PS-656

Evaluating the time course of binaural sensitivity using stimuli that mimic cochlear implant processing

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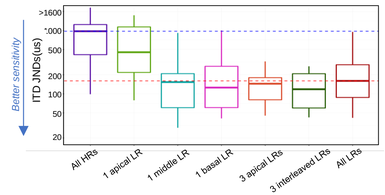
INTRODUCTION

- **Interaural timing differences (ITDs)** are important for sound localization and speech unmasking in multi-talker environments
- **Cochlear implant (CI)** processors use high stimulation rates which are important for good speech encoding, but reduce ITD sensitivity[1]
- Mixed-rate stimulation has been proposed as a means of resolving this tradeoff
  - Fixed rates are used at each individual electrode but **high rates (HRs)** and **low rates (LRs)** are mixed along the electrode array
  - Thakkar et al. (2015) tested ITD just noticeable difference (JND) thresholds using different mixed-rate configurations across five pitch-matched electrode pairs:[2]

Figure 1. *Introducing a single or three LR pairs improved sensitivity from the all HR condition, whether the LRs were added beginning basally, apically, or centrally.*



- Eye gaze data provides information about ITD processing beyond absolute threshold, such as perceptual speed and certainty,[3] which may provide a fuller picture of differences between these configurations

The aim of this study is to determine the optimal number and location of low-rate channels for conveying ITD cues using a mixed-rate configuration.

Hypotheses:

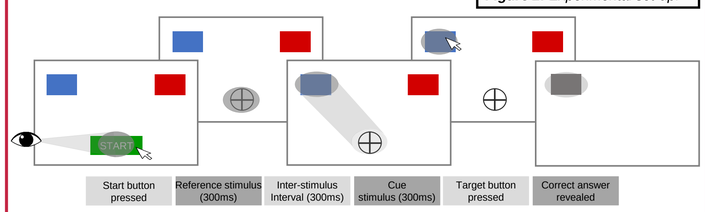
Both processing time and uncertainty will reduce with increasing ITD saliency by:
(1) Increasing ITD size
(2) Adding LR chanels to a mixed-rate configuration

METHODS

Participants: Twelve NH adults (ages 18-30 years)
- The study was performed in NH listeners using stimuli which mimic CI processing to control for variability in bilateral CI users

ITD discrimination task:
- Eye gaze and mouse-click data were collected simultaneously to obtain information about the time course of ITD processing and sensitivity, respectively
- At the beginning of each trial, participants used a mouse to click a start button which triggered the display of a fixation cross and the stimulus playback
- Each trial consisted of two stimulus intervals, the first with a 0 µs ITD and second with a left- or right-leading ITD
- Listeners indicated whether they heard the sound move to the left or right by shifting their gaze to one of two target buttons and clicking one of them once a decision was made
- Method of constant stimuli with randomized ITD presentation was used

Figure 2: *Experimental set-up.*



- A psychometric function was fitted to the mouse-click data to obtain a **just-noticeable difference (JND)** at 70.7% correct[4]

Model for comparing eye gaze data

- The discrimination task was first performed using a transposed tone stimulus (4k Hz center frequency, 128 Hz modulation rate) to serve as a well-established reference for interpreting the gaze data
- ITDs tested = ±30, ±60, ±90, ±120, ±150, ±180, ±210 µs (subset presented for clarity)

Fitting eye gaze data for transposed stimuli

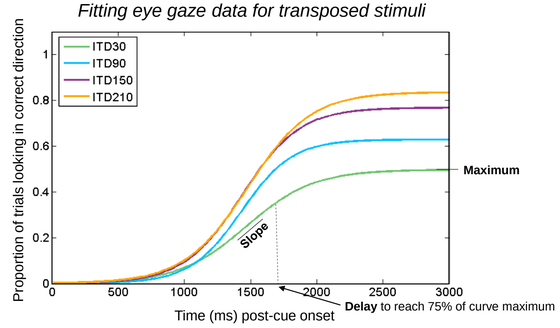


Figure 3. *Curves fit to aggregated eye gaze data. Examples of points corresponding to the different model parameters are shown for an ITD of 30 µs (green curve).*

Fitting Equation

$$\frac{\text{maximum}}{1 + e^{-\text{slope}(\text{time} - \text{delay})}}$$

Maximum = overall percent correct
Calculated from click data

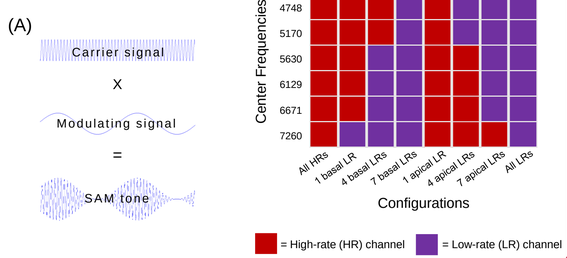
Model parameter estimates
(A) Delay = processing time to reach 75% curve maximum
Time it takes for gaze to be in the correct direction on 75% of correct trials

(B) Slope = increase in proportion correct per 100 ms
Uncertainty and poorer overall performance will decrease slope

Mixed-rate simulation

Stimulus:
- **Sinusoidal amplitude-modulation (SAM)** was applied to a complex of eight sine tones with fixed center frequencies between 4 and 7.3 kHz (**Figs. 4a-4b**)
- 1000 Hz SAM for **HRs** and 100 Hz SAM for **LRs**
- ITDs tested = ±50, ±100, ±150, ±200, ±250, ±300, ±350 µs (subset presented in **Fig. 4b** for clarity)

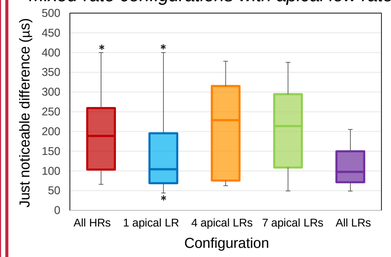
Figure 4: *(A) Example of sinusoidal amplitude modulation of a sine tone. (B) Fixed- and mixed-rate configurations tested.*



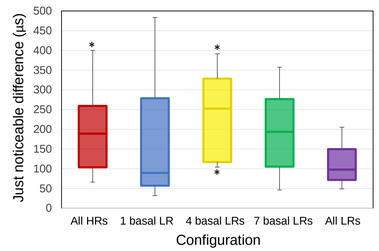
RESULTS

Click data: ITD JNDs

Mixed-rate configurations with apical low rates



Mixed-rate configurations with basal low rates

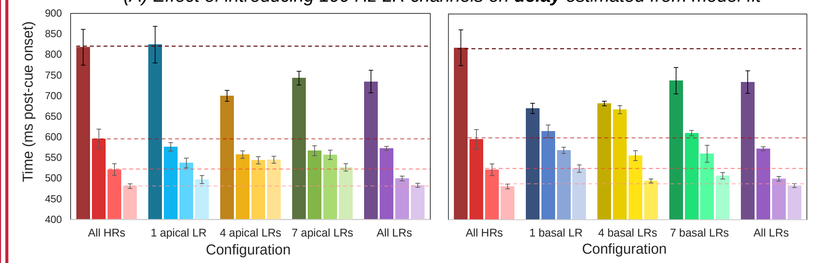


- Only the "All LRs" configuration had significantly lower thresholds than the "All HRs" configuration (p=0.022)

Figure 5: *Group JNDs for two fixed-rate (All HRs and All LRs) and six mixed-rate configurations. Center lines represent the median JND and upper and lower boxes, the first and third quartiles, respectively. Asterisks indicate subjects for which a reliable JND could not be found with the ITDs tested (i.e. threshold >400us or <50us).*

Gaze data: model parameter estimates

*(A) Effect of introducing 100 Hz LR channels on **delay** estimated from model fit*



- Increasing ITD size generally reduced delay in all configurations
- Processing delay in the "All LRs" configuration was consistently lower than the "All HRs" for all ITDs (follow reference lines)
- For some ITDs, introducing LR channels improved processing delay compared to the "All HRs" configuration

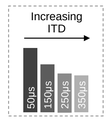
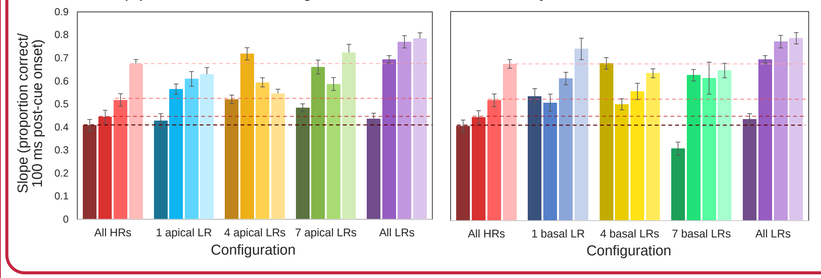


Figure 6: *Offset (A) and slope (B) parameter estimates from group eye gaze data. In each configuration cluster, ITD size increases as colors become lighter (i.e. from left to right) from 50 to 150 to 250 to 350 us.*

*(B) Effect of introducing 100 Hz LR channels on **slope** estimated from model fit*



- For most mixed-rate configurations, increasing ITD size increased slope, suggesting decreased uncertainty
- For all ITDs, slope was consistently higher for the "All LRs" than the "All HRs" configuration (follow reference lines)
- For most ITDs, introducing LR channels increases slope above the "All HRs" configuration (follow reference lines)

CONCLUSIONS

- We observed faster processing time and increased certainty with increasing ITD for both fixed- and most mixed-rate configurations
- The all low-rate configuration (better JND from click data) improved both processing time and uncertainty over the all-high configuration (worse JND), as observed from eye gaze
- Although ITD JNDs were not significantly different between the mixed-rate and all high-rate configurations, we did see a benefit of adding low-rate channels on both processing time and uncertainty for some ITDs tested
- Further investigation is needed to determine which aspects of ITD processing (i.e. sensitivity, processing time, certainty) should be prioritized in implementing a mixed-rate strategy clinically

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