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The influence of background sounds on the localisation of broadband noise in the median vertical plane

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Abstract

Two experiments were carried out to investigate the auditory localisation of a masked broadband (target) noise in the median vertical plane (MVP) for different target and masker locations. The maskers were positioned above and below the target sounds, which were presented at five different elevations near the subject's ear level. The subject estimated the positions of the targets by either verbal judgements or by manual pointing. In both localisation methods, systematic displacements occurred in the perceived target positions, i.e., the subjects localised the targets as shifted away from the maskers. These shifts particularly occurred for targets at central and lower locations. For the upper locations the contrast effect decreased with increasing target elevation. A second experiment revealed that the displacements occurred even if the target sounds were presented 1 s after the offset of the masking sound. These results are consistent with previous findings indicating similar shifts in the horizontal sound localisation.

1. Introduction

The auditory localisation of a sound source in the horizontal plane is based primarily on the processing of interaural (time and level) differences. Under natural conditions, this purely physical information is completed by nonacoustical factors. Thus, the auditory context arising from other sound sources in a multi-source environment has a potential influence on the perceived position of a single sound source: Previous studies investigated the sound lateralisation and the sound localisation in the horizontal plane. They revealed that – under certain conditions – systematic displacements in the perceived azimuth of a target sound occurred, which were directed away from that of the background sound. These shifts were reported both for simultaneously (Canévet & Meunier, 1996; Bridgeman et al., 1997) and successively (Kashino & Nishida, 1998) presented background and target sounds. The magnitude of this contrast effect depended on the spectral similarity of the target and the masking sound (Kashino & Nishida, 1998) and on the signal-to-noise ratio (Braasch & Hartung, 1998).

Sound localisation in the vertical dimension is quite different from that in the horizontal dimension, because for judgements of a sound source elevation monaural pinna-based (spectral) cues are crucial. The present study investigated, whether similar contrast effects occur in the MVP. The auditory localisation of a masked broadband (target) noise in the MVP was tested for different target and masker elevations. In a second experiment the possible influence of a preceding masking sound on the localisation of the target was investigated.

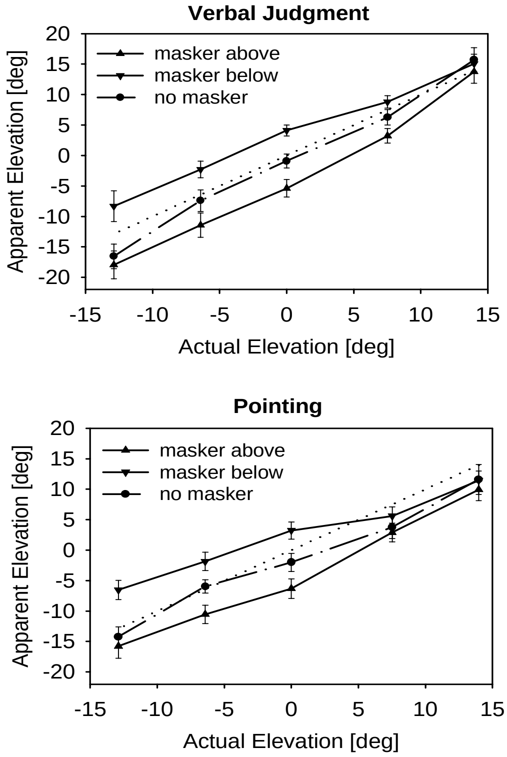
2. Method

Fifteen (Exp. 1) and ten (Exp. 2) normal hearing subjects (age range 20–35 years) volunteered as listeners in the two experiments. They sat on a height-adjustable chair in the centre of a sound-attenuated room in front of a vertical array of loudspeakers (Soundcraft CX-320, 7 cm). Head movements were restricted by an adjustable chin rest. The loudspeakers were covered by an opaque, black, acoustically transparent curtain (0.8 m x 1.2 m), so that the listeners knew neither the actual location nor the total number of the loudspeakers. On the curtain a vertical, white centimetre scale was fixed. The target sounds were presented at five different directions in the MVP near the subjects' ear level (13.4°, 7.1°, 0°, -6.4°, -12°); the maskers were positioned above (22.5°, 30°) and below (-22.5°, -30°) the targets. Both the target sound (500 ms, 65 dB(A)) and the masking sound (2 s, 60 dB(A)) consisted of independent samples of broadband pink noise, generated digitally at 16-bit resolution and a sampling rate of 48 kHz. Bandwidth was limited only by the bandwidth of the speakers (100 Hz to 13 kHz). In the first experiment, targets and maskers were presented simultaneously, but the onset of the target sound was delayed for 1 s. In the second experiment, the target sound started 1 s after the offset of the masker. In a control condition, targets were presented without any maskers. The subjects estimated the elevation of the targets either by manual pointing or by verbal judgements using the centimetre scale.

3. Results

3.1 Experiment 1

Figure 1 shows the means of the estimated target elevations as a function of the actual elevations for the different masking conditions. In the control condition, sound localisation was quite accurate, particularly for target locations near 0° elevation. The root-mean-square errors (averaged across the five target locations) was 7.5° for the manual and 7.3° for the verbal method. On the other hand, the presentation of a masker caused a strong change in performance for both localisation methods: Subjects underestimated the elevation of the targets for the upper maskers, whereas they overestimated the targets elevation for lower maskers. This contrast effect particularly occurred for the central and the lower target locations. For the upper targets the effect decreased with increasing target elevation. The mean differences in the localisation errors between the two masking conditions were 6.3° for the pointing and 7.0° for the verbal judgements. They both reached statistical significance ($t(14) = 4.81$ and $t(14) = 5.12$, respectively; $p < .001$).



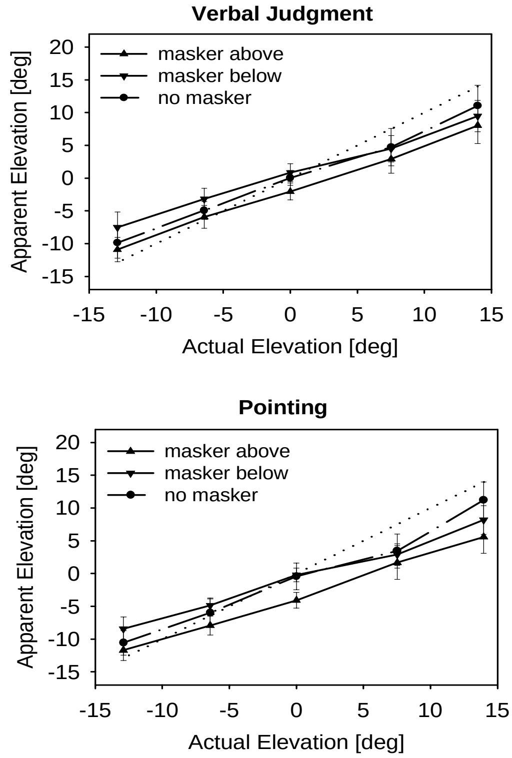


Fig. 1: Apparent target elevation plotted against actual elevation for different simultaneously presented maskers, shown separately for verbal judgement and pointing. Data points represent mean values (± S.E.) from fifteen subjects.

Fig. 2: Apparent target elevation plotted against actual elevation when targets and maskers were presented successively, shown separately for verbal judgement and pointing. Data points represent mean values (± S.E.) from ten subjects.

3.2 Experiment 2

When maskers and frames were presented successively, the contrast effect occurred as well (Fig. 2): Even now the target positions appeared to be shifted away from those of the preceding maskers. On the other hand, the magnitude of the contrast effect clearly diminished in comparison with the simultaneous condition: The mean differences in the localisation errors between the upper and the lower masking conditions were 2.4° in the verbal and 2.8° in the pointing method. Nevertheless, even these differences reached statistical significance ($t(9) = 6.99$ and $t(9) = 5.25$; $p < .01$).

4. Discussion

The results are consistent with previous findings indicating similar shifts in the perceived azimuth. For both localisation methods, the perceived target positions appeared to be shifted away from those of the active masker. The displacements were strongest for target locations near and below 0° elevation. This asymmetry might be related to general differences in the localisation performance at high and low source elevations. The second experiment revealed an after-effect of a preceding sound on the target localisation, which is in line with the simultaneous contrast effect. Thus, the contrast effect cannot be attributed to a purely acoustical superposition of the two simultaneously presented sound waves. The slow decay of the contrast effect rather points at a kind of adaptation in which the auditory system adjusts to the formerly presented sound. According to the discussion concerning an auditory spatial adaptation in the horizontal plane (Canévet & Meunier, 1996; Kashino & Nishida, 1998) we assume that a similar mechanism could operate in the processing of spectral elevation information.

5. References

Braasch, J. & Hartung, K. (1998). Lokalisation von maskierten Breitbandrauschsignalen in reflexionsfreier und reflexionsbehafteter Umgebung. *Fortschritte der Akustik – DAGA 98*, 500-501. **Bridgeman, B., Aiken, W., Allen, J. & Maresh, T.C.** (1997): Influence of acoustic context on sound localisation: An auditory Roelofs effect. *Psychological Research*, 60, 238-243. **Canévet, G. & Meunier, S.** (1996). Effect of adaptation on auditory localization and lateralization. *Acustica*, 82, 149-157. **Kashino, M. & Nishida, S.** (1998). Adaptation in the processing of interaural time differences revealed by the auditory localization aftereffect. *Journal of the Acoustical Society of America*, 103, 3597-3604.