Auditory motion aftereffects with a two-tone adapter

Hisashi Uematsu and Makio Kashino

NTT Basic Research Labs., 3-1, Morinosato-Wakamiya, Atsugi, Kanagawa, 243-0198 Japan

Abstract: Auditory motion aftereffects were measured using an adapter consisting of 250- and 500-Hz tones. Apparent movement of both adapter and test sounds was produced by varying only interaural time differences. No significant difference was found in the magnitude of the aftereffect when the adapter consisted of two components moving in the same direction, or with a single 500-Hz adapter. On the other hand, the aftereffect disappeared when the two components moved in opposite directions. These results suggest that the integration of motion information across frequency bands is not a simple linear addition.

INTRODUCTION

We have been examining the effects of moving adapter sounds on subsequent test sounds (auditory motion aftereffects) to gain insight into the mechanisms used for detecting sound source movement. We have reported that the extent of auditory motion aftereffects, produced by varying interaural time differences (ITDs), depends both on the velocity of the adapter and on the frequency relationship between adapter and test (1). These results are consistent with the idea that the auditory system contains a population of neural units specialized for the detection of ITD changes, and that such neural units exist before the information from different frequency bands is integrated. In the present study, we further examined auditory motion aftereffects using two-tone adapters in order to clarify how ITD-change information is integrated across frequency bands.

EXPERIMENT

Stimuli

We simulated sound source movement by varying only ITD. The components of the two-tone adapter were 250 Hz and 500 Hz, and the sweep duration of the adapter was set to 2 s, where the auditory motion aftereffect using a pure tone (500 Hz) adapter was found to be largest. The ITD of each component in the adapter was changed from −600 μs to +600 μs (simulated rightward motion) or +600 μs to −600 μs (simulated leftward motion). Adapters were presented 5 times. The test tone had duration of one second and was presented once following each adapter. The frequency of the test tone was 500 Hz and the amount of change in ITD (ΔITD) was either 0, ±100, ±200, or ±400 μs (the plus sign represents a rightward movement, and the minus sign represents leftward movement). The absolute values of ΔITDs correspond both to the distance and velocity of the simulated movement because the duration of the test tone was fixed at one second. A raised-cosine ramp (10 ms) was applied at every onset and offset of the adapter and test tones. The sound pressure level of each tone at both ears was adjusted to 60 dB. Stimuli were generated digitally at a sampling rate of 44.1 kHz and presented using 16-bit digital-to-analog converter (Digital Audio Labs, The CardD Plus) through headphones (Sennheiser HDA200) in a sound-insulated booth.

Method

The constant method was used to measure the subjective stationary point, that is, the test tone ITD-change rate necessary to cancel apparent movement due to aftereffect. In each trial, an adapter was presented for approximately 10 s, followed by a test tone. The adapter was selected from one of four conditions in which the direction of each component was different. The ΔITD of the test tone was selected randomly on each trial. Subjects were requested to judge the direction of movement of the test tone. The initial ITD of a test tone was selected randomly from the three values -200, 0, +200 μs in order to prevent the subjects from using the position of onset or offset as a cue for direction of motion. The subjects made 12 (3 initial ITDs × 4 repetitions)
judgments for each test tone. Measurements with single tone adapters were also made as control conditions. Four females (20 to 22 years old) participated in the experiment.

Results
Psychometric functions were obtained using the method of maximum likelihood estimation. The velocities at which each subject perceived no movement of the test tone were then calculated for each type of adapter. The magnitude of auditory motion aftereffect was defined as the difference between the subjective stationary point in each adaptation condition and that in the no-adapter condition. Figure 1 shows the magnitude of aftereffect averaged over the four subjects. The ordinate indicates the magnitude of the aftereffect in terms of the amount of ITD change in one second, and the abscissa indicates the direction of movement of each component in the adapter. Results of the control conditions, in which single tone adapters were presented, are also shown in Figure 1.

![Figure 1](image)

**FIGURE 1.** Extent of auditory motion aftereffects with two-tone adapters (●) and with single tone adapters (○).

Discussion
In control conditions, the 500-Hz tone adapter produced a large auditory motion aftereffect on the 500-Hz test tone, but the 250-Hz tone adapter produced no aftereffect on the same test tone. This result was consistent with previous observations that auditory motion aftereffects disappeared when the frequency difference between adapter and test was larger than half an octave (1). However, in the current experiment, the extent of auditory motion aftereffect was reduced to zero when the two components (250 Hz and 500 Hz) moved in opposite directions, despite the fact that the 250-Hz component did not influence perception of 500-Hz test when it was presented alone. When the two components of the adapter moved in the same direction, on the other hand, the amount of auditory motion aftereffect was similar to that produced by the single 500-Hz tone adapter.

These results indicate that ITD-change information in separate frequency bands are neither processed independently, nor simply added together. Apparently there is a complex across-frequency interaction in which ITD-change information separated in frequency by one octave does not facilitate motion aftereffects, but inhibits them. One possible mechanism involves a combination of sharply tuned excitatory interaction and broadly tuned inhibitory interaction, as was proposed recently in visual motion processing (2). Although the current study demonstrates important aspects of auditory motion detection, further examination is necessary to identify the exact mechanisms of across-frequency integration in auditory motion perception.

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References
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