Human scalp-recorded evoked-potential correlates of linguistic stimuli*

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Interhemispheric asymmetries for verb and noun meanings of "ambiguous" linguistic stimuli (words) were observed in human scalp recordings of click-evoked brain activity. Linguistic stimuli elicited responses of greater magnitude in the dominant hemisphere. Within-hemisphere response latencies and waveforms were different for verb and noun forms of the stimulus word; whereas between-hemisphere waveforms were similar for a given stimulus word form.

There is great current interest in possible neural substrates of language. Primarily through clinical studies, two areas of the human cerebral cortex in the dominant hemisphere have been implicated in the cognition and production of speech (Geshwind, 1970). Recent studies of scalp-recorded evoked potentials have stressed laterality differences to stimuli at the phoneme level, word fragments, nonsense words, or even entire sentences (Buchsbaum & Fedio, 1970; McAdam & Whitaker, 1971; Matsumiya et al, 1972; Morrell & Salamy, 1971; Wood et al, 1971). However, little emphasis has been placed on the influence of "meaning," in a linguistic sense, on the response-evoking qualities of these stimuli.

In the study reported here, we examined scalp evoked potentials as a function of stimulus "meaning," in an attempt to discover possible brain correlates of cognitive processes. The approach was to present Ss with ambiguous linguistic stimuli (words) to be interpreted as either verbs or nouns. For example, the word "fire" can be a noun (a bonfire) or a verb (to discharge a weapon).

METHOD

Ten right-handed coeds were used as Ss. Disk electrodes were placed bilaterally on the regions designated C3 and C4 in the 10-20 system. The EEG was amplified and recorded on FM tape for subsequent computer analysis. To control for artifacts arising from eye movements and eye blinks, activity was recorded from surface disk electrodes, placed at the outer margins of each eye and linked together. All trials in which eye movement occurred were discarded. Auditory stimuli were played from a tape and presented bilaterally through headphones. EEG data were averaged in blocks of 10 stimulus presentations by computer.

This experiment was conducted in three phases. In each phase three homonyms were used as stimuli, delivered in randomized order at intervals of 18-26 sec. Prior to each phase, the S was instructed as to the meanings of the stimulus words. Stimulus words used in the three phases of the experiment were: Phase 1–(1) rock, (2) fix, (3) duck; Phase 2–(1) rock, (2) fly, (3) belt; Phase 3–(1) rock, (2) fire, (3) blow. Note that one word ("rock") appears in all three phases. Phase 1 (disambiguated stimulus, verbal response) consisted of the auditory presentation of the noun or verb form of one of the stimulus pairs, e.g., "a rock" or "to rock." Following a 1- to 5-sec pause, the S, while "thinking of" the meaning that had been given, heard a click to which she was to respond by saying the stimulus word, e.g., "rock." Thus, in Phase 1 the E presented the S with a disambiguated stimulus to which she responded with the stimulus word. The click also served as the trigger to begin data acquisition.

Phase 2 (ambiguous stimulus, verbal response) consisted of the presentation of a stimulus word, e.g., "rock," without any modifiers. The stimulus was ambiguous and could be interpreted as a noun or verb. While thinking of it in one of the two meanings, the S responded by repeating the stimulus word following the click. After a pause, the S verbally reported the meaning she had been "thinking of" while saying the stimulus word. Thus, in Phase 2 the S was allowed to assign a meaning to an ambiguous stimulus. In Phases 1 and 2, the verbal response typically occurred 600 to 1500 msec postclick.

Phase 3 (ambiguous stimulus, nonverbal response) was identical to Phase 2, except that the S was asked *not* to repeat the stimulus word following the click. Rather, she was to only "think of" the meaning she selected for the word. Ten to fifteen seconds after hearing the click, she verbally reported the meaning. Phase 3 served to evaluate the role of the actual generation of the verbal response (in Phases 1 and 2) in the overall brain response to the situation.

RESULTS

Figure 1 shows the average evoked activity from a representative S in Phase 1. Right- and left-hemisphere responses to click using the noun and verb forms of a stimulus word are shown. Note that the waveforms are distinctly different for the verb and noun forms of the stimulus word but are very similar over both hemispheres for a given word form. These word-form differences and hemispheric similarities were found consistently in all Ss. It appears that both hemispheres are actively involved in the processing of linguistic information and that waveform may be associated with meaning. However, it is necessary to distinguish the influences of temporal and meaning variables on the waveforms. Preliminary analysis indicates that meaning has a significant effect on waveform, independent of time. A detailed examination of this issue will be presented in a subsequent paper.

Laterality measurements were computed from the peak-to-peak (N1 to P1, see Fig. 1) amplitude of the evoked EEG. An overall right- vs left-hemisphere analysis

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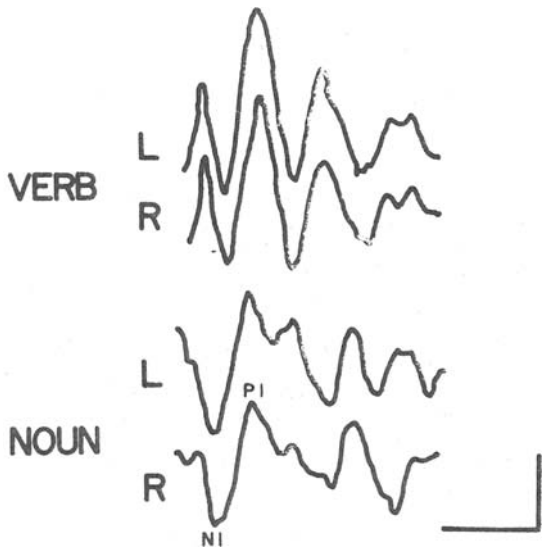

Fig. 1. Mean scalp-recorded click-evoked activity from a S in Phase 1. Each response is an average of 10 trials. Right- (R) and left-hemisphere (L) responses using the noun and verb meanings of the single stimulus word "rock" are shown. Calibration: 200 msec, 5 μV.

revealed that the evoked response from the dominant left hemisphere was larger than the response from the right hemisphere ($t = 3.97$, $p < .01$, mean difference = 0.78 μV). Right- vs left-hemisphere analysis across phases for verbs and for nouns indicated that, in both cases, the dominant left hemisphere exhibited the largest response (verbs: $t = 2.14$, $p < .05$, mean difference = 0.48 μV; nouns: $t = 3.30$, $p < .01$, mean difference = 0.98 μV). The mean right-left difference was twice as large in the noun as opposed to the verb category. Each of the three phases of the experiment was separately analyzed for overall right-left hemisphere differences. The results indicated that there were laterality differences in each phase of the experiment (Phase 1: $t = 6.37$, $p < .01$; Phase 2: $t = 2.60$, $p < .05$; Phase 3: $t = 2.17$, $p < .05$). The left-hemisphere response was reliably greater in each case, with Phase 1 showing the greatest numerical difference. The fact that dominant hemisphere laterality is present in Phase 3 suggests that motor or "premotor" responses were not critical for the evoked responses differences in Phases 1 and 2.

The latency of the evoked waveform was defined as the time between the click and the occurrence of the maximal positivity of the P1 component of the waveform. An analysis comparing right-hemisphere latency to left-hemisphere latency revealed that there were no reliable differences ($t = 1.52$, $p > .05$, right latency = 184 msec, left latency = 180 msec). Latency differences were also analyzed between verb and noun forms of the stimulus words. An analysis collapsing across hemispheres indicated that the evoked waveform latency for verbs was reliably shorter than for nouns ($t = 3.65$, $p < .01$, verb latency = 181 msec, noun latency = 186 msec). The latency to verb forms of the stimulus words was significantly shorter than to noun forms in the left hemisphere ($t = 5.03$, $p < .01$, verb latency = 173 msec, noun latency = 188 msec).

DISCUSSION

The results of this experiment indicate that cortical processing of cognitive stimuli is amenable to examination using surface scalp recordings. Click-evoked responses for ambiguous linguistic stimuli exhibit overall interhemispheric asymmetry with greater magnitude responses in the dominant hemisphere, in agreement with previous studies (Buchsbaum & Fedio, 1970; Matsumiya et al, 1972; Morrell & Salamy, 1971). Further, the degree of asymmetry differed as a function of linguistic meaning. Evoked response latencies showed not only hemispheric asymmetries but also significant linguistic meaning differences, with verbs having a shorter latency than nouns. Finally, waveform patterns appear to differ for the verb and noun forms of each word but are similar over both hemispheres for a given word form.

The major contribution of this study is an experimental paradigm which permits analysis of effect of "meaning" on evoked responses. The stimulus characteristics, i.e., the click and the stimulus words, and the behavioral response are held constant. By using ambiguous words with disambiguating instructions, only meaning is varied. To our knowledge, this is the first experiment to demonstrate a significant influence of linguistic meaning on human scalp-recorded evoked responses.

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