Modeling the temporal profile of contextual plasticity

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ABSTRACT

Contextual plasticity (CP; Kopčo et al., 2007) is a form of spatial auditory plasticity observed in localization experiments in which distractor-target click pairs with a fixed distractor location (the context) are interleaved with target-alone trials. CP is observed as biases in localization of the target-alone clicks of up to 10° in the direction away from the distractors (which not presented on these trials). This adaptation is on the time scale of seconds to minutes. Here we present and analyze the build-up of CP using linear and exponential models. The models are fitted to data in which distractor location (frontal vs. lateral), context distractor type (single click vs. multiple clicks), target location (near vs. far from distractor), and environment (anechoic vs. reverberant) are manipulated. The linear models describe the data as a combination as a fast onset adaptation followed by a slow drift in responses. The modeling results show that the contextual plasticity depends on all the evaluated factors, and that the fast and slow components are affected differently by the factors. Thus, contextual plasticity is likely a result of a combination of multiple adaptive processes on different temporal scales.

BEHAVIORAL DATA (Kopčo et al, 2007, 2017)

Methods

Stimulus and setup:

Target click presented from a random loudspeaker (Fig. 1).
On most trials, a "distractor" click preceded the target.
Distractor location – frontal or lateral to a subject.
On no-distractor trials, the target was presented alone.
Distractor type and distractor-target Stimulus Onset Asynchrony (SOA):

- **Experiment 1 (Kopco et al., 2007):** 1-click; 25, 50, 100, 200, or 400 ms.
- **Experiment 2 (Kopco et al., 2017):** (1-click or 8-click) x (50 or 200 ms. Inter-click-interval in 8-click distractor: 100 ms.

Fig. 1.

Seven target loudspeakers and two distractor loudspeakers positioned in the subjects' right (or left) frontal quadrant (see Fig. 1).
Seven normal-hearing subjects in classroom (four in anechoic space).

Experimental procedure

Each experiment in two different environments: reverberant classroom (CL, background noise of 40 dBA) or anechoic space (AN).
Runs blocked by distractor location (frontal or lateral) and listener orientation (left or right quadrant).
Four 1-hour sessions per experiment per subject.
Each session had 4 runs of 168-trials (random order) in Experiment 1 (Exp 1) and 144 trials in Experiment 2 (Exp 2).

Data Analysis

Assumed left/right symmetry - data collapsed across orientation. Outliers lying 70° and more from a the target were removed. For each combination of parameters, across subject mean response on no-distractor trials was calculated (distractor trials were not considered here).

Results

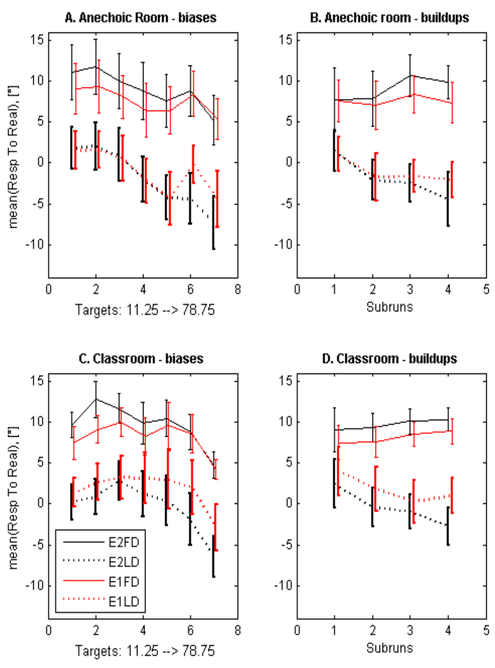

Fig 2. Response bias in no-distractor control trials for all seven targets (A and C panels). Response buildups in four subruns (panels B and D).

In both Experiments and both rooms, Fig. 2, panels A, C, no-distractor responses are shifted

- frontally in lateral-distractor runs,
- laterally in frontal-distractor runs.

In both rooms,8-click distractor causes larger shifts for nearby sources. Black lines (Exp2) are

- above red lines (Exp 1) at left-hand side for frontal distractor,
- below red lines at right-hand side for lateral distractor,
- similar shape of biases for frontal 3 targets (11, 22.5, 34 °) in comparison of Experiments and lateral 3 targets (56, 67.5, 79 °)

Bias grows over time (followed by subruns)

- more for lateral distractor than frontal distractor data (Fig. 2, panels B, D)
- In the anechoic room, onset is similar for both experiments, but biases are higher in the last subruns for Exp 2
- In the classroom, onset is higher by the same value in Exp 2
- 5-way RM ANOVA *(Experiment, Room, Target, Subrun, Distractor),* performed on difference (Responses to Target) data found:
  - **Significant 4-way interaction of Experiment x Room x Subrun x Distractor ($F_{3,9}$=4.84, p=0.0285 **)**
  - **Significant 2-way interaction of Experiment x Target ($F_{6,18}$=6.19, p=0.0012 ***)**

MODELING – DATA PREPROCESSING

Only 4 repeats of all combinations of targets x conditions were performed within run in the original study -> runs divided into 4 subruns -> poor temporal resolution (Fig. 2B,D).
Similar values of biases for frontal three targets (11 – 34°) and for lateral three targets (56 – 79°) especially when comparing the effects of Exp 1 to Exp 2 (Fig. 2A,C).
Data recoded by combining across target triplets, increasing temporal resolution -> 12 subruns (Fig 3) while only considering two target locations (triplets, referred to as T123 and T567).

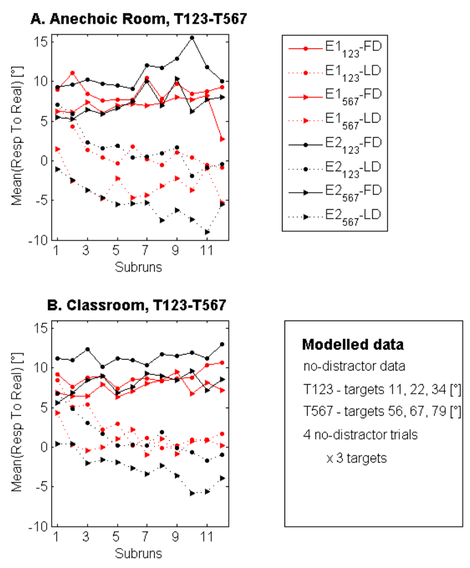

Fig. 3. *Recoded behavioral data – temporal profile of CP buildup for 12 subruns after collapsing target locations across the medial triplet (123) and lateral triplet (567).*

Results (Fig 3):
No-distractor baseline run data not available -> initial offset as well as drift can only be compared for frontal vs. distractor run data.

Frontal data (solid lines):

- linear across 12 subruns -> likely onset bias that's finished building up by subrun 1, followed by a linear drift that is either constant or growing,
- similar across target locations and rooms, mostly differing by vertical offset.

Lateral data (dotted lines):

- slow initial buildup (subruns 1-3), followed by linear drift that's constant or decreasing,
- similar across target locations and rooms, mostly differing by vertical offset.

Modeling (next sections):
Approximate the data from Fig. 3 by using a:

- linear, or
- combined linear and exponential model.

Analyze how the fitted model predictions to identify early (onset) and late (drift) components of CP.

MODELING - LINEAR

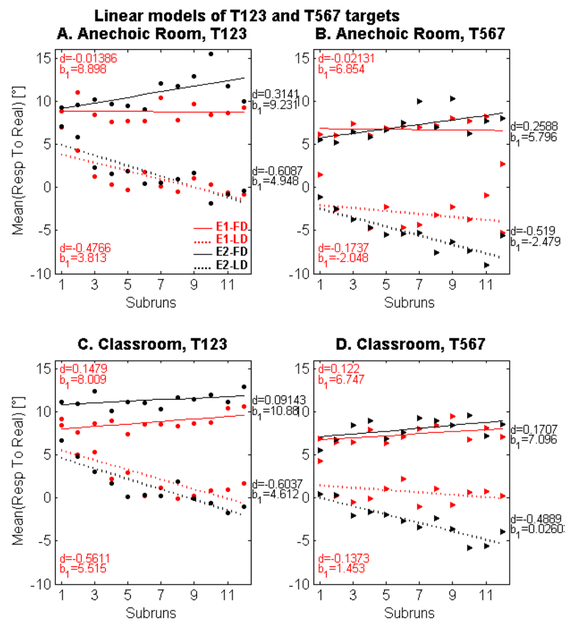

Fig. 4*. Linear models fitted to the 12-subrun data from Fig. 3 Lines represent across-subject mean of individually fitted models (inset parameters b & d). Symbols represent across-subject mean data.*

Linear model $y = dx + b$

- *d* and *b* are fitted params, *x* is subrun no.
- fitted separately to each type of data,
- evaluated for subruns 1 (representing fast onset of CP) and 12 (slow drift of CP).

5-way RM ANOVA with factors Experiment (1, 2), Room (AN, CL), Target (T123, T567), Distractor (Frontal, Lateral), and Subrun (1, 12) performed on 4 subjects found:

- **Significant interaction Experiment x Room x Distractor x Subrun ($F_{1,3}$ = 10.45, p = 0.048)**
- **Significant interaction Experiment x Target ($F_{1,3}$ =19.75, p=0.021)**

Separate partial ANOVAs performed for AN (4 Subjs) and CL (7 Subjs) data found significant interactions:

- CL: Dist x Subr, Exp x Targ, Exp x Dist.
- AN: Dist x Subr, Exp x Targ.

Results:
CP stronger in Exp 2 than Exp 1

- only for sources near distractor,
- for both distractors (black vs. red),
- with different temporal profile in AN vs. CL:
- in AN, difference only in drift, onset equal,
- in CL, difference present from onset.

CP stronger in AN than CL

- only for sources near distractor,

MODELING - LIN AND EXP COMBINED

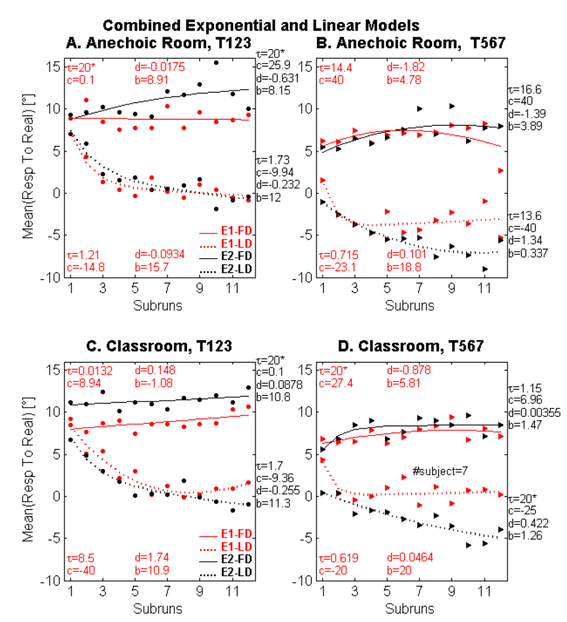

Fig. 5*. Combined models fitted to the 12-subrun data from Fig. 3. Lines represent across-subject mean of individually fitted models (inset parameters b & d). Symbols represent across-subject mean data.*

Linear & exponential model

$$y(x) = c\left(1 - e^{x/\tau}\right) + dx + b$$

where *c, τ, d, b* are fitted params, *x* is subrun no.

- Fitting problematic since pre-adaptation baseline not known.
- Fitting does not converge for individual subject data -> **statistical analysis based on individual data not possible**.

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CONCLUSIONS AND DISCUSSION

Increasing temporal resolution of CP data can be achieved by sacrificing spatial resolution.
Temporal analysis can be simplified by looking at onset and late components from linear fit.
A complex pattern of interactions of examined factors on CP was observed::

- CP is stronger in AN room and stronger and slower to asymptote with multi-click distractor (Exp 2),
- CP drifts linearly for frontal distractors, exponentially for lateral ones.
- CP depends on proximity of targets to distractor – it is stronger and sensitive to multi-click distractor only for nearby targets.

Future directions:

- Polynomial model of 2nd or 3rd order.
- Fix tau in exponential component of combined model.
- Only look at Front Distractor – Lateral Distractor difference for exponential modeling.
- Measure baseline during pre-adaptation and adaptation.