Discrimination of sound source positions following auditory spatial adaptation

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Abstract

Based on current models of auditory spatial adaptation in human sound localization, the present study evaluated whether auditory discrimination of two sound sources in the median plane (MP) improves after presentation of an appropriate adapter sound. Fifteen subjects heard two successively presented target sounds (200-ms white noise, 500 ms interstimulus interval), which differed slightly in elevation. Subjects had to decide whether the first sound was emitted above or below the second. When a long adapter sound (3-s white noise emitted at the elevation of the first target sound) preceded the stimulus pair, performance improved in speed and accuracy. When a short adapter sound (500 ms) preceded, performance improved only insignificantly in comparison with a no-adapter control condition. These results may be linked to previous findings concerning sound localization after the presentation of background sounds (Getzmann, 2002), suggesting an auditory spatial adaptation in which the auditory system adapts to previous sound positions.

1. Introduction

Current models of human sound localization assume a kind of auditory spatial adaptation in which the auditory system adapts to the direction of an active sound source (e.g., Kashino and Nishida, 1998; Carlile et al., 2001). Because this adaptation persists for a while after the end of a sound, prior sounds can modify the processing of subsequent sounds. One consequence of this modification is the occurrence of auditory localization aftereffects, which become manifest when listeners localize the second of two successively presented sounds. Under certain conditions, the position of the second sound appears to be shifted away from that of the first. This contrast effect has been demonstrated for sound lateralization (e.g., Thurlow and Jack, 1973; Kashino and Nishida, 1998) and for sound localization in the horizontal and vertical dimension (e.g., Canévet and Meunier, 1996; Carlile et al., 2001; Braasch and Hartung, 2002; Getzmann, 2002).

Besides sound localization, adaptation might also influence sound discrimination. Kashino and Nishida (1998) suggested that adaptation in auditory perception might improve the detection of changes or differences around a prior adapter sound. Accordingly, Kashino (1998) could show that the discrimination of the interaural time differences (ITDs) of two successively presented low-frequency tones was selectively improved after the presentation of an adapter tone.

The present study examined whether spatial discrimination following adaptation is also improved in the vertical dimension. Subjects had to judge the relative elevation of two successively presented target sounds. There were three experimental conditions: In the strong-adapter condition, a long adapter sound, emitted at the elevation of the first target sound, preceded the target sounds. In the no-adapter condition the target sounds were presented solely. As described by Canévet and Meunier (1996), the auditory contrast effect in sound localization increases with increasing adapter duration, indicating a time dependence in the strength of adaptation. Analogously, improvements in spatial discrimination should be stronger following a long adapter, and weaker following a short adapter. In order to test this assumption, in a third condition a short adapter sound preceded the target sounds. Best performance was expected in the strong-adapter condition, followed by the weak- and the no-adapter condition.

2. Method

Fifteen normal hearing subjects (age range 19-52 years) volunteered as listeners in the experiment which was conducted in a dark, sound-proof, anechoic room. In the subjects' median plane, 31 broad-band loudspeakers (Visaton SC 5.9, 5 x 9 cm) were mounted ranging from -31° to +31° elevation. The adapter sound and the first target sound were emitted by loudspeakers at -21° or +21°, the second target sound was presented at a distance of 2°, 4°, 6°, or 8° from the first. The two adapter sounds (duration 3 s versus 500 ms, intensity 57 dB(A)) and the target sounds (duration 200 ms each, interstimulus interval (ISI) 500 ms, intensity 57 dB(A)) consisted of independent samples of white noise (bandwidth 200 Hz-16 kHz), generated digitally at 16-bit resolution and a sampling rate of 44.1 kHz.

After a short practice period, subjects performed three experimental blocks, in which (a) the 3-s adapter sound preceded the target sounds with an ISI of 500 ms (strong adaptation), (b) the 500-ms adapter preceded the target sounds with an ISI of 3.5 s (weak adaptation), and (c) the target sounds were presented without a preceding sound (no adaptation). After the end of the target sounds, subjects judged whether the second target was emitted above or below the first by pressing one of two response keys. Within the three blocks, each stimulus combination was presented six times in pseudo-random order. Number of errors and mean reaction times were computed for each subject and each adapter condition as dependent variables.

3. Results

Figure 1(a) shows that the overall number of errors decreased with increasing angular separations between the first and the second target sound. Independently from the angular separations, fewest errors seemed to occur in the strong-adapter condition. A two-factor repeated-measures analysis of variance (ANOVA) indicated significant effects of separation ($F(3,42) = 55.32$, $p < .01$) and condition ($F(2,28) = 4.61$, $p < .05$). In order to scrutinize the effect of condition, the number of errors was averaged across the angular separations (Fig. 1(b)). In comparison with the no-adapter and the weak-adapter condition, the number of errors in the strong-adapter condition decreased significantly ($t(14) = 3.23$; $p < .01$ and $t(14) = 2.23$; $p < .05$, respectively). The number of errors in the weak- and the no-adapter condition did not differ significantly ($t(14) = .44$, n.s.).

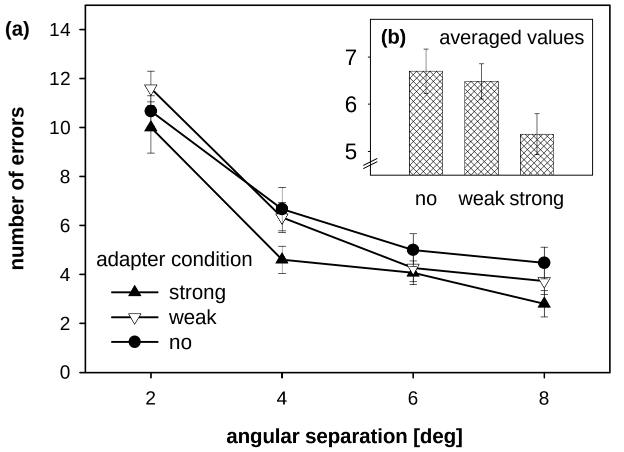

Fig. 1: (a) Number of errors as function of the angular separation between the first and the second stimulus for the three adapter conditions. (b) Mean number of errors averaged across angular separations. Data represent mean values (+/- S.E.) from fifteen subjects.

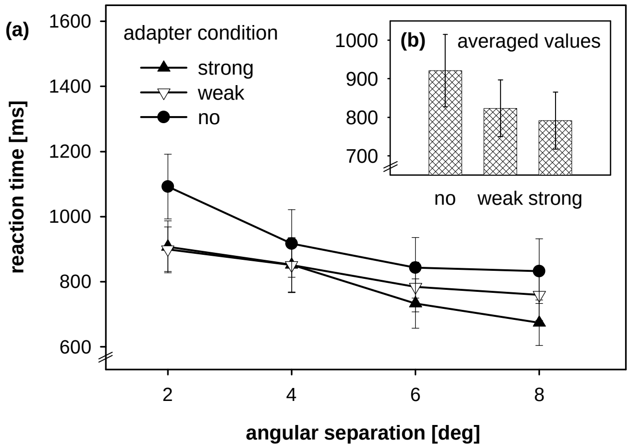

Fig. 2: (a) Reaction times as function of the angular separation between the first and the second stimulus for the three adapter conditions. (b) Mean reaction time averaged across angular separations. Data represent mean values (+/- S.E.) from fifteen subjects.

Figure 2(a) shows a general decrease in reaction times with increasing angular separations. Moreover, largest reaction times seemed to occur in the no-adapter condition. A two-factor repeated-measures ANOVA indicated significant effects of separation ($F(3,42) = 16.92$, $p < .01$) and condition ($F(2,28) = 5.51$, $p < .05$). Again, reaction times were averaged across the angular separations (Fig. 2(b)). As compared to the no-adapter condition, the reaction times in the strong-adapter condition decreased significantly ($t(14) = 3.32$; $p < .01$). The reaction times in the weak-adapter condition did not differ significantly from the no- and the strong-adapter condition ($t(14) = 1.96$, n.s. and $t(14) = 1.03$, n.s., respectively).

4. Discussion

In the strong-adapter condition, the adapter sound improved the discrimination performance in the MP in speed and accuracy. This is consistent with findings in post-adaptation ITD-discrimination: Kashino (1998) reported that the discrimination of ITDs of two successively presented tones improved when the test tones were preceded by an adapter tone of similar ITD than the test tones. With regard to the above-described adaptation hypothesis, one could conclude that the processing of both, interaural and spectral localization cues adapts to prior sound directions. The discrimination aftereffect would thus indicate the benefit of this spatial adaptation. On the other side, the absolute localization of subsequent sounds would be impaired after adaptation which is indicated by the auditory contrast effect (e.g. Kashino and Nishida, 1998; Carlile et al., 2001; Braasch and Hartung, 2002; Getzmann, 2002).

In the weak-adapter condition, the duration of the adapter sound was shortened and the silent interval between the adapter and the target sounds was prolonged. As a result, no significant improvements in discrimination occurred in comparison with the no-adapter control condition. Thus, the effect of adaptation seems to depend on the duration and the timing of the adapter sounds. A similar time dependency was reported for the auditory contrast effect (Canévet and Meunier, 1996). Again, this suggests adaptation as a possible link between the localization and the discrimination aftereffects.

5. References

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