Buildup of Contextual Plasticity in Sound Localization

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1. ABSTRACT

Contextual plasticity (CP) is a form of plasticity in sound localization induced by preceding stimulation. CP is observed as shifts in responses to a click stimulus when, on interleaved trials, the target click is preceded by an identical distractor click coming from a known location. This study examines temporal properties of CP by analyzing behavioral data from two previous experiments [Kopčo, Best, Shinn-Cunningham (2005), ARO Abstract #965; Tomoriová, Kopčo and Andoga (2010), ARO Abstract #827]. In the experiments, the distractor type (single click, train of 8 clicks, or noise), consistency (distractor type fixed within block vs. varying from trial to trial), and location (frontal vs. lateral) were manipulated. The results show that contextual plasticity buildup duration depends on the distractor location. Also, the buildup was stronger with 8-click distractor than 1-click distractor. When distractor type varied, the context type on immediately preceding trial influenced performance in the middle of the run, such that trials following an 8-click context exhibited shifts up to 5° larger than the trials following a 1-click context. No such bi-stable percept was observed in other parts of the run. These results show that CP has complex temporal profile on time scales of seconds to minutes.

2. INTRO

Kopčo et al. (2007)
- examined the effect of immediately preceding *distractor* on target localization,
- for 2-ms noise burst targets, preceded on most trials by identical distractors coming from frontal or lateral speaker (fixed within block),
- varied SOA trial-by-trial, no distractor on 16.6% of trials.

Results:
Shifts in responses
- even in no-distr. trials (open circles in Fig. 1),
- always away from distractor,
- due to the context of distr. trials → **Contextual plasticity (CP)**

CP (computed as difference between FrontDist and LatDist contexts)
- independent of azimuth,
- in anechoic and reverberant environments,
- grows on timescale of 3-4 minutes,
- no baseline → absolute effect size not clear.

Current study:
Analyze Kopčo et al. (2007), Kopčo et al. (2015), Hládek et al. (2016), Andrejková et al. (2015) data to:
- **characterize temporal properties of CP,**
- **identify mechanism(s) of CP.**

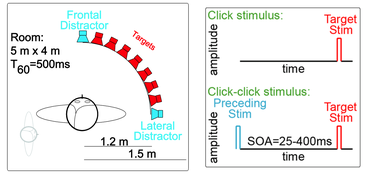


Fig. 1. Experimental setup and stimuli (top row), raw data (middle row), and contextual bias (bottom row) from Kopčo et al. (2007)

3. Vision, motor control, and top-down factors (Kopčo et al., 2015)

Goal
- examine influence of vision, response method / motor transformations, and top-down factors on CP,
- examine spatial and temporal properties of CP w.r.t. actual baseline.

Methods
Same as Kopčo et al. (2007) except:
- only frontal distractor used,
- baseline runs with no distractor,
- context rate (proportion of dist. trials) 75%.
- Exp. 1 varied response method (fixed within run): Closed eyes & pointer, open eyes & pointer, keyboard; SOA = 25 ms,
- Exp. 2 varied contextual task difficulty: SOA = 400 ms (very easy), SOA = 400 ms and distractor presented after target.

Results:
Target-click-only baseline run:
- performance depends on availability of vision and motor response.

CP (computed re. baseline):
- independent of vision, motor control, task difficulty,
- strongest near distractor,
- even when target precedes distractor.

CP buildup
- Buildup within 1 min, much faster than in Kopčo et al (2007) (cf. Fig. 2 bottom to Fig. 1 bottom)

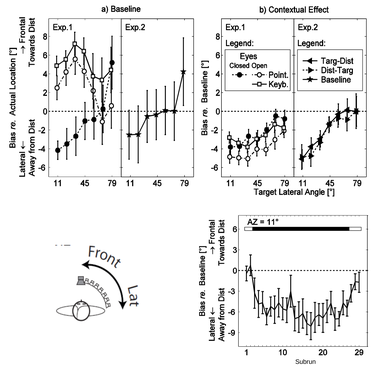


Fig. 2. Baseline performance (top left), contextual effect (top right), and buildup of contextual effect (bottom right).

CP buildup
- **much faster**
  - **when referenced to baseline,**
  - **when evaluated for FrontDist only.**

How is CP influenced by spatiotemporal distribution of distractors?

4. 1-click vs. 8-click vs. noise distractor (Hládek et al., 2016)

Goal
- examine influence of temporal distribution of context stimuli on CP,
- examine influence of distractor-target similarity on CP.

Methods
Same as Kopčo et al. (2007) except:
- only frontal distractor used, baseline runs,
- Exp. 1 varied
  - context rate (prop. of dist. trials) 50, 75, 90%,
  - SOA: 25, 100, 400 ms.
- Exp. 2 varied temporal structure and type of dist.: 1-click, 8-click with ICI of 100 ms, noise with same duration and energy as 8-click, context rate 75%, SOA (effectively) 25 ms.

Results:
CP (computed re. baseline):
- Independent of SOA on context trials,
- grows slightly with context rate 75% vs. 50%,
- grows dramatically for 8-click distractor (i.e., when *effective* context rate 600%),
- almost no effect for noise with equal energy.

CP buildup (for frontal targets)
- fast with 1-click distractor,
- equally fast, but continues to grow with 8-click dist.

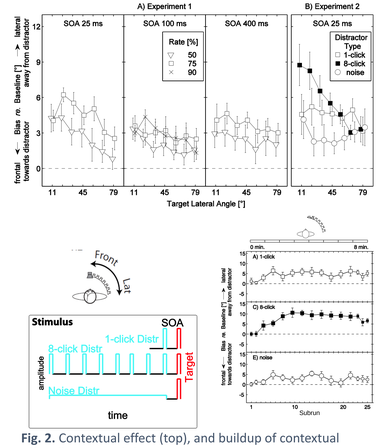


Fig. 2. Contextual effect (top), and buildup of contextual effect (bottom right).

CP buildup
- **depends on (spatio)temporal density of distractor clicks,**
- **continues to grow longer and is stronger for 8-click (re. 1-click), no effect for noise.**

5. CP with 1 & 8-click distractor mixed (Andrejková et al., 2015)

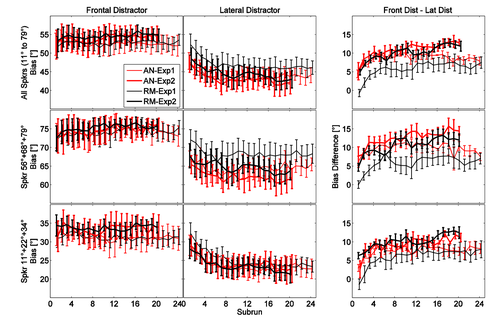
Fig. 4. Anechoic and Room data from Exp. 1 (Kopčo et al., 2007) and Exp. 2 (Andrejková et al., 2015), separated by distractor location (columns) and target region (rows).

Goal
- Examine buildup for FrontDist vs. LatDist, anech vs. reverb room, and 1-click vs. 8-click distractor.

Methods
Same as Kopčo et al. (2007), except:
- 1-click and 8-click distractor interleaved (*effective* rate 360%),
- distractor-trial data converted to CP by subtracting the effect of distractor (same for Kopčo et al., 2007 data),
- In Fig. 4, this is Exp. 2 (Kopčo et al., 2007 is Exp. 1).

Results:
CP buildup (FrontDist – LatDist; Fig. 4)
- depends on both environment and number of distractor clicks (top right; interaction $p < 0.05$):
  - continues to grow even after 5 mins with mix of 1-click and 8-click data,
  - difference larger in Room than Anech,
- is much slower for LatDist (mid column) than FrontDist (left column),
- dependence on dist. type and env. seems larger for targets at 56-79° (mid row) than 11-34° (bottom row) (interaction experiment x region, $p = 0.068$)

Fig. 5: Exp. 2 data separated by type of distractor on preceding trial (1-click, 8-click, NoDist):
- bias larger after 8-click trial than after 1-click or no-dist trial, uniformly across run.



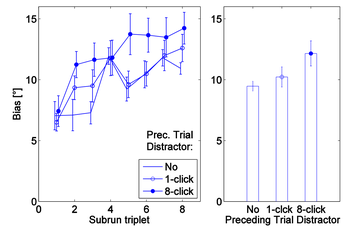


Fig. 5. Exp. 2 data averaged across rooms and separated by preceding trial distractor type.

CP buildup
- **strongly depends on distr. location,**
- **also depends on environment,**
- **effects stronger for lat. targets.**

Adaptation also visible on shorter time-scale of seconds / individual trials.

6. CONCLUSIONS AND DISCUSSION

CONTEXTUAL PLASTICITY

Contextual bias is sensitive to spatiotemporal distribution of distractor stimuli (CP induced by an 8-click distractor is stronger than that induced by a 1-click distractor), is stronger for lateral than frontal targets, and is larger in a classroom than in an anechoic room. Also, it is sensitive to similarity between stimuli, not just acoustic energy distribution.

CONTEXTUAL PLASTICITY BUILDUP

CP buildup takes longer to asymptote for a lateral distractor than a frontal distractor, and for contexts containing 8-click distractors than for 1-click-only distractor contexts. The buildup duration varies between less than 1 min and 5 mins. Despite that, it is visible even on trial-by-trial basis (the time scale of seconds).

POSSIBLE MECHANISMS

These results are consistent with a low-level adaptation mechanism sensitive to the spatiotemporal distribution of stimuli (Dahmen et al., 2010). Alternatively, the mechanism might be related to precedence-buildup since the stimuli (Djelani and Blauert, 2001; Freyman et al., 1991). Finally, it might be related to high-level mechanisms underlying streaming or the effects of expectation (Weintraub et al., 2014).
Importantly, a successful candidate mechanism must be able explain why the shift is always away from the distractor and why the frontal and lateral distractors have different effects.

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