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Temporal Characteristics of Task-dependent Contextual Shifts in Sound Localization

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1. Abstract

A previous study of sound localization with a preceding distractor found that the responses were biased away from the distractor location even on the interleaved baseline trials on which the target was preceded by no distractor [Kopco et al., JASA, 121, 420-432, 2007].

The current study measured the temporal characteristics of this contextual plasticity. Subjects localized 2-ms frozen noise bursts presented either in the left (-11° to -79°) or the right (11° to 79°) hemifield of the frontal horizontal plane, preceded on some trials by an identical distractor coming from directly ahead of the listener (0°). Each 189-trial block used one randomly chosen combination of the target presentation hemifield (left or right), the percentage of non-distractor trials (50%, 25%, or 10%), and the distractor-to-target stimulus onset asynchrony (SOA of 25, 100, or 400 ms). Performance was compared to baseline blocks that only contained no-distractor trials.

Contextual shifts up to 4° away from the distractor location were observed in all conditions, with only small decreases at the longest SOA or when the percentage of distractor trials was the lowest. The contextual shifts were observed at all target speaker locations and the build-up of the shifts was fast, reaching the maximum (or disappearing) within the first 40 trials after the onset (or the offset) of the distractor trials. The general character and the quick build-up of the effect suggest that the task-specific context is a top-down factor and that it can influence localization performance in a variety of experimental and everyday conditions.

2. Introduction

Background

Sound localization affected by:
- acoustics of environment (reverberation),
- complexity of scene (number and spatio-temporal arrangement of targets),
- sensitivity / selectivity of peripheral processing.

However:
- performance of a localization task with a preceding distractor coming from a known location results in shifts in responses on interleaved no-distractor trials (Kopco et al., 2007; see Fig. 2A).
- Possible top-down effect: a priori knowledge of the distractor location results in change of strategy used by listeners.

Current study

Study the effect of context (defined by performance of irrelevant but related task) on localization performance.

Use design similar to Kopco et al. (2007)
Measure:
- how contextual plasticity depends on:
  - frequency of occurrence of "inducing" task,
  - difficulty of the "inducing" task,
- overall temporal and spatial profile of contextual shifts.

Find parameters resulting in strongest effect.

Hypotheses

Contextual plasticity strength:
- will grow with both frequency and difficulty of "inducing" task.

However:
- the dependence will be small, AND
- the effect will build up and decay quickly

because the effect is likely top-down.

3. Methods

Task

Subjects pointed to the perceived location of a target sound.

Two types of trials randomly interleaved:
- distractor "inducing" trials,
- no-distractor "probe" trials.

Experimental procedure

Nine normal-hearing subjects.

Seven target and one distractor loudspeakers (Fig. 1).

Stimulus:
- 2-ms frozen noise burst target,
- preceded on "inducing" distractor trials by identical distractor stimulus
  - coming from the (known) frontal location,
  - having a fixed distractor-target onset asynchrony (SOA of 25, 100, 400 ms).

Four approx. 2-hour sessions.

Session consisted of 15 blocks, each keeping % of probe trials and SOA fixed:
- 1 block of 50% at all 3 SOAs,
- 2 blocks of 25% at all 3 SOAs,
- 5 blocks of 10% only at 100 ms SOA,
- 1 baseline no-inducing trial block.

Subjects changed orientation between blocks.

One block:
- pre-adaptation (14 trials, 2 repeats of one trial per target location),
- adaptation (140 trials, 20 repeats),
- post-adaptation (35 trials, 5 repeats).

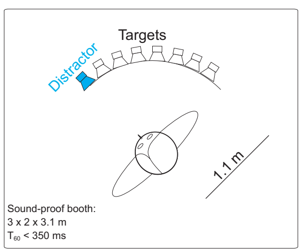


Figure 1 Experimental setup

Data analysis

Consider only no-distractor trials.

Combine data from blocks with same % of probe trials.

Mean perceived azimuth calculated for each subject.

Analyze difference in bias between distractor and baseline blocks.

Plot across-subject means and within-subject standard errors.

4. Results

In Kopco et al. (2007) (Figure 2A):
- bias away from distractor, even on no-distractor trials,
- absolute size cannot be assessed because no baseline,
- temporal properties cannot be assessed because all distractor trial types interleaved.

Current study (Figure 2B):
- overall, data more biased towards middle of response range,
- size of contextual shift depends slightly on inducing trial type.

Contextual plasticity is influenced by complexity and frequency of occurrence of the shift-inducing trials.

In Kopco et al. (2007) (Figure 3A):
- difference in bias of up to 6° (or 9° in anechoic space),
- independent of target location.

Current study (Figure 3B), bias re. baseline:
- up to 5°, always away from distractor,
- depends on target location (also see Figure 4B),
- depends less on inducing trial types.

Interaction between temporal parameters of context and target location is small.

Induced biases are largest for targets near the distractor.

Contextual effect (Figure 4A):
- grows monotonically with inducing trial frequency (compare green bars, or respective 50% and 25% bars),
- depends slightly and non-monotonically on task difficulty.

The dependence of contextual plasticity on temporal parameters of context is small. Bottom-up or acoustic factors are unlikely to cause the effect.

Build-up (and decay) of contextual effect (Figure 5):
- is quick (2-3 mins),
- is sustained through adaptation phase,
- may depend on temporal characteristics of inducing task (C).

Contextual plasticity builds up quickly, suggesting that it is related to a change in strategy (rather than some slow neural adaptation)

Figure 2 A) Mean responses on no-distractor and distractor trials from Kopco et al. (2007) study. B) Mean responses on no-distractor trials in current study.

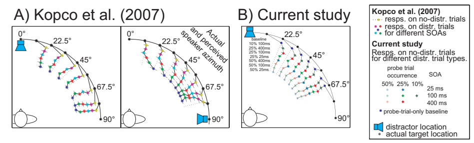


Figure 3 Bias in responses induced by context. A) Kopco et al. (2007): difference between frontal and lateral distractor context. B) Current study: Effect of context re. probe-trial-only baseline.

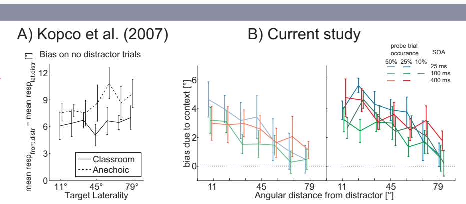


Figure 4 Collapsed data. A) Bias in responses re. actual target location, averaged across target locations. B) Bias in responses re. probe-trial-only baseline, averaged across inducing trial types.

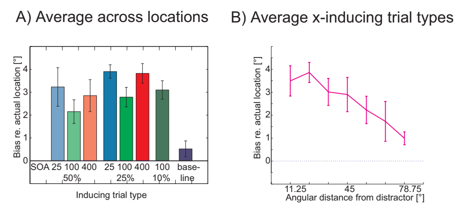
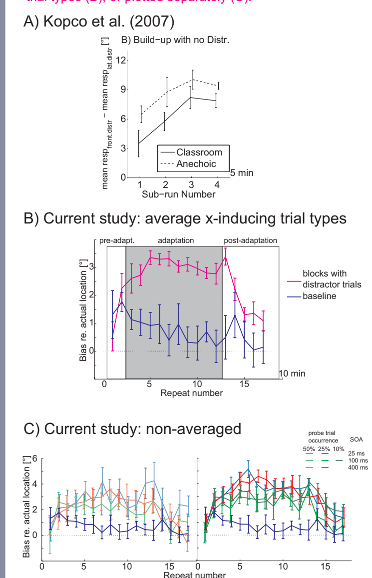


Figure 5 Build-up and decay of contextual bias as a function of the repeat number within a block, averaged across target locations. A) Kopco et al. (2007): difference between frontal and lateral distractor context. B, C) Current study: Responses (re. actual location) averaged across inducing trial types (B), or plotted separately (C).



5. Summary and discussion

Responses on probe trials:
- shifted away from the location of the (now missing) distractor.

The effect size:
- depends slightly and non-monotonically on "inducing" task difficulty (SOA),
- grows slightly with a priori probability of "inducing" trial,
- depends on distance of probe target from the distractor,
- has fast build-up and decay.

Discussion

Contextual plasticity
- unlikely to be related to acoustic factors like reverberation because
  - equal strength even at SOA of 400 ms (note that SOA relates to "inducing" trials),
  - same effect in anechoic space (Kopco et al., 2007),
- unlikely to be related to peripheral auditory processing (which would be slower),
- could be related to mechanisms like "precedence build-up" (Clifton, 1987), occurring on time scale of seconds,
- is likely related to the subjects' specific expectations about the plasticity-inducing task (or engagement in its performance),
- is likely to affect performance in many common situations.

Using 25% of probe trials and 400 ms distractor trial SOA is a robust condition for future studies.

Future studies

Examine dependence of contextual plasticity on:
- spatial characteristics (e.g., distractor location),
- top-down (expectation) vs. bottom-up (stimulus distribution) factors,
- visual input and response method (motor activity),
- subject's engagement in the task (passive listening vs. responding on the "inducing" trials).

6. References

Clifton, R.K. (1987), Breakdown of Echo Suppression in the Precedence Effect, J. Acoust. Soc. Am., 82,1834-1835

N Kopčo, V Best, and BG Shinn-Cunningham (2007). Sound localization with a preceding distractor, Journal of the Acoustical Society of America, 121, 420-432.

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