P300 in Patients with Unilateral Temporal Lobectomies: The Effects of Reduced Stimulus Quality

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ABSTRACT

The effects of stimulus quality on the amplitude, peak latency, onset latency, and duration of the P300 component of the event-related brain potential were studied in patients with either a left or a right anterior temporal lobectomy and in normal controls. Stimulus quality was reduced by adding "noise" letters to words which signalled either a left or a right hand button press. Consistent with an interpretation that stimulus quality affects the subject's degree of equivocation, P300 peak latency, reaction time, and errors were all inversely related to stimulus quality, whereas P300 amplitude was directly related to stimulus quality. There were no significant differences between normal controls and either patient group for any of the ERP parameters or reaction time. Right temporal lobectomy patients made, however, significantly more errors, particularly on the catch trials, which suggests that they did not process the stimuli as thoroughly and accurately as the subjects in the other two groups. The absence of significant group differences in either the lateral symmetry or overall P300 amplitude extends the evidence against the idea that anterior temporal lobe structures make any substantial contribution to the scalp P300 in a visual discrimination paradigm. Because of observed delays in the onset of P300 in the low-quality stimulus condition, procedures were developed to quantify both P300 onset latency and P300 duration. Reduced stimulus quality significantly increased P300 onset latency whereas P300 duration remained unaffected, indicating that stimulus categorization must occur prior to, and not during, P300.

KEYWORDS: P300, Neural generators, Temporal lobectomy patients, Equivocation, P300 onset and duration.

The P300 component of the event-related potential (ERP) has been used as an electrophysiological index of the nature and timing of cognitive processing (Johnson, 1986, 1988a; Pritchard, 1981). Recently, the location of the neural generator(s) of P300 has been investigated using indwelling intracranial electrodes in patients with temporal lobe epilepsy. Using an oddball paradigm, these studies have demonstrated the presence of locally-generated potentials in anterior temporal lobe structures which are functionally similar to the scalp-recorded P300 (Halgren, Squires, Rohrbaugh, Babb, & Crandall, 1980; Squires, Halgren, Wilson, & Crandall, 1983; Wood et al., 1984; Stapleton & Halgren, 1987). In scalp recordings, however, neither the lateral symmetry nor the overall amplitude of P300 was significantly altered after unilateral temporal lobectomy (Johnson & Fedio, 1986; Johnson, 1988b, 1989a; Stapleton, Halgren, & Moreno, 1987). These latter data suggest that anterior temporal lobe structures are neither the sole generator nor a major contributor to the scalp-recorded P300 elicited in the oddball paradigm.

The vast majority of P300 findings are based on recordings from the midline, or near-lateral, electrode sites. Given the accumulating evidence that there are a number of distinct neural generators underlying the scalp-recorded P300 (e.g., Johnson 1989a; Ruchkin, Johnson, Canoune, Ritter, & Hammer, 1990), it is possible that unilateral temporal lobectomies may affect P300 activity at far-lateral electrode sites. However, unless such amplitude ef-
Although the oddball paradigm provides a useful method for eliciting P300 activity, it is not clear which brain functions and structures are involved during its performance. Additional information about the nature and/or generators of the P300 should be gained by using paradigms that provide some functional information about different brain structures. For example, functional asymmetries have been demonstrated between patients with removal of either the left or the right anterior temporal lobe (Milner, 1975). Thus, it has been well established that left temporal lobectomy patients have a verbal memory deficit whereas right temporal lobectomy patients suffer from impaired visual perception under conditions that reduce the normal redundancy of complex stimuli (Kimura, 1963; Lansdell, 1968; Meier & French, 1965; Dorf, Mirsky, & Mishkin, 1965; Rosenthal & Fedio, 1975).

The present study was an attempt to see whether the known differences between left and right temporal lobectomy patients would be reflected in their ERP activity. Thus, we manipulated perceptual difficulty by reducing the quality of visually presented stimuli. Given their visuo-perceptual deficits, right temporal lobectomy patients were expected to have greater difficulty in categorizing the stimuli, and effects extend more medially to a substantial degree, any such findings would appear to bear on generator activity unrelated to those responsible for the extensively studied P300s found over the midline and near-lateral scalp.

Thus to have smaller and later P300s, than either patients with a left temporal lobectomy or normal controls (cf., Johnson & Donchin, 1985). In addition, because peak latency measures do not reveal whether delays in processing occur prior to or during a component’s appearance, P300 onset latency and duration were quantified along with peak latency.

**Methods**

**Subjects**

Seven normal controls, 7 patients with a left temporal lobectomy, and 7 patients with a right temporal lobectomy were tested. The patient groups included 6 left and 6 right temporal lobectomy patients who were reported previously (Johnson, 1988b). The patients had the anterior pole of their left or right temporal lobe surgically removed for the relief of intractable epilepsy. The excision extended an average of 4.5 cm (SD = .7) from the tip of the temporal pole for left temporal lobectomy patients, and 7.1 cm (SD = .9) for right temporal lobectomy patients. The operation consisted of complete removal of pes, uncus, amygdala, and partial removal of the anterior hippocampal gyrus (1.8 cm, SD = .9, and 2.2 cm, SD = .5, for the left and right temporal lobectomy patients respectively). Patients were thoroughly screened to exclude cases with bilateral or extratemporal epileptogenic foci, the presence of any other brain pathology, right hemisphere speech, or any history of psychiatric illness. Patients were matched with normal controls on age and education. Additional patient data and neuropsychological test results are presented in Table 1. A more extensive description on cognitive functioning of these patients extend more medially to a substantial degree, any such findings would appear to bear on generator activity unrelated to those responsible for the extensively studied P300s found over the midline and near-lateral scalp.

**Table 1**  
**Neurophysiological data**

<table>
<thead>
<tr>
<th>Groups</th>
<th>N</th>
<th>Sex</th>
<th>Age (years)</th>
<th>Education (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Range</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td><strong>Controls</strong></td>
<td>7</td>
<td>3M, 4F</td>
<td>28-56</td>
<td>42 (10.9)</td>
</tr>
<tr>
<td><strong>Left Temporals</strong></td>
<td>7</td>
<td>2M, 5F</td>
<td>25-40</td>
<td>34 (6.1)</td>
</tr>
<tr>
<td><strong>Right Temporals</strong></td>
<td>7</td>
<td>5M, 2F</td>
<td>29-50</td>
<td>37 (7.0)</td>
</tr>
</tbody>
</table>

**Preoperative Data**

<table>
<thead>
<tr>
<th>Age, onset (years)</th>
<th>WAIS—Mean (SD)</th>
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</thead>
<tbody>
<tr>
<td>Range</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Left Temporals</td>
<td>6 mo–21</td>
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<tr>
<td>Right Temporals</td>
<td>3–20</td>
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</table>

**Postoperative Data**

<table>
<thead>
<tr>
<th>Years, postop.</th>
<th>Age, surgery (years)</th>
<th>No. Seizure Free</th>
<th>No. Medication Free</th>
<th>WAIS—Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>Mean (SD)</td>
<td>Range</td>
<td>Mean (SD)</td>
<td>VIQ</td>
</tr>
<tr>
<td>Left Temporals</td>
<td>1–14</td>
<td>8 (4.4)</td>
<td>16–36</td>
<td>24 (6.7)</td>
</tr>
<tr>
<td>Right Temporals</td>
<td>4–19</td>
<td>10 (4.7)</td>
<td>20–38</td>
<td>27 (5.6)</td>
</tr>
<tr>
<td>Controls</td>
<td>111 (9.5)</td>
<td>119 (10.2)</td>
<td>115 (9.3)</td>
<td></td>
</tr>
</tbody>
</table>
patients may be found in Fedio, Martin, and Brouwers (1984). All subjects were right handed and had normal, or corrected-to-normal, vision. The patients suffered from small spots of diminished vision in the peripheral visual field. The procedures were explained thoroughly in advance and informed consent was obtained from all subjects. The normal controls were paid for their participation.

Procedure

The subjects had to perform a visual discrimination task with a choice reaction time response in which the perceptual difficulty of the stimuli varied randomly from trial to trial. Stimulus quality was manipulated to allow comparisons between the processing of “normal,” high-quality stimuli and low-quality stimuli. The high-quality stimuli were the words “LEFT” and “RITE,” whereas the low-quality stimuli were “XLXEXFXTX” and “XRXIXTXEX.” All stimuli subtended a lateral visual angle of less than 3° to ensure that the stimuli were well inside the peripheral field cuts. The stimuli were presented on a CRT for 300 ms in a random series with an average ISI of 2910 ms. All four possible stimuli were presented equally often. In each block of 100 trials, there were 10 “catch” trials on which the stimuli were misspelled (i.e., “LFET,” “RTIE,” “XLXFXTX,” and “XRXTXIXEX”). Subjects were instructed to make fast and accurate button presses with the compatible thumb and to withhold their response when they detected the catch stimuli. Maximum acceptable reaction time was 2000 ms. Practice trials (15–30) were presented before data collection was started. Throughout the experimental session, the subjects were seated in a comfortable chair in a darkened room.

Recording

The EEG was recorded with chlorided Grass silver disc electrodes placed on the scalp at Fz, Cz, Pz, F3, C3, P3, F4, C4, and P4, according to the International 10-20 system, all referred to linked mastoid electrodes. The EEG was sampled on-line at 100 Hz for a recording epoch of 2150 ms, including a 150-ms prestimulus baseline. The data were low-pass filtered at 35 Hz (3dB/octave roll-off) and high-pass filtered with a time constant of 10 s prior to digitization. Eye movements (EOG) were recorded from electrodes placed below and above the right eye. Trials with EOG artifacts (i.e., 6 sample points per epoch exceeding 50 μV) were discarded from further analysis. All single-trial EEG and response data, along with accompanying identification, were stored in digital format for subsequent analysis. Only correct trials were used in the averages.

Quantification

To assess the effects of experimental variables on component amplitudes, the mean amplitude within a specified window was computed after subtracting the average activity in the 150-ms prestimulus baseline. Mean amplitude was used because it is less susceptible to the effects of latency variability. A symmetrical window around the peak latency for each component was identified in the individual-subject ERPs at both levels of stimulus quality. For P2 and N350 the window was 80 ms wide and positioned around the peak latency at Fz. The P3 window was 160 ms wide and centered around the peak latency at Pz. Slow Wave was measured within a window from 750-1450 ms.

Peak latencies for P2, N350, and P300 were determined with a peak-picking program which calculated the peak latencies for each component with a midlatency procedure (Tukey, 1978). In this procedure, the maximum amplitude in a time window at a specified electrode is found and then the component’s slopes are searched to find the points at which amplitude was 80% of the maximum value. These 80% latencies are then averaged to yield a measure of the component’s peak latency. To minimize interference from adjacent components, the limits on the search windows and electrode sites used in the peak-picking program were: 100-300 ms for P2 (at Fz), 200-450 ms for N350 (at Fz), and 330-1000 ms for P300 (at Pz). Prior to peak measurement, the individual-subject ERPs were smoothed using a low-pass filter (cutoff=4.8 Hz at 3dB).

The amplitude and latency data for each component were analyzed in separate repeated-measures ANOVAs. Component amplitudes were first analyzed in a design with the factors Stimulus Quality (high/low), Electrode (9), and Group (3), and then in two separate designs, one using the data from the lateral electrodes (left hemisphere/right hemisphere) and the other using the data from midline electrodes (Pz/Cz/Fz). Group effects and simple effects of stimulus quality at each single electrode were also tested. Peak latencies for P2, N350, and P300 were tested in an ANOVA with repeated measures on stimulus Quality (high/low), and the between-subjects factor Group (3). ANOVA results were reported when significant at p<.05. To correct for the use of the repeated-measures ANOVA design, the degrees of freedom were corrected with the conservative Greenhouse/Geisser procedure (Jennings & Wood, 1976).

Results

The grand-average waveforms for the high- and low-quality stimuli at all electrode sites for the normal controls are presented in Figure 1. These data show that the earliest deflections, P2 and N350, were particularly visible at the frontal and central electrode sites. They were followed by a P300, and a small amount of Slow Wave activity, which was positive at all electrode sites. The grand-average waveforms for right and left temporal lobectomy patients (Figure 2) were morphologically quite similar to those of the normal controls, except for the

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2Analyses on baseline-to-peak measurements produced the same pattern of results.
NORMAL CONTROLS

Figure 1. Grand-mean ERP waveforms for the normal controls at all nine electrode sites in response to the high-quality (solid lines) and low quality (dashed lines) stimuli. In this and subsequent figures, stimulus onset is denoted by the “S” on the time scale and stimulus duration by the filled rectangle. Positive voltages are plotted as downward deflections.

LEFT TEMPORALS

RIGHT TEMPORALS

Figure 2. Grand-mean ERP waveforms for the left and right temporal lobectomy patients at the central electrode sites in response to high-quality (solid lines) and low-quality (dashed lines) stimuli.

larger P2 component in the left temporal lobectomy patients.

P300

Amplitude. Although there appeared to be some differences in P300 across groups (Figure 3), the overall ANOVA revealed no significant group effects (p=.88) or Group × Electrode interactions. The former result indicates that there were no substantial differences in overall amplitude whereas the latter result indicates that the apparent alterations in the scalp topography of P300 in the patients were relatively small and not consistent enough to be significant. The ANOVA on Fz, Cz, and Pz data also indicated that the midline P300 scalp distribution was not altered due to the surgery (p=.46).

Possible hemispheric differences in P300 between the two patient groups are key to determining whether the anterior temporal lobe structures make any significant contribution to the scalp-recorded P300 in this task. Planned comparisons showed that P300 activity at the right hemisphere was larger than at the left hemisphere (F(1/18) = 5.2, p<.05). This difference was due to P300 amplitude being larger at F4 and P4 than at F3 and P3, respectively (F(1/18) = 5.2-6.6, p<.05), whereas there were no significant differences between C1 and C3. The hemispheric differences between P300 at the frontal and parietal electrodes were larger in the right temporal lobectomy patients, slightly smaller in the left temporal lobectomy patients, and absent in normal controls (F(2/18) = 6.1, p<.01). These results support the conclusion that when there were topographical differences in P300 activity, it was because the patient groups resembled each other more than the controls, rather than being due to surgically related hemispheric asymmetries between the two patient groups (Figure 3).

The ANOVA on the midline electrodes revealed a pattern of results similar to the overall ANOVA, which confirmed that P300 amplitude was reduced for low-quality stimuli (F(1/18) = 16.7, p<.01), an effect that was largest at the parietal electrodes and gradually decreased toward the frontal electrodes (F(1/18) = 25.9, p<.01; Figure 3). An analysis of the simple effects of stimulus quality at each individual electrode site revealed that these effects reached significance at parietal (ps<.001) and central (ps<.01) electrode sites, but not at frontal (ps>.06) electrodes. Right temporal lobectomy patients did not

Figure 3. Grand-mean P300 average amplitude at all nine electrode sites in response to high-quality (solid lines) and low-quality (dashed lines) stimuli for the normal controls (left panel) and the left (center panel) and right (right panel) temporal lobectomy patients.
Figure 4. P2 latency (at Fz), N350 latency (at Fz), P300 onset (at Pz), P300 peak latency (at Pz), and reaction time as a function of stimulus quality for normal controls (left panel) and the left (center panel) and right (right panel) temporal lobectomy patients. P300 onset latency corresponds to the latency at 50% of the peak amplitude. P300 onsets were not measured in left temporal lobectomy patients.

have smaller P300s, and there were no significant Group X Stimulus Quality interactions in any of the analyses (ps>.85).

Latency. P300 peak latencies (Figure 4) for low-quality stimuli were longer than those for high-quality stimuli, although this difference was only marginally significant \( F(1,18)=3.6, p=.074 \). The increase in P300 peak latency in right temporal lobectomy patients (16 ms) and left temporal lobectomy patients (24 ms) was not significantly smaller than the 67 ms increase in the controls \( p=.53 \).

Although easy and convenient to obtain, peak latencies reveal only the magnitude of overall processing delays without indicating the source(s) of delay. That is, processing delays can occur either prior to a component's appearance, or by increasing the component's duration. Inspection of the grand-average ERPs in Figures 2 and 3 reveals that P300s elicited by low-quality stimuli not only peaked later, but also appeared to have later onsets compared to those elicited by high-quality stimuli. Given these data, we analyzed the effects of reduced stimulus quality on P300 onset latency and duration.

In general, components have been quantified in terms of their amplitude and peak latency, although there have been a few instances in which onset latencies have been measured (Ritter, Simson, Vaughan, & Macht, 1982; Ritter, Simson, & Vaughan, 1983; Renault, Ragot, Lesevre, & Remond, 1982). A component's onset is potentially important as a measure of the beginning of a particular stage of processing. Similarly, a component's duration may index the duration of that processing stage. Ideally, it is desirable to measure onset and offset latencies at the times at which the component departs from and returns to baseline. However, due to component overlap, it may not be feasible to determine these time points either in all subjects within an experiment, or in all experiments. In such cases, onset and offset latencies can still be characterized by using suitably defined points on the leading and trailing slopes of a component. For example, even when onset/offset latencies are not observable, latencies can be measured at amplitudes that are a specified fraction of peak amplitude (e.g., half-amplitude). Although such "fractional" latencies do not provide absolute measures of onset/offset latency, they do provide relative measures, in the sense that "fractional" latencies covary with onset/offset latencies. In addition, the use of fractional amplitudes normalizes the data so that the resulting measures are independent of any within-subject amplitude differences due to experimental manipulations or scalp distribution or across-subject differences in absolute amplitude. The particular fractional onset/offset latency selected depends upon where amplitude measurements can be obtained from a large proportion of the subjects.

Latencies on the leading and trailing slopes of the P300 were calculated in 10% steps of the peak amplitude in the individual-subject waveforms, as shown schematically in Figure 5. To increase the reliability of the measurements, the ERPs were first low-pass filtered (3dB at 4.8 Hz) and, to minimize overlap with early components, the waveforms from Pz were used. A latency search window extending from 330–1000 ms was used to avoid the peak of N350. The data from left temporal lobectomy patients were excluded from this analysis because their large P2 failed to return to baseline before P300 onset.

As shown in Figures 6a and 6c, this analysis demonstrated that there was a fairly consistent increase in all the P300 onset and offset measures with

Figure 5. ERP waveform for an individual subject elicited by the high-quality stimuli, illustrating where the "fractional" latencies on the leading and trailing P300 slopes were obtained (filled circles).
reduced stimulus quality, as was evident in the grand-average waveforms (Figures 1 and 2). It is important to note that, due to individual differences in the ERP waveforms, latency measures could not be made at all levels of amplitude, and therefore the size of the database decreased as baseline was approached. Figures 6b and 6d illustrate the number of subjects for whom measurements could be made at all levels on the leading and trailing slopes. Because of this variable number of subjects across levels, separate ANOVAs were done on P300 onset and duration for the levels between 50% and 90% of the peak amplitude. Given multiple tests (i.e., 5) for each type of latency measure, the critical value was set at .01. The results showed that P300 onset was significantly delayed by low-quality stimuli for both the right temporal lobectomy patients and the normal controls, but that P300 duration was unaffected (Table 2). Although there was a significant group effect and a Group × Stimulus Quality interaction for P300 duration at the 50% and 80% levels, these isolated results indicate that the apparent shorter P300 duration for the patients was not consistent.

**P2**

Overall, P2 amplitudes in left temporal lobectomy patients were significantly larger than those in either controls or right temporal lobectomy patients \( (F(2/18)=4.3, p<.05) \). There were no significant hemispheric differences for P2 either across groups or levels of stimulus quality in the ANOVA on the lateral electrodes. P2 was significantly larger at F1 than at either Cz or Pz \( (F(1/18)=10.8, p<.01) \). Neither P2 amplitude (Figure 7) nor P2 latency (Figure 4) was significantly affected by stimulus quality.

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**Diagram Description**

**Figure 6.** P300 onset and offset times for normal controls (panel A) and right temporal lobectomy patients (panel C). Onset and offset times on the leading and trailing slopes of P300, respectively, were computed at decreasing steps of 10% of the peak amplitude. The number of normal controls (panel B) and right temporal lobectomy patients (Panel D) for which latency could be computed at each amplitude level on the leading and trailing P300 slope are shown.

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**Table 2**

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Onset Latency F Values</th>
<th>Duration F Values</th>
</tr>
</thead>
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<tr>
<td>90% Peak Amplitude</td>
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<tr>
<td>Group</td>
<td>&lt;1</td>
<td>1.3</td>
</tr>
<tr>
<td>Stimulus Quality ( (df=1/12) )*</td>
<td>12.1**</td>
<td>1.0</td>
</tr>
<tr>
<td>G × SQ</td>
<td>&lt;1</td>
<td>2.2</td>
</tr>
<tr>
<td>80% Peak Amplitude</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>&lt;1</td>
<td>2.3</td>
</tr>
<tr>
<td>Stimulus Quality ( (df=1/12) )</td>
<td>42.0***</td>
<td>&lt;1</td>
</tr>
<tr>
<td>G × SQ</td>
<td>&lt;1</td>
<td>6.0*</td>
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<tr>
<td>70% Peak Amplitude</td>
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<td>Group</td>
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<tr>
<td>Stimulus Quality ( (df=1/11) )</td>
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<td>G × SQ</td>
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<td>60% Peak Amplitude</td>
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<td>Group</td>
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<tr>
<td>Stimulus Quality ( (df=1/11) )</td>
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<td>1.7</td>
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<tr>
<td>G × SQ</td>
<td>&lt;1</td>
<td>4.0</td>
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<tr>
<td>50% Peak Amplitude</td>
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<tr>
<td>Group ( (df=1/9) )</td>
<td>&lt;1</td>
<td>5.6*</td>
</tr>
<tr>
<td>Stimulus Quality ( (df=1/10) )</td>
<td>27.2***</td>
<td>1.1</td>
</tr>
<tr>
<td>G × SQ ( (df=1/9) )</td>
<td>&lt;1</td>
<td>20.0**</td>
</tr>
</tbody>
</table>

*df provided only for significant results.

*p<.05, **p<.005, ***p<.001.
No. 3

Schefers, Johnson, and Ruchkin

Figure 7. Grand-mean P2 and N350 average amplitudes at the midline electrodes in response to high-quality (solid lines) and low-quality (dashed lines) stimuli for the normal controls (left panel) and the left (center panel) and right (right panel) temporal lobectomy patients.

N350

Because N350 activity was manifested as a negative deflection that remained on the positive side of the prestimulus baseline (Figures 1 and 2), larger N350s are indicated by smaller mean values (Figure 7). Unlike P300, more N350 activity was elicited when stimulus quality was reduced ($F(1/18)=14.2, p<.01$). Activity over the right scalp increased more than activity over the left scalp as a function of stimulus quality ($F(1/18)=6.9, p<.05$). Across the midline, stimulus quality had its greatest impact over parietal scalp ($F(1/18)=7.9, p<.05$), which was confirmed by tests of the simple effects at $P_z (p<.001)$, $C_z (p=.001)$, and $F_z (p=.02)$. N350 peak latency was not significantly affected by either stimulus quality or group (Figure 4).

Slow Wave

The grand-average ERPs in Figures 1 and 2 show that overall, there was little Slow Wave activity present in either experimental condition, as indicated by a slightly less steep trailing slope of P300 during its return to baseline. There were no effects in any of the ANOVAs on Slow Wave activity that approached significance.

Performance Data

The reaction time and error data are presented in Figure 4 and Table 3 respectively. Reductions in stimulus quality resulted in significant increases in the mean ($F(1/18)=87.6, p<.001$) and standard deviation ($F(1/18)=26.6, p<.001$) of the response times. There was no group effect or Group $\times$ Stimulus Quality interaction on reaction time, indicating that there were no group differences in the speed of processing. Omitted ($F(1/18)=6.0, p<.05$) responses, but not incorrect responses, increased significantly when stimulus quality was reduced. The catch trial data revealed that subjects made more erroneous responses to misspelled words that were low-quality than to misspelled words that were high-quality ($F(1/18)=12.4, p<.01$). The three groups differed in the number of errors with right temporal lobectomy patients making more responses to catch stimuli ($F(1/18)=4.9, p<.05$) and also making marginally more incorrect responses ($F(1/18)=3.4, p=.056$) than either normal controls or left temporal lobectomy patients. There were no significant group differences for the number of omitted responses.

Discussion

ERP activity and behavioral performance were studied in left and right temporal lobectomy patients and normal controls when perceptual difficulty was manipulated. Both the ERP measures and the performance data showed the usual relation to stimulus quality: P300 amplitude and response accuracy decreased while P300 peak latency and reaction time increased when stimulus quality was reduced. Although P300 onset latency increased as stimulus quality decreased, P300 duration did not. Neither P2 amplitude nor P2 latency were affected by the manipulation of stimulus quality. In accord with previous data on essentially the same patients, larger P2s were elicited in the left temporal lobectomy patients than in either of the other two groups.

Table 3

<table>
<thead>
<tr>
<th>Responses/Groups</th>
<th>High Quality</th>
<th>Low Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Omitted Controls</td>
<td>0.5 (0.7)</td>
<td>3.0 (4.0)</td>
</tr>
<tr>
<td>Left Temporals</td>
<td>0.4 (0.7)</td>
<td>0.8 (1.8)</td>
</tr>
<tr>
<td>Right Temporals</td>
<td>0.8 (1.3)</td>
<td>1.7 (2.6)</td>
</tr>
<tr>
<td>Incorrect Controls</td>
<td>0.1 (0.3)</td>
<td>1.2 (1.0)</td>
</tr>
<tr>
<td>Left Temporals</td>
<td>0.6 (1.1)</td>
<td>1.3 (1.4)</td>
</tr>
<tr>
<td>Right Temporals</td>
<td>2.2 (2.4)</td>
<td>2.6 (3.7)</td>
</tr>
<tr>
<td>Catch Controls</td>
<td>9.1 (1.8)</td>
<td>31.5 (19.9)</td>
</tr>
<tr>
<td>Left Temporals</td>
<td>7.9 (9.0)</td>
<td>22.7 (18.9)</td>
</tr>
<tr>
<td>Right Temporals</td>
<td>19.3 (14.9)</td>
<td>49.6 (32.5)</td>
</tr>
</tbody>
</table>

The subjects were also run in two blocked conditions consisting exclusively of either high- or low-quality stimuli. Given that all the results from these conditions were identical to the randomized condition, only the data from the catch trials are included here. This exception was made in order to increase the reliability of the data from this infrequently occurring category of trials.
(Johnson, 1989a). Whereas N350 amplitude was inversely related to stimulus quality, N350 latency was not significantly altered.

The ERP and behavioral data clearly showed that we successfully manipulated stimulus quality. Nevertheless, the expected group differences in P300 amplitude and latency did not materialize. The reason for the absence of a significant result may lie in the behavioral data. The fact that right temporal lobectomy patients did not respond slower than the other two groups while making more incorrect responses and failing to withhold their responses more often on the catch trials, supports the idea that they used a strategy in which speed was traded for accuracy. It is reasonable, therefore, to suggest that these patients processed less of the stimulus (perhaps only one letter) than the subjects in the other two groups. These behaviors are consistent with a visuo-perceptual deficit.

Previous studies have demonstrated the presence of locally-generated potentials in anterior temporal lobe structures that are functionally similar to the scalp-recorded P300 in the oddball paradigm (e.g., Halgren et al., 1980; Squires et al., 1983; Wood et al., 1984; Stapleton & Halgren, 1987; McCarthy, Wood, Williamson, & Spencer, 1989). If these potentials were responsible in whole, or in part, for the scalp-recorded P300, the effects of unilateral removal of one of two of these generators would be manifested at the scalp in one of two ways. If these brain areas were the sole neural source for the scalp P300, we would expect to observe the unequivocal presence of surgically-related hemispheric asymmetries. Alternatively, if these areas were responsible for generating a sizable fraction of the total amount of P300 activity that arose from a number of intracranial sites, then we would expect to observe a decrement in overall amplitude, perhaps with some surgically-related hemispheric asymmetry. To date, however, tests of these hypotheses using patients with unilateral temporal lobectomies have failed to find any significant alterations in the midline or near-lateral scalp-recorded P300 to either auditory or visual versions of the oddball paradigm (Johnson & Fedio, 1986; Johnson, 1988b, 1989a; Stapleton et al., 1987) or to a feedback paradigm (Johnson & Fedio, 1987). Even using a memory paradigm, Smith and Halgren (1989) failed to find either a significant decrement in overall amplitude or a significant asymmetry in P300 activity. The current findings extend this group of negative results to a visual discrimination paradigm.

In order to carefully evaluate the contribution of medial temporal lobe potentials to scalp ERP activity, we eliminated all patients whose disease involved areas outside of the anterior temporal lobe structures, including those with a psychiatric history. Evidence of the stringency of our exclusion criteria can be seen in the fact that six of the seven patients in each group have never had a seizure following the surgery, whereas the remaining two cases have had no more than one per year. This fact strongly suggests that the extent of the diseased tissue was confined to the medial temporal lobe and that it was essentially all removed during the surgery. It is possible, therefore, that altered scalp potentials may be found in post-surgical studies in which the epilepsy patients constitute less homogeneous groups than those described here. Because the same could be true in studies of pre-surgical epilepsy patients, great care must be taken in interpreting the results of studies based on heterogeneous patient groups.

There are a number of possible reasons why the unilateral temporal lobectomies had little effect on the scalp-recorded P300. First, although the rather gross morphological differences between the medial temporal lobe P300-like potentials and the scalp-recorded P300s have been noted (Halgren, Stapleton, Smith, & Altafullah, 1986), surprisingly little has been said about the timing differences between them. In fact, with the exception of the report by Stapleton and Halgren (1987), the latencies of the P300 and medial temporal lobe potentials have not been reported. These authors found that the intracranial potentials followed the scalp P300 by 50 ms for stimuli in both auditory and visual modalities. This result is consistent with measurements made by visual inspection of the figures in other reports in which the latency of the medial temporal lobe potentials were delayed relative to the P300 by up to 100 ms (Halgren et al. 1980; Squires et al., 1983). These latency data raise the possibility that the medial temporal lobe activity is responsible for generating the Slow Wave component that follows the P300 rather than the P300 itself. Both components vary in much the same way in the oddball paradigm. Previous reports, however, have also failed to find any significant group differences or hemispheric asymmetries in Slow Wave activity, which suggests that medial temporal lobe activity is not the neural source for the scalp-recorded Slow Wave (Johnson, 1988b, 1989a).

A second possible explanation of the minimal effect of the surgeries on P300 amplitude involves the propagation of medial temporal lobe activity to the scalp. Altafullah, Halgren, Stapleton, and Crandall (1986) found post-epileptic spike slow wave activity that propagated to the lateral cortical surface from the same general area of the medial temporal lobe. They reported that, in comparison to the attenuation of this slow wave activity, the sur-
face P300 recorded at Fz was about twice as large as would be expected if the medial temporal lobe were the sole generator.

Third, because recent studies have shown that the scalp distribution is different for auditory, visual, and somatosensory P300s (Barrett, Neshige, & Shibasaki, 1987; Johnson, 1989a, 1989b; Johnson, Millner, & Braun, 1991), the fact that McCarthy et al.’s (1989) medial temporal lobe potentials were modality independent would provide additional evidence against the hypothesis that the scalp-recorded P300 activity is related to the medial temporal lobe activity.

The P300 amplitude and latency data, in conjunction with the behavioral results, are consistent with the interpretation that reductions in stimulus quality increase the subject’s a posteriori uncertainty about having correctly identified the stimulus (i.e., equivocation). Under these conditions, stimulus categorization time increases and the amount of information extracted from a stimulus decreases, as reflected by the increased P300 latencies, reaction times and response errors, and decreased P300 amplitudes. These results are in accord with those obtained in previous experiments showing that the subject’s degree of equivocation about having correctly identified a stimulus is a powerful determinant of P300 amplitude and peak latency (e.g., Johnson & Donchin, 1978, 1985; Kok & Looren de Jong, 1980; Ruchkin & Sutton, 1978; Ruchkin, Sutton, & Mahaffey, 1987; McCarthy & Donchin, 1981).

It has been argued that the P300 is elicited after a stimulus has been categorized and that P300 peak latency is directly related to stimulus categorization time (cf., Kutas, McCarthy, & Donchin, 1977). The implicit assumption in this argument is that P300 duration does not vary with the difficulty of stimulus categorization, and thus that the peak latency increase is contingent on the delay in processes prior to P300 rather than being prolonged by increased variation within the P300 process itself. Although not noted previously, the data presented in a number of reports that manipulated perceptual difficulty would support the position that P300 onset latencies are delayed, along with peak latencies, when stimulus categorization is more difficult (e.g., McCarthy & Donchin, 1981; Magliero, Bashore, Coles, & Donchin, 1984; Fitzgerald & Picton, 1983; Perrault & Picton, 1984).

Our examination of the temporal structure of P300 at Fz revealed that, between 50% and 90% of P300 peak amplitude, P300 onset times increased significantly as stimulus quality decreased. At the same time, we showed that P300 duration remained virtually constant across conditions. Together, these data support the assumption that the cognitive processes reflected by P300 are delayed, rather than being prolonged, when stimuli are difficult to categorize. Thus, it is reasonable to conclude that the P300 is not elicited until after the stimulus has been categorized.

The validity of conclusions based on P300 onset latency depend partly on the accuracy of the measurement procedure. For example, there could be a question as to whether different results would be obtained for different fractional amplitudes. However, our multiple analyses indicate that the onset and duration effects are robust, in the sense that they were consistent over a wide range of measurements.

The present study provides additional evidence that the P300-like activity generated in the anterior temporal lobes does not contribute significantly to the scalp-recorded P300 and thus, that P300 is not a unitary phenomenon (Johnson, 1986, 1988a, 1988b, 1989a, 1989b; Johnson et al., 1991; Ruchkin, Johnson, Canoune, Ritter, & Hammer, 1990; Stapleton et al., 1987; Knight, Scabini, Woods, & Clayworth, 1989). The data do illustrate the value of information obtained from quantifying the onset and duration of ERP components. On the basis of the onset latency and duration data, we were able to show that stimulus categorization occurs prior to the onset of, rather than during, the P300. Applying this method of analysis in future studies, and demonstrating which cognitive processes increase P300 duration but not P300 onset latency, should make possible the identification of the cognitive processes that underlie P300 activity.

REFERENCES


Announcements

Postdoctoral Research Position in Event-Related Potentials and Alzheimer's Disease

The Cognitive Electrophysiology Laboratory of the Division of Developmental and Behavioral Studies at New York State Psychiatric Institute, New York City, New York, has a position available at the postdoctoral level. The position is supported by a grant from NIA dealing with memory and Alzheimer’s disease using event-related potentials concurrently recorded during tasks presumed to tap implicit memory performance. The candidate should have experience in the recording and analysis of psychophysiological data with emphasis on event-related potentials, and be comfortable working with patients. Knowledge of computerized data collection and analysis on mini-, micro-, and mainframe computers is essential. Competency with the DOS operating system is critical, and programming skills are highly desirable. The appointment can begin as early as September, 1991. Salary range is based on NIH guidelines with excellent fringe benefits.

Please send (1) a letter of application describing interests and experience, (2) curriculum vitae and representative reprints, and (3) the names and addresses of three references, to: Dr. David Friedman, Department of Medical Genetics, A308, Box 58, New York State Psychiatric Institute, 722 West 168th Street, New York City, New York 10032.

Third International Conference on Alzheimer’s Disease

From July 12th through 17th, 1992, the Third International Conference on Alzheimer’s Disease and Related Disorders will be held at the Palazzo del Turismo, Montegrette Terme, Padova, Italy. The convenors of the conference are: Drs. M. Nicolini, K. Iqbal, B. Winblad, and H.M. Wisniewski. For further information and abstract forms, contact: Conference Organizer, Dr. P. Zatta, CNR-UNIT, Dipartimento di Biologia, via Trieste 75, 35131 Padova, Italy (telephone (49) 8286361, fax (49) 8286359).

Cognitive Psychophysiologicalist

The Cognitive Neuroscience Unit in the National Institute of Neurological Disorders and Stroke has an opening for a cognitive psychophysiologicalist, starting December 1991, who is familiar with event-related potentials (ERPs), to study patients with a variety of neurological deficits. We are seeking a mature individual, with less than three years of postdoctoral experience, who is capable of independent research within an interdisciplinary team. Skills in recording and analyzing ERPs and programming in FORTRAN are essential. Salary ranges from $25,000-$31,000 depending upon qualifications. Please send CV, statement of research interests, explicit description of skills and work experience, the names and telephone numbers of three professionals you have worked with, and reprints/preprints of your work to: Ray Johnson, Jr., National Institutes of Health, NINDS/Cognitive Neuroscience Unit, MNB, Building 10, Room 4C422, Bethesda, MD 20892. The NIH is an equal opportunity employer.
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