Contextual plasticity in sound localization: characterization of spatial properties and neural locus

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Introduction

Background

Localization of a sound can be influenced by other sounds, either simultaneous (Braasch et al., 2002) or preceding the target (Carlile et al., 2001).

In Kopco et al. (2007) listeners localized a target preceded by identical distractor coming from fixed and *a priori* known location. Unexpectedly, their responses were biased (depending on distractor location) also on interleaved control trials in which no distractor was presented. This effect was referred to as "contextual plasticity".and suggests that localization is affected also by context defined by non-target stimuli or *a priori* information.

Several properties of the context. effect were found in follow-up experiments:
- it has quick build-up/decay with onset/offset of trials with distractor (Kopco et al., 2009)
- it grows with more frequent occurence of distractor trials within a run (Kopco et al., 2009)
- it occurs also when the order of stimuli in distractor trials is reversed, i.e., target precedes the distractor (Tomoriova et al., 2010)

Current study

Examines:
1) **spatial aspects of the contextual plasticity** in order to understand the nature of neural representation on which the effect operates:
- Does the effect generalize to "unadapted" locations? What will be the form of generalization?
- Does the effect depend on spatial distribution of contextual stimuli and on where the tested spatial region is located relative to the listener?
- Does the context also affect response variability?
2) **dependency of the effect on response method,** i.e., are visual and motor areas involved in the contextual effect?

Hypotheses
H1: Contextual effect occurs on topographic spatial representation -> Spatial configuration of contextual stimuli will affect the magnitude and the spatial distribution of the contextual effect.
H2: Context will decrease variability of responses (due to distractor acting as an anchor).
H3: Contextual effect occurs in auditory (not motor) spatial representation. Availability of visual signals will reduce the effect.

Methods

Three experiments with similar design were performed. (Some of the results of Exp1 presented also in Tomoriova et al. (2011))

Spatial aspects: Exp1 & Exp2

Setup (see Figure 2)
- 7 loudspeakers spaced in arc around subject,
- 11.25° separation between speakers,
- speaker array centered frontally or laterally (Exp.1), or at +/-45 degrees re. listener (Exp2)

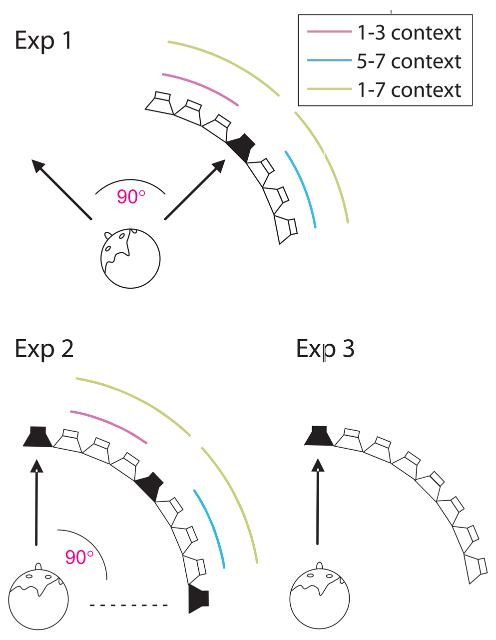
Trials
- of two types:
1) "distractor trials" (represent the context to induce the adaptive changes): distractor sound followed by target sound,
2) "no-distractor trials": target sound alone.

Stimuli
- target & distractor: identical 2-ms frozen noise bursts; distr.-to-target onset asynchrony fixed at 25 ms.

Task
Point to the perceived location of the target sound.

Experimental Procedure
- types of runs (see Figure 3):
1) experimental runs - distractor-trials (75%) and no-distractor trials (25%) randomly interleaved
2) baseline run (reference for computation of the context effect) - no-distractor trials only,
- manipulated factors:
1) Exp1&2: spatial configuration of targets in distractor trials ("distractor-targets configuration"; see Figure 2):
  - 1-3 context (three left-most speakers),
  - 5-7 context (three right-most speakers),
  - 1-7 context (both sides of the central sp.),
2) Exp1: position of the tested region re. listener: frontal or lateral
3) Exp2: location of the distractor: frontal, lateral or intermediate (see Figure 2).

Figure 2 Experimental setup for the three experiments. Distractor position indicated by filled loudspeaker. Black arrows indicate possible subject orientations re. speaker array. Lines above the speaker array show 3 distractor-targets configurations.



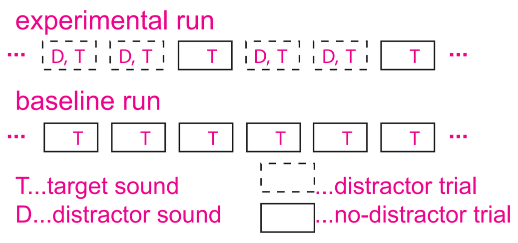
Distractor-targets configuration, tested region orientation re. listener and distractor location fixed within a run.

Data analysis
To determine the effect of the context, differences between responses on no-distractor trials in experimental runs and baseline run were analyzed. All plots show across-subject mean and across-subject standard error.

Dependency on response method: Exp3

Design similar to Exp1&2 except that distractor-targets range was not restricted and only frontal distractor was used.
Manipulated factors: response method (pointing & eyes closed, pointing & eyes open, typig a response on a keyboard)

Figure 3 Example scheme of trial sequence for different types of runs.



Summary and Discussion

Contextual effect:
- causes biases "away from distractor"
- depends strongly on spatial distribution of both contextual ad non-contextual stimuli and affects mainly subregion with the context. stimuli (consistent with H1)
- reduces variability of responses when contextual stimuli are concentrated into a subregion of tested spatial range (consistent with H2, probably caused by more frequent presentation of stimuli from a given subregion).
- in biases, generalizes to locations between the distractor and distractor-targets ("stretching of space")
- is similar for different orientation of speaker array re. listener (consistent with H1).
- is observed for different response methods and is not significantly modulated by visual signal availability, suggesting that it is caused purely by auditory processing (partly consistent with H3).

Results suggest that contextual effect occurs at later stages of processing with topographic spatial representation (not at the ITD/ ILD processing stage).

References
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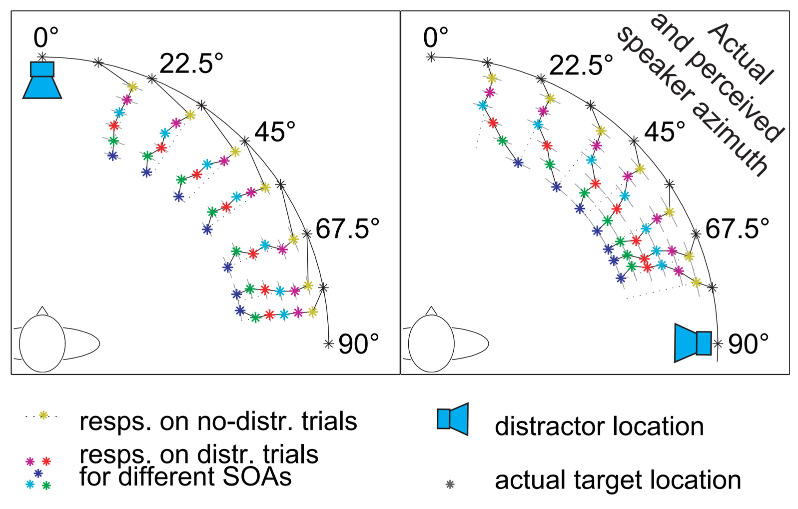
Previous studies

Kopco et al. (2007) (Figure 1)

In the experimental run, trials in which target was preceded by distractor were randomly interleaved with trials in which only the target was presented.

Unexpectedly, responses on no-distractor (control) trials also depended on distractor location (yellow stars in left part of Fig. 1 biased more to the right than in the right part of Fig.1).

Figure 1 Mean responses on distractor and no-distractor trials from Kopco et al. (2007) study.



Results

Spatial aspects: Exp1&2

Contextual efefct in biases (Figure 4).

Contextual biases similar for medial, lateral and intermediate orientation of speaker array re. subject (compare upper two panels and bottom left panel).

Magnitude of the contextual bias does not depend on at which spatial region it is induced.

Contextual bias:
- has direction away from the distractor
- observed in the subregion where the context was presented (blue line separates from 0 at locations #5-7; pink line at locations #1-3),
- only negligible observed in subregion on the opposite side of the distractor as the context (blue line at locations #1-3 and pink line at locations #5-7 in both top panels and bottom left panel),
- generalized to locations between the distractor and dist.-targets (blue line in bottom right panel), inlcuding the distr. location (location #4 in the top panels).

Context elicited biases in the subregion where the contextual stimuli were presented. The biases generalized to locations between the distractor and distractor-targets but only negligibly to opposite side of the distractor.

Only small bias observed when context was presented on both sides of the distractor.

Contextual effect in standard deviation (SD) of responses (Figure 5)

SDs at subregion with contextual stimuli tend to be lower than in baseline (data behind interaural axis not considered due to large localization errors).
No effect observed for 1-7 context.
In Exp2, similar pattern for D0,D45,D90 (data averaged across distractor location)

Context reduced variability of responses in the subregion with the contextual stimuli.

Figure 4 Contextual bias from Exp 1 (upper panels) and for Exp 2 (lower panels). Graphic insets show subject's orientation relative to the speaker array, triangles show distractor location and lines above x-axis show where the dist.-targets were located.

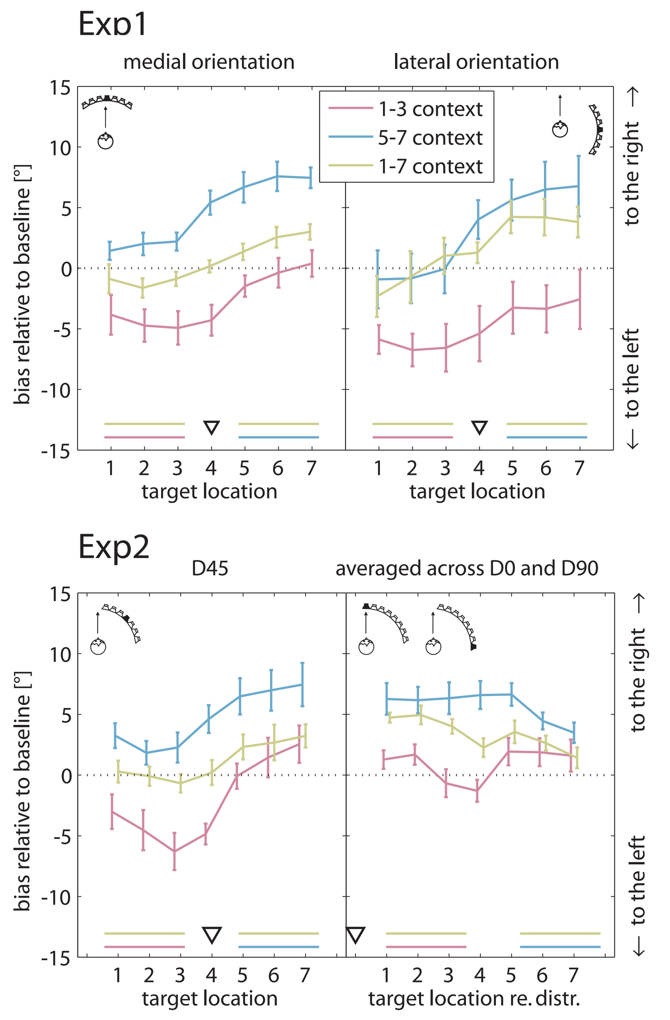
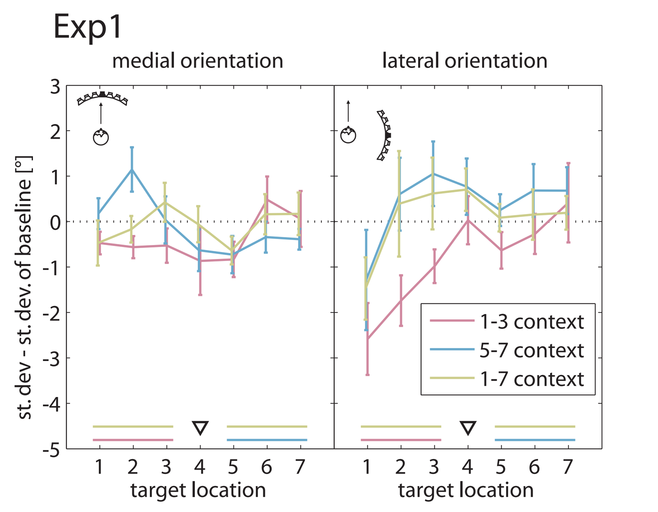
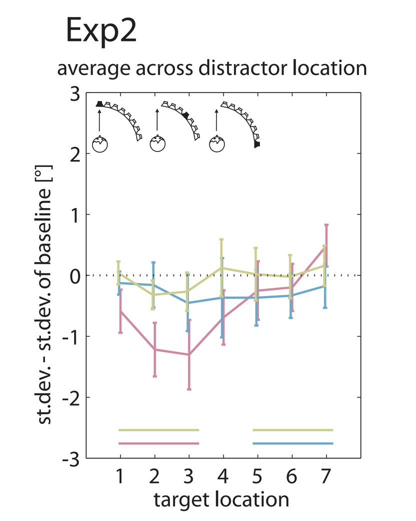


Figure 5 Contextual effect in standard deviation in Exp1 (upper panels) and Exp2 (averaged across distractor location; lower panel)





Dependency on response method: Exp3 (Figure 6)

Baseline responses most accurate for keyboard condition (approx. constant biases re. actual targ. location vs compression/expansion of space in other conditions, and lowest SDs).

Contextual effect in biases and SDs similar for all three response methods.

Response method affected localization accuracy but it did not affect the inducement of the contextual effect. Availability of visual signals did not reduce the contextual effect.

Figure 6 Biases and SDs of baseline responses (upper and lower left panel) and contextual effect in biases and SDs (right panels) from Exp3.