Scaled P300 Scalp Distribution Correlates of

Deception in an Autobiographical Oddball Paradigm

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Running Head: Deception-related P300 amplitude distribution

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ABSTRACT

Participants (n=24) experienced a baseline Block 1: they saw their phone numbers presented in a series with 6 other phone numbers. They were to say "yes" to their phone numbers, "no" to others. They were asked to repeat the first 3 digits of the phone numbers aloud. In Block 2, LIE and CONTROL groups (both n=12) were formed: participants saw a series of dates (e.g., "Mar 9"), $1/7^{th}$ were their birth dates. The LIE participants were asked to lie on 50% of the trials, and to repeat all stimuli aloud. The CONTROLs were to perform honestly in Block 2, but were asked to repeat all stimuli aloud, but a random half of the stimuli backwards. The aim was to equalize task demand between groups. The results were that for both scaled and unscaled P300 amplitude, there were no differences or interactions as a function of group, or block in comparisons of responses to honest, forwards-repeated stimuli ($p>.6$). For block-pooled honest vs dishonest (LIE) responses, there was a main effect of response type on unscaled amplitude (lie responses $<$ true responses, $p<.03$). There was no main effect (CONTROL) of the forwards/backwards manipulation ($p<.15$). In scaled amplitudes, there were no interactions of group or response type with site ($p>.2$) in honest, forwards responses. Comparing all LIE honest with dishonest responses by site yielded a significant interaction of response type x site, $p<.02$, with depressed dishonest responses at Fz and Cz. CONTROL forwards and backwards responses also interacted with site, $p<.001$, but with enhanced backwards responses at Fz, Cz. Post-hoc ANOVAs, using just Cz and Pz showed a significant interaction in the LIE but not CONTROL participants.

Key Words: P300, Deception, Amplitude distribution, Malingering

Introduction

We have previously reported that in various situations, the scaled scalp distribution (profile) of P300 amplitude differs from deceptive to truth-telling conditions, (Rosenfeld, Reinhart, Bhatt, Ellwanger, Gora, Sekera, & Sweet, 1998; Rosenfeld & Ellwanger, in press; Rosenfeld, Ellwanger, Nolan, Wu, Berman, & Sweet, in press). Johnson (1988, 1993) has argued that when the ERP profile differs from one condition to another, one has good evidence that the two conditions involve differing neurogenerator groups.

Although one may take advantage of differential profile for truth-tellers and liars in practical detection of deception applications, one cannot argue from such data that the liar's profile specifically represents deception. In the paradigms previously used (Rosenfeld & Ellwanger, in press; Rosenfeld et al, in press; Rosenfeld et al., 1998), the task demands on the liar were greater than those on the truth-teller: The latter simply had to tell the truth whereas the liar had to maintain an instructed, random-appearing, 50% (approximately) deceptive error rate, and thus also had to decide on each trial whether or not to lie. The observed differences in profile between the two groups could have represented differences in task demand as well as differences in honesty.

In the present study, we have tried to construct an honest control group having task demands comparable to those of the liar group. Specifically, we used an autobiographical oddball paradigm in which participants saw a Bernoulli (randomized) series of seven, repeatedly presented birthdates, 14.3 percent of which were their own birthdates. In the Lie group, participants were told to respond dishonestly on a random half of the trials (of both oddball and frequent type), and to then repeat the stimuli aloud. (Only the first three letters of the month were repeated.) In the control group, participants were told to respond aloud honestly on all trials, but to then repeat a random half of the stimuli aloud backwards, (the rest, forwards). Both groups had comparable task demands in the terms noted above, but one group responded honestly and the other dishonestly. Differing P300 profiles would not be simply attributable to differences in task demands.

We note that Johnson's (1988, 1993) interpretation of the meaning of differing scalp profiles emphasizes the possibility of differing neurogenerator sets. There is another interpretation of the differing scalp profiles in two experimental conditions: It may be that the two conditions evoke different sets of components which differentially overlap the P300 which both conditions evoke in common (Donchin, Spencer, & Dien, 1997). By "differentially overlap", we refer to the possibility of differential contributions of the differing components at differing sites. We note that our fundamental interest is in showing that the brain works differently during deception than during truth-telling. We believe that different scaled scalp distributions between the two conditions provides evidence of that difference in brain function. Whether the difference reflects differing neurogenerator sets for the studied component (P300) or differing sets of evoked components will remain a question for future research.

Why might one expect differing scalp distributions in Lie and Control groups if task demand is matched? We hypothesize that a participant who is lying, even though he/she was directed to do so, has some level of self-awareness on all deceptive trials, that he/she is engaging in a behavior on which society and authority figures frown. Participants may thus find themselves somewhat embarrassed at being observed during lies. In any case, all Lie participants (and no Control participants) know they are lying as they lie, and probably engage in further cognitions following the decision to lie as well as following the act of lying. These cognitions would pertain to knowledge of the mismatch between the true-correct answer versus the answer they produce on a lie trial. We hypothesize that the Lie condition, but not the Control condition, will generate brain activity related (at least) to both the additional cognitions following such mismatch experiences, as well as to self awareness of deception, and that P300 profiles may reflect these differences between Lie and Control conditions.

Differences between Lie and Control groups might also be expected on the basis of the latter's additional task: backwards repetition of stimuli. A comparison restricted to profiles of Lie and Control groups during their respective specific tasks could thus be counfounded by the two task effects simultaneously operating: 1) honest vs. dishonest responding and 2) backwards vs. forwards repetition. We thus ran both groups through two blocks of trials, one (Paradigm 1.) in which all participants behaved alike in responding honestly and repeating stimuli forwards, and a second block (Paradigm 2) in which the Lie participants lied on half the trials with forwards repetition, and the Control participants responded honestly on all trials but repeated half the stimuli in a backwards manner. Thus in each group, we could compare departures in Paradigm 2 from the benchmark/baseline condition of Paradigm 1.

Methods

Participants: The 24 participants (12 per group, 13 female, six of which were in the Lie group) were recruited from the department introductory psychology pool and were fulfilling a course requirement. All had normal or corrected vision.

Procedure. Following signing of consent form, instruction, and electrode attachment, participants were seated in a recliner such that a video display screen was in front of their eyes. The visual stimuli were presented on this screen every 6.0 s, a relatively long interstimulus interval required for verbal responding so as to allow the artifact associated with vocalization to dissipate prior to the subsequent trial. The trial began with the onset of pre-stimulus EEG baseline recording for 104 ms. The stimulus then appeared on the screen and endured for the remainder of the ERP recording epoch = 1944 ms (total epoch = 2048 ms). Immediately after clearance of the stimulus from the screen, the message "Please Respond" was presented and lasted 2 s. The participant was required to respond during this time.

There were two blocks of trials used in this study. In the first block, the visual stimuli were participants' phone numbers ($p = .15$) and other phone numbers ($p = .85$). Both Control and Lie participants were told to respond aloud truthfully and ordinarily in this preliminary oddball Paradigm 1. The timing and parametric settings in this benchmark/baseline block were the same as in the actual test block (Paradigm 2) to be next detailed. In this second block, the stimuli were the first three letters of a month, followed by a number from 1 to 31, e.g., MAR 9. Thus, birth dates could be formed. The participant then said "yes" or "no" signifying birthdate or other date, respectively, and then immediately repeated aloud the three letters of the month symbol.

In the Control group, the participants were instructed to respond honestly "yes" or "no" and to then repeat these month symbol letters aloud backwards on approximately half the trials of both types (birthdate, non-birthdate). They were also instructed to try giving a random, as opposed to patterned, series of forward and backward responses. We suggested to these participants that we were interested in how well people can generate random sequences of responses while doing a foreground task. In the Lie group, participants were instructed to simulate malingered cognitive deficit as in Rosenfeld et al (1998), by making dishonest "errors" on both trial types about half the time in response to the "Please Respond" message. They were told to generate a random, unpatterned series of deceptive responses, since the computer controlling the experiment could discern patterns, and that they would not "beat the test" if patterned responding was discerned. Immediately after their "yes" or "no" response, they were required to repeat the first three letters of the month (in the normal, forwards order). Both groups were told there would be 44 presentations of birthdates randomly interspersed among 276 presentations of other dates. This was done in order to help them score close to the 50% target rate of deceptive or backwards responses. Following the response window (2.0 s) was a second 2.0 s period of no events prior to the start of the next trial.

EEG recording and analysis

EEG was recorded with Grass P511k preamplifiers with gain = 100,000, and filters set to pass signals between 0.1 and 30 Hz (3db points). Electrodes (Ag - AgC1) were attached to Fz,Cz, and Pz referenced to linked mastoids with the forehead grounded. EOG was recorded from a bipolar pair of electrodes above and below the eye. EOG signals > 80 uV led to trial rejection and replacement. Amplified signals were led to 12-bit A/D converters (Keithley-Metrabyte) sampling at 125 Hz, and the digitized signals led to a computer for on-line sorting, averaging, and storage. The computer programs (by the senior author) also controlled stimulus presentation, and performed off-line filtering and analyses.

In the present study, P300 determination is based on a standard baseline-to-peak method: The computer searches within each participant's average ERP within stimulus, paradigm and response categories (see Table 1), within a window which extends from 400 to 1000 ms post-stimulus for the 104 ms segment average (13 data points) which is most positive-going. This segment average is then subtracted from the average of the first, pre-stimulus, 104 ms of the recording epoch. The difference defines unscaled P300 amplitude. The midpoint of the maximally positive segment defines P300 latency.

The method just described is done only with Pz recordings. For the Cz and Fz sites, the temporal boundaries of the maximally positive segment at Pz are used to define the window over which P300 amplitude is calculated. This procedure is utilized to be certain that the same neural process is sampled across sites for purposes of profile construction. It is typically used by researchers who focus on scaled P300 amplitude profiles (e.g. Ruchkin, Johnson, Grafman, Canoune, & Ritter, 1992).

For group analyses, P300 latency and amplitude were based on unfiltered averages for each participant. For display, averages were digitally filtered to pass low frequencies; 3db point: 4.23 Hz. For task-by-site interactions, average P300 amplitudes within each participant were filtered and then scaled using the vector length method (McCarthy & Wood, 1985): Within each group and/or stimulus/response condition, the average Fz, Cz, and Pz values for the condition/group were squared, and the square root of the sum of the squared values was used as a denominator by which individual Fz, Cz, or Pz values within the condition/group were divided.

It is noted that analyses are performed here on both scaled and unscaled data. To look at main effects of group, stimulus type, paradigm, response type, and scalp site on amplitude, it is appropriate to look at unscaled data (McCarthy & Wood, 1985). However, to answer important questions here involving interactions with site, McCarthy & Wood (1985) described the need for analysis on scaled data. What the scaling accomplishes is the removal of possible amplitude differences between conditions, which may confound amplitude distribution differences. The scaling procedure in the present study removes main effects of group, paradigm, response type, and stimulus type, and allows meaningful interpretation only of interactions involving site. Thus, as recommended by McCarthy & Wood (1985), we report analyses on both scaled and unscaled data, as appropriate. (Latency need not be scaled).

Results

Behavioral. The mean numbers of responses in each stimulus-response category (see Table 1 for abbreviations) are shown in Table 2. There are six rows in each group and the numbers in the first row in the Lie group should correspond to those in the first row in the Control group, the second row in the Lie group with the second row in the Control group, and so on. The appropriate correspondences are close except for the second to the last row, (Lie = 101.58 vs. Control = 87.75). A 2X2 ANOVA was performed in which the between-participant variable was group (Lie vs. Control) and the within participant variable was Row 3 vs. Row 4 (Table 2) in both groups. For the Lie group, this is a comparison of (honest) L2/ODD-YES-FOW vs. (dishonest) L2/ODD-NO-FOW. For the Control group, forwards and backwards responses are compared (see Table 2). There was no effect of group ($p > .33$), no effect of Row ($p >.14$) and no interaction ($p > .26$). A similar ANOVA was done comparing Rows 5 and 6 within participants. This was a comparison of honest vs. dishonest responses to frequents in the Lie group. It was a comparison of forwards vs backwards responses in Controls. Here again there was no effect of group ($p >.34$), but the row effect ($F_{1,22} = 4.78$) was significant ($p < .05$), as was the interaction ($F_{1,22} = 4.89$, $p < .04$). This effect reflected the greater difference in the Lie participants in Row 5 vs. Row 6 of Table 2 than in the Controls . The ERP effects described below will mostly involve oddball stimuli (Rows 3 and 4 for both groups in Table 2), in as much as P300s in many participants in response to frequent stimuli were dubious. The present behavioral data indicate comparability between groups for oddball stimulus-response combinations; (the differences found for frequents were small though significant).

ERP data: Qualitative observations in grand average ERPs.

In the first paradigm, there should be no ERP differences between groups in response to either oddball or frequent stimuli, since both groups are behaving exactly alike in this paradigm (see Table 1 and methods). Superimposed grand averages from Lie and Control groups to oddballs are shown in Fig. 1, and to frequents, in Fig. 2. While differences between superimposed waveforms may be noted in amplitude and latency of P300, they did not reach significance (see below). Attention is drawn to the negative (up-going) wave in the Fz trace of Fig. 1 (vertical line) in the Lie average, but absent in the Control average. This was a difference (not in P300 and not significant) between groups before the key manipulation in this study of participants into two groups. Indeed, Fig. 9 shows superimposed grand averages from Lie participants for L1/ODD-YES-FOW trials (honest responses to oddballs) and L2/ODD-NO-FOW trials(dishonest responses to oddballs), and comparable negative waves are seen in both averages. It may be concluded that these negative waves are thus probably unrelated to deception vs. truth effects, and they will not be further considered.

Fig. 3 shows superimposed Lie and Control grand averages for L2/ODD-YES-FOW and B2/ODD-YES-FOW trials (all honest, forwards responses). It appears that the P300 is reduced in the Lie group relative to the Control group. Fig. 4 shows superimposed Lie and Control grand averages for L2/ODD-NO-FOW (dishonest, forwards) and B2/ODD-YES-BAC (honest, backwards) trials, and again, the P300s appear larger in the Control group. Fig. 5 also shows superimposed Lie and Control (honest, forwards) averages, L2/FREQ-NO-FOW vs. B2/FREQ-NO-FOW. Again the Control averages appear to have larger P300s. The same trend is seen in Fig. 6, which superimposes L2/FREQ-NO-FOW (dishonest, forwards), and B2/FREQ-NO-BAC (honest, backwards) trial averages.

Fig. 7 shows superimposed L2/ODD-YES-FOW (honest) and L2/ODD-NO-FOW (dishonest) responses within the Lie group. The former set appears to have more positive P300 responses, especially at Fz and Cz. (The differences would be more obvious if we chose, in the figures, to superimpose pre-stimulus baselines, which the P300 calculation algorithm does do. We chose to present data in figures as they really are, i.e., with random-noise related baseline shifts.) In Fig. 8, comparable superimpositions are shown within the Control group: B2/ODD-YES-FOW (forwards) vs. B2/ODD-YES-BAC (backwards). In this comparison, P300 in the latter category appears more positive.

P300 amplitude data analysis: unscaled data.

In the remaining sections of the P300 results, we will restrict reporting of results to oddball trials, since it was frequently impossible to locate a clear P300 peak in the frequent averages within participants.

Fig. 10 shows the group average, computer-determined P300 amplitude values as functions of site, group, paradigm (1 vs 2), and stimulus-response combination. It appears that within the Lie group, there is little difference in amplitude or slope, between L1/ODD-YES-FOW and L2/ODD-YES-FOW amplitudes (associated with honest responses), but that lying (L2/ODD-NO-FOW) produces a depression of amplitudes. In the Control group, the B1/ODD-YES-FOW and B2/ODD-YES-FOW response curves are also aligned, and indeed do not appear to differ from comparable Lie group honest response curves just discussed. This is as predicted. However, in the Control group, the B2/ODD-YES-BAC amplitudes appear enhanced by the backward condition manipulation.

To obtain statistical confirmation of these effects, we first tested the hypothesis that there would be no group and no paradigm differences during honest, forwards responses L1/ODD-

YES-FOW, L2/ODD-YES-FOW, B1/ODD-YES-FOW, B2/ODD-YES-FOW, as suggested in Fig . 10. The sets of P300 amplitudes classified in this way were submitted to a 3-way ANOVA, with independent variables group (Lie vs. Control), site, and paradigm (L1 vs. L2; B1 vs B2).

The effect of group was not significant ($p >.7$). Neither was the effect of paradigm ($p >.6$). The effect of site yielded $F_{2,44} = 134.34$, $p_g < .001$ (p_g is the Greenhouse-Geiser corrected probability in within-subject tests with df > 1. The correction is for sphericity effects. For df = 1 tests, the usual p-values will be reported.) The interactions were not significant, ($p >.2$), excepting the group-by-site interaction, which yielded $F_{2,44} = 4.18$, $p_g < .04$, reflecting the somewhat steeper slopes for honest, forwards Control curves than for the honest, forwards Lie curves in Fig. 10. (As noted in the methods, without scaling or normalization of amplitudes, all interaction effects or lack of interactions, are possibly confounded and not interpretable).

To get at the key effects involving L2/ODD-NO-FOW (Lie group) vs. B2/ODD-YES-BAC (Control group), we elected to compare each of these response types with their respective pooled truth-telling/forwards-repeating values. (Since the 3-way ANOVA described above showed no differences between groups or paradigm during truth-telling and forwards-repeating trials, the pooling was legitimate.) Thus we averaged L1/ODD-YES-FOW and L2/ODD-YES-FOW to form L/ODD-YES-FOW, and we averaged the comparable Control data to form B/ODD-YES-FOW.

Within the Lie group we then compared L/ODD-YES-FOW (honest) and L2/ODD-NO-FOW (dishonest) and examined site effects. The effect of site was $F_{2,22} = 89.98$, $p_g < .001$. The effect of honest vs. dishonest responses was $F_{1,11} = 7.11$, $p < .03$, reflecting the lower value of averaged L2/ODD-NO-FOW responses in comparison with averaged L/ODD-YES-FOW (the pooled average of L1/ODD-YES-FOW and L2/ODD-YES-FOW). The interaction of site and response type was not significant ($p > .4$). In the Control group, the effect of site was $F_{2,22} = 73.36$, $p_g < .001$. There was no significant effect of forwards versus backwards repetition ($p > .2$), despite the appearance of such a difference in Fig. 10. Neither was the interaction of response type and site ($p > .6$) significant. Thus, although the dishonest response manipulation had a significant effect on unscaled P300 amplitudes in comparison with honest responses, the backwards repetition manipulation did not.

A 3-way ANOVA on unscaled amplitudes was done in which the independent variables were site, group, and response type, only in Paradigm 2: L2/ODD-YES-FOW vs. L2/ODD-NO-FOW, and B2/ODD-YES-FOW vs. B2/ODD-NO-BAC. The effect of site was $F_{2,44} = 137.55$, $p_g < .001$. The main effect of group was not significant ($p > .8$), reflecting the apparent interaction effect that amplitudes in the Lie group are depressed by dishonest responses, whereas the effect of backwards repetition is enhancement of P300 amplitudes in the Control group (Fig. 10). This is supported by the interaction of group by response-type, $F_{1,22} = 4.7$, $p < .05$. There was also a significant main effect of response-type, $F_{1,22} = 4.78$, $p < .05$, probably carried by L2/ODD-NO-FOW vs. B2/ODD-YES-BAC data, in view of the interaction just noted. The (possibly confounded) group-by-site interaction was marginal ; $F_{2,44} = 3.44$, $p_g = .065$. The triple interaction was not significant, ($p > .2$). A post-hoc, 2-way, ANOVA (group x site, just comparing L2/ODD-NO-FOW and B2/ODD-YES-BAC) was done to confirm the difference between L2/ODD-NO-FOW and B2/ODD-YES-BAC which is seen in Fig. 10, and which apparently carried the main effect of response-type in the 3-way ANOVA just reported. The result was confirmatory, with the effect of group being $F_{1,22} = 8.78$, $p < .008$, the effect of site being $F_{2,44} = 86.73$, $p_g < .001$. The interaction yielded $p > .2$.

P300 Amplitude analysis; scaled data.

In this section, we will comment only on interaction effects, since the scaling of data intentionally obviates main effects other than site effects, which are exaggerated (McCarthy & Wood, 1985). Fig. 11 is the scaled equivalent of Fig. 10, and shows scaled P300 amplitudes as a function of site, paradigm, group, and response type. The figure suggests that all curves are similar except for the curve of the Lie group, during the second paradigm, and only on dishonest response trials (L2/ODD-NO-FOW).

Our statistical analysis approach with scaled data parallels the approach used with unscaled data (except with scaled data , we look only at interaction effects). Thus the first analysis performed on scaled data was a 3-way ANOVA on all honest-responding, forward-repetition conditions, i.e., with independent variables: site, group, and paradigm. The four response types separately submitted by group were L1/ODD-YES-FOW, L2/ODD-YES-FOW, B1/ODD-YES-FOW, B2/ODD-YES-FOW. No interactions were expected, and none were found; (all $p > .2$).

Next, as with unscaled data, we combined the honest, forward response trials within each group to use as a benchmark-baseline with which to compare dishonest (Lie) or backwards (Control) responses. L/ODD-YES-FOW is the average of L1/ODD-YES-FOW and L2/ODD-YES-FLOW in the Lie group; B/ODD-YES-FOW is the comparable average within the Control group. Within the Lie group, a 2-way ANOVA on effect of response-type (L/ODD-YES-FOW vs. L2/ODD-NO-FOW) and site yielded a significant interaction of response type-by-site; $F_{2,22} = 6.76$, $p_g < .02$. Within the Control group, the comparable ANOVA on effect of B/ODD-YES-FOW vs B2/ODD-YES-BAC with site also yielded a significant interaction; $F_{2,22} = 10.6$, $p_g < .001$. This was in contrast to what is suggested in Fig. 11, where the curves seem all alike (especially at Cz and Pz) except for the L2/ODD-NO-FOW (dishonest response) curve. It is noted (Fig. 11), however, that whereas in the Lie group, the interaction shows a depression of L2/ODD-NO-FOW in comparison with L2/ODD-YES-FOW (honest vs. dishonest responses), in the control group, the B2/ODD-YES-BAC responses are slightly (but significantly) enhanced in comparison with the B2/ODD-YES-FOW curve.

We performed comparable ANOVAs, post-hoc, on data from just the Cz and Pz sites. In the Lie group, L/ODD-YES-FOW vs. L2/ODD-NO-FOW interacted with site, $F_{1,11} = 24.32$, $p < .001$. However, in the Control group, B/ODD-YES-FOW vs. B2/ODD-YES-BAC did not interact with site ($p > .15$); neither did B1/ODD-YES-FOW vs. B2/ODD-YES-BAC ($p > .1$).

Using data from all three sites, we examined the interaction of L2/ODD-NO-FOW vs. B2/ODD-YES-BAC with site and obtained $F_{2,44} = 11.01$, $p_g < .003$. The two tasks (honest/backwards repetition vs. dishonest/forwards repetition) produced differing scaled scalp distributions in the second paradigm.

Latency Effects

Table 3 shows the Pz latencies of P300 for oddball responses in the two groups, segregated by response type. The Control group latencies are slightly greater than those of the Lie group (although the largest difference in row 1 of the table occurs prior to the group-generating manipulation). For both groups responding honestly and with forwards repetition in both paradigms, a 2-way ANOVA was performed on oddball latencies, with independent variables group and response type; (L1/ODD-YES-FOW, L2/ODD-YES-FOW, B1/ODD-YES-FOW, B2/ODD-YES-FOW). There were no significant effects for group ($p > .2$), response type ($p > .5$) or interaction ($p > .4$).

Another 2-way ANOVA was performed on Pz latencies involving group and honest, dishonest, forwards, and backwards response types; (L2/ODD-YES-FOW, L2/ODD-NO-FOW, B2/ODD-YES-FOW, B2/ODD-YES-BAC). Again there were no significant effects of group ($p > .4$), response type ($p > .6$), or interaction ($p > .6$). The present manipulations had no effects on P300 latencies, suggesting that task demands for the two groups did not differ.

Discussion

We have shown previously (Rosenfeld et al, 1998; Rosenfeld et al., in press) that the scaled scalp distributions (profiles) of P300 amplitude in deception conditions differ from those seen in simple truth-telling conditions. Since the scaled scalp amplitude distribution is independent of amplitude itself (McCathy & Wood, 1985; Johnson, 1988, 1993), it may well be the case that profile can become another brain-wave-based channel (dependent measure) which could be used in practical detection of deception situations. There have now been several demonstrations that P300 amplitude, itself, can be so utilized; (e.g., Rosenfeld, Cantwell, Nasman, Wojdac, Ivanov, & Mazzeri, 1988, Rosenfeld, Angell, Johnson, & Qian, 1991, Ellwanger, Rosenfeld, Sweet, & Bhat, 1996, Farwell & Donchin, 1991; Allen & Iacono, 1992.)

One could not say, however, on the basis of previous studies, that the profile seen in deceptive conditions represented neural activity *specific to the act of deception*, itself, since, as reviewed in the introduction, deceptive and truth-telling conditions previously utilized also differed in task demand: the truth-teller had only to do his/her best on a simple task whereas the deceiver had to (additionally) keep track of his/her deception rate, and decide on each trial whether or not to lie.

The present study was designed to address these considerations by (1) allowing comparison of profiles between two groups (Lie and Control) in which we attempted to equalize task demand to the maximum extent (although perfect equalization may not be possible), and (2) allowing comparison within the Lie group of profiles associated with honest versus dishonest response trials. Differing profiles in dishonest versus honest conditions would suggest different neurogenerator sets associated with each condition (Johnson, 1993; McCarthy & Wood, 1985). It may also be that the two conditions evoke different sets of components which differentially overlap the P300 which both conditions evoke in common (Donchin et al, 1997). In either case, however, the differing profiles indicate differing modes of brain function in each condition.

In fact, we found that scaled profiles differed in Lie group members during honest and dishonest response trials. Since the task demand on the Lie group members was the same throughout the second paradigm task (i.e. during honest and dishonest trials), it is suggested that the significant interaction of response type (honest vs dishonest) by site provides evidence of differential modes of brain operation during the two kinds of trials, and that this effect is not confounded by task demand differences.

The Control group, like the Lie group also had to make a decision on each trial (whether or not to repeat a stimulus backwards), and had to track the same ratio of the two kinds of available responses (50-50). When scaled amplitude data from all three sites (Fz, Cz, Pz) were analyzed, this group also showed an interaction of site and response type (honest forwards repetition vs honest backwards repetition). However, the nature of the change from the forward repetition condition in the Control group was quite different (an upward displacement from forwards repetition baseline) than that seen in the Lie group (a downward displacement), and a robust task x site interaction was obtained in a comparison of L2/ODD-NO-FOW (dishonest, forwards) and B2/ODD-YES-BAC (honest, backwards) profiles. Indeed, if one considered only the Cz and Pz sites, then only the Lie group showed an interaction effect in the response type manipulation (response type x site) whereas the Control group showed no (response type x site) significant interaction. Similarly, in unscaled data from all three sites, significant main effects on amplitude were seen only in response to the honesty manipulation and not in response to the forwards vs backwards repetition manipulation. Thus the honesty-dishonesty manipulation had greater effects than the forwards-backwards manipulation (on unscaled Fz, Cz, Pz amplitudes, and on scaled profiles at Cz and Pz) in this study. Further evidence that group differences are not attributable to task demand differences comes from the latency data: The P300 latencies did not differ between Lie and Control groups. Increases in task complexity involving greater stimulus processing demand from one condition to another are usually reported to increase P300 latency (and to decrease amplitude; Johnson, 1988). The lack of latency differences between groping conditions is consistent with the fact that task complexity and demand did not differ between groups.

It is not surprising that in scaled profile data, the Control and Lie groups had differing curves. The two tasks are quite different in two ways, involving 1) honest (Control) versus dishonest (Lie) responses, and 2) trials with forward (lie) versus backward repetition (Control). One cannot say with certainty that by themselves, these differing profiles are due to honesty differences, repetition direction differences, or both. This is why we also used a first paradigm with all participants responding honestly with forward repetition of stimuli. Since these profile data did not differ from the honest/forward repetition data in the second paradigm, we pooled, within each group, the honest/forward response data from both paradigms and used them as baseline/benchmarks with which to compare dishonest response profiles in the Lie group and backwards response profiles in the Control group. The manipulations within each group produced different scaled profile effects, in terms of shifts from the benchmarks as noted above, and we would attribute the effect in the Lie group to effects of deception. This is consistent with the finding of different profiles for honest and dishonest responses (L2/ODD-YES-FOW and L2/ODD-NO-FOW) within the second paradigm of the Lie group, where within one block, different profiles were obtained. These effects are attributable to deception specifically, since, as noted above, these Lie participants were all treated alike and the only difference between the cognitive states of Lie participants on trials involving honest vs. deceptive responses is this difference in response selection.

It is noted (Fig. 11) that in the Lie group, the scaled L2/ODD-NO-FOW (dishonest response) curve is down shifted at Cz and Fz and upshifted at Pz relative to both the honest condition of Paradigm 1 (L1/ODD-YES-FOW) as well as to the honest response trials of Paradigm 2 (L2/ODD-YES-FOW). It is also downshifted in comparison with all Control group curves at Fz and Cz, and upshifted at Pz. These interactions strongly suggest that the lie response has a unique effect on brain operation. The fact that unscaled amplitudes are uniquely reduced in the Lie group during dishonest responses also supports a unique attribute related specifically with dishonest responses.

The pattern of group effects on unscaled amplitude suggests an explanation of group differences: It is known that a dual task situation in which one task is an oddball task and the other is not leads to changes in (unscaled) P300 amplitude (Donchin, Kramer, & Wickens, 1986): If the other task is independent of the oddball task, it is hypothesized to compete for attentional processing resources with the oddball task as reflected in a decline of P300 (Kramer, Sirevaag, & Braune, 1981). If the other task is embedded within the oddball task, one sees an enhancement of P300 in the dual task (Donchin et al., 1986). We have consistently reported (e.g., Rosenfeld et al., in press) a reduction in P300 amplitudes in lying vs. truth-telling conditions. In the present study we also see this reduction, even when the truth-telling condition (Control group) involves the additional task of backwards repetition. Moreover, the Control group, during backwards repetition trials, showed an enhancement of unscaled P300 amplitudes relative to other response curves (Fig. 10). If this trend had been significant (it was not), it could have been interpreted in terms of the backwards repetition task requiring more attention to stimuli (to allow better rehearsal for backwards responses). In this way the oddball detection task and the backwards repetition task both require attention to oddball stimuli and are thus both mutually embedded, resulting in an enhanced P300. Although the effect of backwards vs forwards repetition on unscaled amplitudes within the Control group did not reach significance, a post-hoc, direct comparison of lie response amplitudes in the Lie group with backwards response amplitudes in the Control group yielded a robust effect ($p < .001$), with the Control group P300s having the clearly greater amplitude (Fig. 10).

It was essential, in the design of this study, that there be no differences among the P300s associated with both paradigms and groups during the honest responses. This requirement was mandated by our plan to pool honest, forwards responses so as to generate benchmark/baselines as described above. However, we also had application issues in mind: In any anticipated uses of these methods with real suspects in the field, it will be essential to have data from a control/baseline session, in which the suspect is known to be responding truthfully, with which to compare, in the same subject, data obtained during a test session in which the subject's (dis)honesty is to be ascertained. The present results in the Lie group which showed no differences between P300 distributions associated with truthful responses from both the first and second paradigms, but differences between pooled truthful responses and dishonest responses, suggest that it should be possible to develop procedures, based on current group results, for future intraindividual diagnosis.

There is another implication regarding the data obtained from both groups during honest, forwards responding: One might have predicted differences between data sets obtained from the two paradigms during honest, forwards responding on the basis of the fact that the first paradigm utilized phone numbers as stimuli, whereas the second paradigm utilized (birth) dates. A participant might have been expected to show different scaled amplitude profiles to these two kinds of stimuli on the basis of different cognitive processing of the two classes. Such differences were not observed. (Of course, such differences might be seen in data from other scalp sites.) This negative outcome suggests that the specific nature of the stimulus does not play a significant role in determination of profile shape in the present context: Rather, an autobiographal oddball stimulus yields a typical Pz > Cz > Fz profile which does not differ as a function of the specific nature of the stimulus, so long as an honest response occurs to the stimulus. Dishonest responses, however, affect the profile. We could have counterbalanced across participants the order of stimulus class used in the present study in order to control (unobtained) effects of differing stimulus classes. We chose not to counterbalance because while this counterbalanced design would have been easily implemented in the present laboratory analog, it would appear to present major problems in intraindividual field tests, and therefore we used the design here reported.

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Table 1: Abbreviation Summary

Lie Group (all responses include repetition of stimuli forwards)

Paradigm	Stimulus	Response	Abbreviation	Honest/dishonest
1	oddball	"yes" (oddball, forwards)	L1/ODD-YES-FOW	honest
1	frequent	"no" (frequent, forwards)	L1/FREQ-NO-FOW	honest
2	oddball	"yes" (oddball, forwards)	L2/ODD-YES-FOW	honest
2	oddball	"no" (oddball, forwards)	L2/ODD-NO-FOW	dishonest
2	freq	"no" (frequent, forwards)	L2/FREQ-NO-FOW	honest
2	freq	"yes" (oddball, forwards)	L2/FREQ-YES-FOW	dishonest

Control (partial backwards repetition) group; all honest responses.

Paradigm	Stimulus	Response	Abbreviation	Honest/dishonest
1	oddball	"yes" (oddball, forwards)	B1/ODD-YES-FOW	honest
1	frequent	"no" (frequent, forwards)	B1/FREQ-NO-FOW	honest
2	oddball	"yes" (oddball, forwards)	B2/ODD-YES-FOW	honest
2	oddball	"yes" (oddball, backwards)	B2/ODD-YES-BAC	honest
2	freq	"no" (frequent, forwards)	B2/FREQ-NO-FOW	honest
2	freq	"no" (frequent, backwards)	B2/FREQ-NO-BAC	honest

Table 2: Average numbers (± SEM) of responses in each possible stimulus-response category. Table 1 and text define category abbreviations.

Lie Group

Row	Category	Number
1	L1/ODD-YES-FOW	24.67 ± .97
2	L1/FREQ-NO-FOW	146.58 ± 5.8
3	L2/ODD-YES-FOW	17.25 ± .85
4	L2/ODD-NO-FOW	15.00 ± .90
5	L2/FREQ-NO-FOW	101.58 ± 4.46
6	L2/FREQ-YES-FOW	86.5 ± 4.24

Control Group

Row	Category	Number
1	B1/ODD-YES-FOW	25.67 ± .99
2	B1/FREQ-NO-FOW	143.67 ± 7.16
3	B2/ODD-YES-FOW	15.17 ±.91
4	B2/ODD-YES-BAC	14.83 ± 1.28
5	B2/FREQ-NO-FOW	87.75 ± 6.54
6	B2/FREQ-NO-BAC	87.8 ± 5.26

Table 3: P300 Pz Latencies (+ SD)

Lie Group		Control Group	
Response Type	Latency (ms)	Response Type	Latency (ns)
L1/ODD-YES-FOW	516 ± 34.9	B1/ODD-YES-FOW	550 ± 53.9
L2/ODD-YES-FOW	518 ± 80.2	B2/ODD-YES-FOW	528 ± 47.3
L2/ODD-NO-FOW	518 ± 49.6	B2/ODD-YES-BAC	539 ± 44.8

Figure Legends

Fig. 1. Superimposed grand average responses to oddballs (birthdates) in Lie (L1/ODD-YES-FOW) and Control (B1/ODD-YES-FOW) groups in first paradigm. Positivity is down in all ERP figures. A vertical line appears over an anomolous negative component (see text) at Fz, seen only in Lie group. In all ERP figures, "Count" = number of sweeps/average. Lie group (thick) and Control group (thin) are superimposed in Figs. 1-6. All honest responses with forward repetition.

Fig. 2. Similar to Fig. 1, except responses to frequent phone numbers are superimposed.

Fig. 3. Same as Fig. 1, but from second paradigm.

Fig. 4. Superimposed oddball (birthdate) responses during lies in the Lie group (L2/ODD-NO-FOW) and during backwards-repetition responses in Control group (B2/ODD-YES-BAC), all from Paradigm 2.

Fig. 5. Superimposed honest, forward responses to frequent dates in Lie group (L2/FREQ-NO-FOW), and Control group (B2/FREQ-NO-FOW) all from Paradigm 2.

Fig. 6. Superimposed dishonest, forwards responses to frequents in Lie group and honest-backwards responses in Control group, all from paradigm 2.

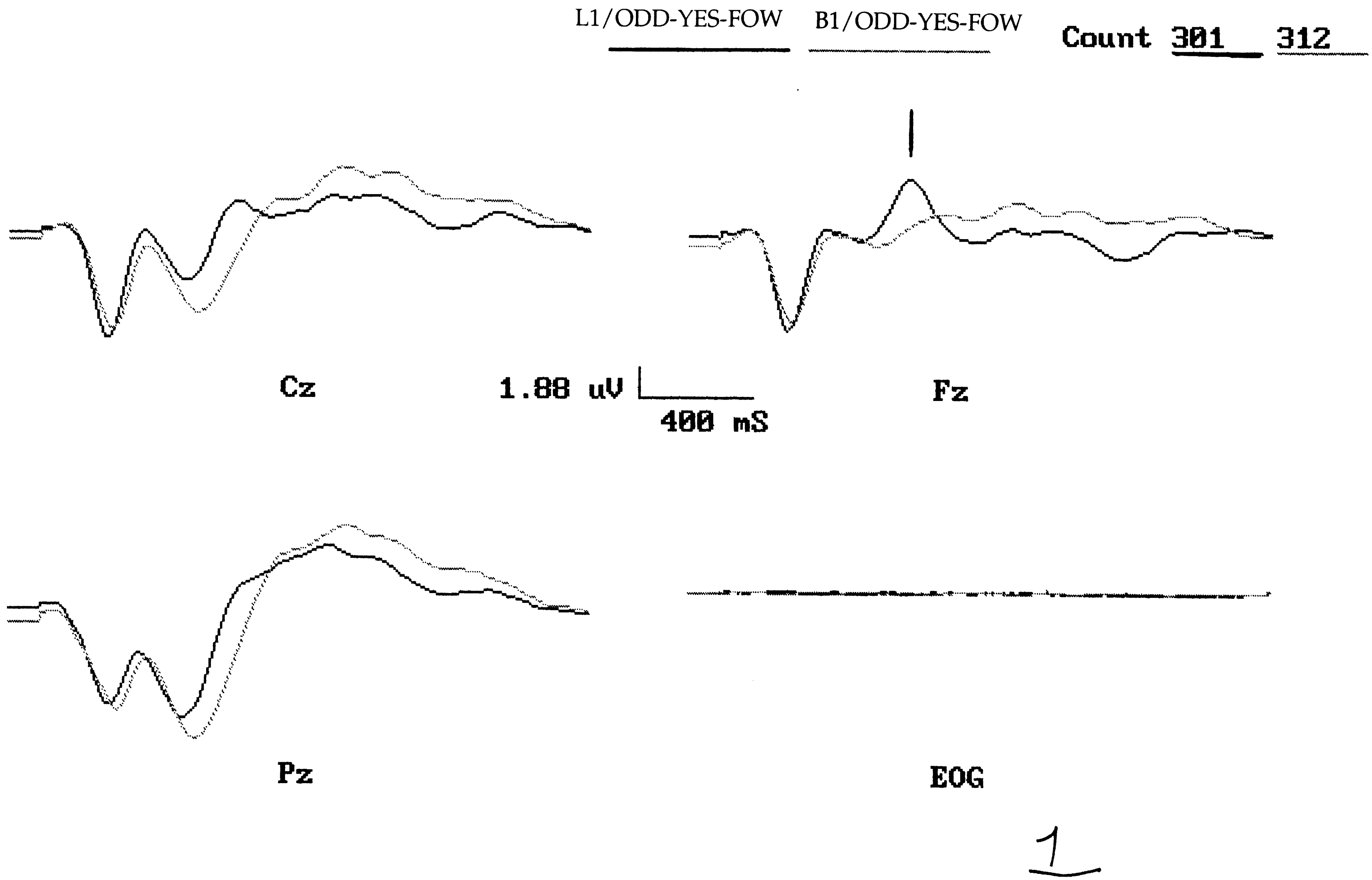
Fig. 7. Superimposed honest (thick: L2/ODD-YES-FOW) and dishonest (thin: L2/ODD-NO-FOW) responses, all from LIE group in Paradigm 2.

Fig. 8. Superimposed forwards (B2/ODD-YES-FOW) and backwards (B2/ODD-YES-BAC) , honest responses in Control group, Paradigm 2.

Fig. 9. Superimposed dishonest, forwards responses in Lie group (thin: L2/ODD-NO-FOW), Paradigm 2, and honest responses in Lie group (thick: L1/ODD-YES-FOW) in Paradigm 1.

Fig. 10. Averages of computer-determined, within-participant, unscaled P300 amplitudes (uV) as a function of site, paradigm, stimulus, and response type.

Fig. 11. Same as Fig. 10, but scaled amplitudes are plotted.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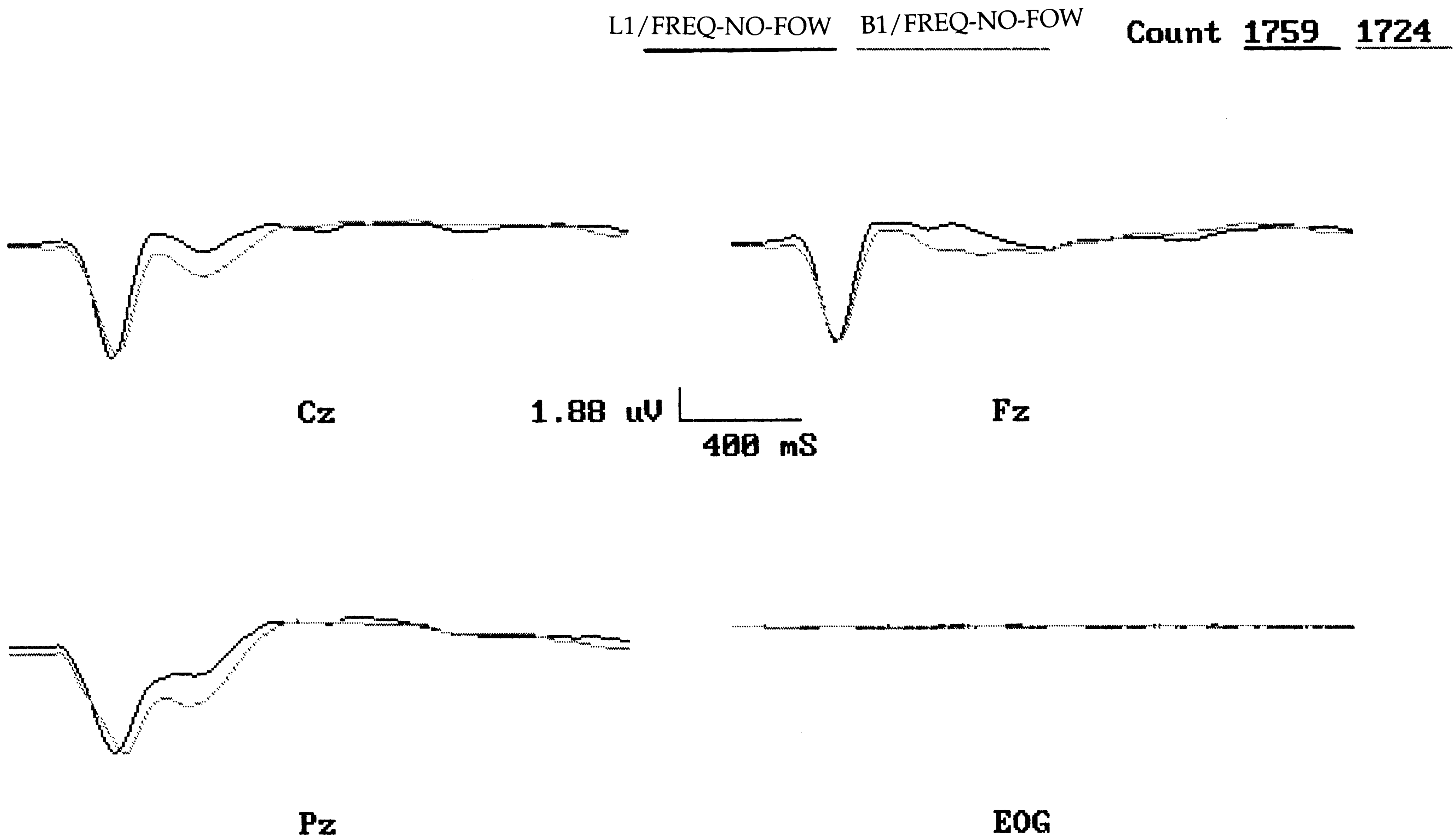
Fz
Pz
EOG
1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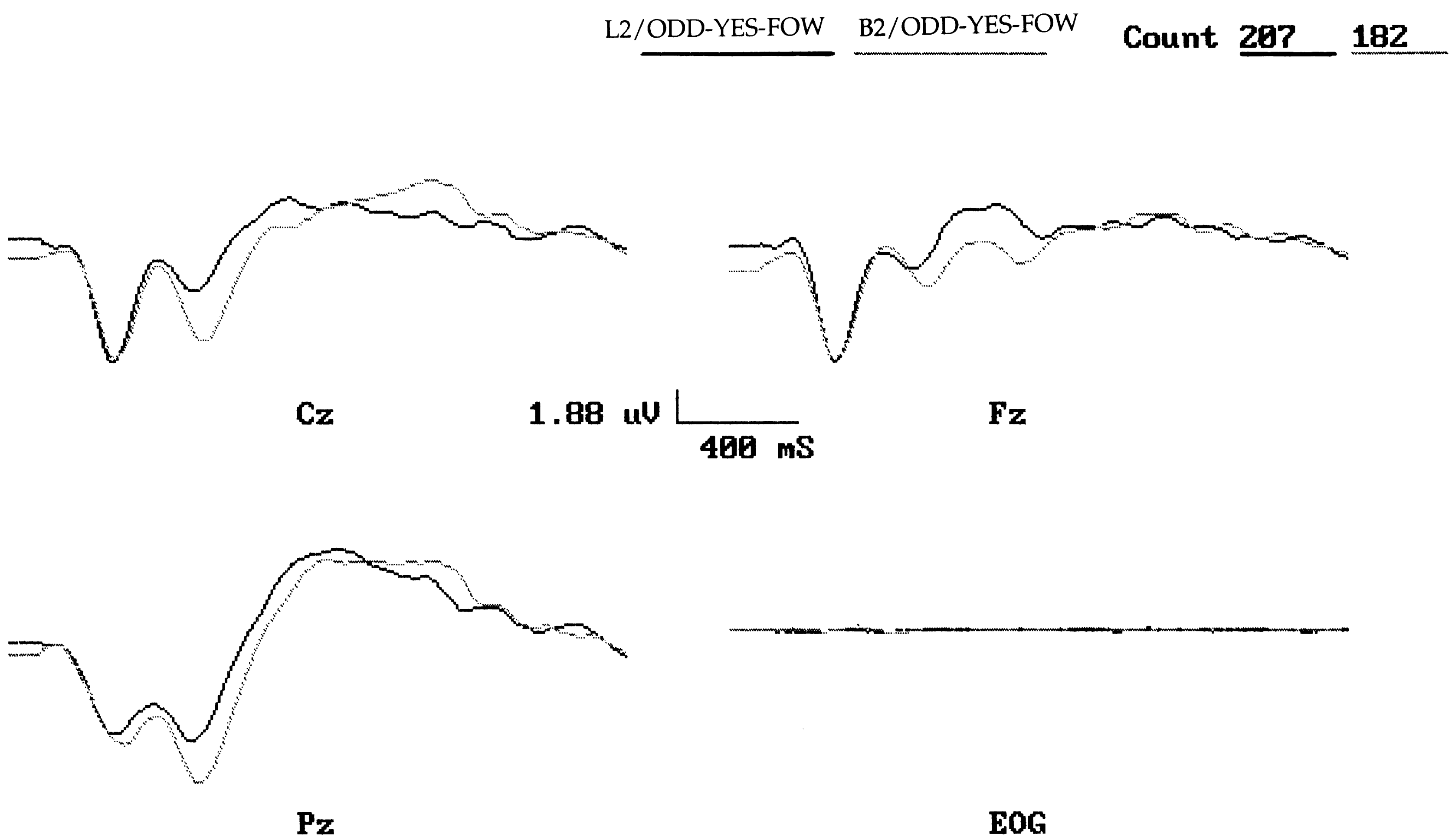
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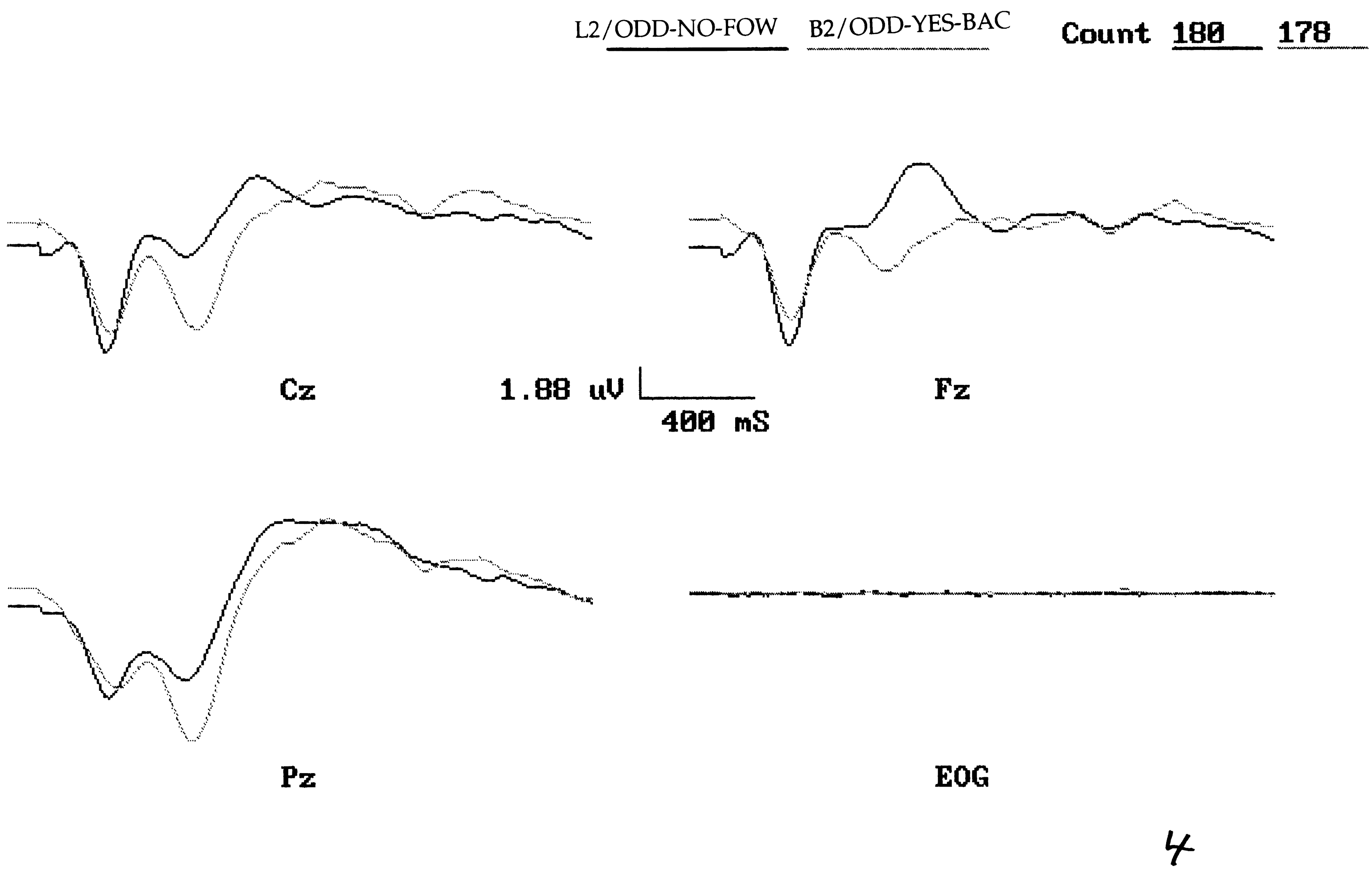
3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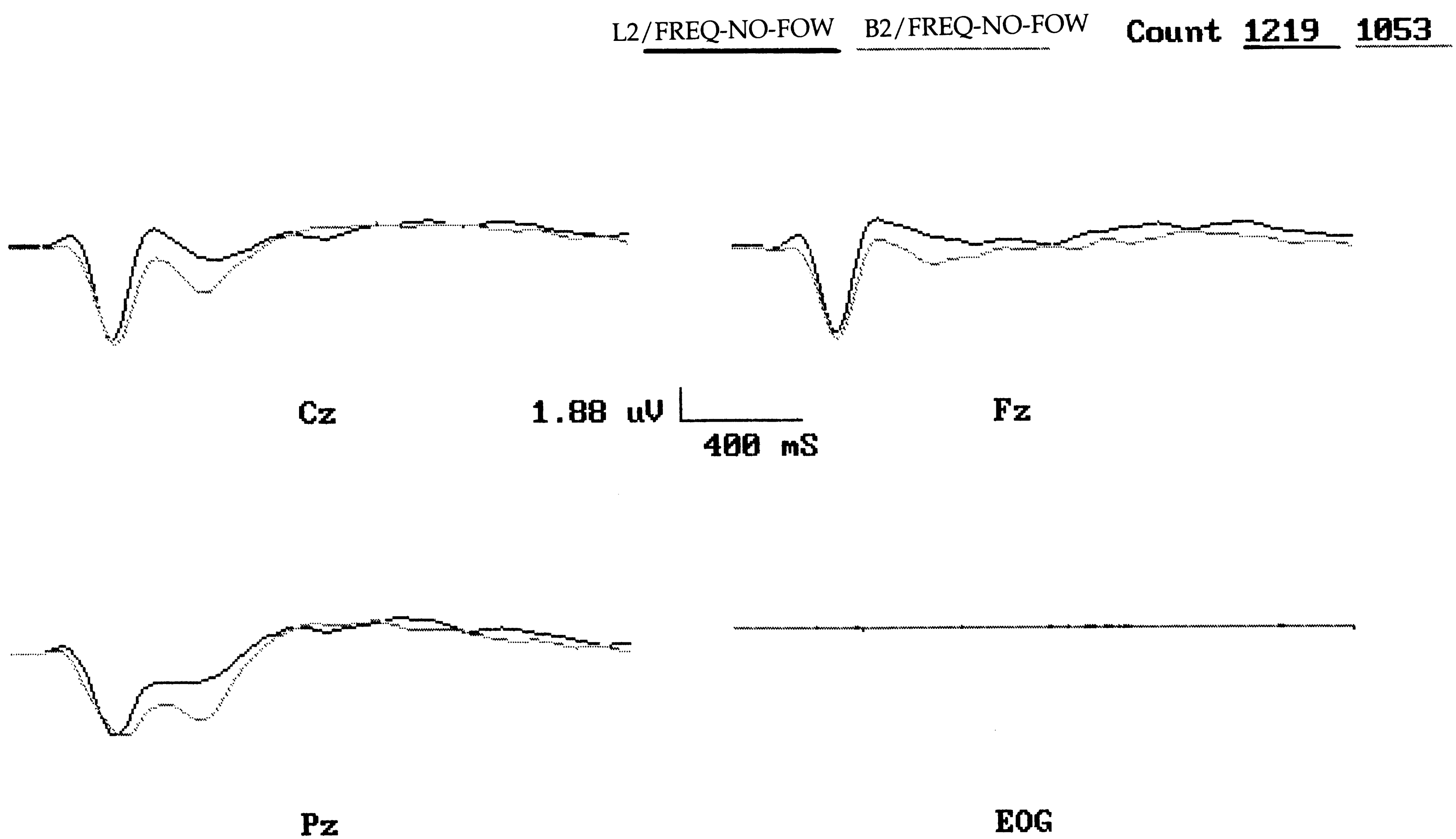

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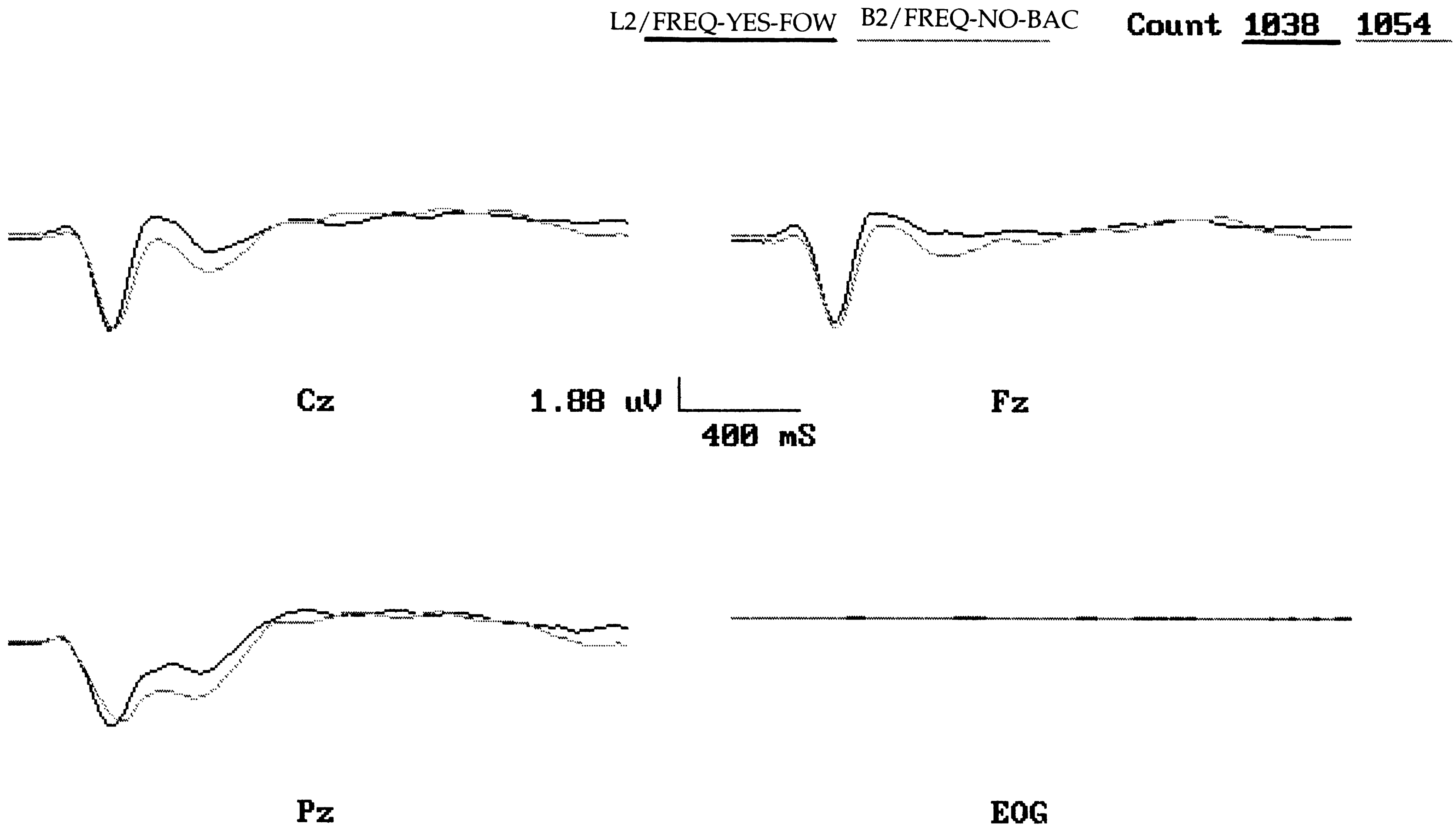
5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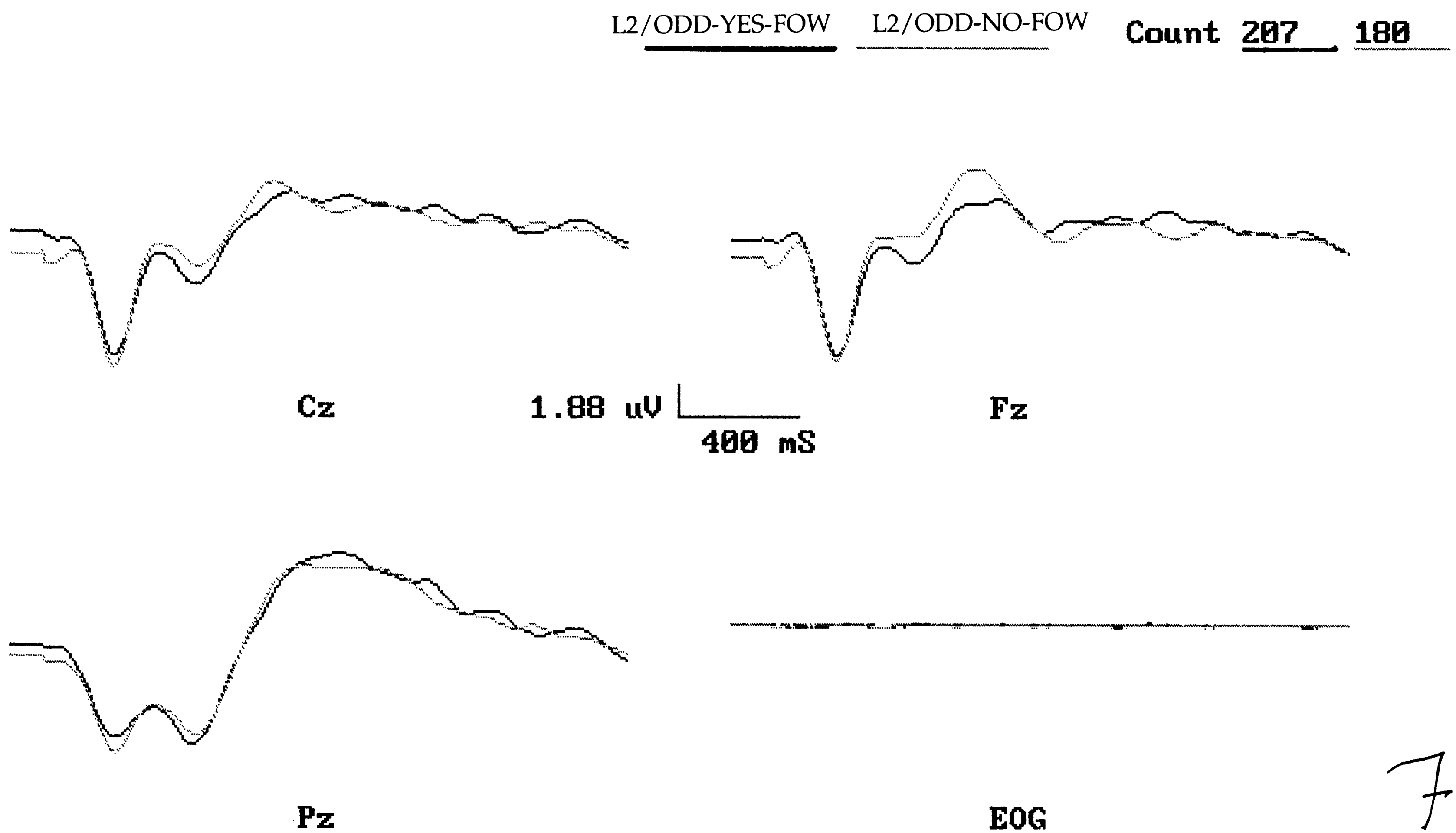
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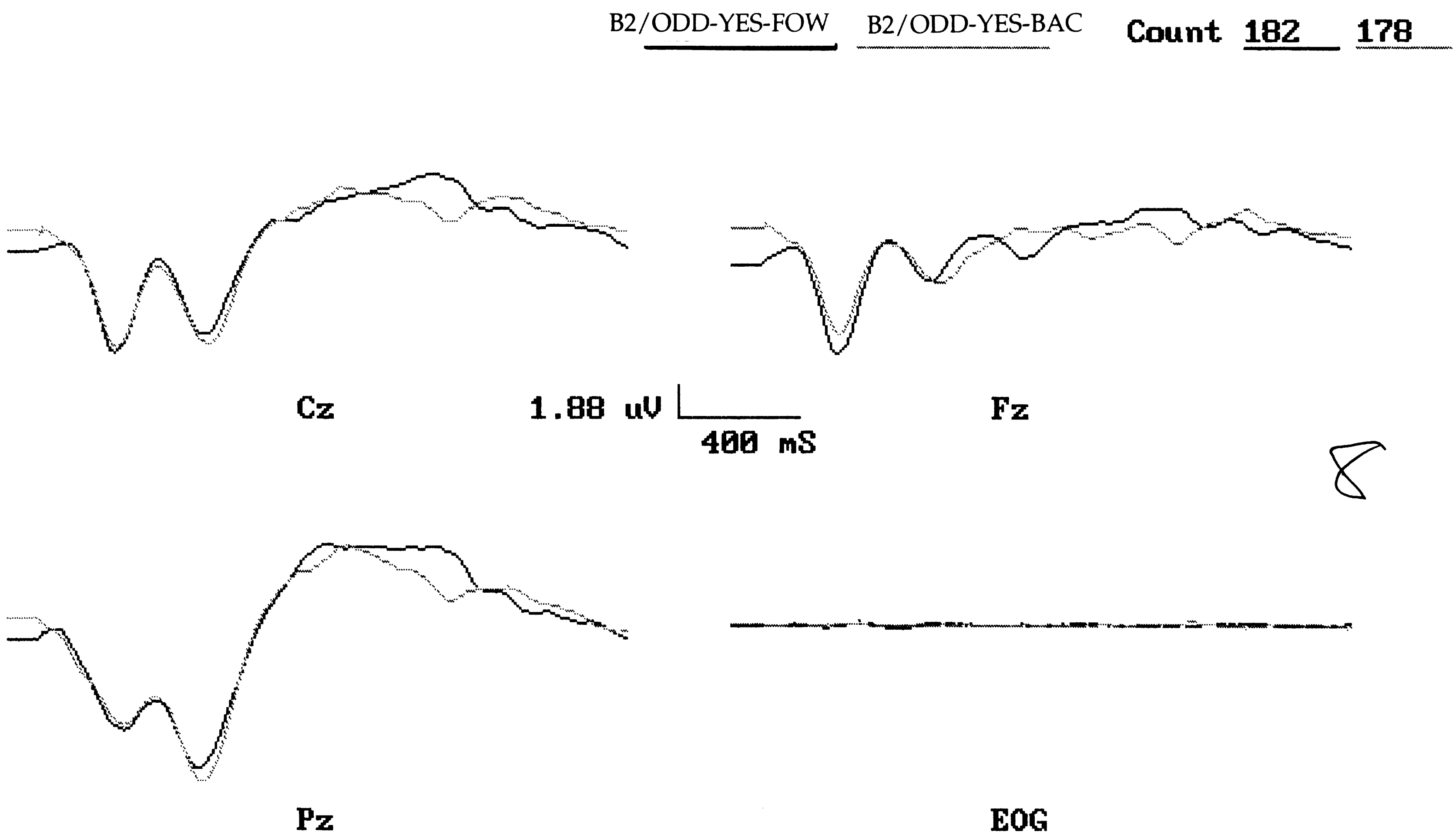
7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Fz
8
Pz
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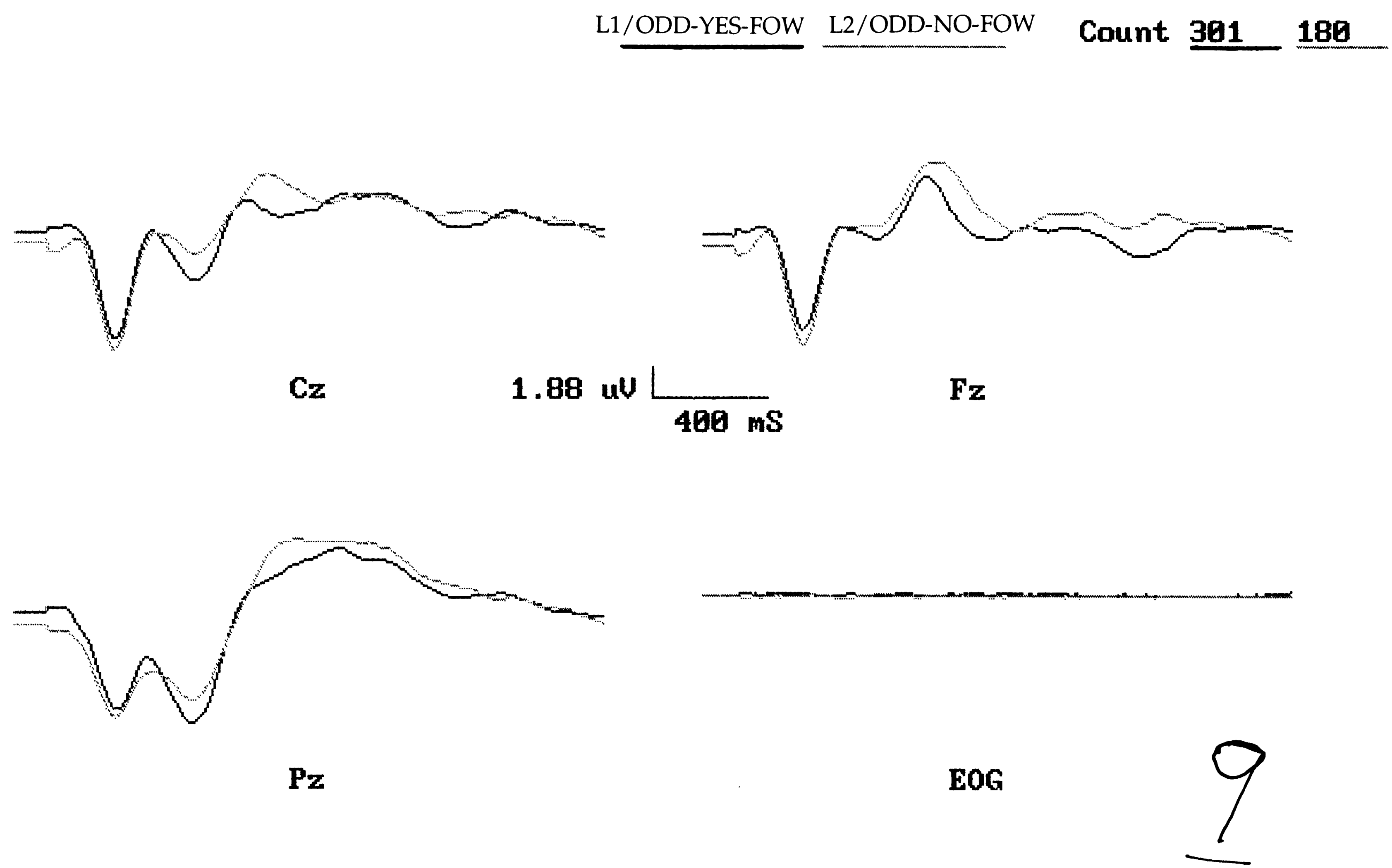
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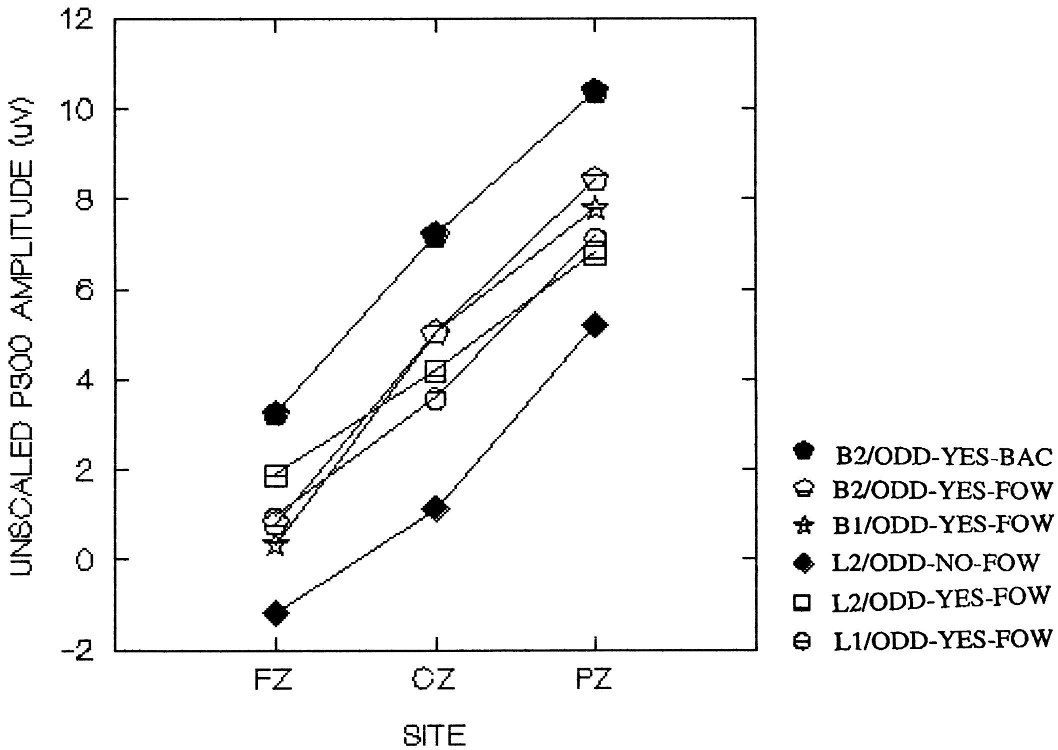
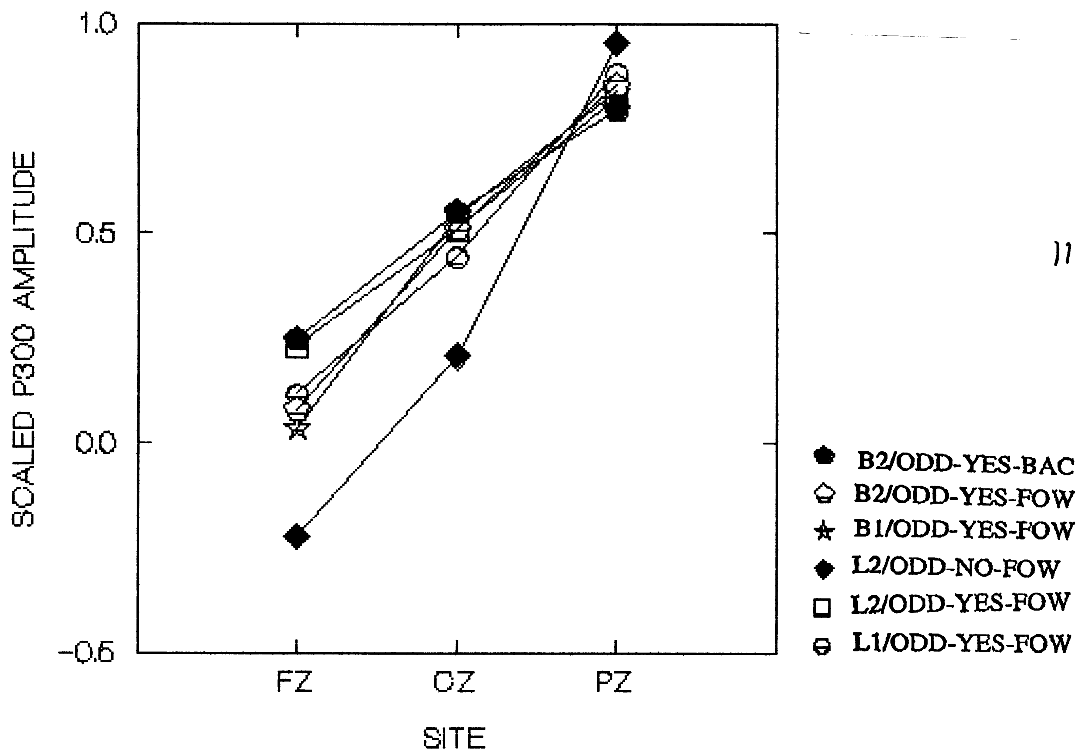
9

P300 AMPLITUDES BY PARADIGMS, SITES AND GROUPS

10



SCALED AMPLITUDES BY PARADIGMS, SITES, GROUPS



11