Descriptive modeling for Contextual Plasticity in Sound Localization

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Abstract

Contextual plasticity (CP) is a form of plasticity in sound localization induced by context represented by preceding stimulation. It is observed as shifts in responses to a target click stimulus when, on interleaved trials, the target is preceded by an identical distractor coming from a known location. Here, we evaluate a model combining exponential and linear trends to describe the build-up of CP. The results show that CP occurs at least on two temporal scales, depending on the stimulus spatiotemporal distribution.

1 Introduction

Contextual Plasticity (CP) is a new form of spatial auditory plasticity exhibited by shifts of up to 10° in responses to single-click target stimuli in the horizontal plane [Kopčo et al., 2007, 2017]. These shifts occur when the target-alone probe trials are interleaved with *contextual* trials, in which the targets are preceded by a distractor with distractor-target inter-stimulus intervals (ISI) of up to 400 ms (typical setup and stimuli are shown in Fig. 1.). CP can build up on the time scale of seconds to tens of seconds. Previous behavioral studies showed that CP is influenced, e.g., by the type of room (Anechoic room - AR, Classroom - CR), location of distractor (frontal, lateral), number of clicks in the distractor (8-click, 1-click), ISI (50 – 400 ms) and the position of the target. A candidate mechanism underlying CP is neural adaptation of the cortical spatial representation to the statistics of the stimulus distribution [Dahmen et al., 2010].

CP is often assessed by computing the difference between target-alone responses in the frontal-distractor (FD) vs. lateral-distractor (LD) runs (note that the distractor is only presented in the contextual trials and is fixed within a run). This contextual bias difference measure of CP represents a combined effect of the frontal and lateral contextual effects acting in opposite directions. In previous studies, we examined the temporal profile of CP on a slow time scale of minutes [Kopčo et al., 2007, 2017] as well as on shorter time-scales of seconds/individual trials [Kopčo et al., 2016]. Here, a model of CP is proposed that consists of two additively combined adaptive processes: a faster one, modeled by an exponential adaptation, and a slower one, modeled by a linear trend. The model is fitted to describe the FD and LD data from Kopco et al. [2007, 2017].

2 Behavioral data

Details of the behavioral experiments are described in Kopčo et al., [2007, 2017].

2.1 Subjects, stimuli, and setup

The experiment was performed in AR and in CR. Stimuli and setup of experiments are shown in Fig.1. On each trial a single target click was presented, either alone or preceded by a distractor coming from an a priori known location. Subject responded by pointing in the perceived target direction.

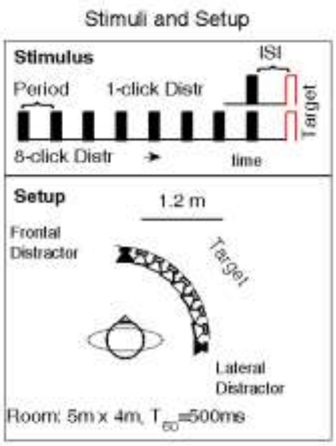

Fig. 1. Stimulus. The arrangement of preceding stimuli sounds (black filled rectangles and target sounds (the final rectangles in the sequences) in contextual trials (no distractor preceded target in probe trials). **Setup.** Diagram of listener loudspeakers positions and a listener's orientation in the classroom. The same setup was used in the anechoic room.

2.2 Data analysis

Kopčo et al. [2017] observed build-up of CP evaluated as the difference between responses in the FD vs. LD distractor runs. Here we focus on how this bias build-up changes over time when assessed separately for the

FD and LD runs. To increase temporal resolution of analysis, distractor-trial responses were also included after subtracting off the effect of the distractor (assuming this effect operates on a much shorter time scale), and by treating the data as no-distractor-trial data. This modification resulted in a 4-fold increase in sampling. The data are shown in Fig. 2A.

3 Modeling

The main goal of modeling was to assess whether the early buildup of CP depends on the distractor location.

3.1 Descriptive model for CP

Individual mean responses (averaged across loudspeakers) were fitted by the following function

$$f(x) = c * \left(1 - \exp\left(-\frac{x}{t}\right)\right) + d * x + b \qquad (1)$$

where *c, t, d* are fitted parameters, *b* is chosen as described below, and *x* is the subrun number (each run was divided into 20 subruns).

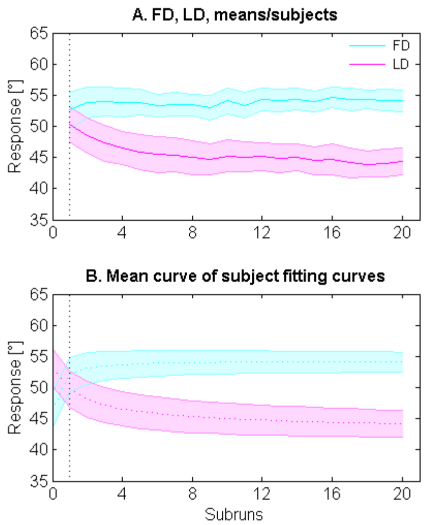

Fig. 2. In panel A, there are shown means FD and LD data across all subjects together with Std. In panel B it is shown the mean curve of subjects fitting curves together with Std.

A critical parameter for the estimation is parameter *b* representing the initial value of response bias which was not measured (corresponding to subrun 0 in Fig. 2). It was chosen as follows: it was the mean across rooms and target locations of the responses in the first subrun which was (a) for the FD fitting curve increased by the standard deviation of lateral responses in the first subrun, and (b) for the LD fitting curve lowered by the standard deviation of the frontal responses in the first subrun. Parameter *d* represents the slow, linear adaptation, *t* is the rate of the exponential adaptation, and *c* its size.

3.2 Results

The across-subject means and standard deviations of the fitted parameters for the two distractor locations are given in the Tab. 1. Fig. 2B shows the predictions of the model for these parameter values, which are in agreement with the behavioral data (Fig. 2A). Statistical evaluation of the models using mixed modeling showed that parameters *t* and *c* differed significantly for the model fits of FD vs. LD data.

Par.	FD	Std FD	LD	Std LD
t	0.7056	0.3695	2.6949	0.9267
c	7.7949	1.7884	-8.2715	0.6419
d	-0.0065	0.0578	-0.0424	0.0563
b	46.4124	2.8064	53.2080	2.9466

Tab. 1. The values of parameters t, c, d, b for the approximating curve by formula (1). FD column is for the frontal and LD column for the lateral distractor curve.

4 Summary and general discussion

The main result is that the estimated value of t is larger, i.e., that adaptation is slower, for LD data than for the FD data (the model predictions are shown in Fig. 2B). This means that the neural spatial representation initially adapts faster in response to frontal stimuli compared to the lateral stimuli. Thus, the location of the distractor might influence not only the size of the adaptation, but also its rate. However, this result is critically influenced by the choice of the parameter *b*, which needs to be further examined.

Acknowledgement

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