Variance in Localization of Click Sounds with a Preceding Distractor

Ľuboš Hládek, Beáta Tomoriová, Norbert Kopčo

Institute of Computer Science, P. J. Šafárik University, 04001 Košice, Slovakia, E-Mail:lubos.hladek@upjs.sk

Introduction

Perceived location of a brief auditory event can be affected by a preceding sound coming from a fixed *a priori* known location. A previous localization study reported biases in click target localization when target was preceded by an identical distractor by 25 – 400 ms [1]. In that study, increases in variance due to distractor were also observed for delays up to 100 ms. While other studies also showed effects of preceding stimuli on localization variance (e.g., reporting increase of minimum audible angle as a function of decreasing stimulus onset asynchrony, SOA [2], [3]), the effect is not well understood. The current study examines the effect of a preceding distractor on target localization variance.

Several mechanisms might be important for the effect. Precedence effect is a mechanism thought to suppress spatial processing of later arriving sounds and influence the perceived position of both earlier and later arriving sounds, resulting in percept of one auditory object for SOAs of up to 10 ms [4]. It is likely that a similar mechanism might affect performance even for larger SOAs for which the two distinct auditory events are clearly perceived instead of one fused sound, resulting in localization variance increases. Perceptual streaming and segregation might also be important. The variance might increase or decrease depending on whether two sounds are perceptually fused or separated [5]. Finally, a sound (distractor) coming from *a priori* known location might also serve as a perceptual anchor [6]. The subject can compare the location of a target relative to the anchor and improve the ability to localize the target.

In the previous study, a repeated presentation of the distractor-target click pairs caused also unexpected change in localization bias in trials without preceding distractor – contextual plasticity [1]. This effect could be conceptually related to adaptation with a constant auditory [7] or visual adaptor [8] but now observed with randomly re-occurring distractor. It is reasonable to assume that contextual plasticity also affects localization variance. The direction of change should then persist for some time after the effect has been induced.

The design of the previous study [1] did not allow to directly investigate the factors of contextual plasticity and how exactly contextual plasticity influences sound localization variance. Here a new experiment was performed to evaluate how temporal properties of the stimuli and rate of occurrence of distractor affect response variance.

Methods

The experiment was conducted in a sound-attenuated booth (3m x 2m x 3,1m). Subjects were seated in front of an arc of loudspeakers separated by 11,25°, spanning 79° from directly ahead to the left or to the right of the subject.

Ten subjects participated in the experiment, and were instructed to close eyes during the experimental run. The task was to localize a target sound presented in self-paced manner. The subject responded by pointing to the perceived azimuth. Camera placed above the subject recorded the responses and the position of loudspeakers.

The experiment was organized in 4 sessions, each consisting of 14 experimental runs and one control run. In the experimental runs target clicks were randomly interleaved with Distractor-Target click pairs, control runs had only Target-only trails. The order of runs and orientation of subject were randomized. Each run has 2 or 4 repetitions with 2 orientations. Each run consisted of 189 trials including pretest and posttest. Only middle 119 trials were used in the current analysis.

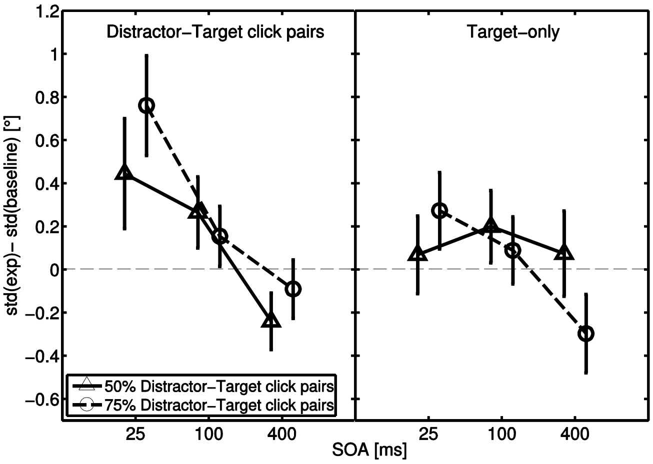

Figure 1: Localization variance in experimental conditions *re.* control condition as a function of SOA, plotted separately for the Distractor-target trials (left panel) or Target-only trials (right panel). Dashed lines with open circles connect conditions with 75% of distractor-target-click pairs, solid lines with filled triangles the 50% condition. Each data point represents across-subject mean (±SEM) of values averaged across target locations, subject orientation, and repetitions..

Target stimuli were 2-ms frozen noise bursts, presented alone in the Target-only trials. Distractor-Target stimuli consisted of two 2 identical clicks, first one (Distractor) coming from directly ahead and the second one (Target) coming from one of the remaining 7 speakers. The ratio of Distractor-Target to Target-only trials (i.e., the distractor-target frequency of occurrence) was set to 75% or 50%. The Distractor-Target SOA was 25, 100, or 400 ms. The ratio and SOA were fixed within a run. All combinations of the ratio and SOA were examined, each representing one experimental condition.

Localization variance was analyzed by computing standard deviations for each experimental run and target speaker separately for the Distractor-Target and Target-only trials. \]

Results

Figure 1 shows localization variability expressed as a difference of the standard deviations in experimental and control conditions. The left-hand panel shows the results for the Distractor-Target trials. A three-way repeated-measures analysis of variance (ANOVA) with the factors of target, SOA, and ratio was performed for these data, and found that response standard deviations significantly changed with SOA (main effect of SOA, $p<0.001$). Also, the interaction of SOA and ratio reached significance ($p<0.05$). The figure shows that standard deviations were higher in conditions with short SOA and got close to the baseline as SOA increased. The ratio of the trial types slightly modulated the effect of SOA, as values at the shortest and longest SOA in the 50% condition are slightly below the 75% condition.

The right-hand panel of Fig. 1 shows the Target-only data from experimental conditions relative to control condition (i.e, the contextual effect). ANOVA identical to the above one showed significant interaction of factors SOA and frequency of occurrence ($p<0.05$). No other main effects or interactions were significant. Data in 50% condition follow performance in baseline while data in 75% change with SOA, increasing above baseline at the short SOA and falling below it at SOA of 400 ms.

Discussion

Variance of sound localization in the environments with multiple sound sources is increased if the target sound is immediately preceded by another sound coming from a known location. Current results confirm previous findings [1] and generalizes them to longer SOAs and different frequencies of occurrence of distractor-target click pairs. As expected very short Distractor-Target SOA decrease ability to precisely localize. On the other hand, at the long SOA, the presence of the distractor might result in an improvement of localization variance with respect to baseline, especially at the 50% ratio (triangles in left panel).

The increase of variance could be attributed to distractor-related reflections which would affect the extraction of target-related cues at the peripheral or binaural processing stages [9]. On the other hand, it is unlikely that similar mechanisms could potentially explain the improvement.

Data in the Target=only trials (right panel) follow performance in baseline condition with slight modulation by SOA if more distractor-target click pairs were interleaved (75% data, open circles in right panel). It is likely that neural representation was adapted during presentation of Distractor-Target click and this adaptation persisted to Target-only trials. This suggest a mechanism that acts on the time scale of seconds, but only if sufficiently frequent interleaved Distractor-Target trials are present. As in the Distractor-Target data, the 75% Target-only data are above baseline for 25-ms SOA and below it for 400-ms SOA. This complex pattern of results is likely attributable to a more central mechanism like attention, anchoring [6], perceptual organization [5], or precedence build-up [4]. For example, at the long SOA the distractor and target might be processed in separate streams, allowing the target to be localized better than in the baseline condition because relative information about its location with respect to the distractor is available. This modified localization strategy can be then used to localize the target in the following Target-only trials, resulting in the observed dependence of the Target-only variance on SOA at 75% ratio.

In summary, auditory localization is subject to adaptation at multiple time scales and here we show that both immediate distractor and contextual plasticity influence variance of localization. It is likely that these results are due to both peripheral and central mechanisms.

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