Journal of Scientific Exploration, Vol. 16, No. 2, pp. 187–206, 2002 0892-3310/02

Differential Event-Related Potentials to Targets and Decoys in a Guessing Task

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Abstract—Event-related brain potentials (ERPs) were recorded from 20 subjects performing a computerized, forced-choice guessing task. On each of 40 trials, ERPs were elicited by digitized images of 4 playing cards, sequentially presented on a video monitor for 150 ms. After the last card was presented, subjects guessed which of the 4 cards would be the target for that trial. Following the subject's guess, the computer randomly selected one of the 4 cards to be the target and presented this as feedback; the remaining 3 cards served as nontarget decoys for the trial. We found that a negative Slow Wave measured at 150–500 ms post-stimulus had greater amplitude when elicited by targets than when elicited by nontarget decoys ($p \leq .05$). This result indicates an apparent communications anomaly because no viable conventional explanation of the ERP differential could be identified. It is the fourth study in our laboratory employing essentially the same design to yield this or a similar ERP effect.

Keywords: event-related potential (ERP)—slow wave—communications anomaly—anomalous information transfer—ESP—guessing task—target stimuli

Introduction

The physiological approach to parapsychology dates back nearly a half century. Physiological responses which have been studied in extra-sensory perception (ESP) research include measures of autonomic nervous system activity such as the electrocardiogram, respiration, and electrodermal responses, and measures of central nervous system activity such as the spontaneous electroencephalogram (EEG) and event-related brain potentials (ERPs). The theoretical rationale for using physiological measures was expressed by the philosopher and parapsychologist John Beloff. If ESP is largely an unconscious process, as is widely believed, such physiological measures have an apparent advantage over the typical verbal response in parapsychological experiments because they may circumvent the conscious decision-making process (Beloff, 1974).

In contrast to the relatively large number of studies using measurements of the spontaneous EEG (primarily, alpha activity) as their dependent variable, the use of ERPs in parapsychological research has been extremely limited. The earliest report of the ERP technique being used to study ESP was published by Lloyd (a pseudonym) in 1973, although Silverman and Buchsbaum (1970, p. 155) referred briefly to an unsuccessful pilot attempt in their laboratory. Lloyd observed ERP-like deflections in averaged EEG epochs of a percipient which were time-locked to the onset of a pacing light flash seen only by the sender. The obtained waveforms somewhat resembled those obtained in response to auditory tone stimulation, with the principal features corresponding to two components: one at 120 ms (N100) and another at 220 ms (P200). The light flashes served as a signal for the sender to "psychically communicate" or "transmit his thought image" to the percipient. The percipient was not informed of the nature of the thought image (a cup of coffee), and presumably was not consciously aware of receiving the telepathically transmitted image, although such awareness was not a focus of the study.

A few years later, Millar (1979) attempted unsuccessfully to replicate Lloyd's finding under conditions similar to those used by Lloyd. However, Millar used a bipolar montage (Cz-O2), whereas Lloyd used a monopolar (Cz) derivation, and Millar computed a variance measure of ERP activity, whereas as described below, Lloyd used a non-quantitative assessment of ERP activity. Therefore, strictly speaking, Millar's study was not a replication of Lloyd's study because it used a different dependent measure. On the other hand, Millar's study was better controlled than Lloyd's because it included a comparison condition in which the sender was not required to make telepathic transmissions, whereas Lloyd's did not, and because it used a quantitative measure of ERP activity, whereas Lloyd's conclusion was based only on a visual comparison of the putative, telepathically-elicited ERP, with auditory ERP components having the same latencies, and with average background activity.

Two parapsychology studies used the contingent negative variation (CNV) as their dependent variable, a slow, negative-going, ERP which is believed to reflect anticipation, expectancy, or cortical priming leading to a response. First described by Walter et al. (1964), the CNV is typically observed in warned reaction time (RT) tasks between the warning stimulus and an imperative stimulus requiring a response. In a pilot study using a go–no go RT task, Levin and Kennedy (1975) reported that a frontally-recorded CNV was larger prior to an imperative stimulus requiring a button press response (green light) than to a stimulus not requiring a response (red light), even though the color of the imperative stimulus was (randomly) selected only <u>after</u> the CNV measurement epoch. Hartwell (1978) studied CNV in a similar warned RT task in which pictures of people served as the imperative stimuli, these pictures being either of the same sex or the opposite sex as the percipient. However, unlike Levin and Kennedy's study, extensive computer analysis of the CNV recorded from frontal, central and parietal scalp sites in Hartwell's study yielded only scant evidence for an anticipation anomaly.

A more recent study by Grinberg-Zylberbaum et al. (1993) reported that ERPs elicited simultaneously from pairs of subjects in separate chambers exhibited a high degree of similarity. However, these results may be regarded as suggestive at best because of several methodological weaknesses, e.g., the investigators failed to perform any inferential statistical tests on their data, they used unusually severe, high-pass filtering of the ERP data, and their controls against sensory leakage appear to have been inadequate.

At about the same time as the Grinberg-Zylberbaum study, Warren et al. (1992a) reported statistically significant ERP differences between target and nontarget stimuli presented during a forced-choice precognition task which was structurally similar to the present experimental task, but which used a different stimulus set. In their single-subject design, Warren et al. tested a gifted psychic who had previously demonstrated above-chance guessing accuracy on an earlier version of this ESP task in an experiment reported by Honorton (1987), a study which was not concerned with ERPs or other physiological variables. Although this subject's guessing accuracy did not differ significantly from mean chance expectation in the Warren et al. (1992a) study, examination of his brain responses to task stimuli revealed significant ERP differences between the target and nontarget waveforms. A positive-going component, peaking at 100 ms (P100), was larger over three anterior, right hemisphere sites in response to target stimuli than it was to nontarget decoys, and a slow negative ERP component measured in the 400–500 ms latency range, was larger to targets than to nontargets over ten widely-distributed scalp sites. A replication attempt using a second batch of data collected from the same subject was partially successful (Warren et al. 1992b). The P100 effect did not replicate, but the slow negative component was again observed to be significantly larger in response to targets than it was to nontargets. However, this time the effect was observed only over left hemisphere scalp sites, whereas previously the effect was observed over both hemispheres. As in the 1992a study, the subject's guessing accuracy did not differ significantly from chance expectation in this second study.

Don et al. (1998) extended the anomalous ERP finding to a group of subjects who were participating in a gambling study and who were unselected for self-reported psychic ability or experience. They were, however, selected for interest and involvement in gambling activities. The subjects performed alternating blocks of gambling and nongambling, i.e., guessing, trials in a forced-choice precognition task. Don et al. considered only data collected during the guessing condition in order to more closely replicate the conditions of our previous studies in which gambling was not a variable. The results of the Don et al. study, as well as a re-examination of our earlier data, indicated that the enhanced negativity was a more time-extended process than measured by the previous 400–500 ms latency range, with ERP differences between targets and nontargets also appearing in the earlier 150–400 ms range, and persisting through 500 ms post-stimulus, this effect being widely distributed across the scalp. As in our previous two studies (Warren et al. 1992a,b), overt guessing performance in this third study also did not deviate significantly from chance expectation.

The present experiment was performed on a subset of the data collected as part of a second, larger study on gambling behavior, in order to replicate the anomalous ERP effect we observed previously. This study incorporated a tightening of experimental controls against likely sources of artifact, in particular controlling for the effects of subjects' guesses on the ERPs to task stimuli. Additionally, we assessed the possibility of bias due to physical differences between the target and nontarget stimuli as well as possible differences in the serial position of the eliciting stimuli. The study method also incorporated some additional manipulations which were germane to the study of gambling, but which may have affected the results.

Materials and Methods

Subjects

Twenty (16 male) self-reported, frequent gamblers, i.e., persons who reported gambling at least once per week, were recruited from notices and advertisements for the present experiment. Subjects were in good health (mean age = 27.4 years; range = 18–49) and had normal, or corrected-to-normal, vision. All subjects gave informed consent and were paid $8 per hour for their participation in the experiment. They were also given a $10 "kitty" with which to gamble during the experiment and could keep any money remaining in their kitty at the end of the session, but owed nothing if their account went negative. (As described below, the present study was concerned only with that portion of the data collected under a nongambling control condition, i.e., a guessing task.)

Stressor Task

Prior to participating in the gambling/guessing tasks, half of the subjects performed 40 trials of a simple, "low-stress" version, while the other half performed 40 trials of a complex, "high-stress" version of an arithmetic problem-solving task used by Warren and McDonough (1995). Although the subjects in that study could easily master the simple arithmetic task, they found the complex task to be extremely difficult, frustrating and stressful. (Subjects receiving either version of the stressor task were pooled for the present analyses.)

Guessing Task

A computerized guessing task was developed, in-house, for this experiment using the Micro Experimental Laboratory (MEL) system. The stimulus set was comprised of a normal deck of fifty-two playing "cards" presented on a computer monitor. On each trial, four playing cards of a given rank were sequentially presented; for example, the four sevens might be presented on one trial (seven of hearts, seven of clubs, seven of spades, and seven of diamonds), the four kings on another, etc. Thus, there were thirteen possible stimulus sets for each trial (two through ace). The four card stimuli presented on each trial were delivered in the center of the video screen in random order using an interstimulus interval of 2200 ms and a stimulus duration of 150 ms. The card stimuli were presented in actual size and full color (standard deck) against a black background. The target card for each trial was randomly selected from among the alternatives using a pseudorandom algorithm[1]; the remaining three cards in the pack served as nontarget decoys for that trial. The target was selected only after the subject made his/her choice for that trial; that is, all trials were conducted as precognition trials. The set (rank) of card stimuli used on a given trial and the order, or serial position, in which the four cards (1 target and 3 decoys) were presented was also determined randomly.

Testing Procedure

Each subject was seated on a comfortable, cushioned chair in a pleasantly decorated testing room with sound-attenuating material on the walls and door to reduce distracting noises. During the experiment, the subject sat alone in the testing room; an intercom permitted communications with an experimenter occupying an adjacent room. The video monitor was located on a table about one meter in front of the subject and at eye level; a keyboard rested in his/her lap.

The testing session comprised 80 trials of the computerized, video-gambling/guessing tasks, which subjects initiated at their own pace by use of the space key on the keyboard. On each trial, subjects were shown four "cards" on a computer monitor. Two and one-half seconds following presentation of the last of four card images, all four cards were displayed on screen together. The subjects then selected one of the cards using the left/right arrow key to move a cursor on the screen and registered their guess using the enter key. The "winning card" was then displayed on the monitor as feedback. The subject's ERPs to the display of the target and the three nontarget decoys were recorded from an array of scalp sites.

There were 40 such trials for each of two conditions. In one condition, subjects played a just-for-fun guessing game, while in the second, the player gambled (50 cents/trial with a $2 payoff for a win). In alternating fashion, two blocks of 20 gambling trials were conducted, alternating with two blocks of 20 guessing trials. Subjects were also counterbalanced to perform the experiment either starting in the gambling condition or the guessing condition. However,

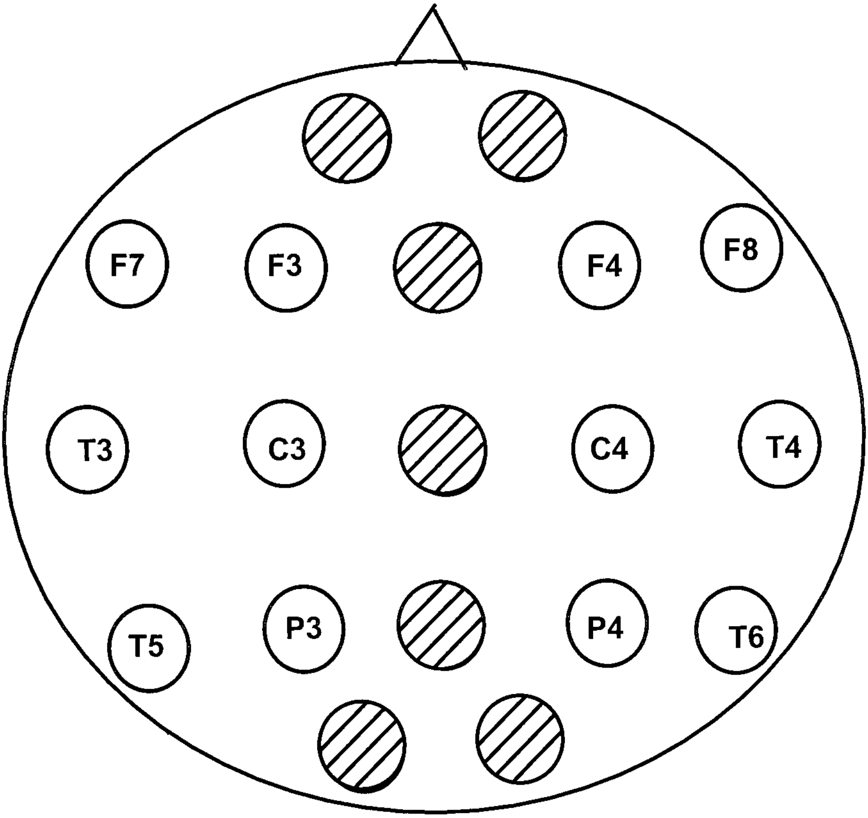

Fig. 1. A top-down, or "bird's eye", view of the head (nose at the top) showing the 19 recorded scalp sites. The 12 analyzed scalp sites are labeled using the nomenclature of the International "10-20" System (Jasper, 1958). Unanalyzed electrode sites are shaded.

the present analyses considered only the 40 trials in the two nongambling, guessing blocks.

After every block, a performance summary and the amount of money remaining in their kitty was displayed to the subject on the monitor. Performance data were output onto a signal channel, recorded on the chart paper of a polygraph, as well as being digitized online, along with the EEG data, and stored on a computer's hard disk.

EEG Recording and Data Reduction

The EEG was recorded continuously while the subjects were performing the gambling/guessing tasks. Signal pulses on the signal channel permitted later, off-line extraction of EEG epochs associated with delivery of the playing card stimuli. Electrodes were applied over the 19 scalp electrode sites as defined by the International "10-20" system (Jasper, 1958), and a forehead ground, using an electrode cap and conducting gel made by Electro-Cap International, Inc.; however, only 12 of these sites were presently analyzed (See Figure 1). Scalp leads were referenced to the left mastoid. The right mastoid, referred to the left mastoid, was recorded on a separate channel for purposes of later digital linking. Impedances for scalp, ground, and reference electrodes were kept below 5 k ohms. In addition, the impedances at the left and right mastoid leads were balanced (equalized). An electrode placed below the right eye, in conjunction with the Fp2 lead located directly above the right eye, was used to monitor eye blinks and movements. The physiological signals were amplified with custom-built Midwest Research Associates DC amplifiers having automatic DC reset capability and a 0.5 high frequency roll-off at 50 Hz. Data were digitized on-line at 256 samples per second.

Data editing was performed off-line and was blind to stimulus category, i.e., target or nontarget. EEG epochs containing eye or movement artifacts, or instances where the voltage on any EEG channel exceeded 60 μV, from 100 ms pre-stimulus to 600 ms post-stimulus, were excluded from analysis by a computer-based, automated editing system developed in our lab. For each subject, averaged ERPs were formed by calculating the mean of all artifact-free EEG epochs in the target and nontarget category in order to enhance the underlying electrical brain waveform. The nontargets used in this analysis were selected from among the three decoys by a random process which was blind to the ERP data, with the constraint that the number of guessed nontargets equaled the number of guessed targets for each subject.[2] The average ERP waveform at each site was digitally linked by subtracting ½ of the voltage of the right mastoid at each time point. As with physically-linked reference electrodes, the purpose of digital linking was to equalize the effective distance between the reference and the active electrodes on either side of the scalp. The Slow Wave (SW) amplitude was then measured as the integral mean value of the ERP waveforms in the latency range 150–500 ms, post-stimulus, relative to the mean amplitude of a 100 ms pre-stimulus baseline. The 150–500 ms latency range was selected on an *a priori* basis in order to maintain continuity with analyses used in our most recent study of this phenomenon (Don et al., 1998). ERP analyses compared the SW elicited by targets and nontargets, regardless of guessing accuracy.

Grand averages (across all 20 subjects) of the target and nontarget ERPs are shown in Figure 2 (note the convention of displaying negative-going voltages in the upward direction). The morphology and amplitudes of the peaks and valleys are consistent with those usually found for visual ERPs in cognitive tasks and with our previous data. The most conspicuous difference between target and nontarget averages is the negative displacement of the target curve relative to the nontarget curve throughout much of the epoch, especially over the right hemisphere sites.

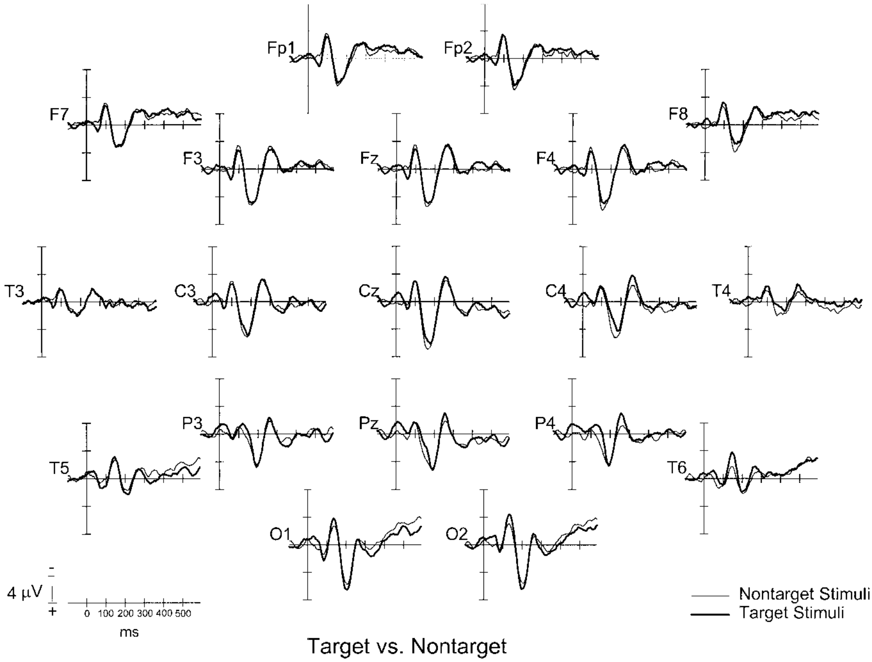

Fig. 2. Grand average ERPs, averaged over all 20 subjects, elicited by targets (thick tracing) and nontargets (thin tracing). Plotted waveforms were smoothed with a 5-point moving average; however, all analyses were performed on unsmoothed data. Negative voltages are plotted in upward direction.

Results

Guessing Accuracy

Guessing accuracy over all subjects and trials did not deviate significantly from mean chance expectation. Collectively, the subjects correctly guessed 204 (27%) targets out of 755 trials, whereas about 189 correct guesses (25%) would have been expected by chance ($p > .10$, two-tailed exact binomial).[3]

Slow Wave (SW)

The SW amplitude measurements from 12 recording sites (F3, F4, C3, C4, P3, P4, F7, F8, T3, T4, T5 and T6) were analyzed in a 4-factor, repeated-measures Analysis of Variance (ANOVA) analysis with three topographic factors, Hemisphere (left, right) × Lateral-Medial (lateral, medial) × Anterior-Posterior (frontal, central, parietal), and the Stimulus-Category factor (target, nontarget). Only main or interaction effects involving the Stimulus-Category factor, i.e., those relevant for the effects under study, are presented here. Main effects of the three topographic factors (Hemisphere, Lateral-Medial, Anterior-Posterior), and interactions among only these factors are not presented or discussed.

The Stimulus Category × Hemisphere interaction was observed to be significant, $F_{1,19} = 4.21$, $p \leq .05$. Inspection of the marginal means suggests that this interaction effect was due to a more negative-going SW for targets (–0.15 μV) than for nontargets (0.48 μV) over the six right hemisphere sites, there being little difference in SW amplitude between targets (0.13 μV) and nontargets (0.09 μV) over the left hemisphere. For purposes of comparison with our previous studies, *post hoc* analyses were performed separately on the earlier (150–400 ms) and later (400–500 ms) portions of the SW. These revealed a significant Stimulus-Category × Hemisphere interaction for the later portion of the SW epoch, $F_{1,19} = 4.29$, $p \leq .05$, the earlier portion of the measurement epoch showing only a trend, $F_{1,19} = 3.03$, $p \leq .10$. As in the planned analyses of the entire SW measurement epoch, these interactions reflected a greater negative-going SW for targets than for nontargets over the right hemisphere.

Post-hoc *Tests of Randomization*

A chi-square test indicated that the target stimuli were presented an approximately equal number of times in each of the 1st, 2nd, 3rd, or 4th serial positions, $\boldsymbol{X}^2 = 1.78$, df = 3, $p > .10$. An analogous chi-square test on the serial positions of (analyzed) nontargets was likewise nonsignificant, $X^2 = 3.36$, df = 3, $p > .10$.

Another chi-square test indicated that the target stimuli comprised an approximately equal number of the four playing-card suits: hearts, clubs, spades and diamonds, $X^2 = 3.33$, df = 3, $p > .10$. An analogous chi-square test on the suits of (analyzed) nontargets was likewise nonsignificant, $X^2 = 0.64$, df = 3, $p > .10$. Similarly, there were nonsignificant differences in the number of black cards (combining clubs and spades) and red cards (combining hearts and diamonds) for targets $X^2 = 0.33$, df = 1, $p > .10$, or for nontargets $X^2 = 0.33$, df = 1, $p > .10$.

Discussion

The present study was designed to replicate an anomalous ERP differential which we observed previously in three separate studies conducted at this laboratory, and to incorporate additional experimental controls and confirmatory tests in order to rule out several likely sources of artifact. Although the experimental design insured that the subjects could not distinguish the target stimuli from the nontargets by normal means, the targets, nonetheless, elicited a significantly larger, negative-going SW in the 150–500 ms latency range than did the nontarget decoys. If this result is not just a statistical fluke, it would appear to represent a communications anomaly, i.e., psi. Our statistical analyses tell us that this result is unlikely to be a fluke. Moreover, the ERP difference observed presently between targets and nontargets is consistent with the findings of our earlier studies which used a similar task (Don et al., 1998; Warren et al., 1992a,b), this replication suggesting strongly that the ERP differential is a real phenomenon.

However, while the statistical evidence suggests that the ERP effect is real, it doesn't say anything about what may be producing the effect. In order to demonstrate a communications anomaly, it is first necessary to exclude all alternative explanations of the results. Are there any conventional factors which might be able to explain the ERP difference between targets and nontargets? All four of our studies of this ERP phenomenon used computerized tasks which incorporated design features to prevent sensory leakage of the target information. Chief among these was the use of a precognition design whereby the target for each trial was not selected by the computer until after the subject's guess was registered, which was at least several seconds after the last of the four eliciting stimuli was presented.[4] Because the selection of the target was still a future event at the time of stimulus delivery, there could not have been any differential sensory cues associated with the presentation of target and nontarget stimuli, such as disk access noises, which might explain the ERP differential.

All of our studies also incorporated a number of experimental controls in order to rule out several other potential sources of artifact. By design, each subject's target and nontarget ERPs were comprised of the same number of EEG epochs. Therefore, although there were three nontarget stimuli presented on every trial, nontarget ERPs were computed using only one nontarget epoch from each trial in order to maintain the same signal-to-noise ratio as the target ERPs, which also used only one epoch per trial. And because we matched one nontarget epoch with one target epoch from each trial, the two stimulus categories were also matched for when, during the session, the stimuli were presented, thus controlling for such generalized psychological state factors as arousal, motivation, or fatigue.

Another possible source of artifact was controlled presently by balancing the number of stimuli guessed (to be targets) by the subjects in the actual target and nontarget categories. The possibility that an ERP to a member of a stimulus set could reflect guessing-related processes associated with the overt choice made several seconds or more later was first reported by McDonough et al. (1992). McDonough et al. found that ERP amplitudes to card stimuli in a forced-choice guessing task similar to the present task were sensitive to whether or not the stimuli were subsequently guessed (to be the target) by the subject. In that single-subject study, stimuli subsequently guessed by the subject as being targets evoked a more positive-going ERP than those not guessed by the subject. This finding, which we termed the "gleam in the eye" effect, suggested somewhat surprisingly that ERPs to task stimuli may reflect a cognitive, stimulus-selection process leading to an overt response (guess) occurring as long as 2.5 to 10 seconds after the eliciting stimulus. This guessing-related effect has since been replicated in a parametric study involving 20 subjects (McDonough et al. 1999). Presumably, the guessing-related ERP effect could also produce artifactual differences between target and nontarget ERPs whenever these stimulus categories have unequal numbers of guessed stimuli. However, guessing-related effects cannot readily explain the presently observed differences between target and nontarget ERPs because the numbers of guessed stimuli in the target and nontarget categories were balanced.

Another possible source of artifact which we presently considered was the serial position of the stimuli in the target and nontarget categories. In order to elicit an individual ERP to each of the four card stimuli, these were presented one at a time, i.e., serially, rather than simultaneously. This method may introduce bias for several reasons, such as the possibility that eye movements or blinks may be more likely to occur for stimuli presented in some serial positions than others, or because of the fact that task stimuli presented in the 1st, 2nd, 3rd, or 4th serial positions deliver different amounts of information to the subject. For example, the first stimulus carries the most information because it informs subjects of the rank of the four cards to be used on the current trial, as well as the suit of the first card. Second, third and fourth cards carry no additional rank information and deliver progressively less information about the suit. Indeed, the fourth card delivers only entirely redundant information; once the first 3 cards are seen, the subject can predict the identity of the fourth card with 100% certainty. This decreasing information content of the serially presented stimuli was a feature of all four studies conducted to date. However, in order to explain the ERP effect, there must be a systematic bias in the serial positions of targets vs. nontargets. While, by necessity, the target and nontarget stimulus must be presented in a different serial position on any one trial, the random selection of targets and nontargets from among these four serial positions should have made it unlikely that there would be any systematic bias over all trials. Indeed, a chi-squared analysis conducted precisely for this reason indicated that there was not a significant difference between the two stimulus categories in terms of the serial position of the stimuli over all subjects and trials included in the ERP analyses. Therefore, we may rule out serial position effects as a viable explanation of the observed ERP differential.

Other potential sources of artifact include physical differences in the stimuli comprising the target and nontarget categories, such as color or pattern. For example, if by chance the target category had more cards of one suit, or color, whereas the nontargets, again by chance alone, had more cards of another suit or color, then such physical differences between the stimulus categories could conceivably produce totally spurious differences in the ERPs. This possibility was considered highly unlikely, again because our randomization procedure should have eliminated systematic bias and because similar ERP results were observed in our earlier studies, which utilized completely different stimulus sets having very different visual qualities. However, just to be completely sure,

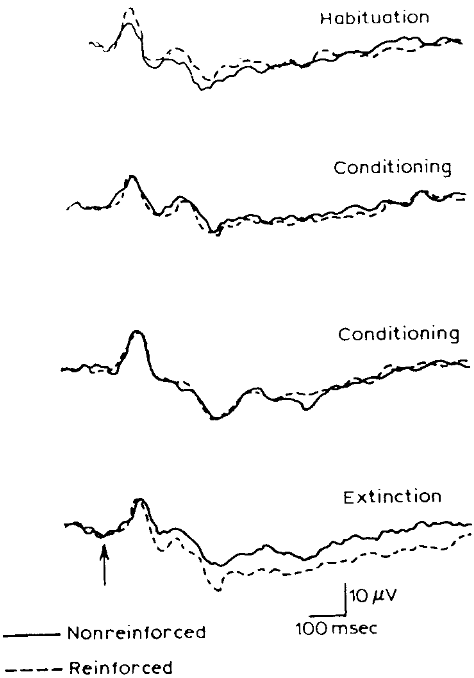

Fig. 3. ERPs to reinforced and nonreinforced tone stimuli from Paige et al. (1987). The difference between the two tracings in the uppermost plot (labeled "Habituation") resembles the ERP differential between the targets and nontargets of the present experiment. Reprinted with permission.

additional chi-square analyses were performed, confirming that neither the suit nor the color of the targets or nontargets were biased in this way.

Having ruled out likely sources of artifact and having no viable normal explanation for the ERP differential, we are left with an apparent communications anomaly. Of course, one can never completely rule out the logical possibility that some hidden artifact may be producing the observed effect. However, interpreting the ERP differential which we observed as a communications anomaly, or psi, is supported by the fact that this study is the fourth consecutive investigation in our laboratory to yield essentially the same ERP phenomenon, and by the fact that all of the hardware and software have been changed over the course of these four experiments. It should also be pointed out that labeling an observed effect as psi does not explain it, but only serves to identify it as belonging to a particular class of anomaly, i.e., that which involves an *ostensibly* paranormal event (Rao & Palmer, 1987). Only if it were conclusively shown to be due to an extrasensory transfer of information could it be regarded as a *genuinely* paranormal event.

In addition to the work conducted at our own laboratory, a previously published report of an ERP study on Pavlovian conditioning seems to provide further, independent support for our findings (Paige et al. 1987). The results of the Paige et al. study, which was not concerned with ESP, were entirely consistent with our own findings. Those investigators observed a significant ERP difference between two tones in the habituation phase of a conditioning experiment, before subjects had any normal means of knowing which of the two stimuli would subsequently be reinforced. It can be seen in the top panel of Figure 3 that the ERP effect observed by those investigators bears a remarkable resemblance to our own findings (after adjusting for scale differences between our plots and theirs). The target, i.e., the subsequently-reinforced tone, elicited a brain potential which appears more negative in the approximate 100–500 ms latency range than the ERP elicited by the nontarget, i.e., the nonreinforced tone. This ERP differential, which the investigators measured as a P300 component (larger for the nonreinforced tone), was reported to be statistically significant; however, apparently unwilling to entertain the psi hypothesis, the authors ascribed it to a Type I error.

We have previously interpreted the anomalous ERP effect as an indicator of unconscious or preconscious precognition. That is, if a precognitive transfer of information did in fact occur, it may be regarded as unconscious or preconscious, by definition, because the subjects' overt guessing accuracy did not differ from mean chance expectation. Thus, although the subjects' conscious guesses were not influenced by the precognitive target information, differential brain responses to target and nontarget stimuli indicated that precognitive information transfer may have occurred outside the bounds of conscious awareness.

If, as it presently appears, target information has been communicated anomalously, we must then ask: what might be the functional significance of the anomalous ERP differential? That is, what brain process, or processes, might be reflected in the ERP difference between targets and nontargets? Beloff (1974) suggested that however the psychic information might get into the percipient's brain in the first place, once there it will probably be treated in the same way as information obtained through normal means. Warren et al. (1992a) and Don et al. (1998) also argued that what we are seeing is not a novel type of ERP component associated with the reception of psychic information by the brain, but rather the operation of conventional information-processing mechanisms.

A number of negative components have been described in the conventional ERP literature which appear to reflect various aspects of information processing, particularly involving attention-related cognitive processes. Although still speculative at this stage, several of these components may offer plausible explanation of the anomalous ERP effect. For example, the N2, a negative ERP peaking at about 230–275 ms is typically elicited by infrequent stimulus changes embedded in a train of standard stimuli, whether these deviant stimuli are targets or nontargets (For reviews, see Donchin et al., 1978; Näätänen, 1982). The present SW measurement epoch encompasses a centrally-dominant negative peak at about 260 ms, which is likely to be an N2 component (See Figure 2). Therefore, possibly the targets of the present experiment were perceived as deviant; perhaps a psychically mediated attribute tagged the targets as deviant in the context of the nontargets, which were three times as likely to occur. Interestingly from the present perspective, the N2 component has even been associated with infrequent target stimuli which subjects failed to consciously detect (Näätänen et al. 1982). More recently, Suwazono et al. (2000) reported enhanced amplitude for a centrally-dominant N2 to novel visual stimuli which were not themselves targets, but which predicted the occurrence of subsequent target stimuli, an effect which they interpreted as an index of an alerting system facilitating target detection.

Another negative ERP component, the processing negativity, is associated with relatively long-duration attentional processes beginning as early as 50 ms and commonly extending for several hundred milliseconds thereafter (For review, see, Näätänen & Michie, 1979). Processing, or selection, negativities are typically observed in selective attention experiments and measured as a difference waveform obtained by subtracting the ERPs elicited by stimuli delivered in a non-attended channel from those elicited by stimuli delivered in an attended channel. Our experimental situation was very different from the standard selective attention paradigm in that we did not define an attended channel on the basis of discriminable sensory attributes. Had we done so, of course, it would have ceased to be an ESP experiment. However, if the presently observed SW effect does represent a processing negativity, one could infer that subjects allocated more attentional resources to the targets than they did to the nontargets even though, ultimately, they did not select them any more often, as indicated by nonsignificant performance measures. Thus, the negativity might reflect more of a pre-attentive process than a conscious allocation of attention, as in a standard selective attention task. It might also suggest that designating a subset of the experimental stimuli as targets, in some sense, defines an attended channel.

In a similar vein, McCallum et al. (1989) observed a negative-going fronto-central slow wave (350–500 ms) that was greater for stimuli delivered to the attended ear than to the nonattended ear and which may be akin to the later portion of the present SW, which, as seen in Figure 2, likewise appears to have a predominantly fronto-central distribution. McCallum et al. observed this negative slow wave to be greater for a target recognition task than for a no-task condition and to be greater for targets than for nontargets. Similarly, De Jong et al. (1988) also observed a negative frontal slow wave which was greater for attended than for nonattended stimuli.

In addition, seminal work by Kutas and Hillyard (1980, 1984) has shown that a late negative ERP component, the N400, can be produced by a wide variety of verbal target stimuli that deviate in meaning from the preceding episodic or semantic context (For review, see Kutas & Van Petten, 1988). Moreover, a number of studies have observed N400-like components, as well as an earlier N300, to be elicited by incongruous or unprimed pictorial stimuli (Barrett et al., 1988; Barrett & Rugg, 1989, 1990; Holcomb & McPherson, 1994; McPherson & Holcomb, 1999). The earlier N300 component seems to have a more frontal distribution than the N400 and may be specific to the processing of pictorial information since it appears not to be elicited by verbal stimuli (Barrett & Rugg, 1990; Holcomb & McPherson, 1994; McPherson & Holcomb, 1999). Typically elicited in semantic priming tasks, the N300 seems to be relatively robust with respect to eliciting conditions, having also been observed in response to nonrepeated items in a continuous recognition task (Friedman, 1990). Similarly, Smith and Halgren (1987) observed a negative component peaking at 445 ms following presentation of photographs of novel faces but not faces that were repeated. Therefore, perhaps the psi targets of the present experiment were similarly perceived as incongruous, unprimed, or novel in the context of the three-times-more-repetitive nontargets. The frontal distribution of the N300 component described in the literature overlaps partially with the later portion of the present SW, which, as seen in Figure 2, appears larger over fronto-central scalp sites, making the N300 a plausible candidate for explaining the anomalous SW effect. A more anterior than posterior distribution of (the later portion of) the SW was also seen in our earlier data, this gradient sometimes reaching significance, e.g., Warren et al. (1992a).

In this regard, although we did not analyze data recorded from the occipital scalp sites in this study, visual inspection of Figure 2 suggests that the negative-going ERP differential between targets and nontargets observed at the presently analyzed sites may have been expressed as a positive slow wave over the occiput. Nash et al. (1994) also observed that a slow wave (which differentiated deviant from standard tones) was negative-going when recorded from anterior scalp sites but positive-going over posterior scalp.

The hemispheric distribution of the present SW effect also deserves mention because of the variability observed among our four studies. In two of our previous studies, the ERP differential observed between target and nontarget stimuli was bilaterally symmetric, whereas in another, the effect appeared mainly over the left hemisphere. Presently, the effect appeared predominantly over the right hemisphere. While we cannot point definitively to any factor which might be responsible for these apparent discrepancies, we offer the following possibilities. First, the topographic variability among these studies may have been partly due to differences in the EEG reference among studies. Our earlier studies were conducted using the physically-linked ear reference following a decades-long standard practice in ERP research, whereas the present study used the more recent ERP procedure of recording with a single-sided reference and then algebraically computing ERPs to "digitally-linked" ears. Second, the evidence showing that processes related to the guessing response can affect ERPs to task stimuli raises the strong possibility that some of the between-study variability may be due to changes in response manipulanda as our task evolved. In our first two studies, the Apple II computer's game paddle was used as a response manipulandum; in our third study, the newer Apple IIe computer's joystick was used; and in the present study, conducted with an IBM-compatible personal computer, we switched to a keyboard response. However, although the presently observed right-hemispheric dominance of the ERP differential was unexpected based on our previous results, the similarities to those earlier data in terms of the morphology of the ERP effect and its relationship to stimulus category convinces us that we are seeing essentially the same ERP phenomenon as in those previous studies.

Summary and Conclusion

The ERP differential observed between target stimuli and nontarget decoys indicates an apparent communications anomaly, or psi, because the experimental design and subsequent confirmatory tests ruled out likely normal explanations of the result and no other viable conventional explanations could be identified. That we cannot yet explain the functional significance of the ERP differential underscores the fact that this is still a report of work-in-progress. We use the terminology "negative Slow Wave" both because it is descriptive of the polarity and morphology of the observed ERP effect, and because it is noncommittal as to which, if any, of the previously identified negative ERP components it may represent. Moreover, it is quite possible that more than one kind of negative component was elicited by our task. All we can do now is point to the family of negativities and suggest that what we are seeing is akin in some ways to this one or that one.

Future research should be aimed at identifying the mechanisms underlying the ERP phenomenon, whether normal or paranormal. For example, some of the potential artifact problems stemmed from the need to select one (out of three) nontarget epochs from each trial for comparison with the target epochs. Seemingly, therefore, an experimental task which used only two choice stimuli on each trial, one target and one nontarget, would avoid this whole class of problems. A future study could also manipulate the frequency of the target stimuli, i.e., relative to the nontargets, a manipulation which could shed light on the identity of the anomalous ERP, as some of the negative components discussed above are frequency sensitive. As another example, a task which did not require subjects to guess the target would also make interpretations more straightforward, if that could be done in a way which does not eliminate the phenomenon.

In conclusion, the present results illustrate the usefulness of examining unconscious physiological indicators of ESP, where the subjects' conscious guesses may be at chance levels. Since Beloff's initial review, other promising results have emerged from a series of studies which examined the unconscious autonomic detection of staring using electrodermal activity (EDA) as a dependent variable (For reviews, see Braud et al. 1993a,b). Also, Radin and colleagues reported evidence that the EDA preceding the delivery of emotional stimuli indicates an unconscious precognitive reactivity to future events by the autonomic nervous system, an effect they termed "presentiment" (Bierman, 1997; Bierman & Radin, 1997; Radin, 1996, 1998).

Finally, because a majority of neuroscientists today espouse psychoneural identity theory, a philosophical position which denies the efficacy of consciousness, and who thereby also have little sympathy for parapsychology, it is appropriate to say a few words here in defense of the minority opinion, i.e., against the epiphenomenalist or materialist viewpoint. For one, physical causation is always imperfect or incomplete. For example, there is always some degree of randomness following from quantum indeterminacy, and this 'looseness of fit' may allow room for consciousness to influence the brain without violating physical law (For an elaboration of this argument, see Hodgson, 1994). Second, the mere fact that there exist correlations between mental events and brain events does nothing to indicate the direction of causation and so cannot be considered to unambiguously support the epiphenomenalist identity thesis. That is, the observation of mind-brain correlations is also consistent with the opposing view that conscious (or unconscious) mental events may sometimes influence the physical brain rather than only the other way around. While identity theory, a variant of materialism, does not necessarily preclude the existence of ESP phenomena, other philosophically permissible solutions to the mind-body problem, such as interactionist dualism or idealism, which view consciousness as causally efficacious and having an existence separate from (not reducible to) that of matter, would seem more amenable to the possibility of ESP. On this later view, it is perhaps not so farfetched to wonder whether immaterial mind might sometimes slip past the physical barriers of space and time.

Acknowledgment

This article was based on a paper presented (under a different title) at the 42nd Annual Convention of the Parapsychology Association, Palo Alto, CA, August 4–8, 1999. We gratefully acknowledge the Kairos Foundation for their generous support of this project.

Endnotes

[1] Random numbers between 1 and 4 were generated by the RRANGE function included in the MEL software (version 1.0), seeded by the pulse count of the system timer. A frequency test on 1000 numbers generated by this function did not indicate significant deviations from randomness, $\boldsymbol{X}^2 = 0.296$, *d.f.* = 3, n.s. The serial dependency of the algorithm's output was not tested; however, given that each subject experienced only 80 trials, it seems extremely unlikely that they could have detected and used to their advantage any slight deviations from randomness that may have existed.

[2] For every subject, one of the three nontargets presented on each trial was initially selected for analysis as follows: The output of the rand() function

from Microsoft C/C++ version 7.0 (seeded using the time() function) was scaled to give an integer between 1 and 4, and then we took the corresponding decoy as the nontarget for that trial. If that number was the same as the target, a new random number was generated.

After forming the initial nontarget lists, in order to balance the number of guessed stimuli between the target and nontarget categories for each subject, the initial lists were modified by deleting randomly selected target or nontarget epochs from each subject, as needed, to match the number of guessed stimuli in these two categories. The particular trials which were deleted for this purpose were selected by using random numbers taken from the RAND Table (Rand Corporation, 1955) starting at an arbitrary entry point. For some of the random numbers, table entry was accomplished by holding the scroll-down key of the computer keyboard for several seconds (after loading an electronic copy of the table into the Microsoft MS-DOS text editor, version 2.0.026), using as a starting point the beginning of the row that the cursor landed on. For other random numbers, we used the output of a hand calculator's random function to select a row number for entering the table, again taking random numbers starting at the beginning of the indicated row. The reason we used random numbers from the RAND tables for this analysis instead of getting algorithmic random numbers, as we did previously, is because this analysis was conducted after all programming and data collection were completed, and we did not wish to do additional programming in order to obtain random numbers. Addressing an anonymous reviewer's concern, we note that in all instances the selection of random numbers was made blind to the EEG data and so could not have biased the results.

[3] Because of equipment malfunction, six subjects did not perform the planned 40 guessing trials; therefore, the numbers of such trials did not precisely equal 800 (20 subjects $\times$ 40 trials/subject).

[4] One could argue that the task may have involved clairvoyance rather than precognition because the "random" target selection was made by a completely deterministic process, i.e., a pseudorandom algorithm seeded at the start of the session by the system clock. Thus, although the target-selection algorithm was not invoked, nor was feedback presented to the subject, until several seconds after stimulus delivery, the information about the targets' identity already existed as electronic code at the time of stimulus delivery and, in principle at least, might have been clairvoyantly accessible. However, this argument cannot account for the comparable results obtained in our earlier studies, which used a true, hardware-based RNG for target selection.

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