to be followed by a Target, the S2 that required a unique response, and this Target-signaling attribute of a Probe, as opposed to its status as a concealed knowledge item, could lead to a P300-generating salience.

To control for this potential confound, innocent control groups were run in which there were no personally relevant Probes, but there was one Irrelevant stimulus which also had the high probability of signaling the subsequent Target presentation. Fortunately, the false positive rates in the controls were 0–8% as opposed to the >90% correct detection rates in guilty subjects. Clearly, however, to avoid the confound, one could also have run guilty subjects with symmetrical conditional probabilities as shown in Table 2. One objective of the present study is comparison of effects of the two conditional probability matrices in Tables 1 and

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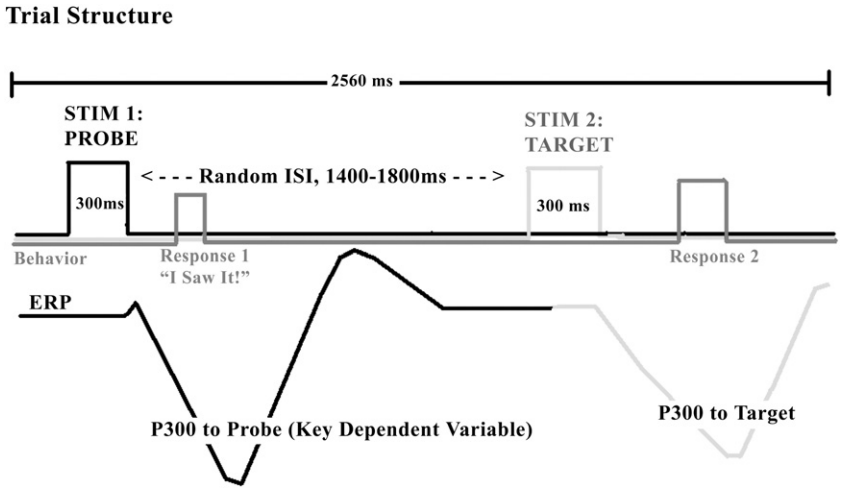

Fig. 1. The structure of an example trial of the new CTP is shown in terms of stimuli, responses, and ERPs as an f(time).

2 on Probe-evoked P300 amplitude and classification accuracy among knowledgeable ("guilty") and non-knowledgeable ("innocent") subjects.

While the low false positive rates in Rosenfeld et al. [7] indicated that the asymmetric conditional probability matrix used in that study was not the reason for the high detection accuracy in that study, it may still be the case that an asymmetric matrix may lead to better detection of concealed knowledge than a symmetric matrix (despite the freedom of the latter from a possible conditional probability confound) due to a possible *interaction* of guilty status and conditional probability: If the Probe is recognized by the guilty subject as concealed information, this recognition could interact with and facilitate observation of the Probe's greater probability of being followed by a Target. To the innocent subject, however, the Probe is simply another Irrelevant stimulus. The symmetric conditional probability matrix eliminates the confounded interpretation, but may also eliminate the interaction just noted that may lead to better detection. In Rosenfeld et al. [7], there was preliminary evidence presented in support of such an interaction with the asymmetric matrix. Thus, as long as the false positive rates remain low with the asymmetric matrix, it may prove to be the more effective protocol. Careful analysis of error rates and reaction times to second stimuli with both matrices, (not done in the 2008 report) may give further insight into these possible interaction issues. Thus, a second objective of the present study was to determine which (if either) probability matrix lead to better detection of deception based on P300 as well as on behavioral data.

2. Methods (all approved by the Northwestern University IRB)

2.1. Subjects

24 experimental participants were obtained from an introductory psychology college course for credit. They were randomly placed in either a symmetric (12 subjects: 2 male, average age 19.1) or asymmetric (12 subjects: 2 male, average age 18.9) conditional probabilities design as in Tables 1 and 2). All were in a simple guilty protocol, that is, they all saw one concealed information item, their birthdates among other Irrelevant dates, and were not instructed to use any countermeasures. The participants used their dominant hand to press buttons. All had normal or corrected vision.

Another group of 12 control participants (5 males, average age = 20.3) was assigned to an innocent group in a *symmetric* condition. (We had information for comparison on 24 control (innocent) subjects in the *asymmetric* condition from Rosenfeld et al. [7]). The innocent subjects saw only Irrelevant dates, i.e., not their birthdates, but were otherwise treated like the symmetric guilty subjects.

2.2. Procedures

Detailed Trial Structure (see Fig. 1; this material is from Rosenfeld et al. [7]): each trial began with a 100 ms baseline period during which pre-stimulus EEG was recorded. Then, as EEG recording continued, a .5 cm tall first stimulus was presented for 300 ms in white font on a computer display 1 m from the subject's eyes. This word was either a Probe or an Irrelevant item. Subjects were instructed to signal their having seen the first (Probe or Irrelevant) stimulus. They did so by pressing the left button immediately after they saw the S1 stimulus. Thus, no decision was made in response to this first stimulus; the response simply indicated the subject's having seen the stimulus, so we refer to this response as the "I saw it" response.

The first stimulus was followed by a randomly varying inter-stimulus interval with a dark screen that endured for 1400 to 1800 ms. At the expiration of this dark interval, the Target or one of four Non-Target stimuli were presented: All these were 5-digit strings of ones (11111 was the Target) twos (22222), threes, etc. Subjects were instructed to press a right button for a rare Target and a left button for a Non-Target. Both Probes and Irrelevants could be followed by Targets

Table 1
Asymmetric probabilities.

Trial pair type: S1–S2	Number	Probability
Probe–Target	33	.09
Probe–Non-Target	33	.09
Irrelevant–Target	33	.09
Irrelevant–Non-Target	250	.72
All Probes	66	.19
All Irrelevants	283	.81

Note: a "Probe–Target" trial is one in which a Probe is followed by a Target. An "Irrelevant–Target" trial is one in which an Irrelevant is followed by a Target, and so on. Likewise for Table 2.

Table 2
Symmetric probabilities.

Trial pair type: S1–S2	Number	Probability
Probe–Target	33	.09
Probe–Non-Target	33	.09
Irrelevant–Target	141	.40
Irrelevant–Non-Target	142	.40
All Probes	66	.19
All Irrelevants	283	.81

or Non-Targets. Here is an excerpt from the exact instructions given to all three groups.

"For this experiment, you will be asked to view the computer monitor in front of you and respond to stimuli presented. The stimuli will be a series of dates. One of the repeating stimuli may have personal meaning for you. We expect your brain will respond to your personal information even if you try to keep it secret in your mind.

In each trial, you will be presented with two items, one after the other. First, a date is very briefly presented, and then it disappears. Then, after about a one second delay, a string of numbers is presented. There are two responses to be made, one to each stimulus.

After any date is presented, press the LEFT ('No/I Saw It') button as soon as possible. This signals that you saw the stimulus, which is why we call it the 'I saw it' button.

After about one second, a string of one of five numbers (111111, 222222, 333333, 444444, 555555) is next presented. Your task is to determine whether or not the number you see is your Target, which is 11111.

So if it changes to 111111, your 'Target' number, you press the RIGHT ('yes') button on the response box.

For any of the other Non-Target numbers it may change to, press the LEFT ('no) button on the response box (You will recall that this button served earlier as the 'I saw it' button.)"

We also force attention to the first stimulus by interrupting the run unpredictably every 20–30 trials when the first stimulus expires and requiring the subject to speak its identity. Prior to the run, the subject is alerted that missing more than one of these check-ups results in test failure. This also tends to discourage simple CMs such as vision blurring. The detailed trial events diagrammed in Fig. 1 indicate a trial with a Probe followed by a Target, or a Probe–Target trial. Also shown is a hypothetical ERP channel. Note that since this diagram is of a Probe–Target trial, an early P300 in response to the Probe is shown, followed by a later P300 in response to the Target. We emphasize that the later P300 was of interest only in the first report [7] to establish that the Target did indeed function as a Target normally does (forcing attention and eliciting a P300), but the key variable of interest with respect to concealed information detection is the P300 response (or lack of same) to the first Probe or Irrelevant stimulus.

2.3. Data acquisition

EEG was recorded with Ag/AgCl electrodes attached to sites Fz, Cz, and Pz. Analysis here was confined to Pz. The scalp electrodes were referenced to linked mastoids. EOG was recorded with Ag/AgCl electrodes above and below the right eye. They were placed intentionally diagonally so they would pick up both vertical and horizontal eye movements, as verified in pilot study and in Rosenfeld et al. [5,7]. The artifact rejection criterion was 80 μV. (Across all conditions, artifact rates varied from 10–20%.) 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 P511 K amplifiers with a 30 Hz low pass filter setting, and high pass filters set (3db) at .3 Hz. Amplifier output was passed to a 16-bit 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; 3db point = 6.0 Hz.

P300 at Pz was measured using the peak–peak (p–p) method, which we have repeatedly found to be the most sensitive in P300-based deception studies (e.g., [8]): The algorithm searches within a window from 500 to 800 ms for the maximally positive segment average of 100 ms. The midpoint of the maximum positivity segment defined P300 latency. After the algorithm finds the maximum positivity, 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.

2.4. Analyses, error handling

Standard ANOVAs were run to determine group effects. Any within-subject tests with >1 df resulted in our use of the Greenhouse–Geisser (GG) corrected value of probability, p(GG). All error trials (as well as artifact trials) were discarded and replaced so that analyses were done only on error free trials. (An error occurred when the subject pressed the wrong button–in terms of the instructions–to a given stimulus.) This was also true for the within-subject analyses described in the next paragraph.

2.5. Within individual analysis: bootstrapped amplitude difference method

Standard ANOVA group analysis methods were applied to the usual P300 variables. Additionally, as this is a *diagnostic* deception detection method, we also diagnosed guilt or innocence *within individuals*. To determine whether or not the P300 evoked by one stimulus is greater than that evoked by another *within an individual*, the bootstrap method [9] was used on the Pz site where P300 is typically 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 combined Probe–Target and Probe Non-Target set (all single sweeps) and draws at random, with replacement, a set of n1 waveforms. It averages these and calculates 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 (Target and Non-Target) sweeps for that subject, and n2 is the actual number of accepted Irrelevant sweeps for that subject multiplied by a fraction (about .23 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, say, 90% confidence (the criterion used in preceding studies, (e.g., [2,4,5,8]) 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

Table 3
Error rates.

A. "I saw it" error rates				
Symmetric				1.31%
Asymmetric				0.82%
All				1.06%
	PT	PN	IT	IN
B. Target/Non-Target error rates				
Symmetric	8.27%	4.64%	9.28%	4.71%
Asymmetric	6.97%	4.74%	23.68%	1.07%
All	7.62%	4.69%	16.48%	2.89%

Comparisons between group (symmetric/asymmetric) and stimulus type (Target/Non-Target and Probe/Irrelevant) for error rate in percentage. Table A contains error rates to the first stimulus presentation ("I saw it" response). Table B has the error rates to the second stimulus presentation (T/NT response).

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. (t-tests on single sweeps are too insensitive to use to compare mean Probe and Irrelevant P300s within individuals; see Rosenfeld et al. [4].)

3. Results; asymmetric and symmetric groups

3.1. Behavioral: error rates

Table 3A shows the error rates for the first "I saw it" response in both groups. With no decision to be made in response to this stimulus, the error rates were expectedly low in both groups, averaging about 1.0%. Moreover, there was no difference in error rates between groups, ($p>.4$).

The error rates to the second (Target vs. Non-Target) stimulus are shown for both groups and four stimulus types in Table 3B, and they are plotted in Fig. 2, top panel, where it appears that seven of the eight values are less than 10% , but the rate for Target stimuli preceded by Irrelevant stimuli (average of all Irrelevants) in the asymmetric group is >20%. A 2(Group, between group)×2(Probe vs. Irrelevant, repeated)×2(Target vs. Non-Target, repeated) ANOVA was done. There was no main effect of Group, $F(1, 22)=1.3$, $p>.26$. There was a main effect of Probe vs. Irrelevant, $F(1, 22)=9.24$, $p<.007$, and a main effect of Target vs. Non-Target, $F(1,22)=30.8$, $p<.001$. Probe vs. Irrelevant×Group interacted, $F(1,22)=6.49$, $p<.02$, as did Target vs. Non-Target×Group, $F(1, 22)=8.0$, $p<.01$, and Probe vs. Irrelevant× Target vs. Non-Target, $F(1,22)=9.84$, $p<.006$. Also, the triple interaction was significant, $F(1,22)=8.16$, $p<.01$.

This triple interaction is most relevant to our main question about differences between symmetric and asymmetric groups, since it means that within each group, the two-way interactions of Probe vs. Irrelevant×Target vs. Non-Target are not the same. In support of this notion, two post hoc, 2×2 ANOVAS run separately within each symmetry group yielded no 2-way interaction in the symmetric group; $F(1, 11)=.16$, $p>.69$, but a clear interaction in the asymmetric group; $F(1, 11)=10.2$, $p<.01$. It is also noted that the main effects were not significant in the symmetric group; The $F(1,11)$ for Target vs. Non-Target was marginal at 4.37, $.06<p<.07$, and the $F(1,11)$ for Probe vs. Irrelevant was .34, $p>.5$. In contrast, in the asymmetric group, the $F(1,11)$ for Target vs. Non-Target was 30.4, $p<.001$, and the $F(1,11)$ for Probe vs. Irrelevant was 9.5, $p<.01$.

We also note that within the asymmetric group, each and every value of the Irrelevant–Target (S2) error rate for each subject was greater than that for the Irrelevant Non-Target. The mean rate for the former was 23.4% vs. 1.1% for the latter, yielding a mean difference of 22.3% with a .95 confidence interval running from 11.7% to 33.0%, $t(11)=4.6$, $p=.001$. It is also the case in the asymmetric group that 10 of 12 values of error rate for Irrelevant–Target were greater than the values for Probe–Target. The mean rate for the former was, again, 23.4% vs. 7.1% for the latter, yielding a mean difference of 16.3% with a .95 confidence interval running from 5.0% to 27.6%, $t(11)=3.2$, $p=.009$. We report these individual data (and likewise for RTs, below) as further potentially diagnostic indices in addition to P300 data.

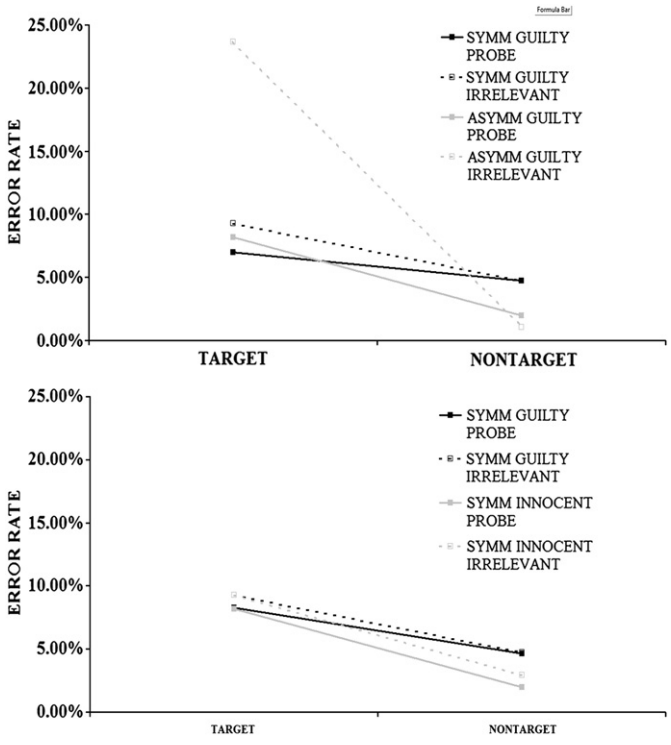

Fig. 2. Top panel: error rates in asymmetric and symmetric guilty groups to Target and Non-Target stimuli. Lower panel: error rates in symmetric guilty group (re-plotted from above) and in symmetric innocent groups to Target and Non-Target stimuli.

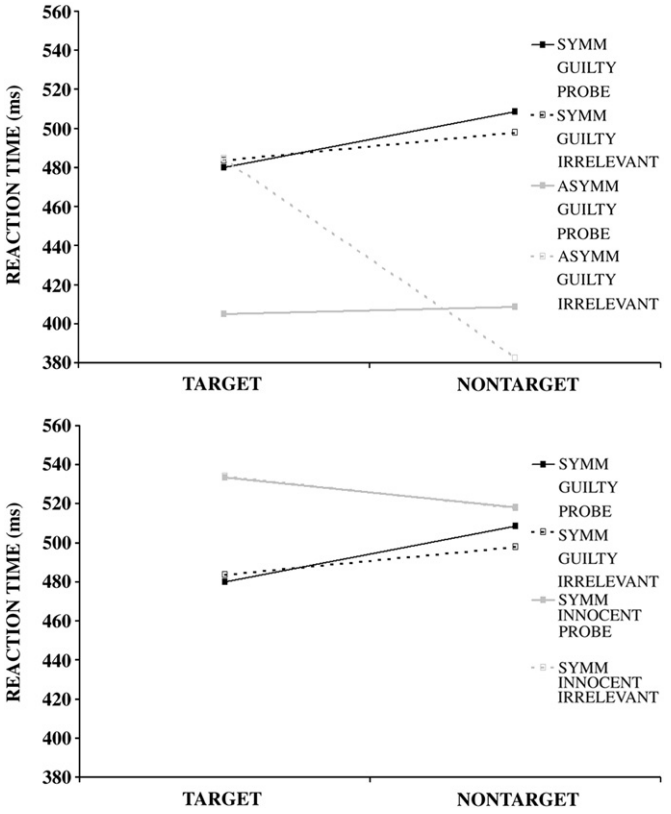

Fig. 3. Top panel: reaction times (RTs) in asymmetric and symmetric guilty groups to Target and Non-Target stimuli. Lower panel: reaction times (RTs) in symmetric guilty group (re-plotted from above) and in symmetric innocent groups to Target and Non-Target stimuli.

3.2. Behavioral: reaction times (RT)

For the RT to the first stimulus ("I saw it"), the average of all RTs (Probes and Irrelevants combined) in the symmetric group was 432.7 ms, vs. 383.9 ms for the asymmetric group; $t(11)=3.14$, $p<.01$. A preliminary 2(group)×2(Probe vs. Irrelevant) ANOVA yielded a main effect of group with $F(1, 22)=12.7$, $p<.003$, but no effects of

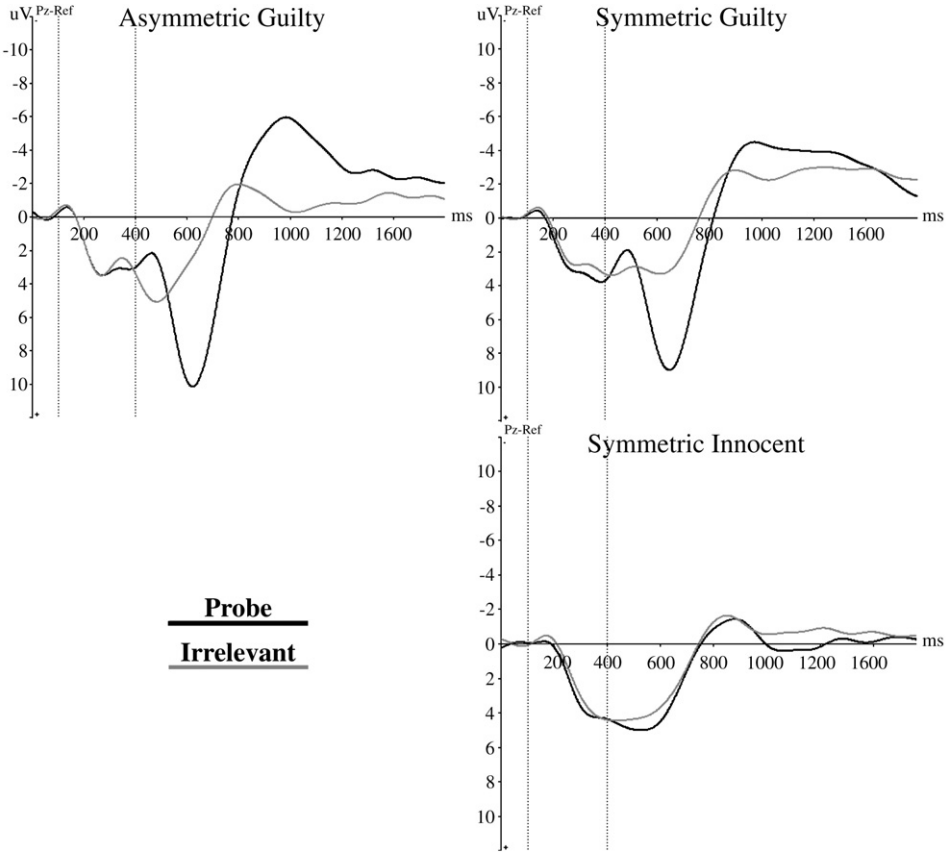

Fig. 4. Grand average ERPs to Probe and Irrelevant stimuli in the three groups run in this report. The vertical dotted lines represented onset and offset of S1.

Probe vs. Irrelevant, F (1,22) = .007, p>.9, or interaction, F (1,22) = .656, p>.4. (Thus we did the t-test below with combined Probes and Irrelevants.) We note that although others [2,10] have reported larger Probe RTs than Irrelevant RTs in related protocols, in our original CTP report [7] we did not see this effect in a second week of testing, after a first week in which we did see this effect; this was in two studies. Apparently, the influence of habituation and practice, not here controlled, determines whether or not this RT effect is obtained.

The RTs to the second stimuli, sorted by preceding stimulus (Probe vs. Irrelevant) and second stimulus (Target vs. Non-Target) are plotted in Fig. 3, top panel. It appears again, as with the error rates, that there is an interaction of Target vs. Non-Target × Probe vs. Irrelevant in the asymmetric group but not in the symmetric group. This is supported by a triple interaction in the 3 way ANOVA of Group (between groups) × Probe vs. Irrelevant (repeated) × Target vs. Non-Target (repeated): F (1,22) = 13.74, p<.001. Other effects in this 3-way ANOVA: Group, F (1,22) = 7.96, p<.02; Probe vs. Irrelevant (average of all), F = 6.69, p<.02. Target vs. Non-Target was ns, F (1,22) = 2.0, p>.16. The interaction of Probe vs. Irrelevant × Group was F (1,22) = 11.1, p<.003. The interaction of Target vs. Non-Target × Group was F (1,22) = 12.9, p<.003. The interaction of Probe vs. Irrelevant × Target vs. Non-Target was F (1,22) = 23.5, p<.001. As with error rates, the post hoc 2-way ANOVA within the symmetric group had no significant effects: For Probe vs. Irrelevant, F (1,11) = .22, p>.6; for Target vs. Non-Target, F (1,11) = 1.39, p>.25, and the 2-way interaction was F (1,11) = 1.07, p>.3. In contrast, in the asymmetric group, for Probe vs. Irrelevant, F (1,11) = 23.7, p<.001; for Target vs. Non-Target, F (1,11) = 41.1, p<.001, and the 2-way interaction was F (1,22) = 26.2, p<.001.

We also note that in the asymmetric group, each and every value of Irrelevant–Target reaction time (mean = 484.5 ms) was greater than the corresponding Irrelevant Non-Target reaction time (mean = 382.33 ms) yielding a mean difference of 102.17 ms with a .95 confidence interval running from 78.18 to 126.16 ms, t (1,11) = 9.37, p<.001. We note further that in the asymmetric group, each and every value of Irrelevant–Target reaction time (mean = 484.5 ms) was greater than the corresponding Irrelevant *Probe*–Target reaction time (mean = 405.00 ms) yielding a mean difference of 79.5 ms with a .95 confidence interval running from 50.28 to 108.72 ms, t (1,11) = 5.99, p<.001.

3.3. P300 amplitudes and hit rates

The grand averaged P300 waveforms for the two groups are shown in Fig. 4, top two panels, and the computer calculated P300 amplitudes of Probes vs. average of all Irrelevant waveforms are shown for both groups in the Fig. 5 line graph (along with the symmetric innocent control data, discussed below). There appears to be 1) little difference in effects between groups, 2) the usual difference expected between Probe and Irrelevant P300 amplitudes, and no interaction. These

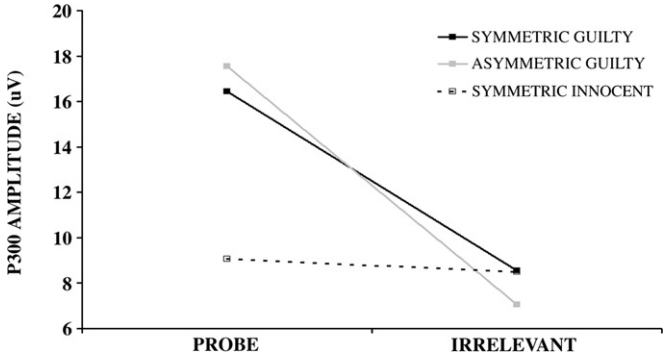

Fig. 5. Computer calculated P300 amplitudes (in microvolts) to Probe and Irrelevant Stimuli in the three groups run in this report.

impressions are confirmed by a 2-way ANOVA in which the ns effect of groups is F (1,22) = .009, p>.9; the ns interaction is F (1,22) = 1.68, p>.2; and the effect of stimulus type is F (1,22) = 82.99, p<.001. The hit rates, based on the typically used bootstrapped comparisons of Probe vs. all averaged Irrelevant P300 amplitudes at a 90% confidence interval were 12/12 (100%) in the asymmetric group and 11/12(92%) in the symmetric group. If one uses the very stringent criterion of Probe vs. the *maximum* Irrelevant amplitude [7], one still detects 9/12 (75%) in the asymmetric group, vs. 7/12 (58%) in the symmetric group. Fisher exact tests comparing these two set of proportions did not approach significance (both p>.3).

It is noted that the apparent negative component at 1000 ms seems larger in the asymmetric than in the symmetric group. This effect was not significant. This component was studied by Soskins et al. [8] and was related to P300 recovery time to baseline and is correlated also with P300 (b–p) amplitude.

4. Results; symmetric innocent group

4.1. Behavioral: error rates

For the first response to the first stimulus, the error rate averaged .008. It was not significantly different than the mean error rate in the symmetric guilty group (.015), t (22) = .92, p>.3). For the second response, results are shown in the bottom panel of Fig. 2, directly under the comparable results for the guilty groups in the top panel of Fig. 2. In the bottom panel, the guilty Probe and Irrelevant are also re-plotted from the top panel. The symmetric/innocent group data appear to vary between 3 and 10%, quite comparable to results for the symmetric/guilty group. A 2 (symmetric guilty vs. symmetric innocent) by 2 (Probe vs. Irrelevant) by 2 (Target vs. Non-Target ANOVA yielded an ns effect of Group; F (1,22) = .42, p>.5, and ns effect of Probe vs. Irrelevant; F (1,22) = 1.7, p>.2, and no significant 2-way or 3 way interactions (all p>.4). There was a main effect of Target vs. Non-Target; F (1,22) = 15.1, p<.002. A 2(Probe vs. Irrelevant)×2(Target vs. Non-Target) ANOVA within the symmetric innocent group yielded only a significant Target vs. Non-Target effect; F (1,11) = 11.8, p<.006. The other effects were ns at p>.17.

4.2. Behavioral: reaction times (RT)

RTs to the first stimulus averaged 415.9 ms. An independent groups t-test comparing this mean with the mean of the symmetric guilty group (432.7 ms) was ns, t (22) = .465, p>.6.

RTs to the second stimuli are plotted in Fig. 3, lower panel, along with the re-plotted values from the guilty symmetric group. A 2 (symmetric guilty group vs. symmetric innocent group) by 2 (Probe vs. Irrelevant) by 2 (Target vs. Non-Target) ANOVA was done. Most effects were ns at p>.35, the ns interaction of group and Target vs. Non-Target in Fig. 3 lower panel was p>.12.

4.3. P300 amplitudes and hit rates

The innocent symmetric grand averages are shown in the lower panel of Fig. 4 and the associated line graphs for Probe and Irrelevant P300s are shown in Fig. 5. There do not appear to be differences between Probes and Irrelevant waveforms and this is supported by a correlated t-test within the group comparing P300 amplitudes (p–p at Pz); t (1,11 = 1.58, p = .14). The hit rates (guilty diagnoses), based on the typically used bootstrapped comparisons of Probe vs. all averaged Irrelevant P300 amplitudes at a 90% confidence interval was 0/12. If one uses the very stringent criterion of Probe vs. the *maximum* Irrelevant amplitude [7], one of course also detects 0/12. (From Rosenfeld et al. [7] the comparable *asymmetric* false positive rates for both comparisons of Probe vs. all Irrelevant and Probe vs. maximum Irrelevant were both 1/12 (8%).) A 2-groups t-test comparing the Probes from both symmetric guilty and symmetric innocent groups yielded t (22) = 3.39, p<.004, as suggested in Fig. 5.

With hit rates and false alarm rates, it is possible to compute the signal detection theoretical parameter A' [11] which is a measure of test efficiency. $A' = .5 + (((y-x)\times(1+y-x))/(4\times y\times(1-x)))$ where y is the hit rate and x is the false alarm rate. A' is a function of the distance between a receiver operating characteristic (ROC) curve and the main diagonal of the plot of hits against false alarms. It varies between 1.0, indicating perfect discrimination between honest and dishonest responders, and 0.5, indicating random discrimination. In the asymmetric group, based on Probe vs. all averaged Irrelevant P300 amplitudes and Probe vs. maximum Irrelevant, respectively, A' values were 1.0 and .94. In the symmetric group, based on Probe vs. all averaged Irrelevant P300 amplitudes and Probe vs. maximum Irrelevants, respectively, A' values were .96 and .90.

5. Discussion

We found no effect of symmetry vs. asymmetry (of conditional probability of Target following Probe) on Probe-minus-Irrelevant P300 amplitude, nor, therefore, on detection rates. This is consistent with the evidence from Rosenfeld et al. [7] that false positive detection rate in innocent control subjects experiencing an asymmetric probability matrix was quite low (0–8%). Thus, one can be reasonably confident that a guilty decision based on Probe-minus-Irrelevant P300 amplitude in a subject experiencing an asymmetric probability matrix (as in Table 1) relates to the personal meaningfulness of the Probe stimulus, and not to the salience acquired by the Probe due to its greater likelihood of its being followed by Target. This was the major question addressed by this study.

Even assuming that subjects in the asymmetric group were well aware, early on, of the predictive salience of a Probe likely being followed by a Target, there is no evidence that this putative awareness leads to larger Probe P300s or Probe-minus-Irrelevant differences in P300 amplitude. Nevertheless, there was evidence seen here that the asymmetric conditional probability matrix does produce effects on other behavioral variables pertaining to the second (Target vs. Non-Target) stimulus. For example, as is evident in Fig. 2, top panel, in the asymmetric group, there was a clear interaction of Probe vs. Irrelevant with Target vs. Non-Target, as well as main effects of Probe vs. Irrelevant and Target vs. Non-Target. These effects were not seen in the symmetric group. The driving factor in the asymmetric group appears to be the dramatically elevated error rate for Targets following Irrelevants. We suggest, as we did in the 2008 paper, that this is a response perseveration effect: There are many more Non-Targets following all first stimuli, particularly Irrelevants. This suggests that subjects tended to expect Non-Targets and were thus primed to respond on the Non-Target (left) button, and often did so mistakenly when Targets were presented. RT data also support this view, as discussed below. Indeed even within the symmetric guilty group, the Target effect was almost significant at p<.07, and in the 3-way ANOVA with both guilty groups, the Target effect was significant. Even in the symmetric innocent group, (Fig. 2, lower panel) there was a large main effect of Target vs. Non-Target. It will also be recalled that subjects always press the left button as the "I saw it" first response, and probably keep their finger there in anticipation of the second stimulus, even though there is no difference in probability of left (Non-Target) vs. right (Target) button press for the second stimulus in the symmetric group.

These effects on error rate were largely reflected by effects on RT (Fig. 3, top panel). Regarding RT, the significant triple interaction of Target vs. Non-Target × Probe vs. Irrelevant × group relates again to the interaction in within-group 2×2 ANOVAs of Probe vs. Irrelevant × Target vs. Non-Target in the asymmetric group, but not in the symmetric group. The elevated RT to the Target following an Irrelevant in the asymmetric but not symmetric group again probably relates to the

general expectation of the Non-Target in the asymmetric group. Errors are to be thus expected in that situation, but subjects can correct their tendencies to press the Non-Target button, however that adjustment appears to take a bit more time, leading to elevated RT for Irrelevant followed by Target.

There is, however, an effect of group seen in RT, not seen with error rate. In the symmetric group, no prediction should be possible regarding the second stimulus following the first stimulus. Thus, these subjects need to await that second stimulus more carefully, thus taking more time to respond to it. However, prediction is possible in the asymmetric group, explaining to some extent why overall, RTs are faster, especially to the more frequent Non-Target. The asymmetric group subjects are likely to pay closer attention and be more vigilant following Probe presentations, vigilance leading to speeded responses, whereas Irrelevant trials are likely to be even casually responded to correctly with the Non-Target button. However although the Irrelevant-followed-by-Non-Target is the most expected and thus has the shortest RT, the Irrelevant-followed-by-Target is the least common and least expected, thus requiring a large adjustment and leading to a long RT. In the symmetric innocent group (Fig. 3, lower panel), there were no significant effects, as with the symmetric guilty group.

A group effect was also seen in RT to the first ("I saw it") stimulus, with asymmetric group subjects showing the faster (by about 49 ms) RT. This difference is in the same direction as the group difference in RT to the second stimulus, raising the possibility of a chance ($p<.01$) difference between groups. It seems more likely that further response generalization was occurring such that the greater likelihood of asymmetric subjects (with 283 Non-Target trials vs. 175 in symmetric subjects) responding on the left (Non-Target) button to S2 of trial n, better readied them to respond on that same button for S1 of trial $n+1$.

In summary, only the asymmetric conditional probability matrix appears able to produce behavioral effects regarding the second stimuli. Moreover, we found that these group behavioral effects, unlike P300, were not able to help with diagnosis of guilt and innocence. This appears consistent with the notion that they represent secondary response perseveration, as suggested above and in Rosenfeld et al. [7], rather than representing some carryover from the effects of first stimuli which *are* represented in ERPs and which are thus diagnostic of concealed information recognition.

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