Faculty of Science
Perception and Cognition Laboratory

Mechanisms of Contextual Plasticity in Human Sound Localization

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Introduction

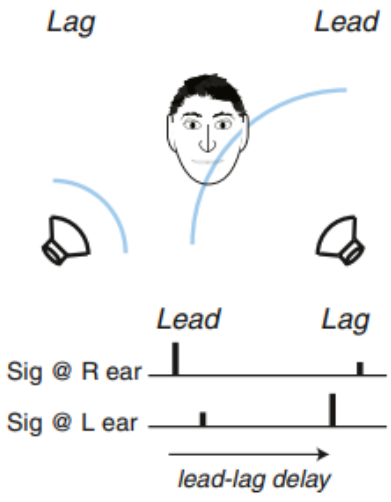
- The localization of sound sources is important for navigation and communication.
- The auditory system analyses acoustic signals, ...
- Humans learn from (adapt to) previous experience ...
- Here – to examine the neural mechanisms of adaptation in horizontal sound localization on time scale of sec. to min.

Outline

- Introduction
- Some motivating studies
- Neural mechanisms
- Experiments
- Results
- Conclusion

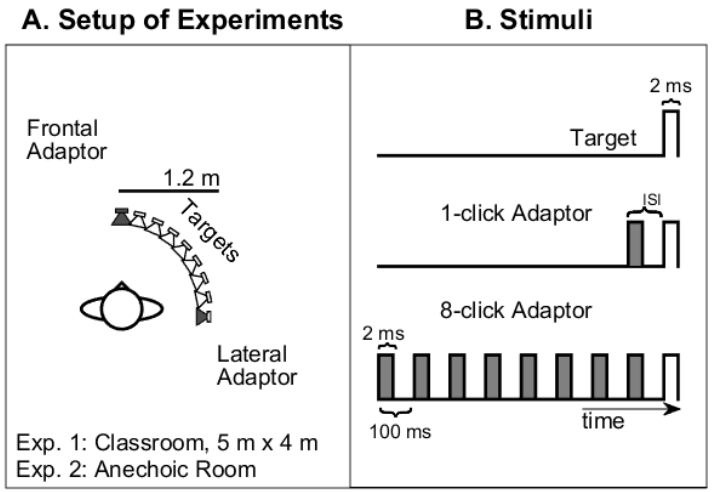
How preceding sound influences the recent target sound

Problem	Delay
The precedence effect [1, 2]	5 ms
The precedence buildup [3, 4]	20 ms
The localization aftereffect [5]	n* 10 ms
Effect of preceding distractor [6]	25 – 400 ms
Contextual plasticity	to 5 min



[1] Litovsky, R. Y. et al. (1999). The precedence effect. *JASA 106(4)*
[2] Brown, A. D. et al. (2014). The precedence effect. *JAR in Otolaryngology*
[3] Thurlow, W. R. and Jack, C. E. (1973). Some determinants of localization-adaptation effects for successive auditory stimuli. *JASA 53(6)*
[4] Freyman, R. L. et al. (1991). Dynamic processes in the precedence effect. *JASA*
[5] Phillips, D. P. et al. (2005). Psychophysical evidence for adaptation of central auditory processors for interaural differences in time and level. *Hearing Res., 202*
[6] Carlile, S. et al. (2001). Systematic distortions of auditory space perception following prolonged exposure to broadband noise. *JASA, 110(1):416-424*

Contextual Plasticity (CP)



- form of localization aftereffect
- observed as biases in localization of click target stimuli, interleaved with **adaptor – target trials**, which are the same clicks preceded by **fixed–location adaptor**
- reponses away from the location of the adapting stimulus

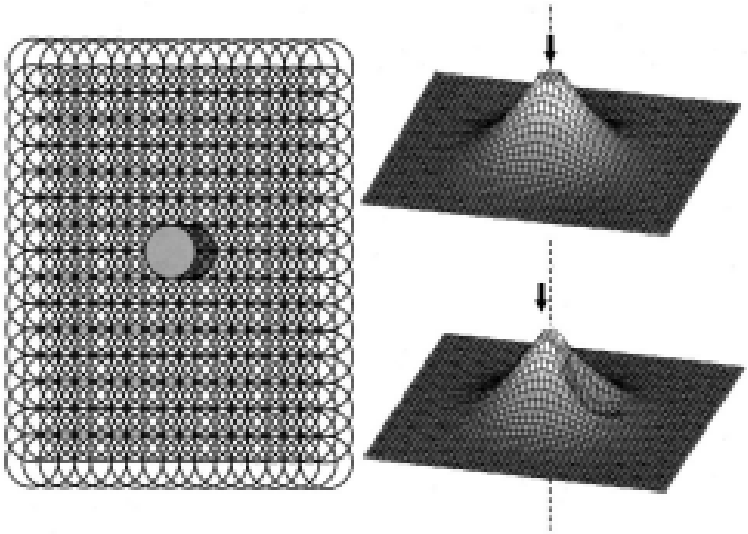
[7] Kopčo, N. et al. (2007). Sound localization with a preceding distractor. *JASA,121*
[8] Hládek, Ľ. et al. (2017). Temporal characteristics of contextual effects in sound localization. *JASA, 142(5)*,
[9] Andrejková, G. et al. (2023) Timescales of adaptation to context in horizontal sound localization. *JASA, 154(4)*

Neural mechanisms

- behavioral experiments, but ... physiological functions
- the basis for an ability to localize clicks and low frequency tones is the time difference of sounds in two ears
- **L. A. Jeffress, 1948** – the mechanism for representing a time difference depends upon two well established physiological functions:
  - the slow rate of conduction of small nerve fibers, and
  - the phenomenon of spatial summation.
- **S. Colburn and N. Durlach, 1978** – the classical model of binaural processing

[10] Jeffress, L. A. (1948) A place theory of sound localization. J Comp Physiol Psychol 41, 35–39 .
[11] Colburn, S. and Durlach, N. I. (1978) Models of binaural interaction. In Handbook of perception. New York: Academic Press.

Carlile's model

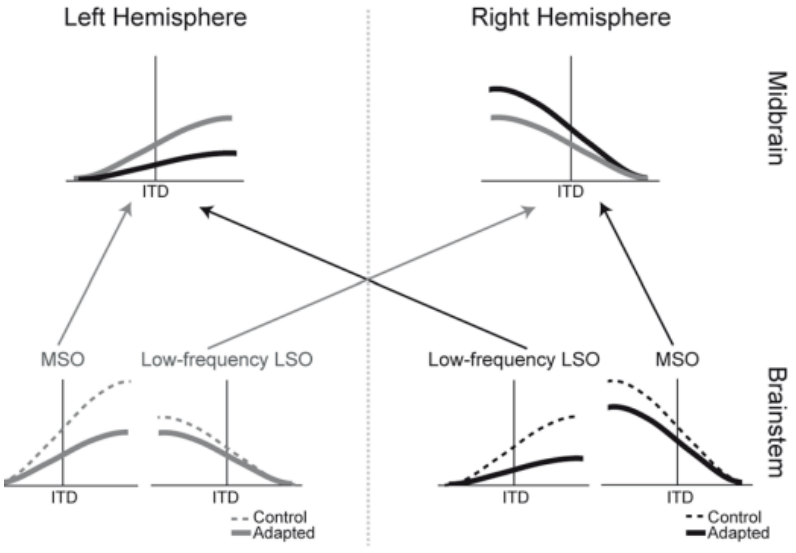


- population of units, tuned to a different spatial location, encodes auditory space

- primary goal of auditory spatial perception is to accurately encode the sound source location, and
- result of adaptation: to a repeated presentation of a stimulus from the same location is a fatiguing, causing a suppressed response from the corresponding channel

[6] Carlile, S. et al. (2001). Systematic distortions of auditory space perception following prolonged exposure to broadband noise. *JASA, 110(1):416-424.*

Lingner's model



- a coding hemispheric balanced model,
- lateral and medial superior olives (LSO and MSO)
- independently calculated results for sound localization from both hemispheres
- goal of adaptation: to increase separability sources in the region from which most stimuli are presented,
- increased discriminability between targets near the adaptor

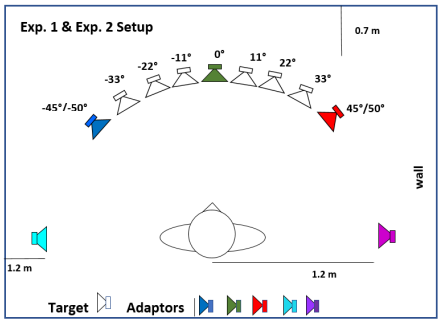
[12] Lingner, A., Pecka, M., Leibold, C., & Grothe, B., A. (2018). A novel concept for dynamic adjustment of auditory space. Sci. Rep., 8(1), 1–12.

In the current study (Standard Deviations analysis):

Carlile: **SD** in responses to target near the adaptor will be increased in the adapted vs. unadapted population
(the auditory space representation is suppressed near the adaptor - this adaptation)

Lingner: increases separability sources in the region from which most stimuli are presented,
SD decreases near adaptor, resulting in increased discriminability

Experiments



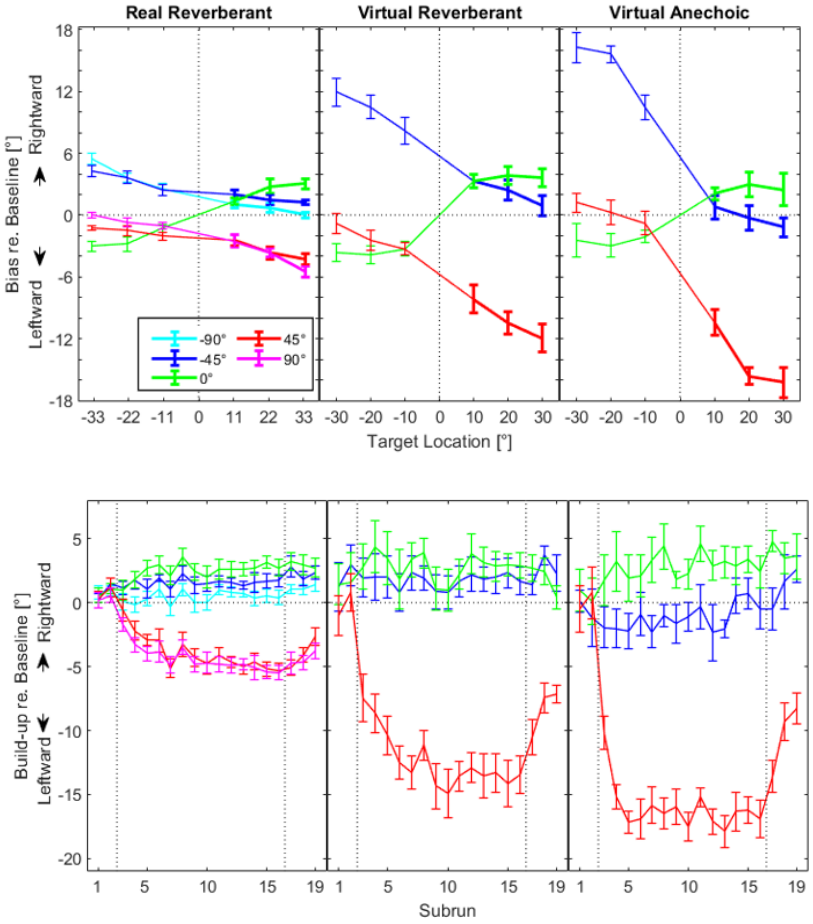
Passive exposure to adaptors is sufficient to induce CP

Exp. 1 RE – real midsize reverberant room, 6 target speakers, 5A – adaptor speakers, 8 subjects

Exp. 2 VE – virtual environment using headphones, reverberant and anechoic, 3A, 9 subjects

Stim. 2ms clicks, passive listening of adaptor sounds (12 clicks)

Bias and BuildUp to Baseline



Results in SDs

- **In RE:**

  $2 - 4^o$, the largest values close to the adaptor for the 45^o A, the smallest far from the adaptor for the -45^o A.

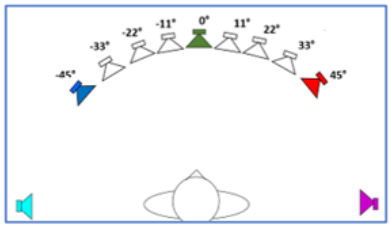
- The adaptors in RE always caused an increase in the response variance, significant main effect of adaptor.

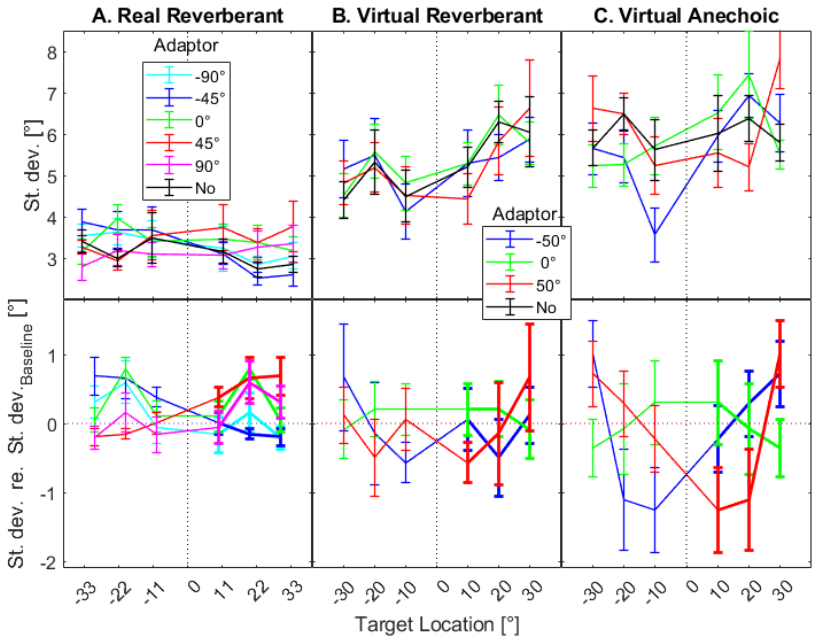
- **In VE:**

  errors are larger $3.5 - 7^o$ and have greater variability.

- 50^o A – increases for nearest target, followed by decreases in more distant target SDs

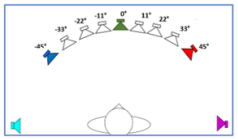
Standard Deviations (SD)

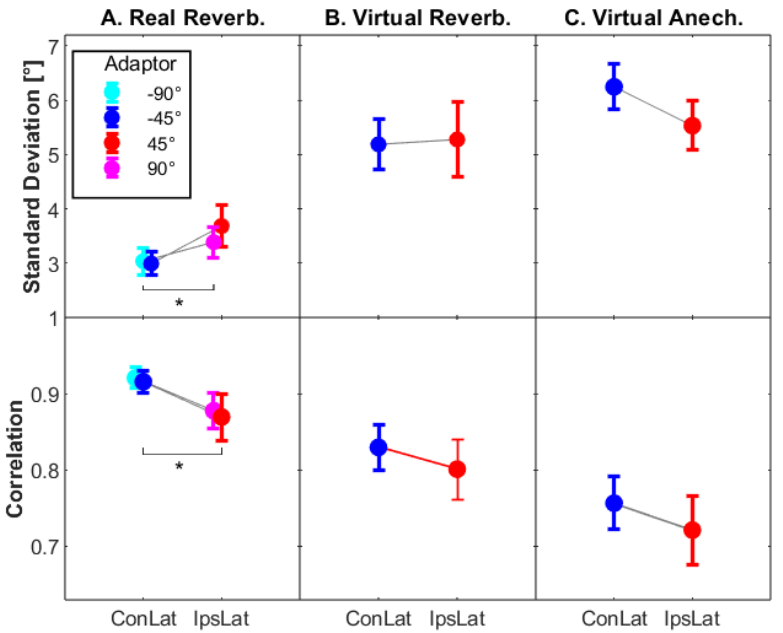




SD vs Correlation Coefficients

- Correlations between positions of presented target sounds and responses to these targets
- Comparison of triplets near (IpsLat) and far (ConLat) from adaptors
- Significant interaction target x adaptor for lateral adaptors in VE



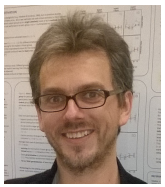


Results of SD are more consistent with Carlile's model, but there is the exception in virtual anechoic environment

Conclusion

- It is more likely that listeners use different strategies when localizing sounds in RE and VE (particularly VAE)
- in RE: It is likely that listeners use absolute localization allowing them to map the acoustic cues to an actual sound source location.
- in VE: in which the cue-to-location mapping is ambiguous, listeners might be changing their strategy and using relative localization, e.g., localizing the targets relative to the known location of the adaptor.
- This interpretation – consistent with the Carlile and Lingner studies, as the former one was performed in RE while the latter one was performed in VAE.
- **Future directions:** In VE to analyze responses for lateral adaptors in positions $+90^o$ and -90^o.

Thank you very much for your attention



- **PhD positions in Slovakia and USA**,
  Marie Curie EU-funded project on Spatial Audio Virtualization and Gamification for Hearing Assessment and Enhancement
  https://pcl.upjs.sk/sav/
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