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Trial-to-trial Contextual Adaptation in Sound Localization

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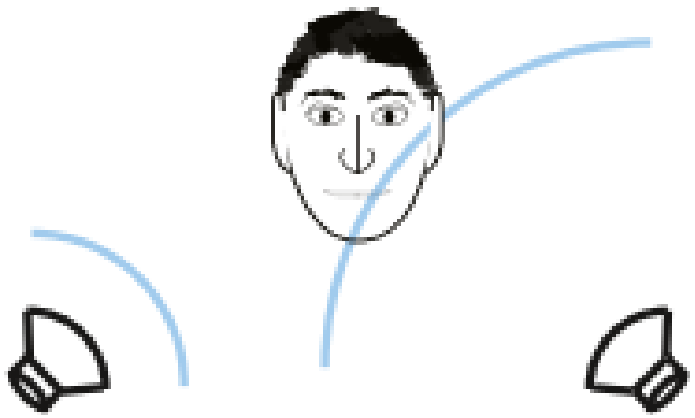
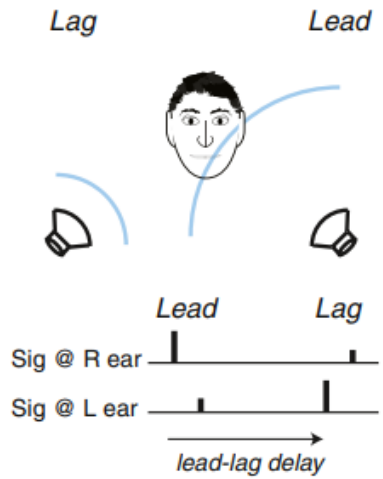
Introduction

- Human's adaptation to multiple concurrent stimuli in complex, continuously changing environments.
- Humans learn (adapt) from previous experience and improve the used perceptual strategies.
- This contribution – to examine the neural mechanisms of adaptation in sound localization.
- Study of plasticity in horizontal sound localization on time scale of seconds to minutes.



Some motivating studies

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	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):1573-1577*
[4] Freyman, R. L. et al. (1991). Dynamic processes in the precedence effect. *JASA 90(2):874*
[5] Phillips, D. P. et al. (2005). Psychophysical evidence for adaptation of central auditory processors for interaural differences in time and level. *Hearing Res., 202:188–199*

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The localization aftereffect

- The effects of a stationary adapting noise stimulus on the subsequent auditory localization in the vicinity of the adapting stimulus.
- Adaptation – presenting 4 min of continuous noise at the start of each block of trials and was maintained by a further 15-s noise burst between each trial.
- Subjects – to determine the location of noise burst stimuli (150 ms) in the proximity of the adapting stimulus.
- Results – following adaptation there was a general radial displacement of perceived sound sources away from the location of the adapting stimulus.

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

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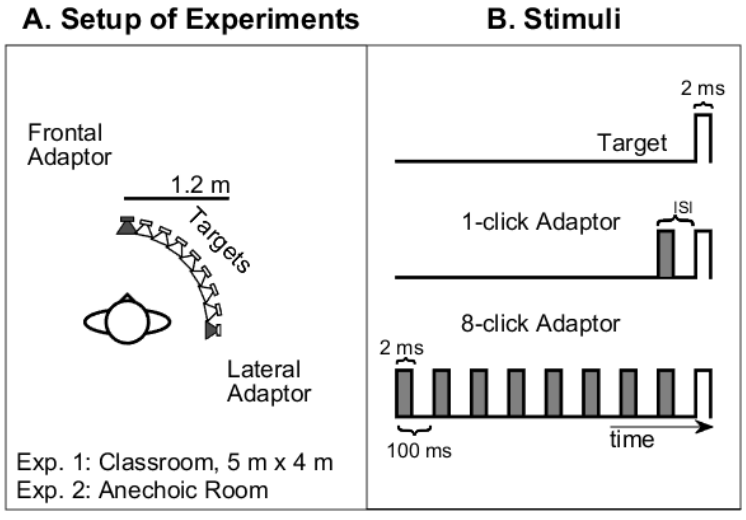
Contextual Plasticity



- Observed as biases in localization of **click target stimuli**, interleaved with **contextual adaptor–target trials**, which are the same clicks preceded by **fixed–location adaptor**
- Contextual plasticity is a form of localization aftereffect.

[7] Kopčo, N. et al. (2007). Sound localization with a preceding distractor. *JASA121*
[8] Hládek, Ľ. et al. (2017). Temporal characteristics of contextual effects in sound localization. *JASA, 142(5)*,

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Slow and fast components of CP

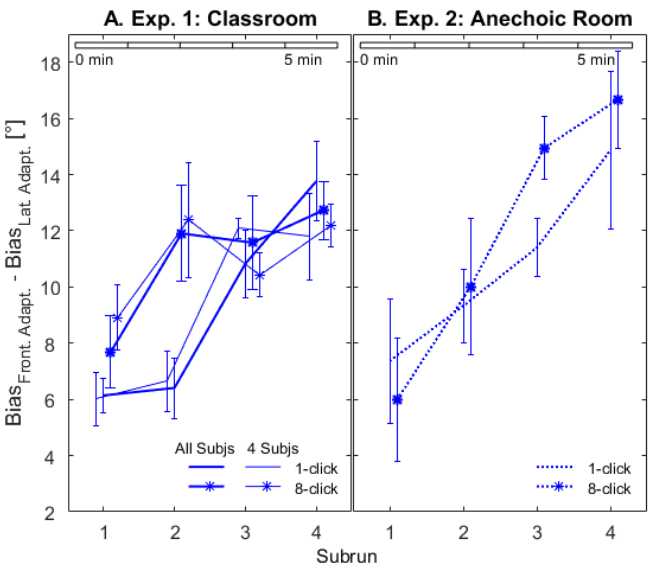

Figure: Effect of the context adaptor (1-click vs. 8-click) in the immediately preceding trial on CP. [9]

- One effect of varying the context on a trial-to-trial basis – the adaptation continued to evolve over the duration of an exper. run (around 5 minutes)
- CP was affected by the immediately preceding context trial – larger following 8-click vs. 1-click adaptors

[9] Andrejková, G. et al. Timescales of adaptation to context in horizontal sound localization. *JASA Under review*

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In the current study

We used data from [10] which showed that:

- R1: If CP is mainly caused by adaptation to the adaptors, independent of their role in the listener's task, then it is observed when the listener only passively listens to the context.
- R2: CP is observed in virtual environment, and it is stronger in anechoic than in real environment, as no anchoring of stimuli as objects in real world is available to calibrate perception.

[10] Linková, S. et al. (2022) Contextual plasticity in sound localization vs. source separation in real and virtual environments. In: Kognícia a umelý život XX, Třešť.

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Hypotheses

Investigated the short-term dynamics of the adaptation by analyzing the effect of the type of trial immediately preceding a given trial (where the preceding trial could be A or T).

H1: The adaptation process is fast enough for the type of previous trial to have an observable effect on the bias of the given trial. The preceding A is in a fixed position and it contains more energy / multiple clicks than the preceding T – we expect stronger bias for the preceding A.

H2: SDs depend on the environment of the experiment. It will manifest itself more strongly in a real environment.

H3: A is repeated several times and affects with more energy, causing larger biases and also a larger variability in responses.

Exp.1 - real reverberant, Exp. 2 - virtual real and anechoic

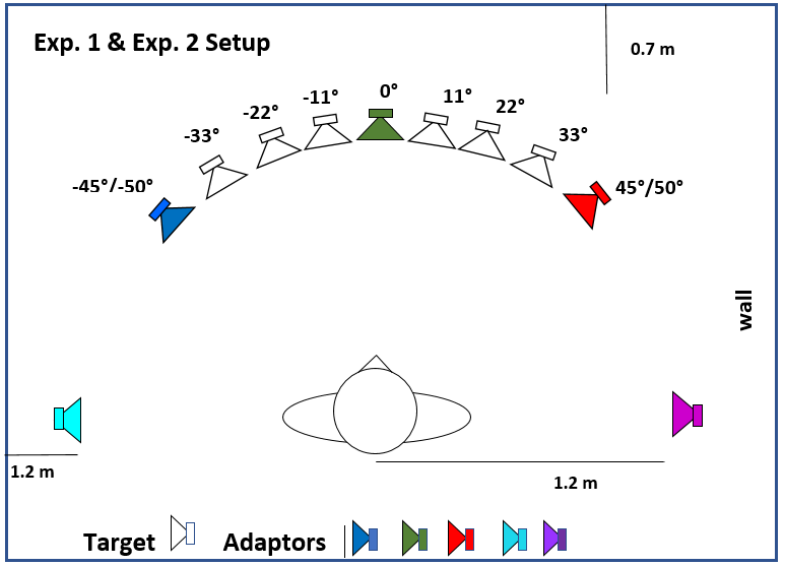
RRE - real reverberant; VRE, VAE, VE - virtual environments

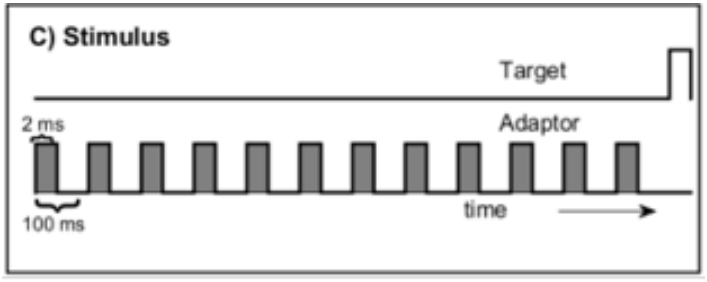
Setup: 5/3 A and 6 T positions

Stimuli: T – 2 ms click, A – 12 * 2 ms click

One trial: only T or A presented;
If T – respond by entering number combination seen at perceived location;
If A – just hit Enter.

RUN: Divided into subruns (1 presentation of each T);
2 + 14 +3 subruns





Subjects and methods

Exp. 1: 8 normal-hearing subjects,

Exp. 2: 9 subjects (+1 excluded due to outliers)

Exp. 1: 3 sessions, each of 6 rand. ordered runs (1 for each A + baseline)

Exp. 2: 3 sessions, 8 rand. ordered runs (1 for each A + baseline)*2 environments.

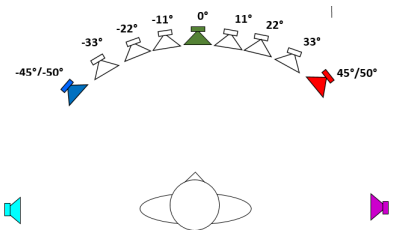
Data Analysis:

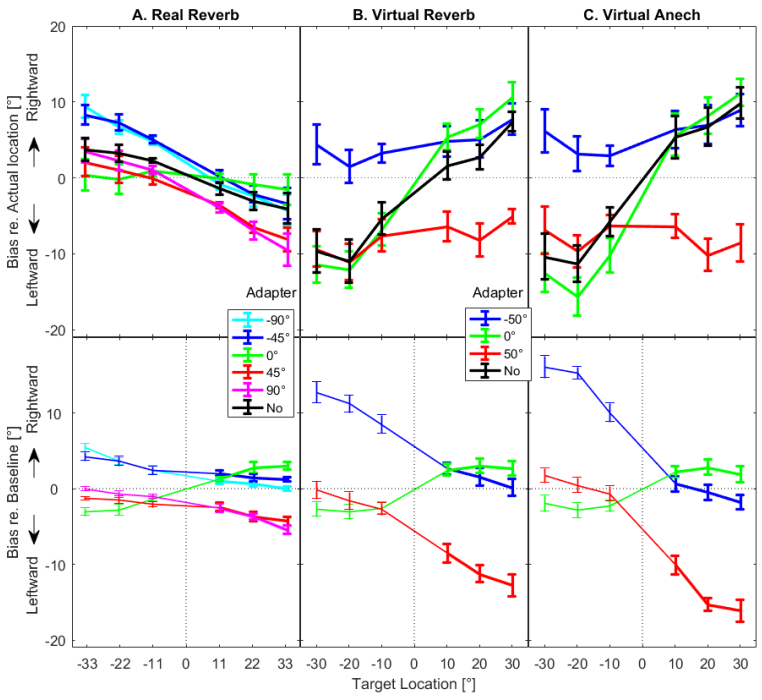
Only later portion of adaptation parts considered (subruns 7-16)

Variance: Std. dev. computed separately for each combination of session, target, run and subject; then averaged

Results combined across left-right symmetric conditions

Results - biases, averaged accross preceding trials

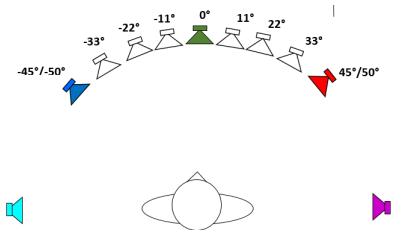


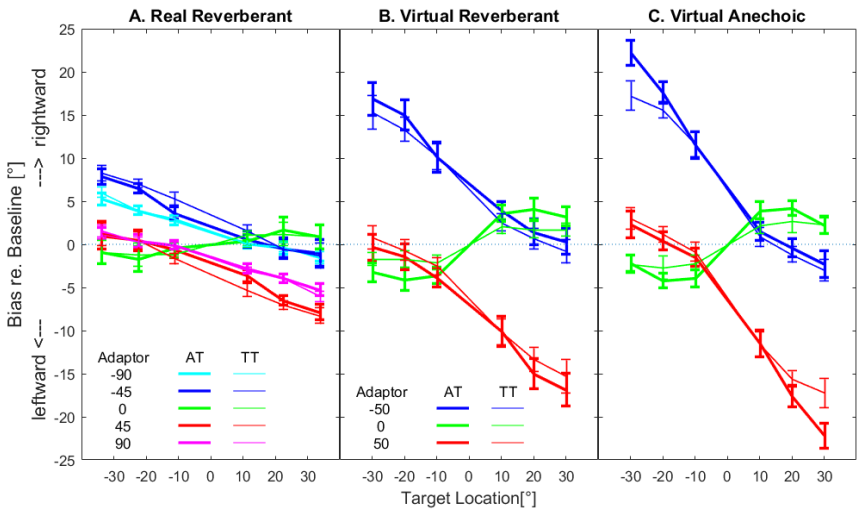


Repulsive Contextual bias in responses that:

- depends strongly on A location and T locations
- is modulated by environment (stronger in Virt. En. and the strongest in VAE)
- the pattern of results is consistent across the environments and adapter locations
- biases away from the adapter that decrease with increasing separation between adapter and target

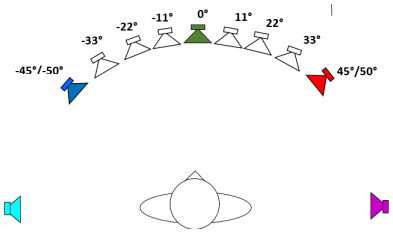
Effect of type of preceding trial on response bias

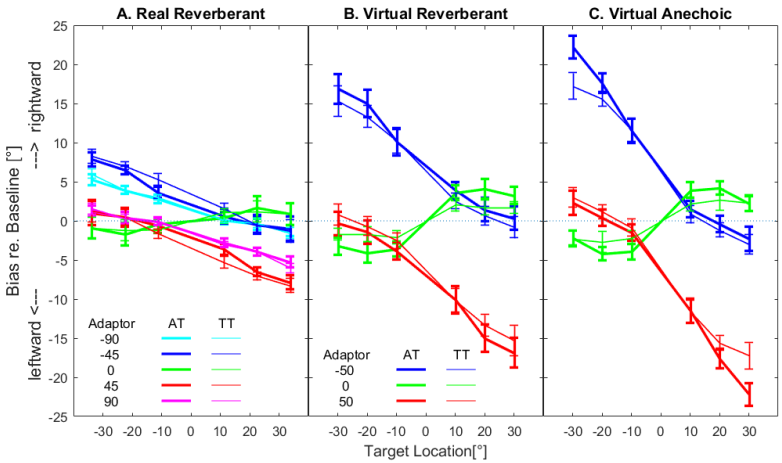




- the immediately preceding stimulus has a modulatory effect, mainly in virtual environments
- the strongest effect of T is for Lat. A and nearby targets in VAE; the difference between AT and TT is 5°(blue lines at -30°)
- similar, but weaker effects are also observed in VRE and for the FA (green lines)

Responses to T according to previous type of target (A/T)





- In RRE, A causes, if anything, a smaller CP, only observed for A$\pm$45° and targets at $\pm$11°

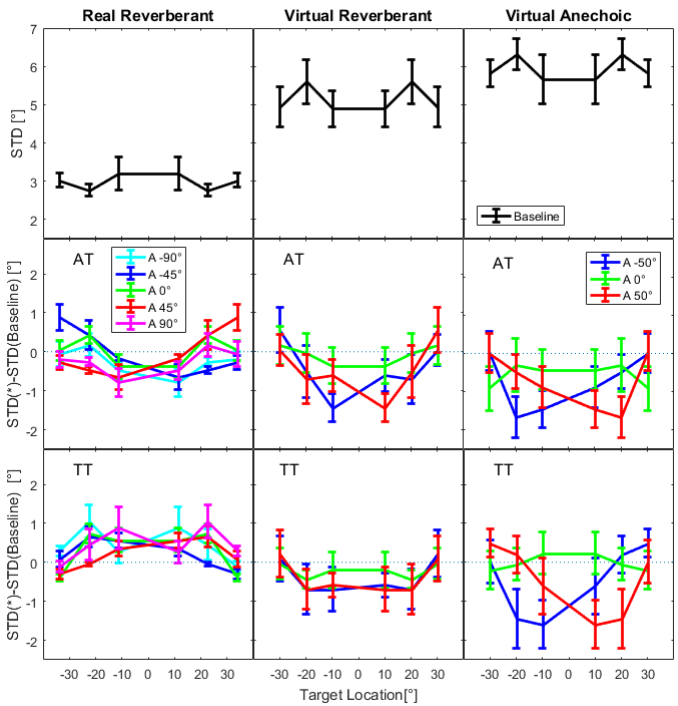
Main observation:

- In VE, adaptation is also on the 5s time scale and bias A is stronger than T.
- This is not observed in RRE.
- The adaptation mechanism is different for VE and RRE.

ANOVA

- On virtual environment data were significant:
  - adapter x **previous stimulus**: $F(2, 16)=7.56$, $p=0.005$,
  - environment x **previous stimulus**: $F(1, 8)=5.76$, $p=0.043$,
  - target x **previous stimulus**: $F(2, 16)=5.10$, $p=0.02$,
  - adapter x target x **previous stimulus**: $F(2, 16)=0.36$, $p = 0.703$,
  - target x environment x **previous stimulus**: $F(4, 32)=4.41$, $p=0.006$.
- On real reverberant environment data were significant:
  - adapter: $F(4, 28)=38.42$, $p=0.00$,
  - target: $F(2,14)=6.57$, $p=0.009$,
  - adapter x target: $F(8, 56)=5.45$, $p=0.00$,
  - adapter x target x **previous stimulus**: $F(8, 56)=3.13$, $p=0.005$.

Evaluation of standard deviations (SD)

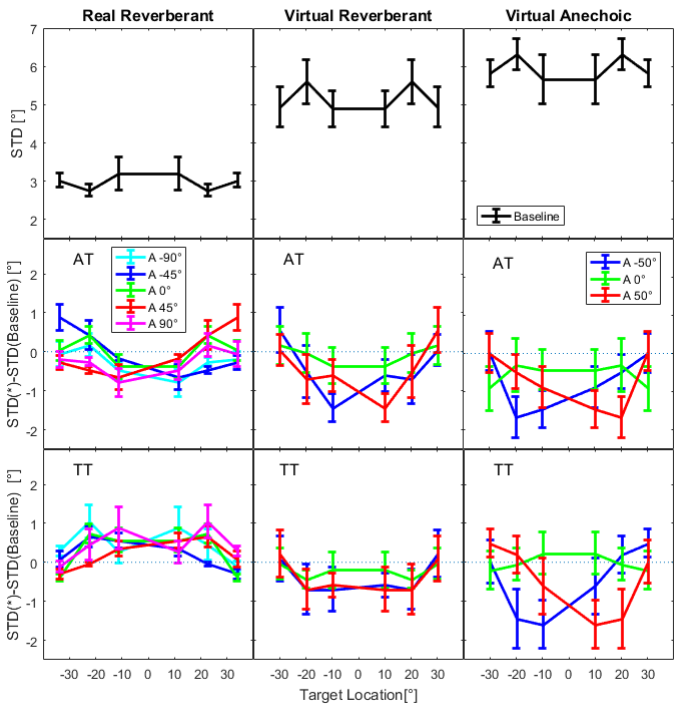


RRE SDs – to be significantly higher when the previous stimulus was T vs. when it was A. That pattern only held for central targets and not for peripheral.

ANOVA

- **previous stimulus**: $F(1, 7)=16.02$, $p=0.005$,
- adapter: $F(4, 28)=4.17$, $p=0.009$,
- **previous stimulus** x target: $F(2, 14)=9.21$, $p=0.0028$,
- a nearly significant int.: **previous stimulus** x adapter: $F(4, 28)=2.60$, $p=0.058$

Evaluation of standard deviations (SD)



VE

- In the virtual environment, we observe a trend that the errors in the adaptor runs will decrease.
- No significant effect of preceding trial was observwd..

Mechanisms of CP

Two candidate mechanisms have been proposed to explain adaptation phenomena similar to CP:

- fatigue due to extended activation reduces responses in spatial channels near adaptor location [5]
- spatial representation adapts to improve source separation at the cost of introducing localization biases [10]

[5] Carlile, S. et al. (2001). Systematic distortions of auditory space perception following prolonged exposure to broadband noise. *J. JASA, 110(1):416-424.*
[11] Lingner, A. et al. (2018). A novel concept for dynamic adjustment of auditory space. Sci Rep 8, 8335

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Mechanisms of CP

Predictions for location discrimination performance after adaptation according to mechanisms:

- worse for targets near adaptor (vs. far from adaptor) [5]
- better for targets near adaptor [10]

Conclusion

- The results confirmed hypothesis H1, but only in a virtual environment, while a small opposite trend was observed in a real environment.
- H2 is confirmed. SDs behaves in the real environment as an anchor. It behaves differently in the virtual environment, it shrinks in adapter runs.
- SDs is different for AT and TT in the real environment and is significantly dependent on the passing trial. In an anechoic environment, dependence is not proven. Hypothesis H3 is fulfilled for the real environment.
- These results illustrate complex interactions between environmental factors and stimuli in spatial auditory plasticity.

Thank you for your attention

Invitation to our workshop – 2024, May