Spatial summation in the evoked cortical response to auditory stimuli[1]

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Six Ss were presented monaurally and binaurally with stimuli of 0.5, 2.0, and 4.0 kHz at 40 and 70 dB sensation levels. Their computer averaged evoked potentials indicated substantially larger amplitudes ($N_1 - P_2$) with bilateral stimulation, regardless of frequency. Stimulation at 70 dB SL gave greater responses than that to 40 dB.

The cortical evoked potential (CEP) has been well exploited as a means of assessing cortical activation time-locked to and, therefore, either directly or indirectly caused by peripheral sensory input. The vast majority of such studies undertaken over the past several years have attempted to evaluate the variety and mode of CEP changes that accompany parallel changes in the stimulus parameters. The present study seeks to expand a similar suggestion made by Davis and Zerlin (1966) that the amplitude component of the CEP may increase under binaural stimulation, relative to the "control" or "reference" amplitude of the N_1 to P_2 peak obtained under monaural conditions. Bartlett, Eason, and White (1968) have previously shown the evoked response technique to be useful in demonstrating bilateral summation with visual stimuli. Similarly, Davis and Zerlin found that for tone pips of 2.4 kHz presented at a "comfortably loud" level to four young adults, the average response was 16.2 μV for either ear alone and 19.5 μV for the two ears together, approximately a 20% increase. Unfortunately, no other stimuli were utilized, therefore, cross-comparisons were impossible with their data. The present study, then, is designed to reexamine the nature and the extent of any such CEP amplitude increases found in audition under bilateral vs unilateral conditions while permitting cross-comparisons by the utilization of three different frequencies at each of two sensation levels.

METHOD AND APPARATUS

Grass silver disc electrodes were used in conjunction with a bentonite mixture to pick up the brain potentials. Electrode placement was at the vertex with left ear as ground and right ear as referent. Initial amplification was provided by two Tektronix FM-122 low-level preamplifiers wired in series to provide a total amplification factor of roughly 100,000. The EEG was monitored on a Tektronix Model 564 oscilloscope and sampling was performed by a medium-resolution (400-address memory) TMC Computer of Average Transients (CAT). The stimuli to each ear were bifurcated at the output of a single Hewlett Packard 200 CD sine wave generator to assure equal phase during binaural reception, and were fed through two channels of an electronic switch (Grason-Stadler 829-D) which shaped the envelope of the resulting stimuli; a slow (50 msec) rise-decay setting was used in order to maximize the energy concentration of the short tones. Triggering of the electronic switch as well as on-time (75 msec) and interstimulus interval (3.0 sec) were controlled by a Tektronix Model 162 waveform generator in series with two Model 161 pulse generators. Stimulus attenuation for each ear was provided by two Hewlett Packard 350-A attenuator sets. Grason-Stadler TDH-39 headphones were used since a coupler was commercially available through which these headphones could be calibrated. By the use of a Brüel and Kjaer frequency spectrometer, care was taken, both pre- and posttrials, to assure equality of sound pressure level (± 1 dB) at each earphone for every frequency and sensation level utilized. Waveforms were graphed by a Moseley 7035-A X-Y plotter and stimuli were counted automatically by a General Time Corporation electronic counter which also served to stop computer-sampling after the preset number of stimuli had been presented.

Six unpaid Ss, three men and three women, were chosen unsystematically as volunteers from a general psychology course at the University of Arizona. S was seated in a double-walled soundproof, electrically-shielded room in the Auditory Research Laboratory of the Speech Department, and S could communicate with E through an "intercom." At the onset of each experimentation period, S's threshold was measured at each ear by noting the point where the stimulus failed to be detected for each of three descending series replications. The median value was used in instances where different thresholds were observed in the replications. Sensation levels for stimuli presented in the binaural condition were determined by exceeding each ear's separate threshold value by equal amounts.

Sixty-five stimulus presentations were averaged at each frequency (500, 2000, and 4000 Hz) and sensation level (40 and 70 dB). S was asked to attend to the stimuli as much as possible and to count the number of presentations for each series. Any trial for which S was wrong by more than 3, was discarded on the grounds that his attention was significantly lowered on such occasions.

The CAT was programmed to sample the EEG for 500 msec immediately after stimulus onset. The resulting averaged waveform for each condition was then recorded by the X-Y plotter. Vertical distance from N_1 peak to P_2 trough was converted to its microvolt equivalent and this value recorded as a single entry for each S under every condition.

RESULTS AND CONCLUSIONS

A total of 18 amplitude entries was made for each of the six Ss—right (R), left (L), and both (B) ears—at each of the three frequencies and two sensation levels. Three two-way analyses of variance were performed to determine significance of differences observed for the "ear" (R,L,B) treatment effect, as well as for frequency and sensation level. The effects of frequency upon

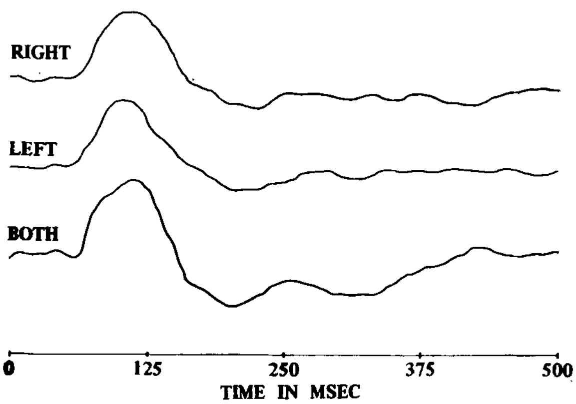

Fig. 1. Evoked potential records obtained from Subject C.M. Each wave represents the summation of 65 responses to 2 kHz, 70 dB stimuli presented to right, left, and both ears.

amplitude observed across Ss was not significant ($F = 0.285$, $df = 5,10$). However, amplitudes at 70 dB were significantly larger ($p < 0.005$) than those for all conditions at 40 dB computed across Ss ($F = 29.66$, $df = 1,5$); and amplitudes obtained under the "B" condition were significantly larger ($p < 0.001$) than those observed for either ear alone ($F = 11.006$, $df = 5,10$). A Duncan's multiple range test showed that when groups were collapsed across both frequency and Ss, the differences between the means of all possible paired combinations of the remaining six groups (R_{40}, L_{40}, B_{40}, R_{70}, L_{70}, B_{70}) were all significant beyond $p < 0.01$ except for the separation of R_{70} and L_{70} which was not significant. The mean amplitude response of the right ear collapsed across all Ss and conditions was 10.4 μV as compared with 10.2 obtained for the left ear. The mean amplitude of responses to stimuli presented to both ears was 12.9 μV—an increase of 21%, closely corresponding to the 20% increase found previously by Davis and Zerlin.

We may conclude on the basis of this research that the CEP technique can provide clear evidence for binaural summation of loudness. CEP amplitude for all Ss is significantly larger for bilateral stimulus presentation regardless of either frequency or sensation level. The amount of increase seems to be slightly greater than 20%, irrespective of frequency or sensation level.

Since CEPs almost always show a considerable amount of inter-S variability, no specific analysis was performed to assess these inter-S differences. "Eyeballing" provides sufficient verification of this trend, and the inter-S consistencies reflecting regular response increases binaurally were held to be of greater interest.

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NOTES

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