Temporal resolution of the binaural system for lateralizing purely binaural modulations

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Abstract

To investigate the binaural processing for rapidly changing cues, a purely binaural modulation was created by periodically alternating segments of broadband noise between two different interaural time difference (ITD) values. The present studies investigate whether the binaural system is fast enough to segregate the two ITD streams or if the binaural system is sluggish such that it integrates the two spatial locations into a single, smeared sound image. The influence of an additional diotic amplitude modulation (AM) on the described stimulus was also part of this investigation. Results indicate that the binaural system is indeed fast enough to accurately lateralize target tokens 3 - 7.5 ms in duration when the target ITD is greater than ±200 us from the interfering ITD. The temporal position within the AM phase for the target ITD does not seem to affect lateralization performance. These results are in line with the notion that there is modulation sensitive functionality subsequent to the point of binaural interaction.

Introduction

The binaural system has been depicted as "sluggish" for binaural masking level difference configurations [1] and for tracking changes in interaural temporal differences [2]. However, it has also been shown that the binaural system can detect very brief ITD changes [3]. The primary goal of the research presented in this paper is to determine if these brief ITD changes can be accurately lateralized. An additional study investigated the influence of an AM envelope on the spatial percept of the brief ITD changes. Using a tonal carrier, [4] has shown a weighting of the spatial cue during the rising part of an AM envelope. The current experiments investigate if a similar perceptual emphasis is seen for a broadband noise carrier.

Stimuli & Methods

A schematic of the signal employed for this paper is shown in Fig. 1. The stimulus is composed of broadband, Gaussian noise with periodically alternating ITDs. It should be emphasized that both the left and right channels are continuous noise without any monaural cues for detecting the binaural switching.

This stimulus permits systematic changes in the switching period where the duty cycle can be used to adjust the relative durations of the two ITD segments. In a pilot experiment prior those reported here, listeners were asked to qualitatively describe their percept of this binaurally switching stimulus. Assuming a sufficiently large (∼200 us) interaural separation, listeners reported this stimulus to be composed of two components: a continuous and a modulating component. The ITD with the shorter duty cycle corresponded to the modulating component whereas the ITD with the longer duty cycle was related to the continuous noise percept. Although the two ITD sections are spectrally identical, the perceptual differentiation via temporal characteristics motivated our specific instructions, which directed the listeners to the modulating component for the lateralization task in this study.

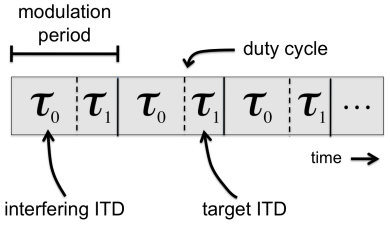

Figure 1: A schematic of proposed broadband noise stimulus that periodically alternates between two different ITDs. The ITD with the smaller duty cycle is reported as having a percept of modulation.

For our experiments, one ITD was set to zero (referred to as the *interfering ITD*) while the other ITD was uniformly distributed between ±625 us (referred to as the *target ITD*). The modulation periods employed were 240, 120, 60, 30, 15 ms. Although not all combinations were tested, the duration of the target ITD noise sections ranged from 3 to 60 ms and target ITD duty cycle ranged from 2.5 to 75%. The duration of all test stimuli used in this paper was 600 ms, which were presented at a level of 70 dB SPL.

An acoustic pointer task was employed to determine if listening participants could lateralize the binaurally modulating sound source in the first and third intervals of a three-interval presentation. The second interval was a 300 ms continuous broadband noise that could be adjusted left or right by the listening participants to match the perceived location of the modulating sound.

The same pointer task was used for the second study in which an AM was imposed onto the stimulus of the first experiment. The binaural modulation period was fixed at 60 ms. Target ITD durations were either 3, 6, 9 or 15 ms and were inserted into either the rising, peak, or

falling slope positions of the AM envelope, i.e. the binaural modulation period was identical to AM period. A fourth condition was also tested such that the monaural and binaural modulation rates were not equal. For this condition, the binaural modulation period was held at 60 ms and the AM period was changed to 75 ms such that the random temporal positions of the target ITD would be presented twice during the 600 ms stimulus.

Results

Slopes of the linear models fit to data from the seven listening participants are reported in Fig. 2 as triangles with the x's representing the model fit to the population data. A slope of one represents perfect target lateralization and slope of zero represents lateralization towards the diotic, interfering ITD. For comparison, baseline lateralization performance of 300 ms broadband noise at a fixed ITD was conducted (open circles in Fig. 2). Filled triangles represent a statistically significant difference in individual performance from the baseline condition.

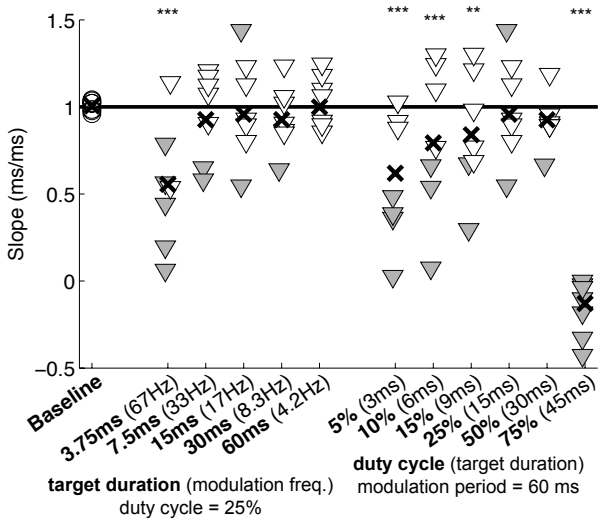

Figure 2: Slopes of the linear models fit to the test data where a value of unity represents perfect target lateralization. The x's represent the performance across the population of participants where the asterisks signify a statistical difference from the baseline performance. Triangles indicate individual performance where the filled symbols indicate a significant difference from the individual's baseline performance.

When the test conditions are blocked on either a fixed duty cycle of 25% or on a fixed modulation period of 60 ms (respectively, left and right groups of test conditions in Fig. 2), it is apparent that lateralization accuracy improves as the duration of the target ITD increases. Several listeners are able to accurately lateralize down to 3 - 6 ms where only a duration of 7.5 ms is required for the entire population. Another notable result is for the condition where the duty cycle with respect to the target ITD was 75%. In this condition participants adjusted the acoustic pointer to match the interfering ITD.

Lateralization performance when an AM envelope is imposed on the stimulus of the first study is plotted in Fig. 3. Similar to the first study, the duration of the target

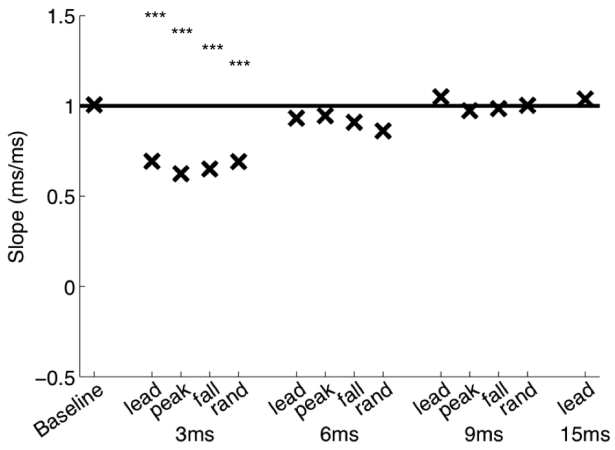

Figure 3: Slopes of the linear models fit to the population data from the second study. Asterisks indicate a statistical difference from the baseline performance.

ITD influences lateralization accuracy. However, only 6 ms segments of target ITD was necessary for accurate lateralization across the population of participants. The position within the AM envelope where the target ITD was inserted does not have a statistically significant effect on absolute lateralization accuracy.

Summary

Not only is the binaural system fast enough to detect brief changes in ITD [3], it is also able to accurately lateralize brief ITD changes as shown in the present study. Results indicate that a percept of modulation is attributed to the brief ITD segment with a smaller percentage of the modulation period. Since this modulation percept is mediated purely by the binaural system, it is suggested that modulation sensitive functionality exists subsequent to binaural interaction. Unlike in [4], the heavier perceptual weight of the spatial cues during the rising portion of the AM envelope was not observed for our broadband stimulus.

References

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