Lateralization of a Coherent Noise Source within Diffuse Background Noise using Interaural Level Differences

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Abstract

In complex auditory environments the primary binaural cues used for localization of acoustic objects on the horizontal plane are distorted due to background noise and reverberation. Depending on the signal-to-noise ratio (SNR), the aggregate interaural level difference (ILD) for the source plus noise is systematically shifted from the ILD of the target sound source. The research presented here evaluates the perceived lateralization of distorted ILD cues due to background noise. Results show that some subjects had a tendency to use the aggregate ILD when the target was presented in noise; however, other subjects were still able to utilize the actual target ILD. Subsequent investigation with additional noise conditions was conducted on the sub-group of subjects who tended to utilize the target ILD. When mean performance across subjects was evaluated for each test condition, no difference in lateralization performance was seen between the various test conditions. However, different intra-subject lateralization strategies were seen for some of the subjects depending on the test condition.

Introduction

It is well-known that ILDs lead to a perception of spatial lateralization [1]. Correct localization of free-field stimuli with spatially positioned maskers has been shown [2]. However, it is still uncertain to what extent listeners can accurately lateralize stimuli in diffuse background noise.

The ILD of an isolated target stimulus can be represented as the ratio of energies between the left and right ears, where a unity ratio represents a diotic presentation. When a diffuse background noise is added equally to both the left and right channel, the ratio of energies will be closer to unity depending on the SNR. This aggregate stimulus results in an effectively smaller ILD, i.e. is shifted toward the midline. The reduced ILD will be referred to as the “aggregate ILD” for the remainder of this paper.

It is unknown whether or not listeners utilize the actual target ILD or the aggregate ILD for lateralization purposes. It is possible that the duration of background noise before and after the target could influence the ability of the listener to perceive the target ILD. When there is a temporal disparity between the background noise and target, the ILD of the background noise is known to the listeners. Thus, in principle, this knowledge could be used to infer the ILD of the target. This is not possible without an onset disparity, and the aggregate ILD is expected to be heard.

The aim of this research is to determine if human listeners use the aggregate ILD, which is dependent on the SNR, to lateralize a target in noise or if the actual target ILD can still be heard. It is also of interest to investigate if the ability to use either the target or aggregate ILD is dependent on the disparity between the target and background noise onsets.

Methods & Stimuli

For all lateralization experiments, participants completed an adaptive three-interval acoustical pointer task on headphone presented stimuli. The first and third intervals contained a coherent target stimulus with the same target ILD which was temporally centered within diffuse background noise. The ILD of the second interval (presented in isolation without background noise) was adjusted left or right by the listener to match the perceived lateral position of the target ILD in the first and third intervals.

Both the perfectly correlated target stimulus and uncorrelated background noise used in this research were broadband (20 Hz - 20kHz), thus, no spectral cues were available to the listeners. The target stimulus was always 300ms in duration and temporally centered within each of the intervals. The ILDs used for this experiment were ±10dB, ±6dB, ±4dB, ±2dB and 0dB. (The results for ±10dB ILDs were highly variant, therefore, they are excluded here.) For every test condition, each subject was presented four repetitions, which were randomly and uniformly distributed around each of the specified ILDs mentioned previously.

The target stimuli were first generated at 65dB SPL, and the ILD was applied by changing the levels at both ears in opposing directions by an equal amount in dB. The overall level of the acoustic pointer, i.e. the second interval, was roved over a 10dB range around 65dB SPL to ensure that listeners were unable to use monaural cues for the task. Also, the pause duration between the intervals was jittered from 250ms to 750ms, thus hampering listeners from using a temporal grid to focus on the target onsets.

Listeners were allowed to practice lateralizing the stimuli until they were comfortable with the task, and this typically lasted 20 minutes. To ensure that SNRs used for the test were easily detectable, thresholds of detection at each of the center ILDs were measured.

Experiments & Results

To establish a baseline performance for each subject, lateralization accuracy was measured for the isolated target stimulus without background noise. In total, baseline performance was measured for ten subjects. Two of the ten subjects were unable to complete the task with reasonable accuracy and were excluded from future experiments. The remaining eight listeners completed the lateralization task when the target stimulus was temporally centered in 800ms of uncorrelated background noise, i.e. 250ms beyond either side of the target stimulus, at a SNR of +3dB. As will be described shortly, a sub-group of five participants was selected for additional test conditions based on their performance in the preliminary test condition.

Since it was of interest to analyze the trends in lateralization performance between presented ILD versus adjusted ILD for all listening conditions, the slopes of best-fit linear regression lines were determined. A slope of 1dB/dB represents perfect lateralization. Figure 1 shows the linear regression slopes for both the baseline condition and the initial test condition for each of the eight participants. It can be seen that some subjects were able to accurately lateralize the target stimulus in noise, however, it appears that some of the subjects adjusted the pointer closer to the aggregate ILD. If the population performance between Subjects 1-5 and Subjects 6-8 is compared using a repeated measures ANOVA linear contrast analysis, these groups perform similarly for the isolated target but perform significantly different $F(1,30) = 31.50$, $p < 0.001$ when the target is presented in noise. It is interesting to note that the subjects performing closer to the aggregate ILD showed significantly higher detection thresholds (~2dB higher) than the other subjects $F(4,56) = 3.06$, $p < 0.05$.

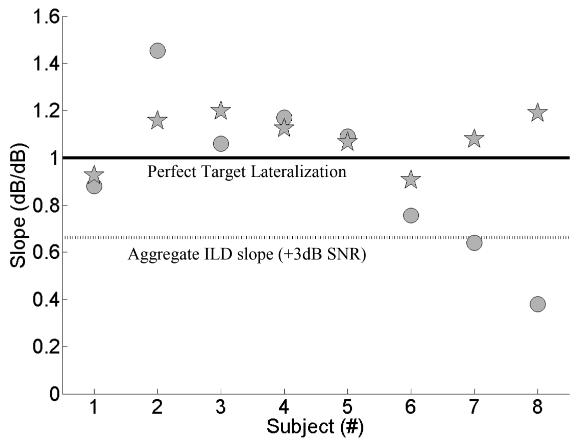

Figure 1: Slope comparison of best-fit linear regression lines for lateralization performance in isolation (stars) and in noise (circles) for each subject.

The non-aggregate lateralization performance of Subjects 1-5 in this initial test condition prompted further experiments to determine if changes to the temporal onset disparity (between the background noise and target) or the SNR would affect lateralization performance. To test the effect of the onset disparity, the SNR was fixed at +3dB, and performance was compared for onset disparities of 250ms, 125ms and 0ms. Additionally, to compare the effect of SNR, the onset disparity was held at 250ms, and lateralization performance with SNRs of +3dB and 0dB was compared.

Figure 2 shows the slopes of the linear regression lines for the population in each test condition. As a whole, performance is essentially the same for all conditions, however, some intra-subject detail could potentially be lost with such a conclusion. In fact, when comparing the performance between baseline performance and the various test conditions for each of the participants, significant differences were found. Instances where the performance trend was different for a particular subject was sometimes inconsistent between test conditions, thus, the individual data is not presented here. Some of the subjects followed a lateralization trend somewhere between the aggregate ILD and the true target ILD, whereas other subjects overcompensated and adjusted the acoustic pointer to an ILD further lateral than the target ILD. Although no systematic relationship can be found between the test condition parameters and performance, it is worth pointing out that the lateralization strategy for some subjects in some test conditions was different than their strategy with an isolated target stimulus.

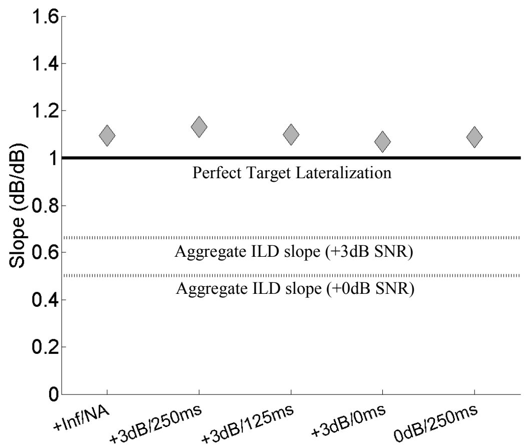

Figure 2: Comparison of mean lateralization performance for the sub-group (Subjects 1-5) for each test condition.

Discussion & Summary

Although some subjects showed a tendency to perceive the aggregate ILD for lateralization, many subjects were able to utilize the actual target ILD. Additional test conditions at different SNRs and with different onset disparities showed little effect on mean performance across subjects, but significant intra-subject differences were found between test conditions and the baseline lateralization performance.

Either way it is remarkable that some listeners are able to extract the target ILD in noise, especially when there is no onset disparity between the target and the background noise. This implies that some listeners do not require a period of the background noise in isolation to extract the target ILD and that they employ some unknown strategy for finding the target ILD.

References

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