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Some new data on the lateralization of noise signals with large interaural time differences

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Blodgett, Wilbanks, and Jeffress (1956) showed that the human auditory system can utilize interaural time differences considerably greater than those which can arise in a free sound field to lateralize noise signals. Some new data are reported on the effect of large interaural time differences upon judgments of sidedness. The results show that subjects can detect interaural time differences as large as 10 msec as differences in direction or position, and that subjects can distinguish between uncorrelated noise and noise signals with interaural correlations as small as r < .02 as differences in sidedness.

When noise is presented to a listener binaurally through earphones and an interaural time difference is introduced via a time delay in the channel to one ear, the sound image, which at zero delay is centered and seems compact, moves rapidly to the leading side, reaching a maximal displacement at about .8 msec and retaining its compact character. Through increasing delays up to several milliseconds (depending upon the band of noise employed), it remains in this position. As the interaural time difference is increased, the sound loses phenomenal compactness, becoming more and more diffuse, eventually losing all sidedness. It is then indistinguishable from uncorrelated noise.

Some years ago, Blodgett, Wilbanks, and Jeffress (1956) did a study in which they determined, for various bands of continuous noise, the maximal time difference that could be introduced without loss of sidedness. Blodgett et al. used two octave-band noise signals centered at 160 and 3,600 Hz. They found that listeners, on the average, could still detect as sidedness interaural time differences as large as 10 msec and 6 msec for the low-frequency and high-frequency bands, respectively. One of their subjects could detect sidedness with an interaural time difference on the order of 20 msec.

The magnitude of the interaural time difference required to bring about a complete loss of laterality gives the upper limiting value within which time differences can be employed in the localization, or lateralization, of noise. The argument is that this gives a measure of the upper limits of the temporal range through which the auditory system is able to effect a correlation between the events at the two ears.

The present study is an extension of this earlier work on the lateralization of noise signals with large interaural time differences, that is, time differences far in excess of those naturally occurring in man (viz., larger than about .6 msec), when a sound source is directly off to one side.

This study was part of a master's thesis by Michael W. Pate. The principal results were presented at the Eighteenth Annual Meeting of the Psychonomic Society, November 1977, Washington, D.C. Requests for reprints should be sent to W. A. Wilbanks, Department of Psychology, University of Georgia, Athens, Georgia 30602.

METHOD

In the present study, three narrow-band noise signals were used: (1) a 100-Hz noise centered at 250 Hz; (2) a 320-Hz noise centered at 800 Hz; and (3) an 800-Hz noise centered at 2,000 Hz. These noise bands were obtained by passing the output of a Grason-Stadler noise generator through a Princeton Applied Research (PAR) tuned amplifier and Krohn-Hite filters. For each noise, the upper and lower 3-dB down points were approximately 4/5 and 6/5, respectively, of the center frequency.

The duration of the signals (150 msec) was controlled by an Iconix electronic counter that triggered a Grason-Stadler switch, simultaneously gating the noise to each ear with a 10-msec on-off time. The overall level of each signal was approximately 80 dB SPL.

Each noise was recorded on the twin tracks of an Audio Instruments tape recorder, and interaural time differences were introduced by lateral displacement, during playback, of one of the reproducer heads. Interaural time difference was measured with an Atec electronic counter. The tape delay unit was accurate to approximately .5 msec.

Sidedness thresholds were obtained in the following manner. The noise signal was programmed to occur in a single temporal interval marked for the observer by a light. The sequence of events within each trial was (1) beginning (warning light), .1 sec; (2) pause, .8 sec; (3) 150-msec observation interval marked by a light; and (4) response period, 2.0 sec. One hundred such trials constituted a single session.

The leading channel was commutated on a quasirandom schedule so that on 50% of the trials the right channel was leading. Following each signal presentation, the subject pressed one of two response keys indicating whether the right or left channel was leading in time.

For each noise band, the time delay was varied to generate psychometric functions relating percentage correct choices to time difference. A minimum of 600 trials was given to each observer for each value of interaural time difference. From these psychometric functions, the interaural time difference for 75% correct choices was determined.

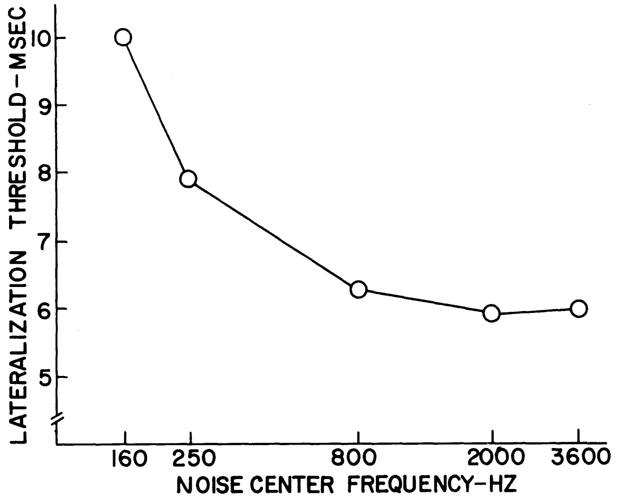

Figure 1. Mean interaural time difference in milliseconds for 75% correct lateralization judgments as a function of noise center frequency.

RESULTS AND DISCUSSION

The averaged results for our subjects are shown in Figure 1. Here the ordinate is the interaural time difference in milliseconds for 75% correct lateralization judgments, and the abscissa is the center frequency of the noise band. The results of the previous study by Blodgett et al. (1956) for octave-band noises centered at 160 and 3,600 Hz are included.

The results of the present study are in agreement with the earlier work. With narrow-band noise signals, the largest interaural time difference that can be detected as sidedness is much larger than that naturally occurring, about .6 msec, when a sound source is directly off to one side. Examination of Figure 1 shows that with a noise centered at 160 Hz subjects can still detect as sidedness an interaural time difference as large as about 10 msec. As the center frequency of the noise is raised to 3,600 Hz, the value of the threshold decreases to about 6 msec. The length of delay that can be detected as sidedness is greater, for all subjects, with noise bands of low-frequency content.

As the interaural time difference between events at the two ears is increased, the interaural correlation of the noise signal decreases, eventually reaching its mean-square value of zero. In this case, it would be like using two independent noise sources as inputs to the two ears. Interaural time difference for 75% correct judgments for the three noise signals used in the present study were about 8 msec for the band centered at 250 Hz, 6 msec for the 800-Hz signal, and a little less than 6 msec for the 2,000-Hz signal. The absolute values of the interaural correlations of these noise bands were determined with a PAR Correlation Function computer and found to be $r = .1$, $r < .02$, and $r < .02$, respectively. In other words, the data show that listeners can still make better-than-chance lateralization judgments with noise bands whose correlations differ only slightly from zero; that is, listeners can still effect a correlation between the events at the two ears, determining that the input to one ear is the same as that occurring many milliseconds earlier at the other.

That listeners can distinguish uncorrelated noise from noise with an interaural correlation only slightly greater than zero is consistent with the work of other investigators. Pollack and Trittipoe (1959a, 1959b) found that listeners can distinguish between noise with an interaural correlation of zero and with a correlation smaller than $r = .1$. Jeffress, Blodgett, and Deatherage (1962) found that subjects can make better-than-chance centering judgments on signals with interaural correlations as small as $r = .1$.

To briefly summarize, when noise is presented binaurally and the interaural correlation of the signal is reduced by effecting a time delay in the channel to one earphone, the maximal delay that can be introduced without loss of sidedness is quite large, being on the average, as large as 10 or 6 msec, depending on the frequency content of the noise. Listeners can still detect as sidedness interaural time differences that reduce the interaural correlation of the noise to almost zero; that is, listeners can effect a correlation between the displaced events almost occurring as random events at the two ears.

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