# Mechanisms of Contextual Plasticity in Sound Localization

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## Introduction

**Adaptation in sound localization**
The perceived location of a sound source can be affected by preceding auditory stimulation (Litovsky et al., 1999; Carlile et al., 2001; Kashino & Nishida, 1998).

*Contextual plasticity (CP)*

- new form of plasticity described first in Kopčo *et al.* (2007)
- exhibits itself as biases from distractor on trials with no distractor, when interleaved with distractor+target trials in which distractor comes from fixed location (Figs. 1-3).

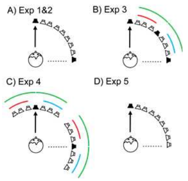


Figure 1 Experimental setup. Distractor location is indicated by the black speaker. Red/blue/green colors represent context-targets locations in left-half context/right-half context/full-context condition, respectively.

**Motivation**

- CP analyzed so far by comparing responses averaged across the adaptation part.
- However, responses in different conditions drift towards front. This drift has different rates (Fig. 3).
- **Aim**: Characterize and quantify the drifts and examine to what extent they can explain CP.

Preliminary analyses: drift rate tends to increase with increasing laterality of the distractor (Fig. 3).

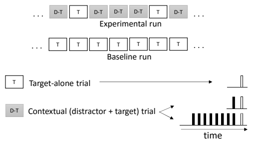


Figure 2 Schematic view of the runs. Each block represents one trial. D = distractor stimulus, T = target stimulus (in contextual trials referred to as "context-target").

**Hypothetical mechanism to explain drifts:** All stimuli, distractors and targets, were identical clicks. The drifts might be related to the fact that the stimuli are not distributed around straight ahead where the localization acuity is the highest (Makous & Middlebrooks, 1990), but are concentrated at the side. Because of that, the auditory system might activate a process to adjust the auditory spatial representation such that the mean of the distribution becomes aligned with midline (e.g., to increase spatial sensitivity). Similar mechanisms were proposed in Dahmen et al. (2010) or Maddox et al. (2014). We predict that the more lateral is the mean of the stimulus distribution for a given condition, the larger will be the observed medial drift.

## Methods

- Data from 5 previous CP experiments were analyzed: Exp1, Kopco et al. (2007); Exp2, Kopco et al. (2017); Exp3&4, Tomoriova et al. (2014); Exp5, Kopco et al.(2015). Experimental setups are shown in Fig 1.
- For each condition, the mean lateral position (*mp*) was computed as the mean of stimulus locations used in that condition, such that each location was weighted by the number of clicks presented from that location, independent of whether a given click was a distractor or a target (Fig. 4).
- To evaluate the slope of the drift, a linear fit of the temporal profile of responses (as in Fig. 3) during the adaptation part of the run was performed for each subject & condition:
  $y = k*x + q$,
  where y corresponds to bias, x corresponds to subrun, and parameters $k$ and $q$ represent the slope of the drift and its intercept.
- The relationship between laterality of the distribution (*mp*) and slope of the drift ($k$) was evaluated (Results section, Fig. 5).
- The significance of the linear relationship between *mp* an $k$ was assessed using linear mixed model with Subject as a random factor and *mp* as quantitative fixed factor: k~mp+(1|Subj), summarized in Table 1.
- In addition, the effect of non-spatial factors (reverberation and response method) on the drifts was examined.

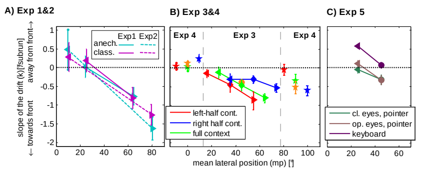
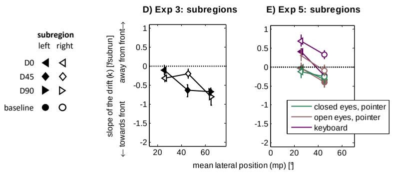


Figure 5 Across-subject mean and standard error of the slope of the linear fit, as a function of mean lateral position. Data points from conditions which differ only in distractor location are interconnected for better visualization. A,B&C) Drifts averaged across whole stimulus range. D&E) Drifts computed separately for left & right half of the stimulus range.

| Experiment | b | SE | Chi2 | deltaF | p |
|---|---|---|---|---|---|
| Exp1 | -0.0321 | 0.0059 | 16.022 | 1 | < 0.0001 |
| Exp2 | -0.0325 | 0.0043 | 22.764 | 1 | < 0.0001 |
| Exp3 | -0.0106 | 0.0026 | 14.645 | 1 | < 0.001 |
| Exp4 | -0.0067 | 0.0013 | 24.156 | 1 | < 0.0001 |
| Exp5 | -0.0221 | 0.0051 | 16.542 | 1 | < 0.0001 |

Table 1. Results of Linear mixed model

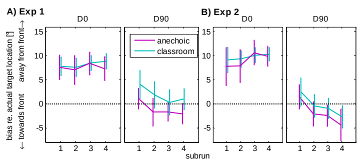
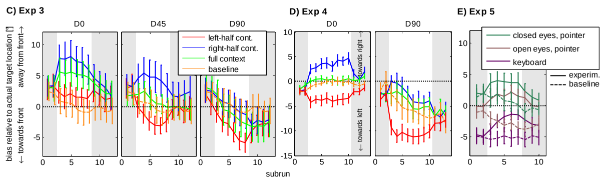


Figure 3 Temporal profile of responses during the course of the run. Across-subject mean bias (+-SEM) relative to actual target location as a function of a subrun (corresponding to 42 trials in Exp 1, 35 trials in Exp 2, 28 trials in Exp 3-5). Grey regions in Exp3-5 indicate pre- and post-adaptation subruns in which only target-alone trials were presented.

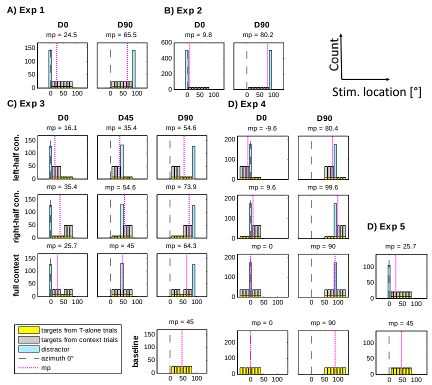


Figure 4 Distribution of stimuli (as the number of stimuli per location) for different experiments and conditions. Black dashed and magenta dotted lines indicate azimuth 0° and the mean lateral position (*mp*), respectively. Proportion of different types of stimuli is depicted in each bar by different color.

## Results

**Drift analysis (Fig. 5, significance reported in Table 1)**

1) Analysis of data averaged across all 7 speakers (panels A&B&C).

Exp 1&2:

- $k$ decreases from 0 approx. -1.5 °/subrun with increasing *mp*,
- no effect of reverberation.

Exp 3&4:

- $k$ decreases from 0 to approx. -0.9°/subrun with increasing *mp*,
- the decrease is less consistent when change in *mp* is driven by a change in context-target locations (e.g., for '>' symbols of different colors, k tends to increase with *mp* for Exp. 3),

Exp 5:

- $k$ decreases with increasing *mp* by approx. 0.5°/subrun for each response type,
- keyboard data offset vertically up compared to the other response methods.

Medial drifts become stronger with increasing laterality of stimulus distribution. However, only when distribution changes due to distractors, not distractor-targets (in Exp. 3).

2) Drifts analyzed separately for speakers #1-3 and speakers #5-7.

Exp. 3 (panel D):

- For the frontal and the lateral distractor (left/right-pointing triangles), both parts of the stimulus range have similar drifts.
- For the intermediate distractor (diamonds), left-half of the stimulus range (for which CP induces medial biases) drifts more than the right half (for which CP induces lateral biases).

Exp. 5 (panel E):

- For each response type and each speaker range, the decrease in $k$ with increasing *mp* is preserved (even though there are more vertical offsets, meaning that some drifts are actually lateral, not medial).

Strength of drifts is also influenced by the location of the distractor re. examined region. Drift away from distractor is observed in addition to the drift towards midline examined here.

## Conclusions

Stronger drifts towards front were observed with increased laterality of the distribution, consistent with the hypothesized effect. Such drifts can in part explain CP, assuming that initially responses with different distractor locations are unbiased. However, they are most probably only a minor contributor, since:

- There are large initial biases (Fig. 3),
- There is also a drift away from distractor (panel C), which sometimes counteracts the drift toward midline, and which is likely to be the main factor behind CP.
- Change in *mp* caused by change in context-target locations results in different change in drifts that what is predicted by the current hypothesis.

While the drifts are influenced by the response method used (stronger with hand-pointing than with keyboard), the relative change in drifts is response method-independent.

The current study has several limitations, e.g.: So far the drifts were analyzed only in terms of their strength. The responses' initial positions (starting point of the drift) need to be considered to understand how the drift might influence CP. Mean lateral position might not be the appropriate statistic for characterizing how strong the adaptation of representation is (e.g., max, median, skewness might better characterize the effect).

**References**
Carlile, S., Hyams, S., & Delaney, S. (2001). Systematic distortions of auditory space perception following prolonged exposure to broadband noise. J Acoust Soc Am, 110(1), 416–424.
Dahmen, J. C., Keating, P., Nodal, F. R., Schulz, A. L., & King, A. J. (2010). Adaptation to Stimulus Statistics in the Perception and Neural Representation of Auditory Space. Neuron, 66(6), 937–948.
Kashino, M., & Nishida, S. (1998). Adaptation in the processing of interaural time differences revealed by the auditory localization aftereffect. J Acoust Soc Am, 103(6), 3597–3604.
Kopčo, N., Andrejková, G., Best, V., & Shinn-Cunningham, B. (2017). Streaming and sound localization with a preceding distractor. J Acoust Soc Am, 141(4), EL331–EL337.
Kopčo, N., Best, V., & Shinn-Cunningham, B. G. (2007). Sound localization with a preceding distractor. J Acoust Soc Am, 121(1), 420–432.
Kopčo, N., Marcinek, Ľ., Tomoriová, B., and Hládek, Ľ. (2015). Contextual plasticity, top-down, and non-auditory factors in sound localization with a distractor J Acoust Soc Am, 137(4), EL281-EL287
Litovsky, R. Y., Colburn, H. S., Yost, W. A., & Guzman, S. J. (1999). The precedence effect. J Acoust Soc Am, 106(4 Pt 1), 1633–1654.
Maddox, R. K., Pospisil, D. A., Stecker, G. C., & Lee, A. K. C. (2014). Directing Eye Gaze Enhances Auditory Spatial Cue Discrimination. Current Biology, 24(7), 748–752.
Makous, J. C., Middlebrooks, J. C. (1990). Two-dimensional sound localization by human listeners. J Acoust Soc Am, 87(5), 2188–200.
Tomoriova, B., Marcinek, L., Hladek, L., & Kopco, N. (2014). Contextual plasticity in sound localization: characterization of spatial properties and neural locus. In: Proceedings of 7th Forum Acusticum 2014.

**Acknowledgement**
This contribution was supported by Slovak Research and Development Agency under grant project APVV- 0452-12 and by the TECHNICOM project, ITMS: 26220220182, of the EU RDP.