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On Hemispheric Differences in Evoked Potentials to Speech Stimuli[1]

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A recent publication in this Journal (Friedman et al. 1975) reviews the history of the search for evoked potential correlates of hemispheric asymmetries for speech signals, presents new data and concludes that "while evoked potentials may sometimes reflect differences in hemispheric functioning, this effect is marginal at best" (p. 18). The purpose of this note is to provide confirmation of that conclusion from a study of our own. Our report can be brief because we have covered much the same ground as Friedman et al; a full manuscript that includes all details omitted here (on methods used, data obtained, and statistical procedures) is available on request.

Methods

Subjects were young men (4) and women (4), who volunteered and were paid for their services. All were right-handed and audiologically normal.

Standard EEG recording techniques were used, with gold disc electrodes located at C_z and over the presumed left and right parietal association areas (mid-way between T_3 and P_5, and T_4 and T_6, respectively). Reference leads were on the mastoids, linked. Ag-AgCl electrodes at the corner and beneath one eye monitored eye movements. Each of the three EEG signals was amplified by a Grass P-15 (gain: 100X) in series with a Tektronix FM 122 (100X) and band pass filtered between 0.2 and 100 Hz. Evoked responses were monitored on-line with a Mnemotron CAT 400A computer and also recorded on an Ampex SP 300 instrumentation recorder for off-line averaging by a PDP-12 computer.

Stimuli consisted of binaural, 250 msec, 65 dB SPL natural speech syllables (pa, ba) or pure tones with 5 msec rise-fall times (250 Hz, 600 Hz). Each stimulus was accompanied by a computer-generated synchronous trigger pulse. Randomized lists of either speech or tone signals were constructed so that one stimulus, the frequent one, occurred 100 times while the other, the infrequent or target stimulus, occurred at random intervals 22 to 35 times in the list. The interstimulus interval was 1.9 seconds.

Procedure

The subject wearing earphones (TDH-39) lay on a cot in a darkened IAC sound booth, with eyes fixed on a point on the ceiling. Subjects were instructed to listen for the targets, count them (without overt motor gestures), and report the count at the end of the run. They first listened to four lists--two speech and two tone; each stimulus (e.g. pa or 250 Hz) appeared in one of the lists as the target and in the other as the frequent. The four lists were then repeated, in counterbalanced order, to provide a replication.

Response averaging and analysis

The tape-recorded EEG signals were sampled by the PDP-12 at 1 kHz for 512 msec. A true average was computed for each channel. The averaging program also compared the amplitude of calibration pulses in each channel and corrected these averages so that they were stored at identical gain. Evoked responses at each electrode site for each subject in each condition were plotted on an analogue X-Y plotter (BBN 715) and measured by hand. Composite curves over all 8 subjects for each electrode site in each condition were also computed and plotted.

RESULTS

Fig. 1 shows the composite of the averages of all eight subjects for each of the four conditions of the study. Both tone and syllable stimuli elicit the two deflections widely reported to result from clicks (see, e.g. Picton et al. 1974): N_1 (latency about 100 msec) and P_2 (190). P_3 (about 350 msec) is small for the frequent syllables but large (as expected, e.g. from Picton and Hillyard

1974) for the targets. The vertex response closely resembles that seen at the hemispheres, but it is larger in amplitude (as expected from mapping studies, e.g. Picton et al. 1974). The vertex P_3 shows notable differences in the four conditions which in part are shared at the hemispheric sites; for instance: 1) there is a prominent negative peak (at about 250 msec) in the target speech response, and 2) target tones evoked a P_3 that is larger, "sharper" and shorter in latency (by some 13 msec) than that evoked by target speech.

Data analysis

The vexing question of how to estimate the significance of the rather small differences noted in Fig. 1 has been thoughtfully addressed by Friedman et al. (1975). We have employed three methods, as follows:

Method 1. Meaningful differences in response waveshapes, latencies, etc. are likely to be evident to the eye. We therefore asked a jury of 10 persons skilled in recording and measuring human evoked responses to match the averages obtained from each individual subject with the composites shown in Fig. 1. Since there were 8 subjects and 4 conditions, each judge performed a total of 32 such matches. Together they correctly matched 182 records (57%) with the composite to which it belonged. Their discrimination of frequent from target responses was even better (92% correct). Their ability to distinguish a syllable from a tone response, however, was poor (for the frequents, 84 correct vs. 64 incorrect identifications; for targets, 94 vs. 52). Thus the naked eye readily sees differences between the upper and lower rows of Fig. 1 but has difficulty detecting differences in the columns.

Method 2. Every response (8 subjects, 4 conditions, 3 electrode sites) latency and amplitude (for N_1, P_2, and when present, P_3) was measured and their mean and standard deviation calculated. A series of repeated-measures ANOVA tests showed no difference at $p \leq .05$ among conditions or subjects in the peak amplitude measures. In particular there was no significant difference in peak amplitude between the right and left hemisphere responses within (or between) any of the conditions. In the latency measures two interesting results emerged. 1) The latency difference in the N_1 peak between the speech (frequent or target) and the tone (frequent or target) conditions is significant ($F = 12.39$ for 1,7 degrees of freedom); and 2) the P_3 peak latency at the two hemisphere sites differed between the speech and tone conditions ($F = 7.96$ for 1,7 degrees of freedom).

As Friedman et al. (1975) have argued, some statistical procedures are less conservative than others for evaluating the significance of differences between evoked potentials. Repeated tests of significance increase the probability of obtaining "significant" differences by chance. Our findings with respect to hemispheric differences are computed for an uncorrected alpha of .05. Were we to correct this criterion as Friedman et al. suggest, it would only underscore the lack of significant differences.

Method 3. Following Wood et al. (1971; see also Wood 1975), we compared across subjects and conditions using the Wilcoxon match-pair signed ranks test at each digitized point in the responses. Significant points of difference ($p \leq .02$) in tone vs. speech responses at left and right hemisphere were rare for frequent tones, but reasonably common for targets, principally in the P_3 region, with somewhat larger areas of difference on the left. These significant differences mainly reflect an approximately 30 msec P_3 latency difference measurable in the responses to speech vs. tone targets. However, on the average, these P_3 latency differences are greater on the right, and so the larger number of points on the left cannot be wholly explained by such latency differences.

Since 512 tests were performed with each comparison, some small number, an average of approximately 10, might be expected to differ by chance. To test this the Wilcoxon test was separately applied to the first and second halves (replications) of the data collected from each subject. The comparisons were made over left and right electrode sites, speech and tone stimulus conditions, and frequent and target stimuli. The results show no more points of significance than might be expected by chance, and thus lead to two interlocking conclusions: 1) this particular test does not produce spuriously significant points more often than would be expected by chance; and 2) the first and second halves of our experiment (purposely designed to be identical) are indeed good replications.

When each of the replications was separately analyzed as described above for the combined data, they agreed with each other and with the conclusions given above for the combined data. A smaller number of significant differences was noted in the replications, a fact which reflects the greater variability in them, since combining them increases the S/N ratio by 2 (Vaughan 1974).

DISCUSSION

The main purpose of this experiment was to create the optimal conditions for demonstrating an electrophysiological difference due to cerebral dominance, if any exists. To do this, we 1) chose the cortical evoked response and recorded this over scalp areas which are implicated in the processing of auditory signals and which, on the left side, are known to be involved in the perception of language. 2) We presented two different stimulus sets: a speech set and a tone set, and tested the hypothesis that, of the two, the speech set would evoke reliably larger potentials on the left. 3) To minimize the effects of the unavoidable physical differences in speech and non-speech signals, we required the subjects to perform a vigilance task in which they counted infrequent (target) stimuli, a task which produces a P_3 wave irrespective of modality of presentation or signal characteristics. 4) The measures of interest were the response wave shape to the different stimuli and the peak amplitude and latency of its P_3. We conclude:

1) Waveshape. Speech sounds evoked a response pattern that remarkably resembles that to tones or clicks. Similar P_3 waves were obtained to both tone and speech targets, but the latency of P_3 to speech is the longer of the two. This latency shift may mean that different processes occur in the identification of the speech and non-speech stimuli. Additionally, a small P_3 wave occurred in four out of eight subjects for the unattended, frequent speech stimuli, a result that supports Friedman et al. (1975) who reported similar findings and speculated that all speech stimuli may invoke the P_3 producing mechanism.

2) Hemispheric differences. Analysis of variances on peak amplitude and latency measures showed no significant differences between hemispheres. The Wilcoxon test showed significant differences between the hemispheres for the target tasks in the P_3 region of the response; some but not all of these differences can be explained by P_3 latency differences. Hence it is possible that P_3 to speech is larger on the left than P_3 to tones.

If one credits, as we do, the overwhelming clinical and behavioral evidence for hemispheric asymmetry during processing of speech signals, it is not unreasonable to expect a corresponding lack of symmetry in electrophysiological measures of hemispheric responsivity. Available recording and analyzing techniques would appear to be precise enough to detect even very small evoked-response differences, as our results and those of other groups (summarized by Friedman et al. 1975) can be said to demonstrate. The interhemispheric electrophysiological differences reported to date, however, are so tiny as to be barely believable. Hence, either the evoked response method is virtually blind to the crucial events we believe must be there, or the hemispheric differences are barely present in the conditions under which the measurements are currently being made.

SUMMARY

Eight subjects listened to lists of speech sounds (pa or ba) or pure tones (250 or 600 Hz). Within each list one of the sounds (the "frequent") occurred more often than the other (the "target") in a ratio of approximately 4:1. Subjects were required to count the targets in each list; concurrently, evoked responses to both targets and frequents were being separately averaged from electrodes at vertex and at symmetrical left and right parietal locations. The evoked responses show the expected sequence of deflections at all three electrode sites, including large P_3 waves (about 350 msec latency) to the target stimuli. However, the left and right hemispheric responses to speech or tones, either frequent or target, were strikingly similar, both to the eye and by statistical tests intended to reveal differences between them.

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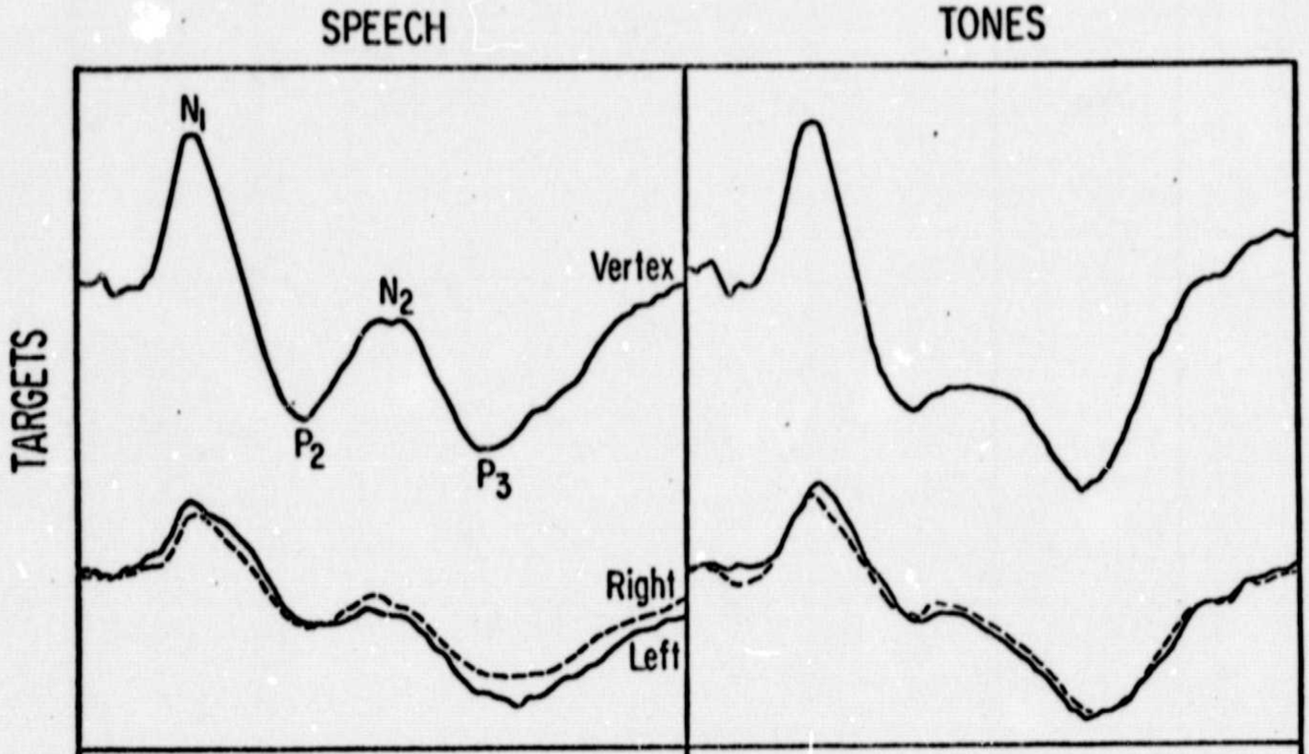
FIGURE LEGENDS

Figure 1. Composite of the average evoked potentials for eight subjects. N = 704 for the target stimuli, N = 3040 for the frequent.


SPEECH
TONES
TARGETS
FREQUENTS
N1
N2
P2
P3
Vertex
Right
Left
5μV
100 msec
Right
Left