Contextual Plasticity in Sound Localization vs. Source Separation

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Introduction

Contextual plasticity (CP) is a localization aftereffect occurring on the time scale of seconds to minutes. It has been observed as a bias in horizontal sound localization of click target stimuli presented alone, when interleaved with contextual adaptor-target trials in which the adaptor was at a fixed location while the target location varied. The observed bias is always away from the contextual adaptor location, even though the adaptor is not present on the experimental trials. In a previous study [Linkova et al. (2021) ARO Abstract #W30], two experiments showed that 1) this phenomenon is not dependent on engagement of the subject in an active localization task on the contextual trials (Exp. 1), and 2) CP is also observed, and is stronger, in virtual environments, both reverberant and anechoic (Exp. 2). Here, correlation and variance analysis is performed on the previously collected data, to evaluate two hypotheses about neural mechanisms underlying CP.

Current study

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

- Carlile et al. (2001): fatigue due to extended activation reduces responses in spatial channels near adaptor location.
- Lingner et al. (2018): spatial representation adapts to improve source separation at the cost of introducing localization biases.

Predictions for location discrimination performance after adaptation:

- Carlile et al. (2001): worse for targets near adaptor (vs. far from adaptor),
- Lingner et al. (2018): better for targets near adaptor.

Here, we evaluate these opposing predictions for two bias-independent localization measures: stimulus-response correlation and response standard deviation.

Methods

Setup (Fig. 1A):

- Exp. 1 in real midsize reverberant room, 6 target speakers, 5 adaptor speakers
- Exp. 2 in virtual midsize reverberant or anechoic room, 6 target speakers, 3 adaptor speakers (slightly shifted locations)

Stimuli (Fig. 1B):

- Target (T): 2-ms frozen noise click
- Adaptor (A): train of 12 such clicks presented at rate of 10/sec
- In Exp. 2 created by convolving with non-individualized BRIRs/HRTFs from a similar room.

One trial:

- only T or A presented
- If T presented, respond by entering number combination seen at perceived location
- If A presented, just hit Enter.

Runs:

- Divided into subruns (1 presentation of each T)
  - T-only pre-adaptation, 2 subruns
  - adaptation w/ T & A equiprob, 14 subruns
  - T-only post-adaptation, 3 subruns
- A location fixed within run (silent in baseline).

Subjects and Experiments:

- Exp. 1: 8 normal-hearing subjects, Exp.2: 9 subjects (+1 excluded due to outliers)
- Exp. 1: 3 sessions, each of 6 randomly ordered runs (1 for each A + baseline)
- Exp. 2: 3 sessions, 8 rand. ordered runs (1 for each A + baseline)*2 environments.

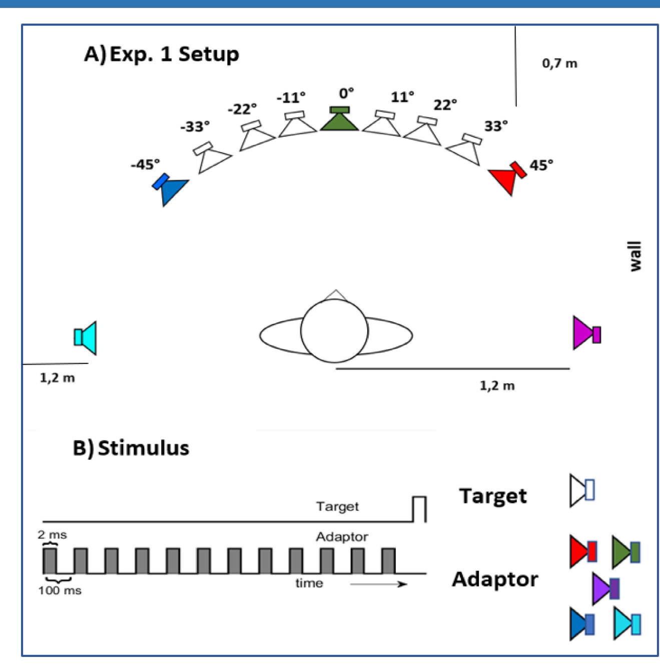

Fig. 1. Setup and stimuli. A) Setup of Exp. 1 in real room (Exp. 2 setup similar). B) Target and adaptor stimuli.

Data Analysis:

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

Pearson's Correlation Coefficient:

- Targets divided into triplets of 3 right-most (RT) and 3 left-most targets (LT)
- Responses for each triplet correlated with real positions within a run
- Results combined across left-right symmetric positions (-90° LT, +90° RT)

Variance:

- Std. dev. computed separately for each combination of session, target, run and subject; then averaged
- Results combined across left-right symmetric conditions

Previous Results: Bias and its Build-up

Passive exposure to Adaptors induces a repulsive Contextual bias in responses that:

- depends strongly on adaptor location (compare lines) and target locations
- is modulated by environment (stronger in Virtual Env. and the strongest in Virtual Anech)

Build-up of Contextual Plasticity:

- depends on Adaptor location (slowest for Frontal Adaptor)
- depends on the environment (slowest for Real Reverberant and fastest for Virtual Anech)

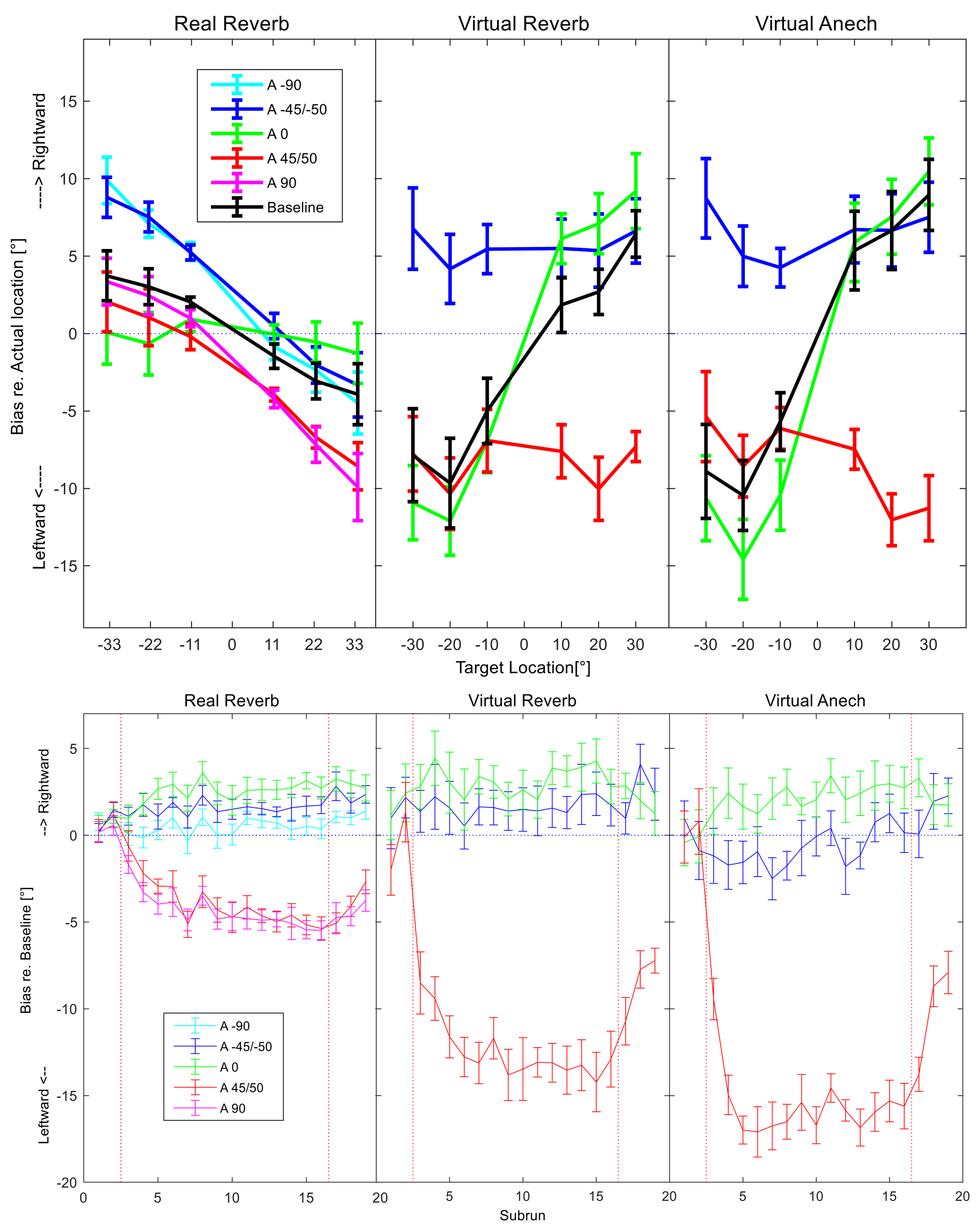

Fig. 2. Top: Results of Exps. 1 & 2 averaged across time. Bottom: Temporal profile of build-up in contextual bias averaged across Target locations and referenced to baseline.

Results: Short-term Dynamics

Effect of Immediately Preceding Trial Type (A or T) on target localization bias:

- no effect in real reverberant env. ($p > 0.09$, panel A),
- bias mostly larger for trials preceded by A than those preceded by T in both virtual environments and both Adaptor locations ($p < 0.05$, panels B & C)

Quick adaptation component observed only in virtual environments.

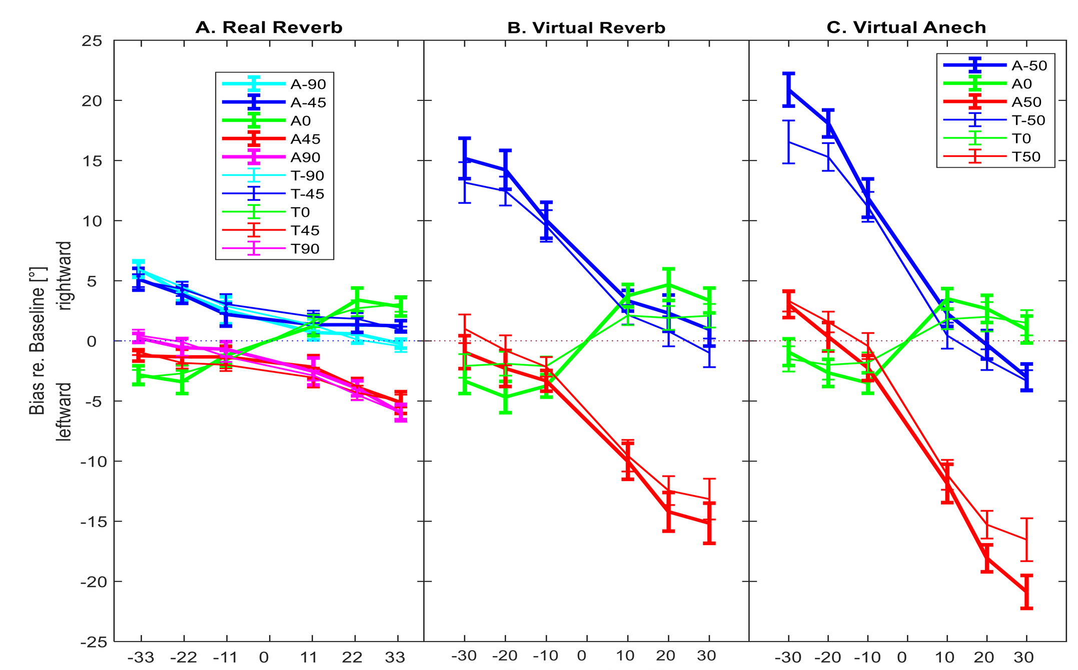

Fig. 3. Effect of immediately preceding trial type (A or T) on the response bias re. baseline. Thick lines show the bias in target responses following an adaptor trial, thin lines following a target trial. Data collapsed assuming left-right symmetry.

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Results: Correlation and Variance

Correlation (Pearson's r, Fig. 4)

- better in Real Reverb than in Virtual Reverb, and in Virtual Reverb than Virt Anech ($p < 0.05$)
- better for targets far (Contralat.) than near (Ipsi-lat.) re. Lat. A ($p < 0.0001$)
- better without than with Frontal A ($p < 0.005$)

Correlations always consistent with Carlile et al. model.

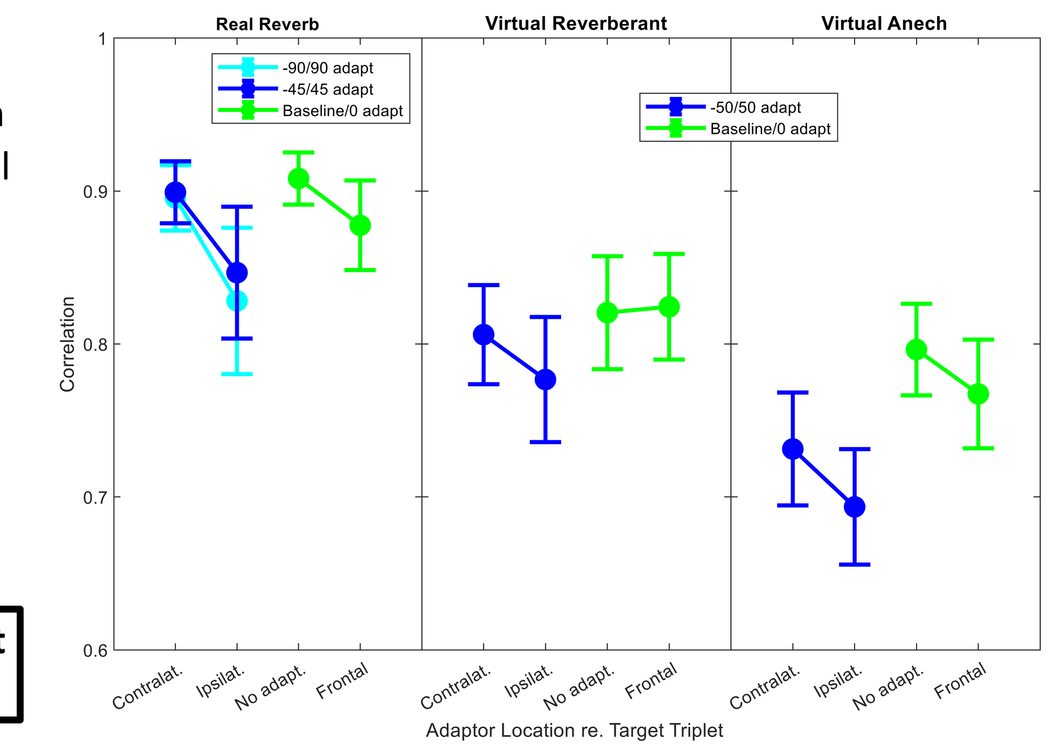

Fig. 4. Across-subject mean *r* between responses and actual target location for the right-most target triplet and one adaptor location (±SEM).

Standard deviation (Fig. 5) *re.* baseline:

- increases for targets near Adaptor in Real Rev ($p < 0.05$)
- no significant effect in Virtural Reverb,
- trend for effect in Virtual Anech, such that st.d. increases near Adaptor and decreases further away ($p = 0.09$)

Variance effects more consistent with Carlile et al. model.

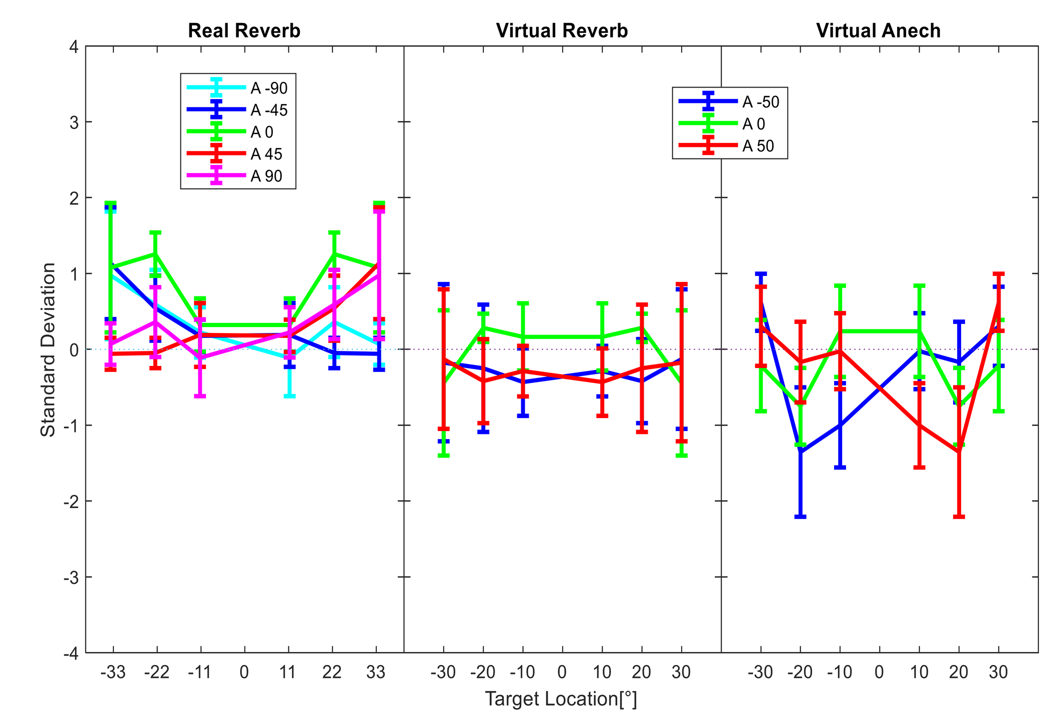

Fig. 5. Across-subject mean standard deviation in responses (±SEM) after referencing data to the baseline and collapsing them assuming left-right symmetry.

Discussion and Conclusions

Both stimulus-response **correlation** and response **standard deviations increase near adaptor** re. far from adaptor (or re. no-adaptor baseline) →

- not consistent with Lingner et al. (2018) suggestion that spatial resolution improves near adaptor,
- consistent with Carlile et al. (2001) suggestion that adaptor causes fatigue / suppression of activation in nearby channels, assuming that the suppression causes noisier responses.

CP is likely caused at least partially by suppression in spatial representation, even for the brief stimuli used here (compared to Carlile et al., 2001, or Lingner et al., 2018).

Standard deviation in virtual anechoic environment has some tendency to improve for targets not immediately neighboring the adaptor → Lingner et al. (2018) effect might have to be driven by the fact that the experiment was performed in virtual anechoic space, causing:

- expansion of space even in baseline (Fig. 2),
- rapid adaptation to preceding trial type (Fig. 3),
- lower overall accuracy in terms of correlation (Fig. 4).

Future steps: Add more subjects or analyze only std. devs. in trials preceded by T trails.

No evidence of rapid trial-to-trial adaptation in real reverberant environment, but clear rapid adaptation in virtual environments → additional adaptation mechanisms or change in strategy.