Passively Induced Contextual Plasticity in Sound Localization vs. Source Separation

Norbert Kopčo, Stanislava Linková, Gabriela Andrejková

Perception and Cognition Lab, Institute of Computer Science

P. J. Šafárik University in Košice, Slovakia

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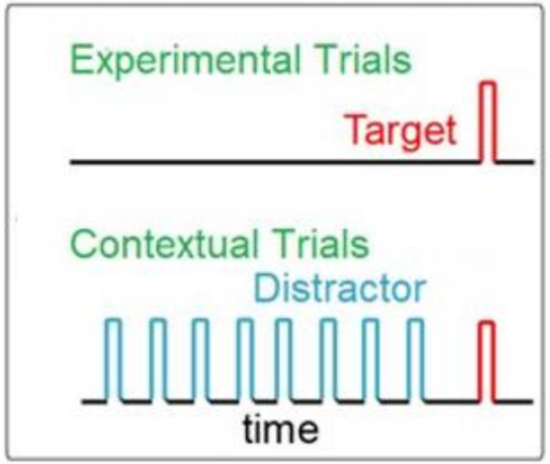
Introduction

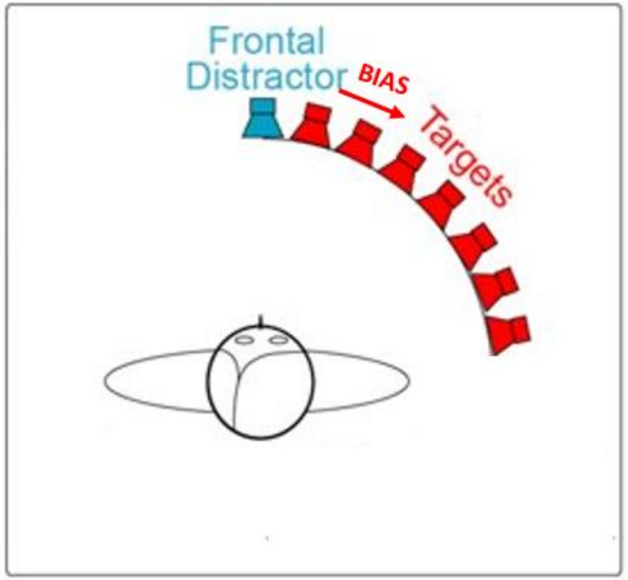
Various **adaptive** effects observed on slow time scales:

- Localization **aftereffects** (Thurlow & Jack, 1973; Carlile et al., 2001; Dingle et al., 2012; Laback, 2023)
- **Precedence** effect **build-up** (Freyman et al., 1991; Djelani and Blauert, 2001)



Contextual plasticity, CP (Kopčo et al., ‘07, ‘15, ‘17, Andrejkova et al., ‘23)

- observed as bias in localization of **click target** stimuli, when interleaved with ***contextual*** **distractor-target trials** (identical **target clicks** preceded by **fixed-location distractor**)
- **Bias** always **away** from distractor
- reported in **real** reverberant and anechoic **environments**

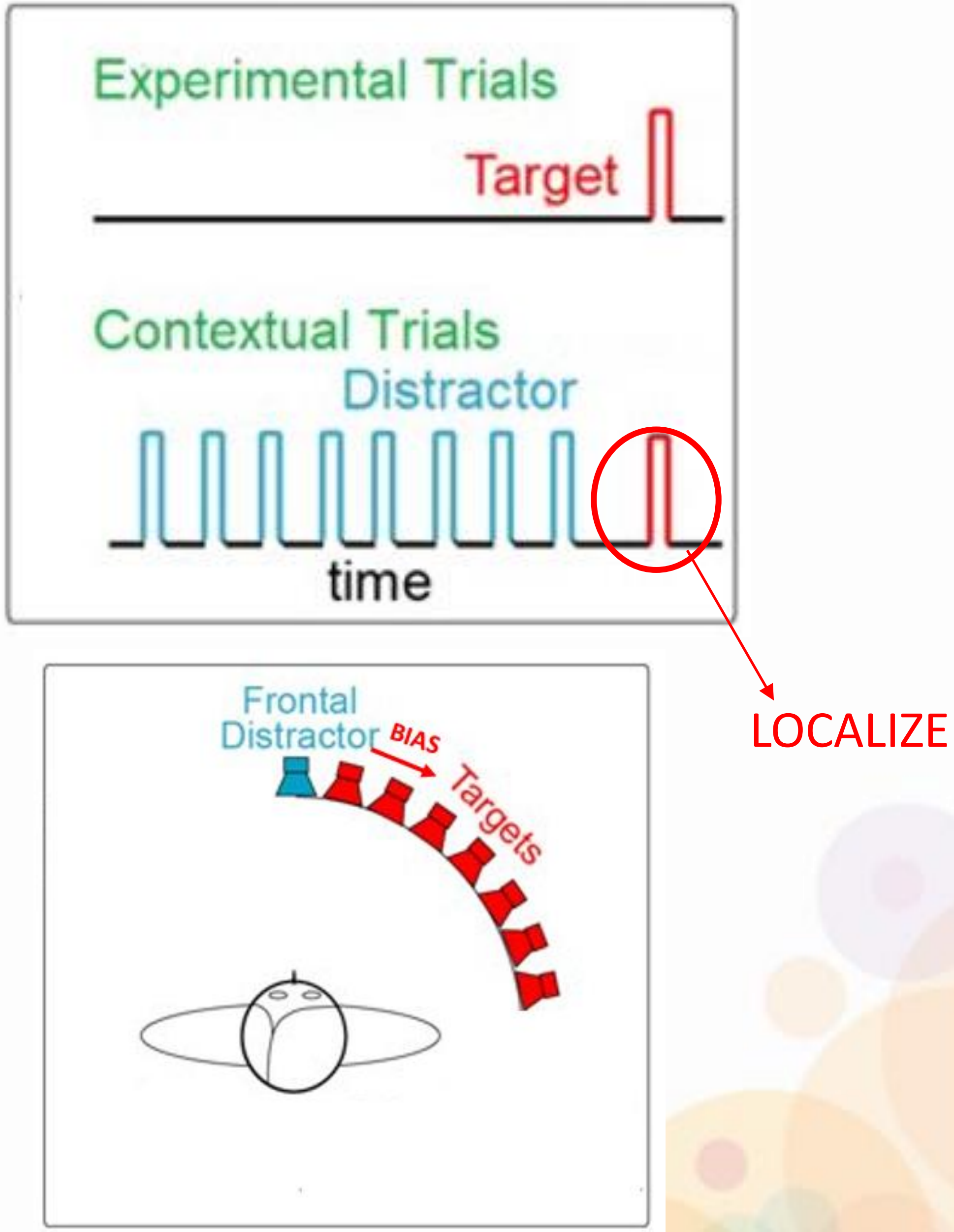


Experiment 1

In previous studies, listener's task in contextual trials:

- **active task**
- **on contextual trials,** localize targets presented after a preceding **DISTRACTOR** coming from a fixed location
- Strategy to respond **"away from distractor"** causing bias?

Previous studies:



Experiment 1

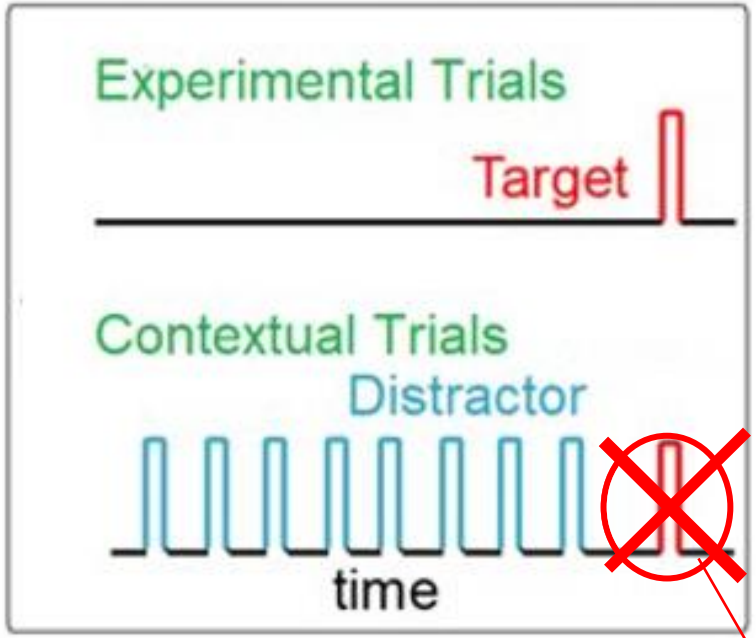
In previous studies, listener's task in contextual trials:

- **active task**
- **localize targets presented after a preceding DISTRACTOR**
- Strategy to respond **"away from distractor"** causing bias?

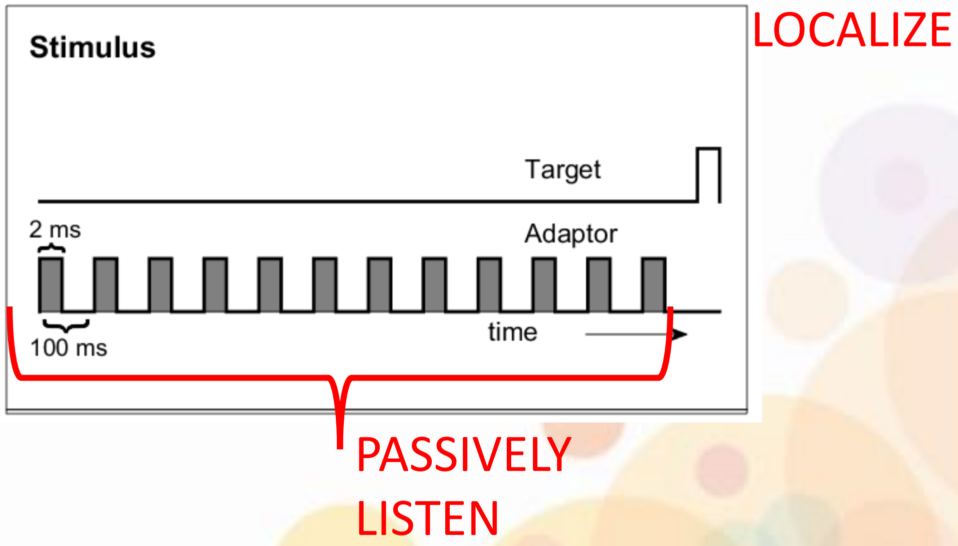
Experiment 1

- Is CP dependent on engagement of the subject in an **active localization task** on the contextual trials?
- **Remove target** from context trials
- Only **passive listening** to **adaptor click train** during context trials (real reverberant environment)

Previous studies:



Current experiments:



Experiment 2

All previous studies performed in **real** anech or reverb environment.

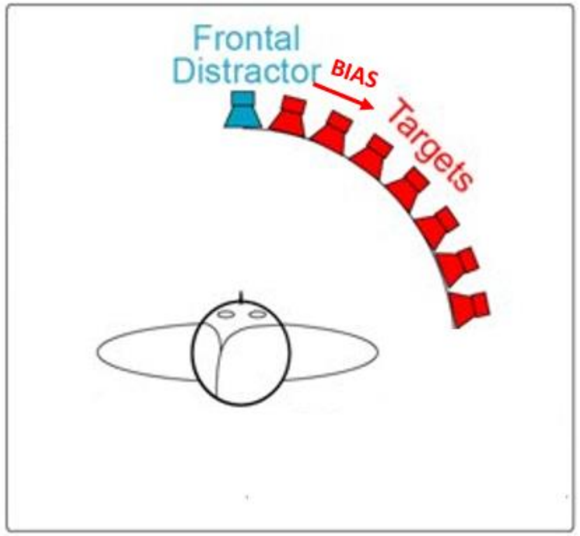
Experiment 2

- Is CP also **observed in virtual environments, both reverberant and anechoic**? Is it stronger/weaker?
- Use setup like in Exp 1, but in **virtual ANECHOIC** and **REVERBERANT** environment

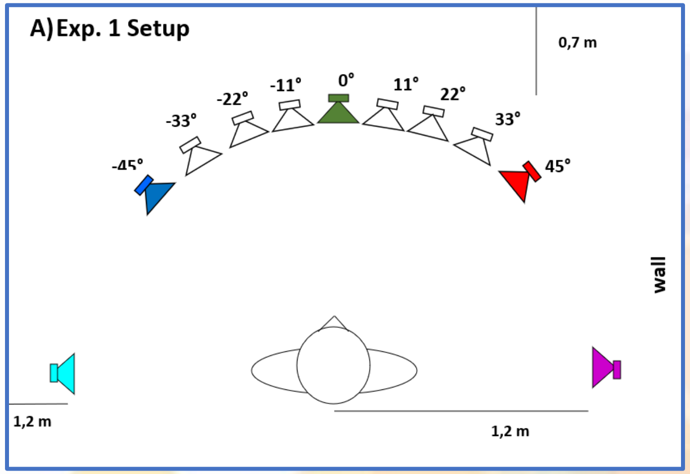
Exp 1 & 2

- Use left-right symmetric setup (previously single quadrant)
- Mechanism of CP

Previous studies:



Current experiments:



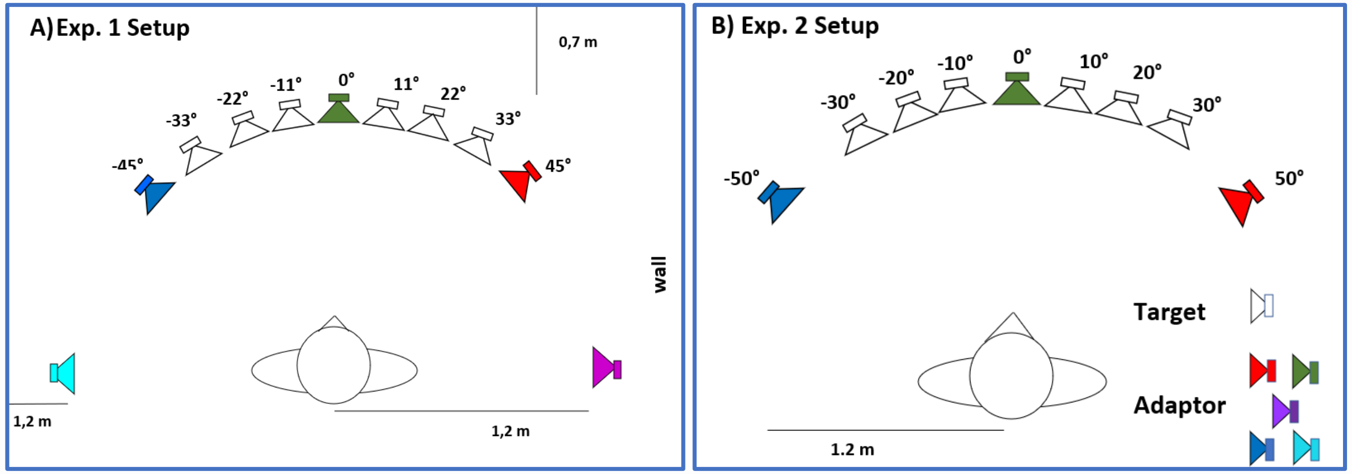
Experimental Setup and Stimuli

Experiment 1 (panel A)

- real midsize reverberant room, 6 target speakers, 5 adaptor speakers

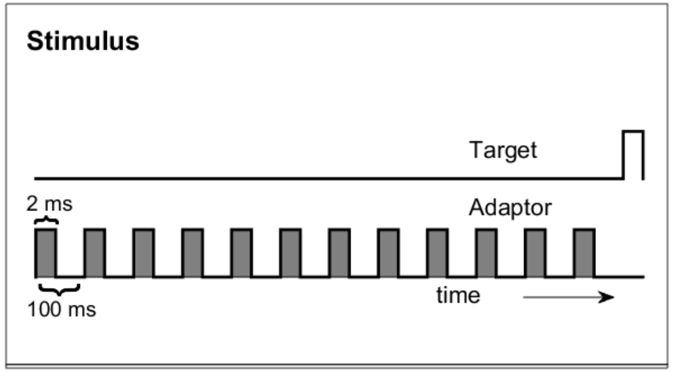
Experiment 2 (panel B)

- virtual midsize reverberant or anechoic room, 6 targets spkrs, 3 adaptor spkrs
- Non-individualized HRTF/BRIRs



Stimuli

- Target (T): 2-ms frozen noise click
- Adaptor (A): train of 12 such clicks presented at rate of 10/sec



Experimental Methods

One run

- keeps adaptor position fixed
- divided into subruns (1 subrun = 1 stim presentation from all 6 target spkrs)
    - pre-adaptation (target-only, 2 subruns),
    - adaptation (target or adaptor in a **ratio 1:1,** 14 subruns)
    - post-adaptation (target only, 3 subruns)

One session

- one run for each adaptor position + (no adaptor) baseline

Experiment

- 3 sessions, each with randomized order of runs

Hypotheses, Predictions and Evaluation

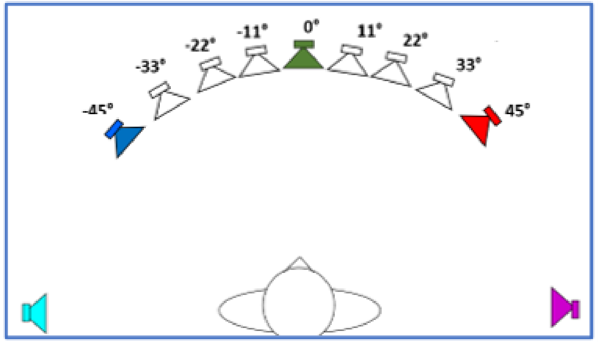
Experiment 1

- HYPOTHESIS H1:
  CP is mainly caused by adaptation to the distractors/adaptors, independent of their role in the listener's task. → CP will be observed when the listener only passively listens to the context.

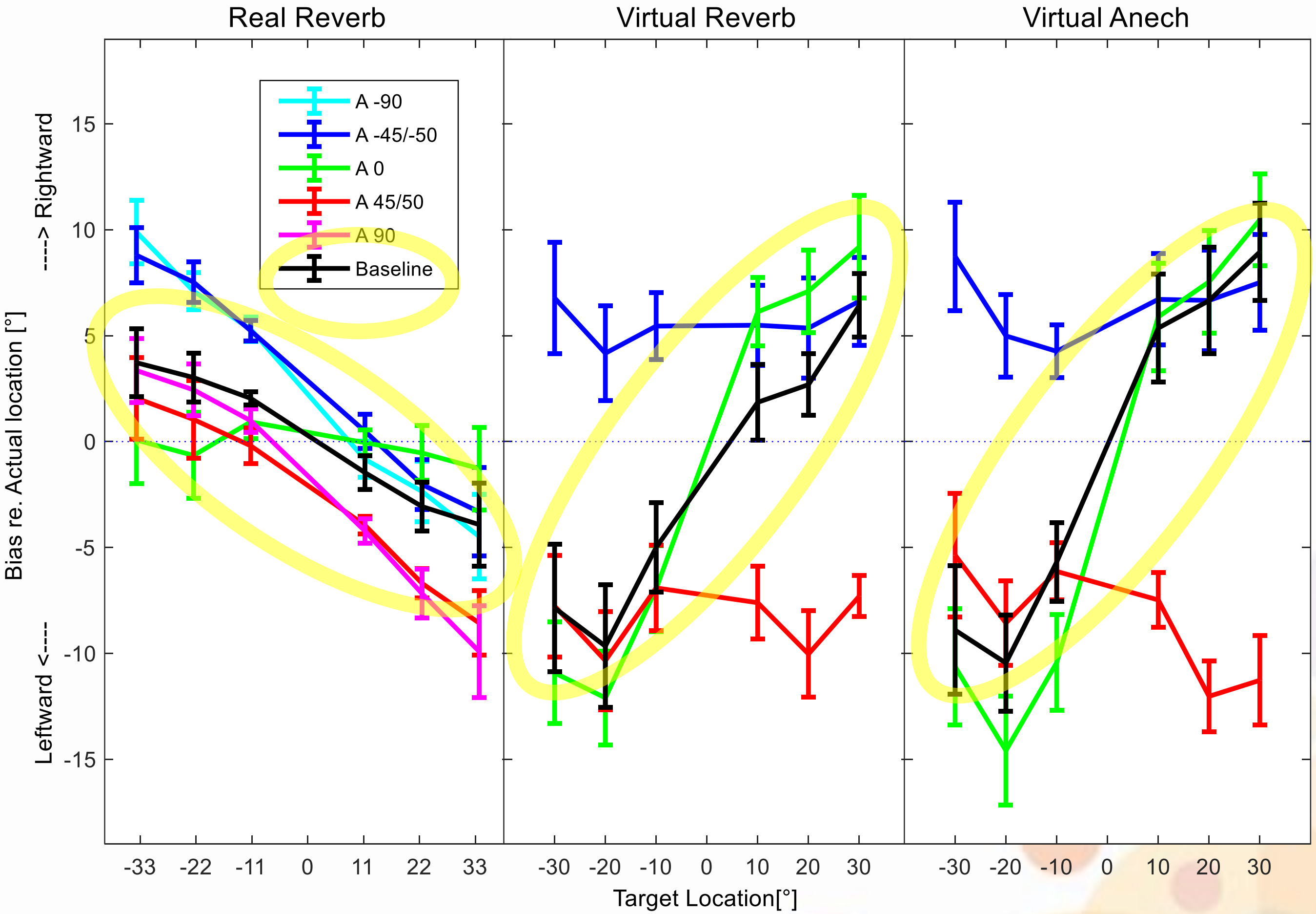
Experiment 2

- HYPOTHESIS H2**: CP might be observed in virtual environment, and it would be stronger than in Exp. 1 (real environment), as no anchoring of stimuli as objects in real world is available to calibrate perception.**

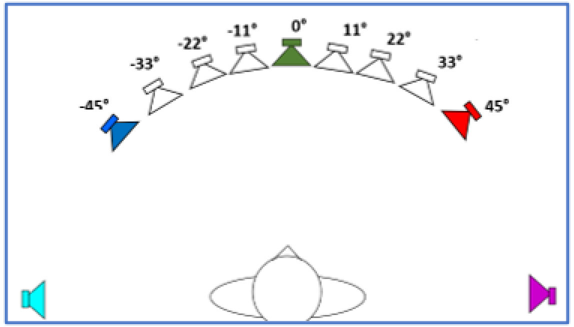
Results: Bias re actual location



- in baseline, **compression in real** and **expansion in virtual** environments
- depend strongly on adaptor location
  - Exp. 1: Adaptor x Target interaction ($p < 0.001$)
  - Exp. 2: Adaptor x Target x Env. ($p < 0.001$)



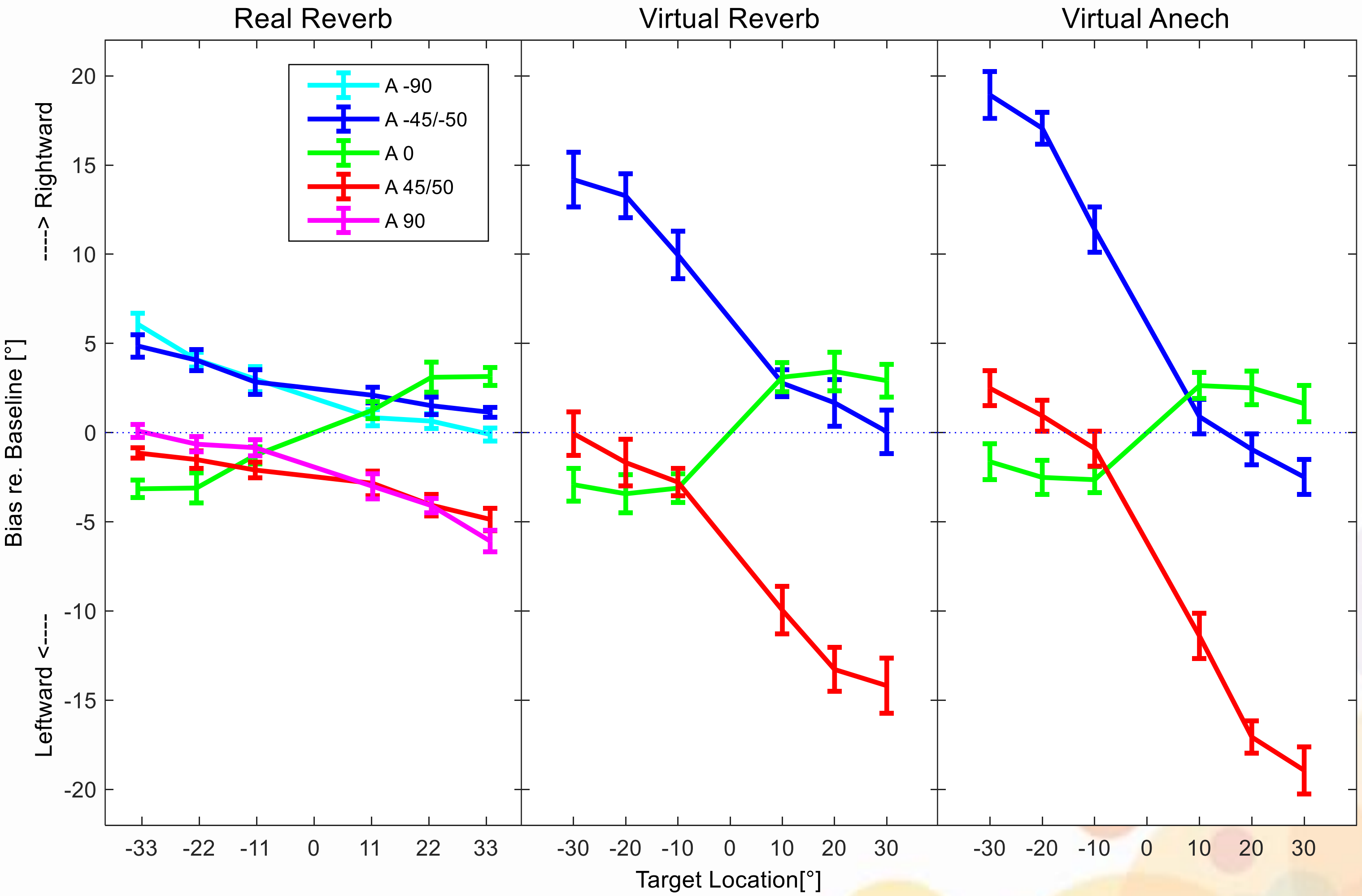
Results: Bias re. Baseline



(data mirrored assuming left-right symmetry)

- Bias away from adaptor
- stronger for lateral adaptors than frontal
- lateral (but not frontal) stronger in virtual than real environment
- stronger in virtual anech than in virtual reverberant

Contextual bias induced by adaptors PASSIVELY, and ALSO IN VIRTUAL ENVIRONMENTS



Mechanism of CP / LA

Two candidate mechanisms have been proposed to explain **localization aftereffect** phenomena similar to CP:

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

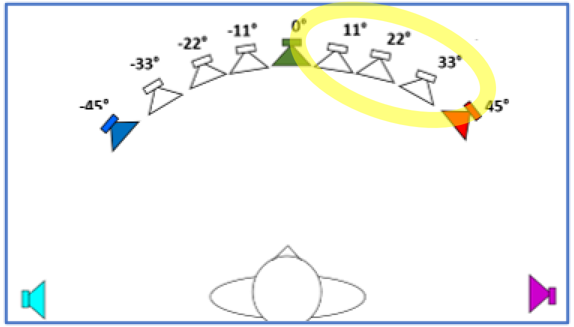
Predictions for location discrimination performance after adaptation:

- **Carlile: worse for targets** near adaptor (vs. far from adaptor)
- **Lingner: better for targets** near adaptor

Predictions about mechanism underlying CP:

- HYPOTHESIS H3: **Localization discrimination will be worse for target near adaptor (Carlile),** as suggested by previous CP results

ITR, Correlation and Std. Dev. Analysis Methods



Information Transfer Rate and Pearson's Correlation Coefficient:

- Targets divided into triplets of 3 right-most targets and 3 left-most targets
- ITR: for each triplet, ITR computed as an overall measure of performance
- Correlation: Responses for each triplet correlated with real positions within a run

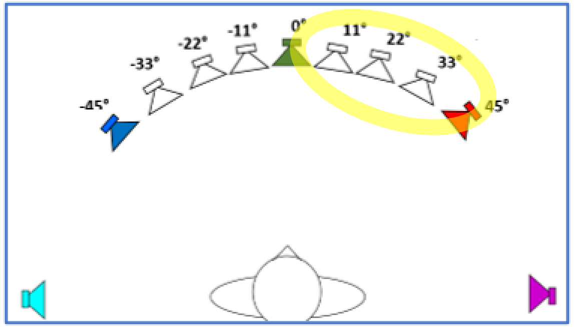
Variance:

- Std. dev. computed separately for each combination of session, target, run and subject; then averaged across target triplets

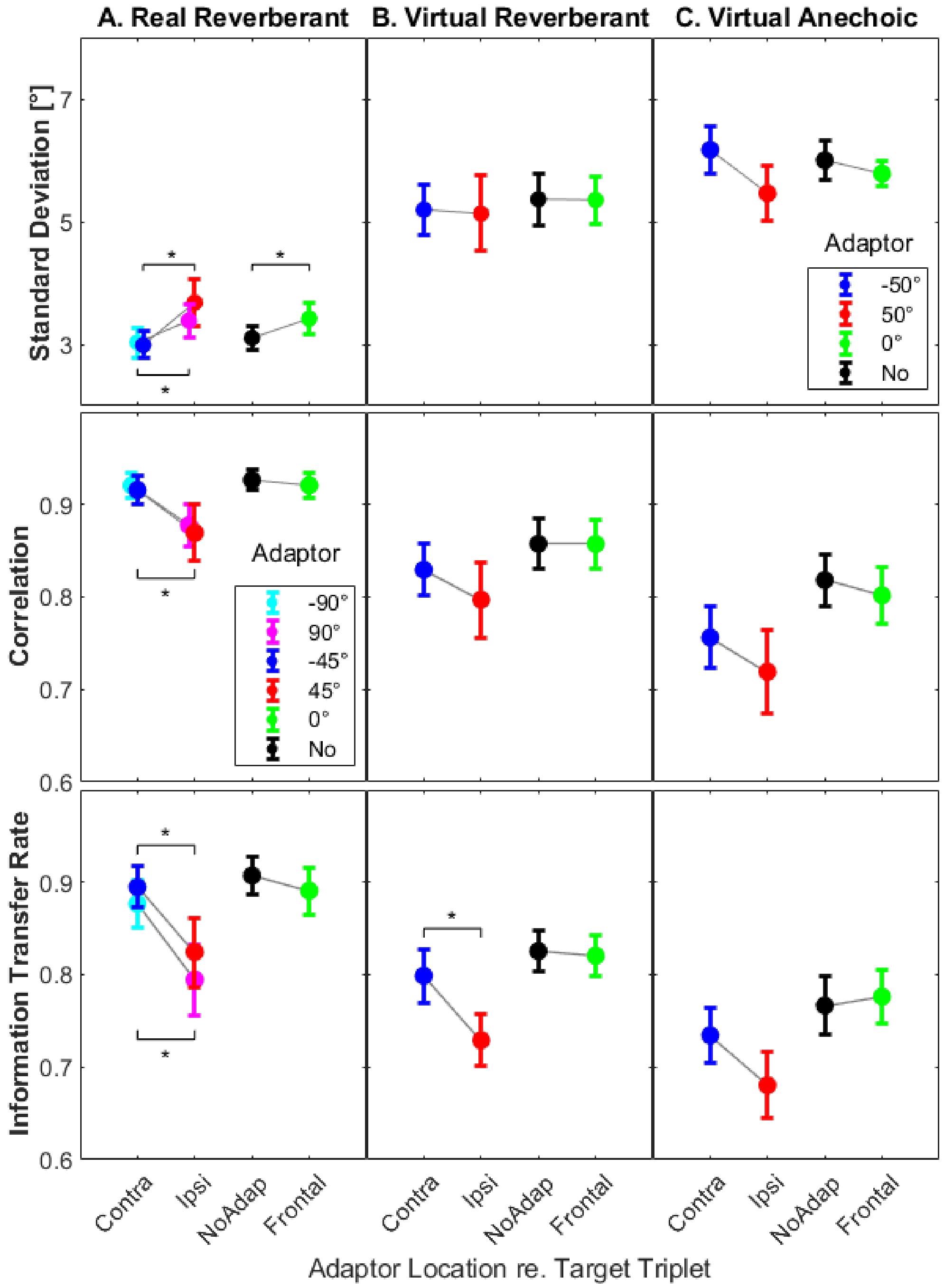
Results combined across left-right symmetric positions, e.g.:

Ipsi: -90° A & left triplet combined with +90° A and right triplet

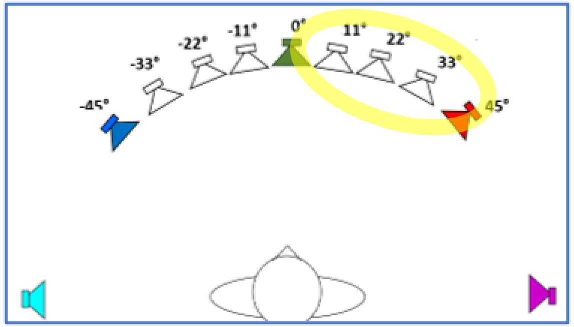
Results: St. dev, Pearson's R, ITR



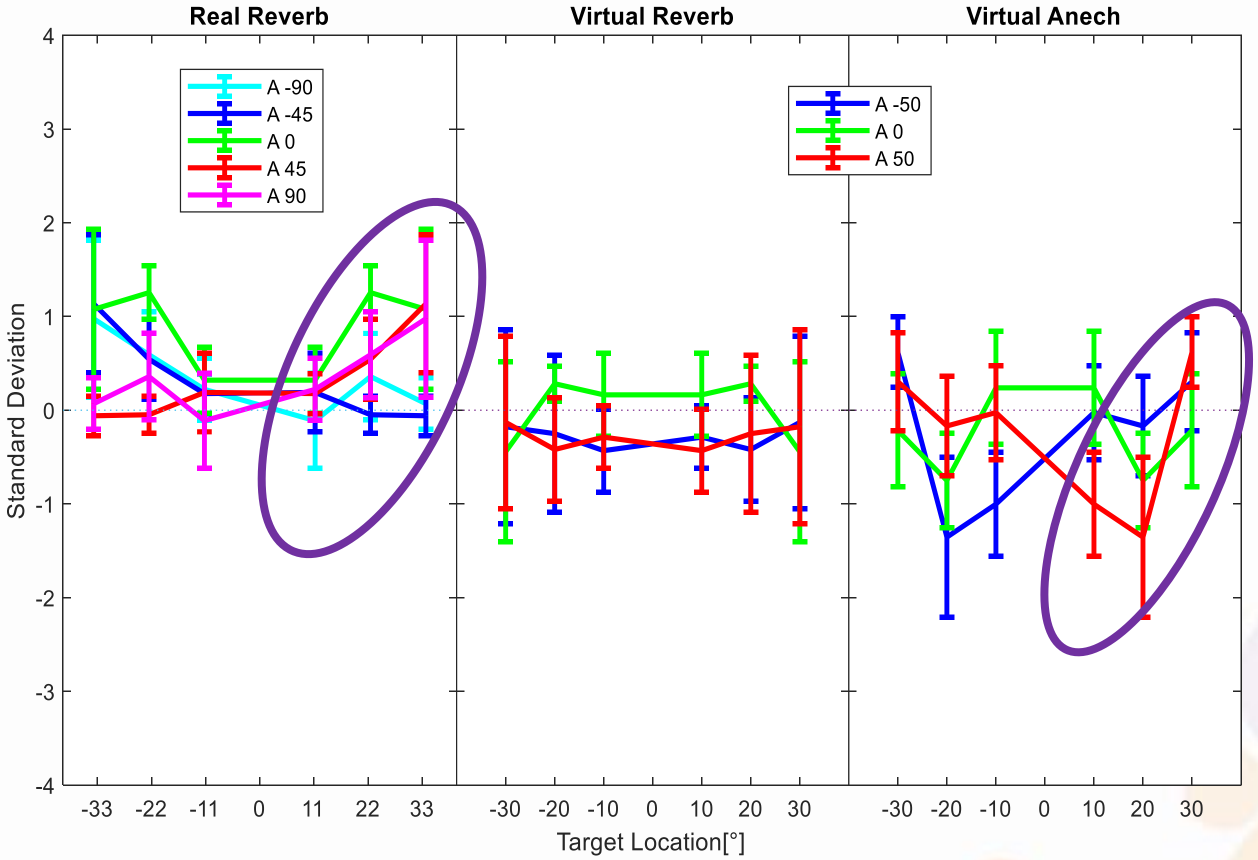
- Overall, performance better in RR than VR than VA
- ITR most sensitive measure, then CC, std. dev not always consistent
- better for targets far (contralateral) than near (ipsilateral) re. lateral adaptor
- Mostly better without than with frontal adaptor
- **consistent with Carlile's model**



Results: Standard Deviations



- increases for target triplet near adaptor in real reverb ($p < 0.05$)
- no significant effect in virtual reverberant
- trend for effect in virtual anech, such that standard deviation increases near adaptor and decreases further away ($p = 0.09$)
- **more consistent with Carlile's model (however, Virtual Anech might support Lingner)**



Conclusions and Discussion

Passive exposure to adaptors is sufficient to induce CP

- CP similar to LA; contribution active task performance / strategy still possible

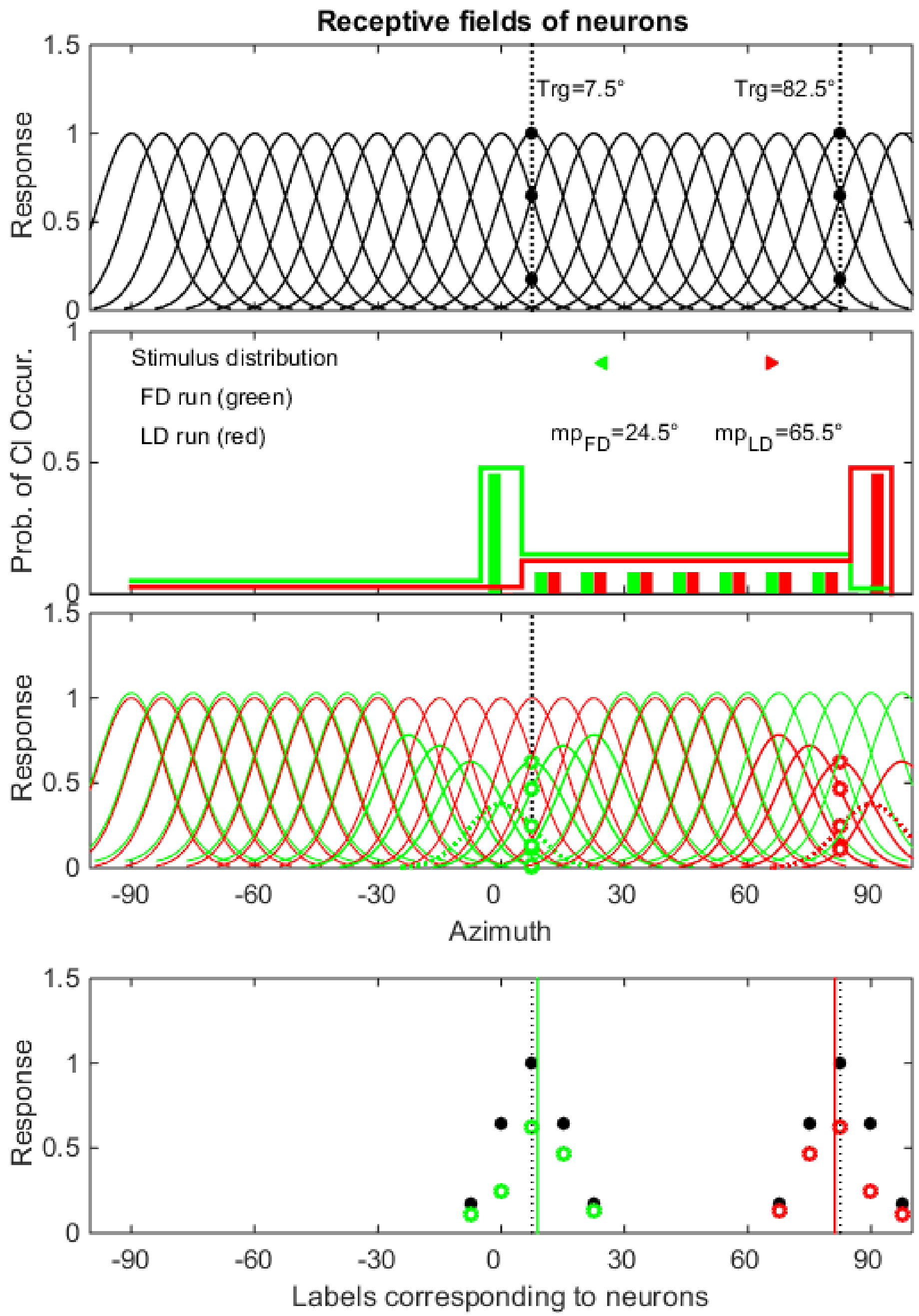
CP observed also in virtual environment;
- it is SOMETIMES stronger in virtual than real environment (Also slightly stronger in anechoic than reverberant virtual environment.)

- less certainty about the virtual environment
- using relative vs. absolute localization strategies, interpreting adaptor as an anchor and responding relatively to it

ITR, correlation and response standard deviations increase near adaptor -> performance after adaptation is worse near adaptor -> localization, not segregation

However, in virtual anechoic environment st.d. has some tendency to improve for targets near (but not immediately neighboring) the adaptor (Lingner et al., 2018):

ITR a good candiate as a novel **overall performance measure** in localization tasks

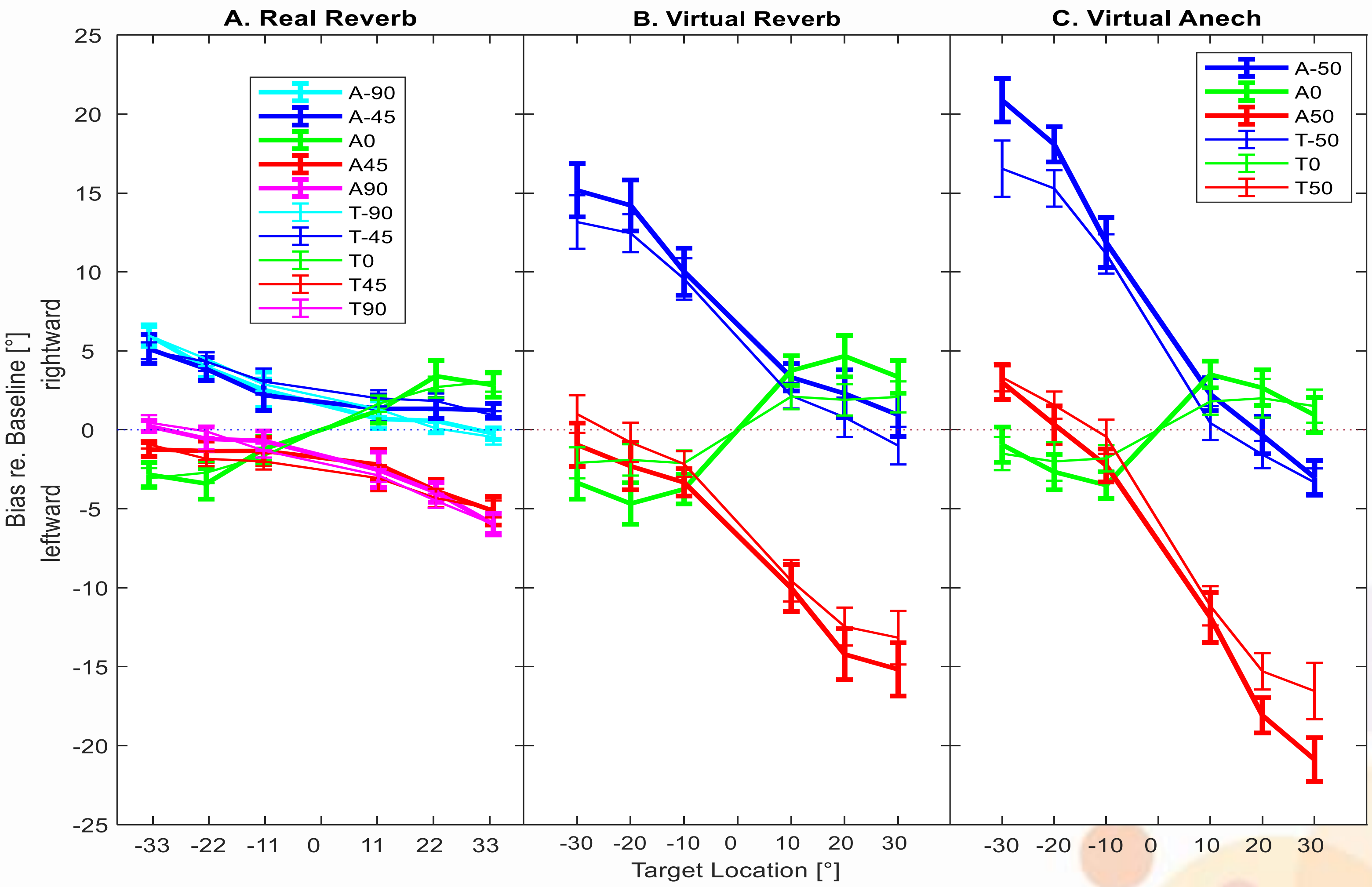


Receptive fields of neurons
Trg=7.5°
Trg=82.5°
Response
Stimulus distribution
FD run (green)
LD run (red)
mp_{FD}=24.5°
mp_{LD}=65.5°
Prob. of CI Occur.
Azimuth
Labels corresponding to neurons

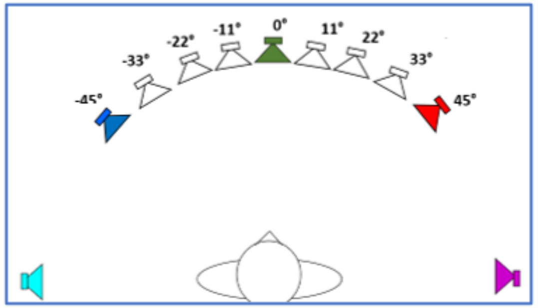
Results: Bias Dynamics on a Short-Time Scale

Effect of immediately preceding trial type (Adaptor or Target) on target localization:

- no effect in real reverberant env. ($p > 0.09$, panel A),
- **bias larger for trials preceded by adaptor** in both **virtual environments** and both adaptor locations ($p < 0.05$, panels B & C)
- quick adaptation - 5 sec



Results: Build-up of Bias



- run duration **12 minutes**
- very slow for the frontal adaptor in all environments
- ipsilateral adaptor:
  - fastest in virtual anech
  - slower in virtual reverb
  - slowest in real reverb
- no clear pattern for contralateral adaptor