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Effects of Intersignal Interval on the Human Auditory Evoked Response

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Average evoked responses were recorded from human vertex in response to tone pulses presented at intersignal intervals (ISI) ranging from 0.25 through 10 sec. Tone pulses were 20 msec in duration with 20-msec rise and decay times. Frequencies investigated were 500, 1000, and 2000 Hz. Response amplitude was found to be a linear function of $\log_{10}$ISI. Response latency did not change significantly with ISI, except perhaps in component N_2 of the response, which appeared to increase in latency as ISI increased. These relations obtained regardless of frequency.

INTRODUCTION

THE auditory evoked vertex response (EVR), a long-latency nonspecific response from human scalp, has been shown to be sensitive to the intersignal interval (ISI) employed during response averaging. Keidel and Spreng (1965) found a large amplitude difference between EVR's obtained using a short ISI of 3–5 sec and those obtained with an extremely long ISI of 30 sec. Davis *et al.* (1966) reported data from six subjects that suggest that EVR amplitude increases with ISI as a negatively accelerating function. The purpose of the three experiments reported here was to further investigate the relations between various components of the EVR and ISI.

I. METHOD

During the experimental sessions, normal-hearing adult subjects sat in a sound-treated room reading fiction of their choice. Electrical potentials were recorded from the scalp with an active electrode at the vertex, a reference electrode on the mastoid contralateral to the test ear, and a ground electrode on the left forehead.

Signals consisted of 20-msec pulsed pure tones (500, 1000, and 2000 Hz) with 20-msec rise and decay times. In all three experiments, signals were presented at 60-dB sensation level (SL). Variations in ISI in these experiments ranged from 0.25 through 10 sec.

Figure 1 is a summary of the experimental conditions involved in the three experiments. In *Expt. 1*, five subjects (S's) were presented signals at 500 Hz and four S's were given signals at 2000 Hz. Intersignal intervals were presented in ascending order, from 0.25 through 2 sec.

Experiment 2 used 1000 Hz. Intersignal intervals were 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, and 6.0 sec. Five S's were given ISI's in ascending order; another five S's were presented ISI's in descending order. A 5-min. break occurred in the middle of the test session between the 2- and 2.5-sec ISI conditions.

A repeated-measures design was used in *Expt. 3* to explore differences between responses to 500 and 2000 Hz. Each of the 13 S's was tested at 500 and 2000 Hz in two test sessions—one frequency per session—with at least a one-day interval between sessions. Frequency order was randomized. The following ISI's were ran-

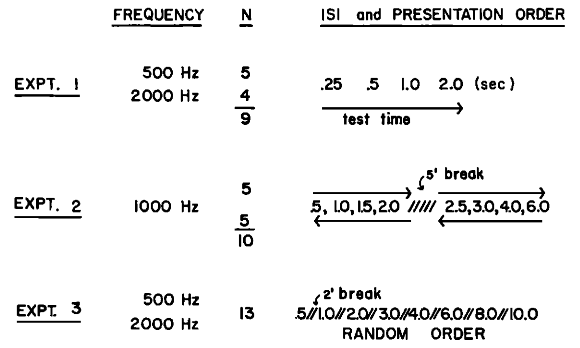

FIG. 1. Summary of experimental conditions involved in the three experiments investigating EVR's and ISI.

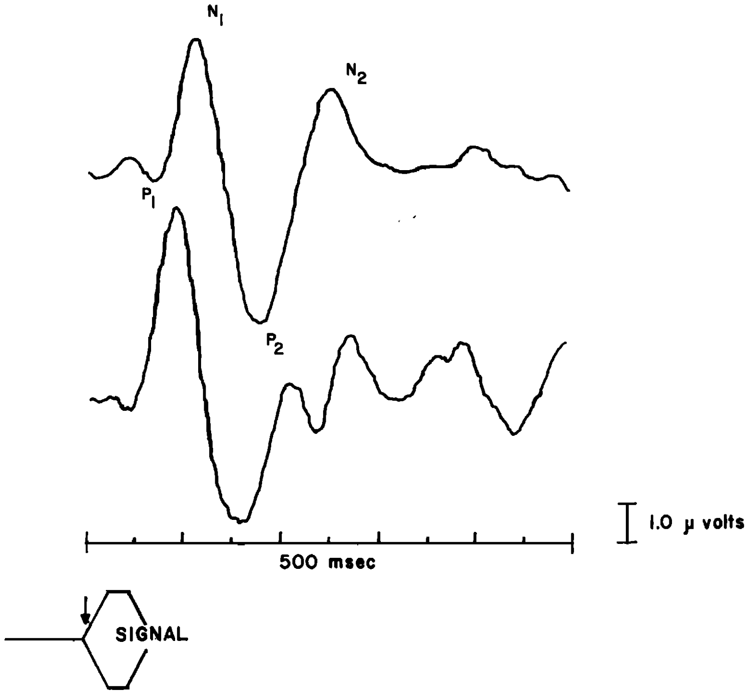

FIG. 2. Average evoked vertex responses obtained from a human subject and a schematic representation of the acoustic stimulus.

domly presented to each subject for each frequency: 0.5, 1.0, 2.0, 3.0, 4.0, 6.0, 8.0, and 10 sec.

Thirty-two 500-msec epochs of the post-stimulus EEG were averaged by either a Mnemotron CAT or a Fabri-Tek FT1052 signal averager. In the 0.25-sec ISI condition of *Expt. 1*, a 250-msec epoch was used. Average responses from the signal averager were graphically recorded for later determination of peak-to-peak amplitude and latencies.

II. RESULTS AND DISCUSSION

Figure 2 shows two average responses and a schematic representation of the tone pulse. Latencies were calculated from the point in time at which the tone pulse had reached 10% of its maximum amplitude. Peak-to-peak amplitude was measured for the various components of the average response: P_1–N_1, N_1–P_2, and P_2–N_2.

A. Latencies

Mean peak latencies and corresponding standard errors of the mean are shown in Fig. 3 for each of the ISI conditions. Intersignal interval is plotted along the abscissa in $\log_{10}$ of time. The solid triangles at ISI's of 0.25, 0.5, 1.0, and 2.0 sec are the average of responses to 500 and 2000 Hz from the S's in *Expt. 1*.

Relatively little difference in latency as a function of ISI is seen for components P_1 and N_1. This result agrees with the findings of Davis *et al.* (1966). A slight increase in the latency of component P_2 can be seen at the longer ISI's; a large shift in latency with ISI occurs in component N_2. Determination of latency was complicated by the occurrence of double peaks in components P_2 and especially N_2. The lower average response in Fig. 2 shows an example of the double negative peaks at the latencies usually referred to as N_2. Whenever such double peaks occurred, latency was measured using the first of the two peaks. The change in latency of N_2, then, may be not only a latency shift, but also a reflection of the occurrence of double peaks in the response, and thus perhaps an indirect measure of error in judgment of response.

B. Amplitude

Figure 4 shows mean peak-to-peak amplitudes and corresponding standard errors of the mean for each of the ISI's at 500, 1000, and 2000 Hz. Intersignal interval is plotted logarithmically on the abscissa with response amplitude on the ordinate in microvolts. Of primary interest is the function for the N_1–P_2 amplitude measure, which increases about 1.85 μV with each twofold increase in ISI from ISI's of 0.25 sec to at least 6.0 sec. The function probably continues beyond 6.0 sec since Keidel and Spreng (1965) reported very large amplitudes for ISI's of 30 sec, amplitudes within a first approximation of what one would expect by extrapolating the present data.

The data in these experiments are best fit with a straight line on a semilogarithmic plot. Figure 5 (Curve

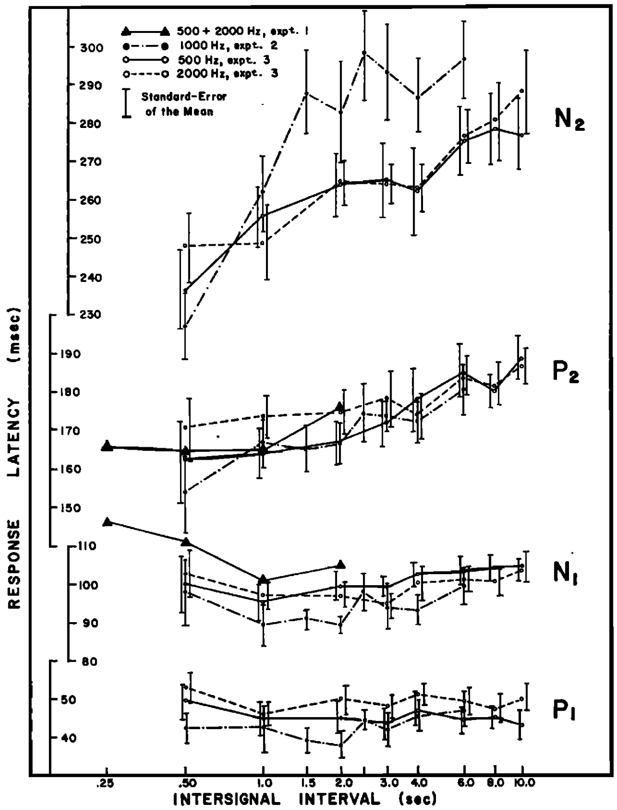

FIG. 3. Mean latencies and corresponding standard errors of the mean for the various EVR components. Each datum point represents the average across subjects within each experiment. Intersignal interval is plotted in log time on the abscissa against response latency in milliseconds on the ordinate.

A) shows the results of a least-squares analysis on the composite means of N_1–P_2 amplitudes. The slope of the linear function for each of the response components is as follows: P_1–N_1 amplitude: 2.2 μV/($\log_{10}$ ISI); N_1–P_2 amplitude: 5.6; and P_2–N_2 amplitude: 3.9.

These results are not directly comparable with those reported by Davis *et al.* (1966) since the absolute amplitude of their responses was considerably higher than in the present study. The larger amplitude of their responses may be partially due to the greater intensity of their signals [85 dB hearing level (HL), ISO] than the 60 dB SL used in the present study. When their results for N_1–P_2 amplitude are replotted with ISI in log time (Curve B in Fig. 5), the slope of their function is 19.1 μV/($\log_{10}$ ISI). The slope is much steeper than the 5.6 μV/($\log_{10}$ ISI) slope reported in the present study for the same response component.

There was considerable variability between S's in the slopes of the individual functions. Some S's demonstrated very steep functions while others gave relatively flat functions. Those S's with the less-steep functions tended to be the ones with smaller response amplitude.

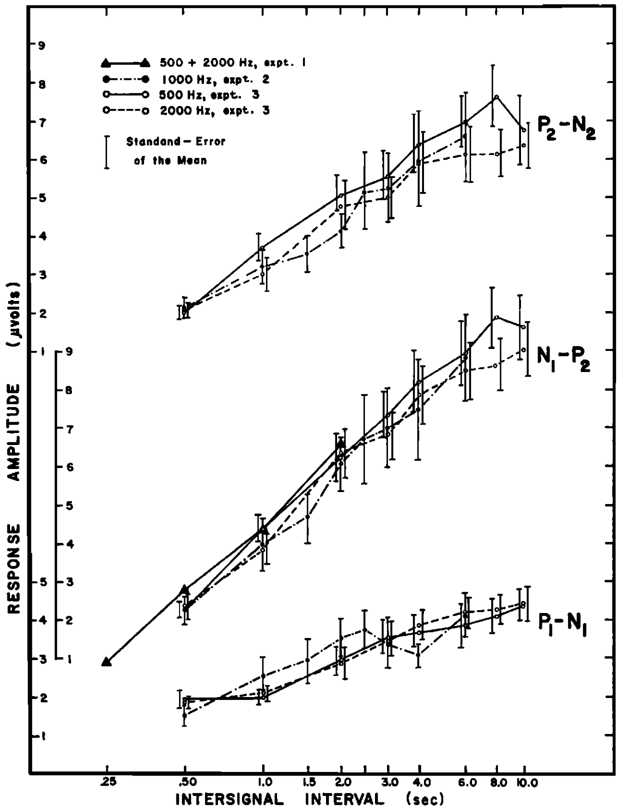

FIG. 4. Peak-to-peak amplitudes of the EVR as a function of ISI. Datum points are group means within each experiment.

From results reported by Keidel and Spreng (1965) and from unpublished findings in our laboratory, it appears that signal intensity and ISI may interact. For example, steeper input–output intensity functions (response amplitude as a function of signal amplitude) occur when long ISI's are employed than when short ISI's are used. It may also be true that a steeper ISI

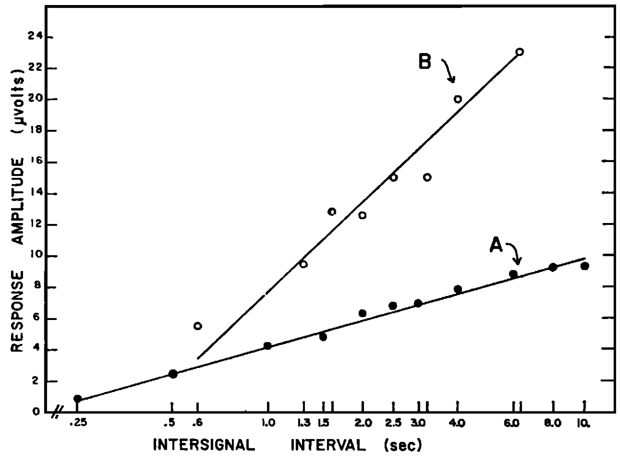

FIG. 5. Least-squares analysis on group means. Data for Curve A are from the N_1–P_2 amplitudes reported in the present study. Data for Curve B were taken from Davis *et al.* (1966).

function (response amplitude as a function of ISI) may result when more intense signals are used. Comparison of Curve A and B of Fig. 5 suggests that such a relation may occur since the major difference between the two sets of data is the level of the acoustic signal. The signals used in the present study were 10–20 dB less than those used by Davis, which may account for the large difference in slope between the two curves. The interaction between signal intensity and ISI certainly needs further investigation before this discrepancy can be resolved.

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