Spatial Aspects of Contextual Plasticity in Sound Localization

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Introduction

Background

Various studies show that spatial hearing is an adaptive process, i.e. the mapping "spatial cues -> perceived sound source location" is not fixed but can undergo changes (Moore et al., 2004).

Changes in localization of a target can be eliceted also by another sound, for example by:
- presenting a distractor which overlaps in time with target (Braasch et al., 2002),
- prolonged exposure to sound which precedes the target (Carlile et al., 2001).

Kopco et al. (2007) studied localization of a transient sound source preceded by identical distractor. Biases in localization responses were found:
- on trials where target was preceded by distractor (as expected),
- also on interleaved control trials in which no distractor was presented (see Figure 1A). This effect was referred to as "contextual plasticity" and suggests that localization is also affected by the context defined by the non-target sounds.

Follow-up experiments found that context. effect:
- builds up/decays quickly after the onset/offset of the distractor trials (Kopco et al., 2009) (seef Figure 1B)
- grows with increasing frequency of distractor trials (Kopco et al., 2009)
- depends on spectro-temporal similarity between the target and the distractor sounds (Tomoriova et al., 2010; see Figure 1C).

Current study

Measure the **spatial aspects of contextual plasticity**, such as:
- dependence on spatial region used to induce plasticity (specifically, will the effect differ when induced "in front of" vs "to the side of" the listener?),
- generalization of the effect to sub-regions where it was not induced (will the effect induced on one side of distractor generalize to the opposite side?),
- form of the generalization of the contextual effect (does contextual plasticity cause shifting or expanding of the spatial auditory map? I.e., is the underlying neural representation cartesian or polar?).

Hypotheses
H1: contextual biases will be larger when induced near median plane compared to lateral plane (because the acuity near median plane is larger).
H2: contextual biases will generalize to sub-region where no distractor trials were presented and will cause shifting of the whole region in one direction.
H3: The form of generalization will not depend on whether the effect was induced near median or near lateral plane, because we assume that adapting structure is relatively central in processing pathway.

Methods

Setup (see Fig. 2)
- 7 loudspeakers spaced in arc around subject,
- 11.25° separation between speakers,
- subject oriented either laterally (left/right) or medially relative to the middle speaker (black arrows); orientation fixed within a run.

Trials
- of two types:
1) experimental trials (represent the context to induce the adaptive changes): distractor sound followed by target sound,
2) control trials: target sound alone.

Stimuli
- target: 2-ms frozen noise burst,
- distractor: identical as target, presented before target on experimental trials, coming always from the middle speaker,
- distractor-to-target interval fixed at 23 ms.

Task
Point to the perceived location of the target sound.

Subjects
Seven normal-hearing subjects participated.

Experimental Procedure
- 4 sessions, each of 7 runs,
- types of runs (see Fig. 3):
  1) experimental runs - experimental (75%) and control trials (25%) randomly interleaved + pre-adaptation part and post-adaptation part consisting of control trials only.
  2) baseline run (reference for estimation of the context effect) - control trials only,
- targets in experimental trials restricted to one of the three context configurations (see Figure 2):
  - 1-3 context (to the left of distractor),
  - 5-7 context (to the right of distractor),
  - 1-7 context (to both sides from distractor),
- context configuration and subject orientation fixed within a run.

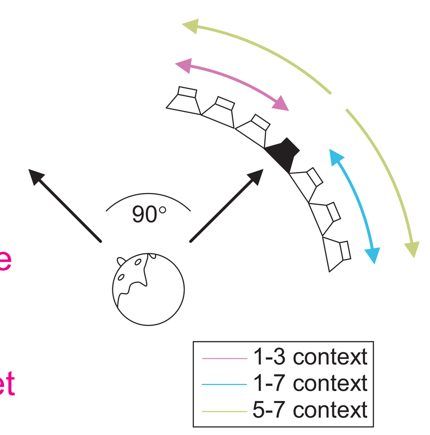


Figure 2 Experimental setup. Distractor position indicated by filled loudspeaker. Black arrows indicate two possible subject orientations re. speaker array. Arrows above the speaker array show 3 context configurations. Numbers indicate target positions as labeled in graphs.

Data analysis
To estimate the effect of the contextt, differences between control trials in experimental runs and baseline run were analyzed.
All plots show across-subject mean and within-subject standard error.

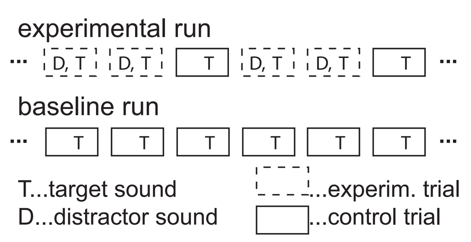


Figure 3 Example scheme of trial sequence for different types of runs.

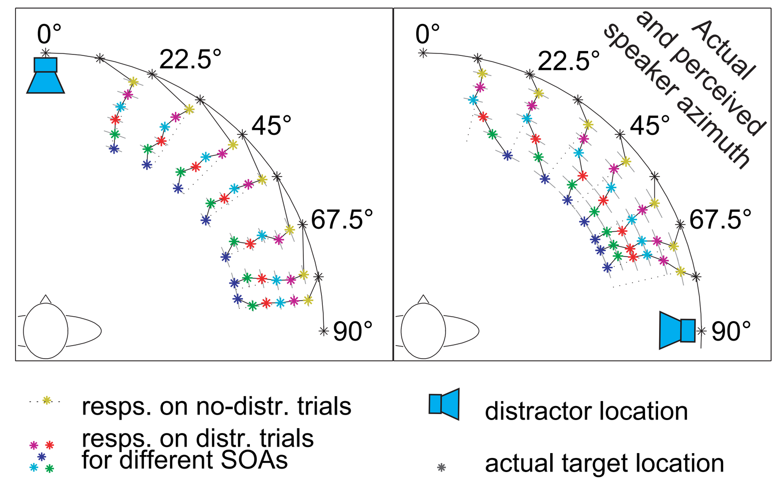
Previous studies

Kopco et al. (2007)
(Figure 1A)

Experiment consisted of trials with targets randomly interleaved with trials where target was preceded by distractor.

Biases were found not just in distractor trials, but also in no-distractor trials (compare yellow stars in left and right part of Fig. 1).

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

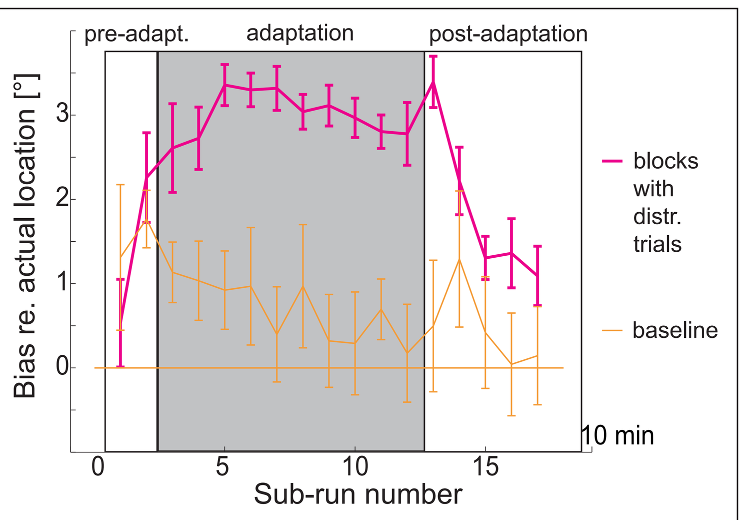


Kopco et al. (2009)
(Figure 1B)

Added baseline run consisting of only no-distractor trials as a reference for estimation of the effect. Studied also temporal profile of adaptation.

Found that contextual effect builds-up and decays quickly (2-3 minutes).

Figure 1B Build-up and decay of contextual adaptation from Kopco et al. (2009) study.

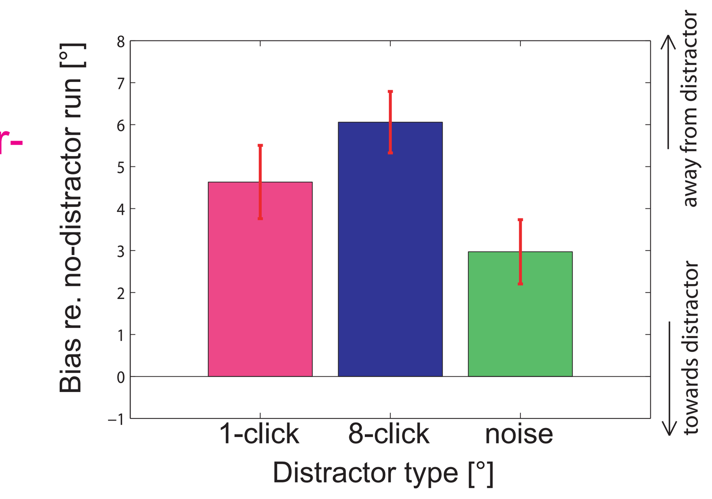


Tomoriova et al. (2010)
(Figure 1C)

Examined effect of different types of distractor.

Found that contextual effect depends on spectro-temporal similarity between target and distractor: largest biases found for 8-click,reduced for 1-click (identical to target) and smallest for noise (least similar).

Figure 1C Contextual bias for different types of distractor



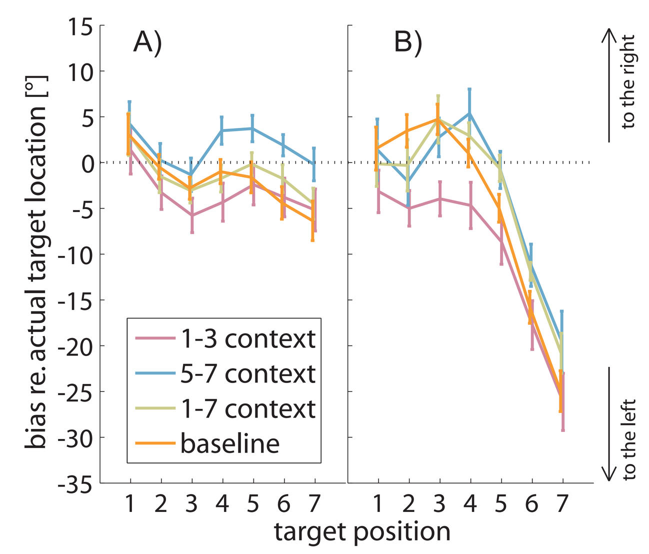
Results

Responses in all types of runs (even baseline run) shifted towards the center of positions range (Figure 4).

Despite large biases re. actual location, differences between context configurations and baseline similar for both orientations (see also Figure 5).

To estimate the effect of the context, biases re. baseline condition plotted (Figure 5).

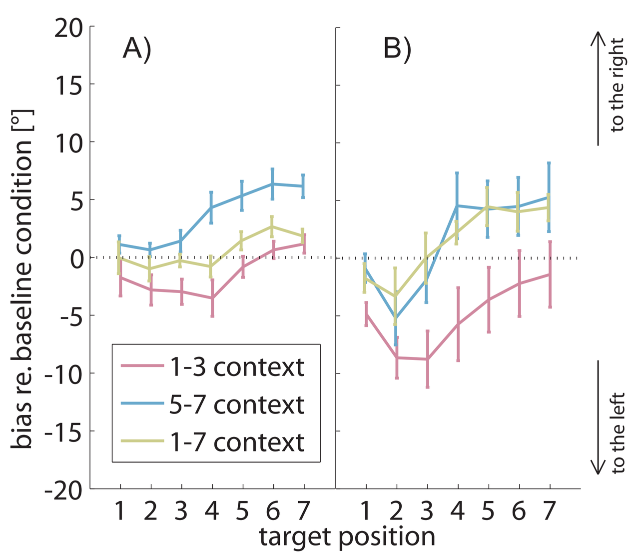
Figure 4 Bias in responses re. actual target locations for medial (panel A), and lateral (panel B) subject's orientation.



Contextual effect is similar for lateral and medial orientation.

Contextual bias up to 5-10 degrees away from distractor observed in the subregion where the context was presented (see target positions #1-3 for pink line and #5-7 for blue line), including distractor position (target position #4).

Figure 5 Contextual bias for medial (panel A) and lateral (panel B) subject's orientation.

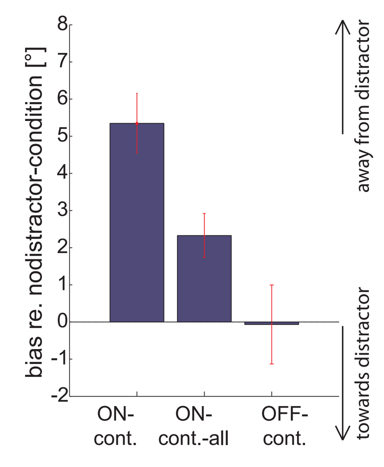


No bias observed in subregion where context was not presented (#1-3 for blue line and #5-7 for pink).

Only small biases observed when context presented in whole positions range (yellow line).

Data regrouped according to target-context spatial coincidence (Figure 6), and averaged across subject's orientation and positions within subregion to summarize the size of the contextual effect.

Figure 6 Contextual bias for three target-context spatial coincidence groups.



Data included in groups:
ON-context: - data from subregion where context was induced.
OFF-context: - data from subregion where no context was induced.
ON-context-all: - data from 1-7 context condition

Context elicited biases in the sub-region where it was induced but not in the opposite subregion.

Contextual effect was weak when context was presented at both sides of the distractor.

Summary and Discussion

Contextual bias:
- is similar for both orientations, suggesting that contextual plasticity is not dependent on spatial acuity (not consistent with H1).
- is observed only for subregion where the context was presented and does not generalize to other subregion (not consistent with H2)
- is much smaller when induced on both sides on distractor than when induced on only one side. This suggests that some form of generalization (or dependency between subregions) might occur (consistent with H2).
Despite ambiguous results for generalization, the underlying representation might be explained by Cartesian population code (Carlile et al., 2001), in which each spatial location is represented by a neural unit and each unit influences the activation of its neighbours within a certain radius):
- small radius would cause shifts only in subregion where context was presented and for the central speaker which is nearest (consistent with results when context on one side of distractor)
- large radius would include units in the opposite subregion and for context presented on both sides the shifts will partially cancel out (consistent with results for context on both sides of distractor).
The dependency of the generalization of the contextual effect on whether the plasticity was induced ahead or to the side of the listener was not found (consistent with H3), again supporting Cartesian form of neural representation.

Overall summary

The contextual plasticity:
- could be bottom-up (adaptation of neural spatial representation) or top-down effect (change in attentional distribution or other). Results support top-down explanation since the effect is not dependent only on distractor energy (8-click and noise had same energy and total duration but different contextual biases),
- has quick build-up and decay what also supports the top-down explanation,
- is probably occuring at a processing stage at which space is not represented by the binaural cues (ITD, ILD), i.e., on later stages such as cortical spatial and/or motor representations.

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