

Preserving sensitivity to interaural timing differences in bilateral cochlear implant listeners: effects of rate and place of stimulation with multi-electrode stimulation

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INTRODUCTION

1. Interaural time difference (ITD) sensitivity decreases with increasing stimulation rates in bilateral cochlear implant (BiCI) listeners¹. Cochlear implant speech processing strategies use high-rate multi-electrode stimulation (~900 pps), which may not be optimal for perceiving ITD cues.
2. Mixed-rate multi-electrode stimulation has been suggested to improve ITD sensitivity with low rates while maintaining speech understanding at high rates. This is usually achieved by presenting low rates at apical electrodes and high rates at basal electrodes².
3. However, across the BiCI listener population, ITD sensitivity is not necessarily the best at apical-most interaural electrode pairs³.

The aim of this study was to test the efficacy of mixed-rate strategies in maximizing binaural sensitivity for bilateral CI listeners, and to determine which electrode pair(s) are ideal for presenting low-rate ITDs optimally.

LISTENERS

ID	Age (Yrs)	Age at onset of Deafness	Left CI Use (Yrs)	Right CI Use (Yrs)	Etiology
IBK	73	22 years	10	4	Heredity
IBQ	84	53 years	10	13	Meniere's Disease
IBY	50	52 years	8	4	Unknown
ICB	65	9 years	10	13	Heredity
ICJ	66	13 years	6	6	Unknown

Table 1: Five BiCI listeners with demonstrated ITD sensitivity participated in this study.

METHODS

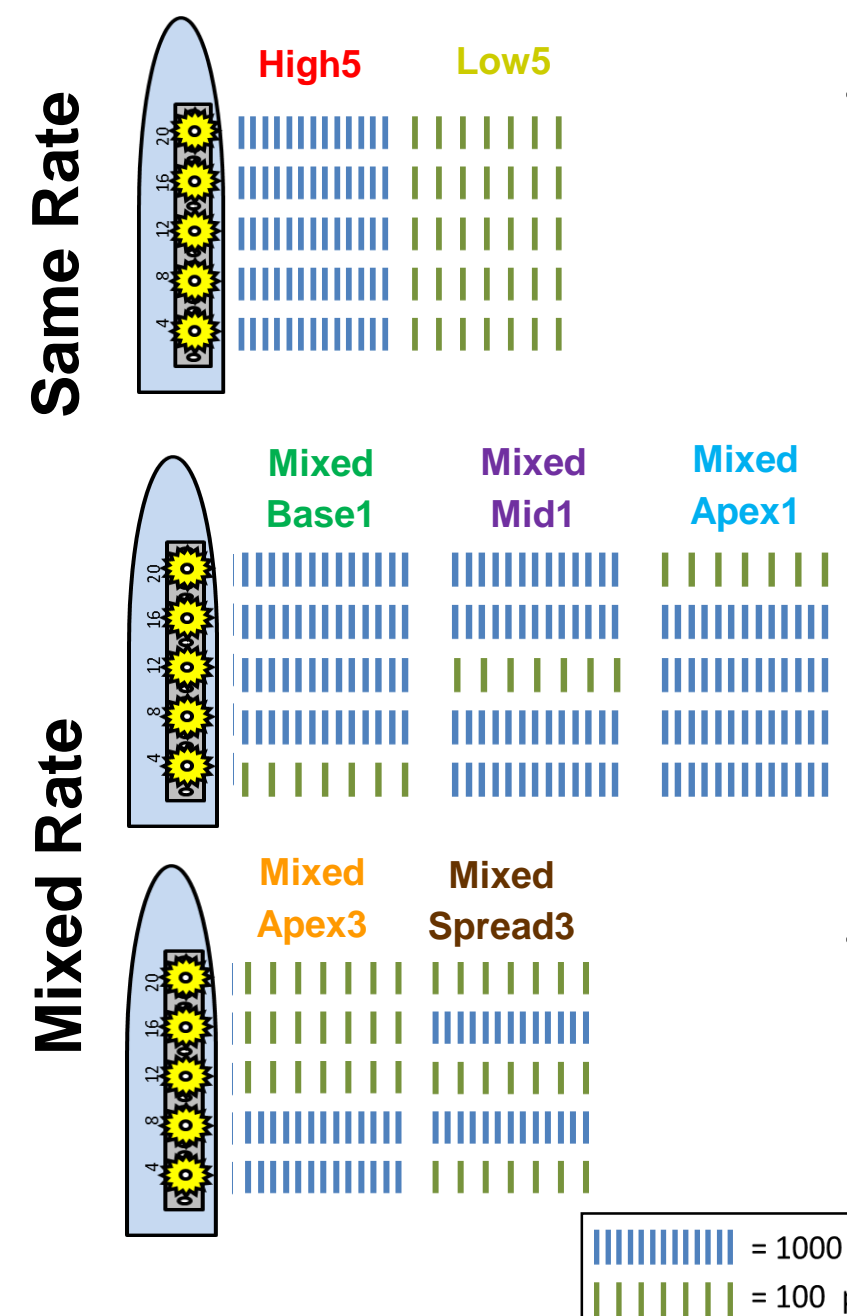


Figure 1: Multi-electrode configurations

- **Stimuli:**
 - 5 pitch-matched pairs of electrodes were stimulated in each condition.
 - Stimuli were presented in various multi-electrode configurations (see Fig. 1).
 - 300 ms constant-amplitude biphasic pulse trains using stimulation rates of 1000 pulses per second (pps) and/or 100 pps.
 - Stimulation rate was consistent across the ears, but varied according to place.
 - Presented at comfortable levels using monopolar stimulation via a bilaterally-synchronized pair of L34 Processors.
 - Loudness-balanced across the ears and across rates with each configuration.
 - ITD = ±100, ±200, ±400, ±800 μs.
 - 20 repetitions @ each ITD.
- **ITD Discrimination Task:**
 - 2-Interval 2-alternative forced-choice task.
 - BiCI listeners were instructed to report whether they heard the sound move to the left or to the right.
 - A psychometric function to obtain a just-noticeable difference (JND) threshold at 71% was fit using a bootstrap procedure of percent correct data⁴.

RESULTS

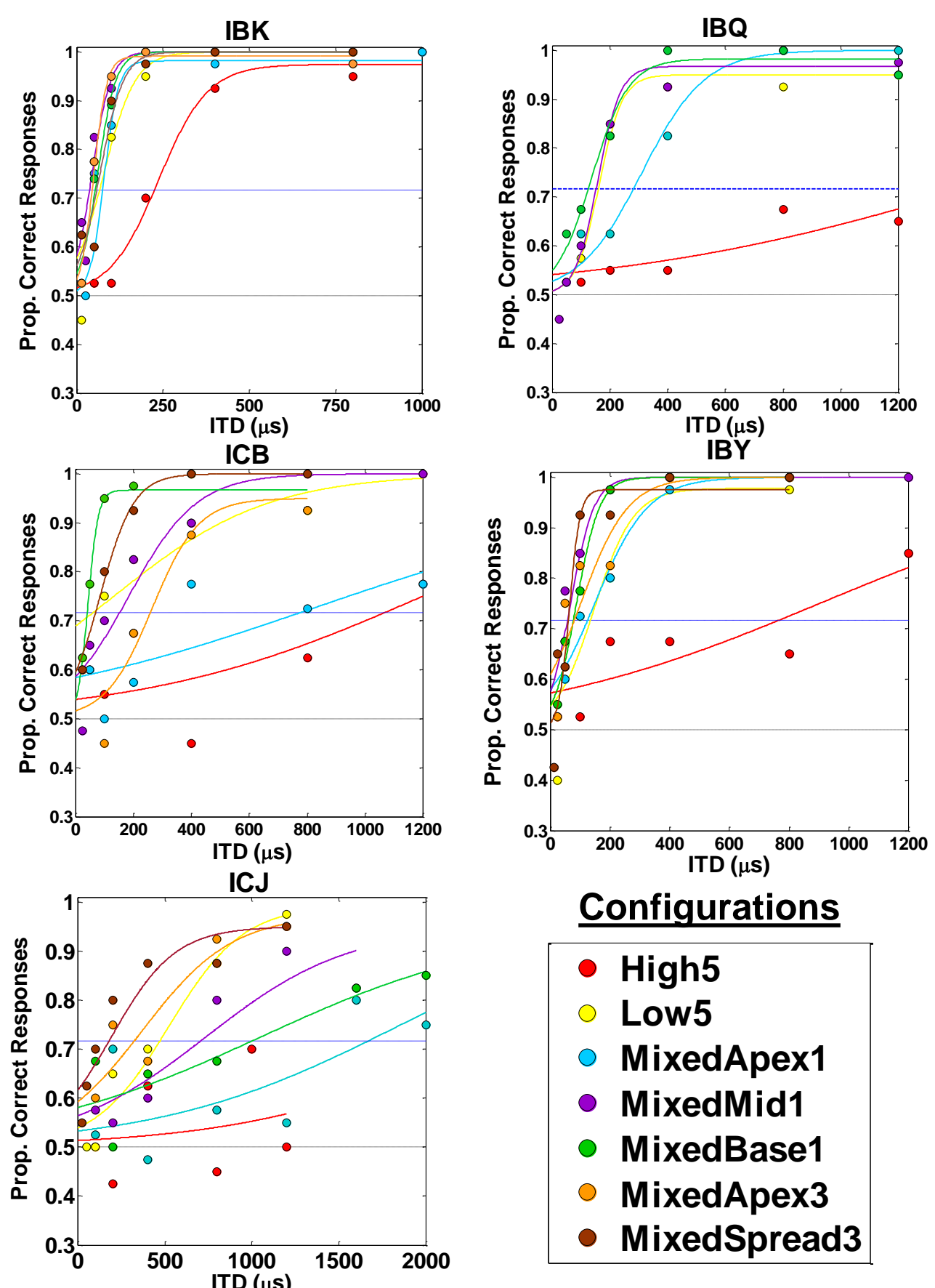


Figure 2: Individual psychometric functions showing percent correct as a function of ITD. Each line on the graph depicts a specific configuration (also listed in the lower right panel). The red bold line highlights the condition with high rates at all 5 electrode pairs.

- When comparing the fixed-rate configurations, all subjects showed poorest ITD sensitivity with High5 configurations and best performance with Low5. A significant difference was found between the High5 and all other configurations [$F(6,34)=4.361, p = 0.003$] (Fig. 2).
- **Listeners IBK, IBY, and IBQ** showed a large improvement in ITD JNDs from the High5 configuration when low rates were introduced.
- **Listeners ICB and ICJ** showed large improvements in ITD JNDs from the High5 configuration only when three low-rate electrode pairs were introduced (see Fig. 3b).

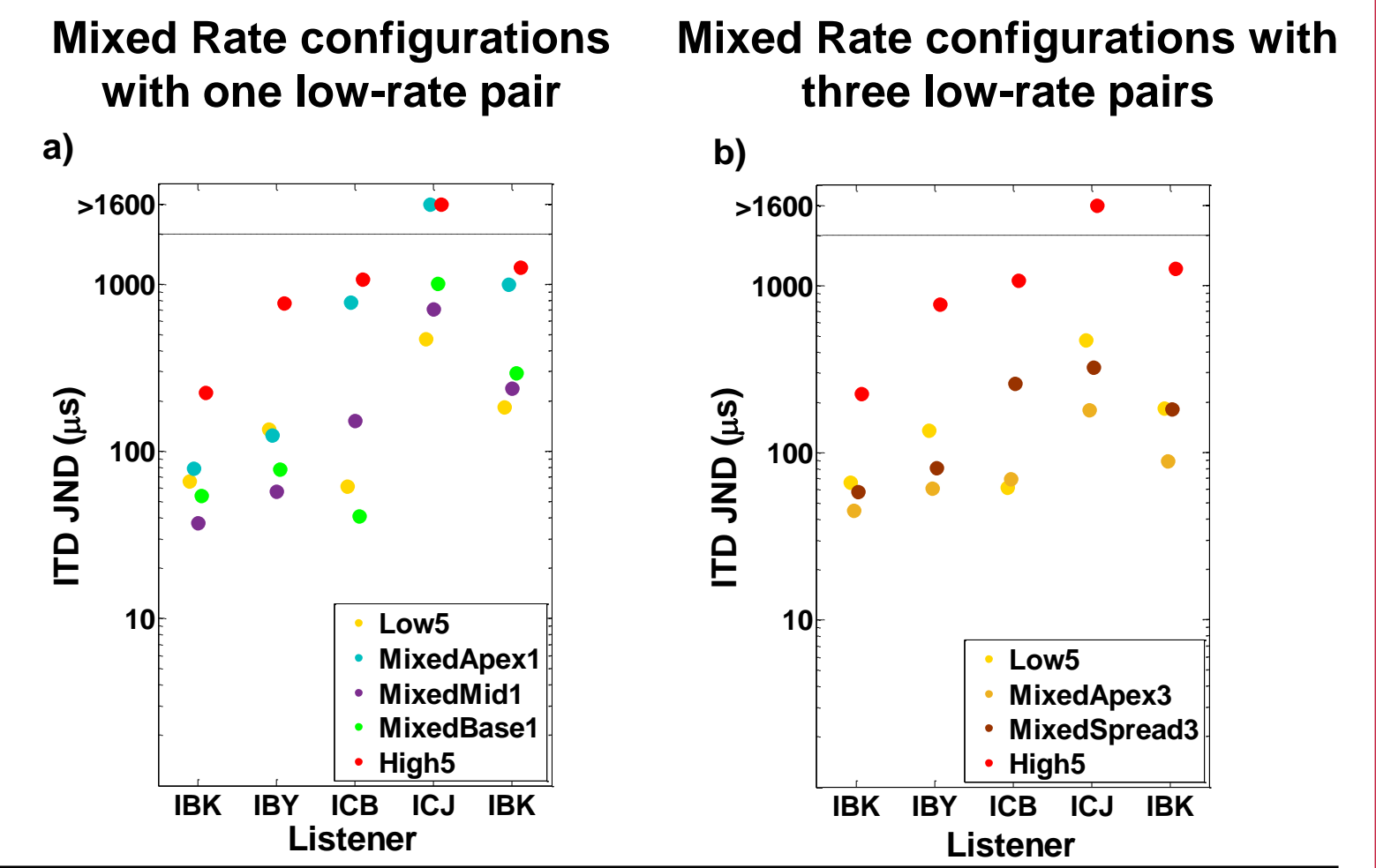


Figure 3: 71% ITD-JND thresholds (μs) plotted per listener by configuration; values are in accordance with psychometric functions determined in Fig. 2.

COMPARISON BETWEEN MIXED-RATE AND SAME-RATE CONFIGURATIONS

- Performance in mixed-rate configurations when only one low-rate pair was introduced is comparable to Low5 (Fig. 4a) and much better than High5 (Fig. 4b) configurations. This was also seen when three low-rate pairs were introduced (Figs 4c and 4d).
- In all mixed-rate configurations introducing low rates at the apical electrode pairs led to consistently poorer performance.

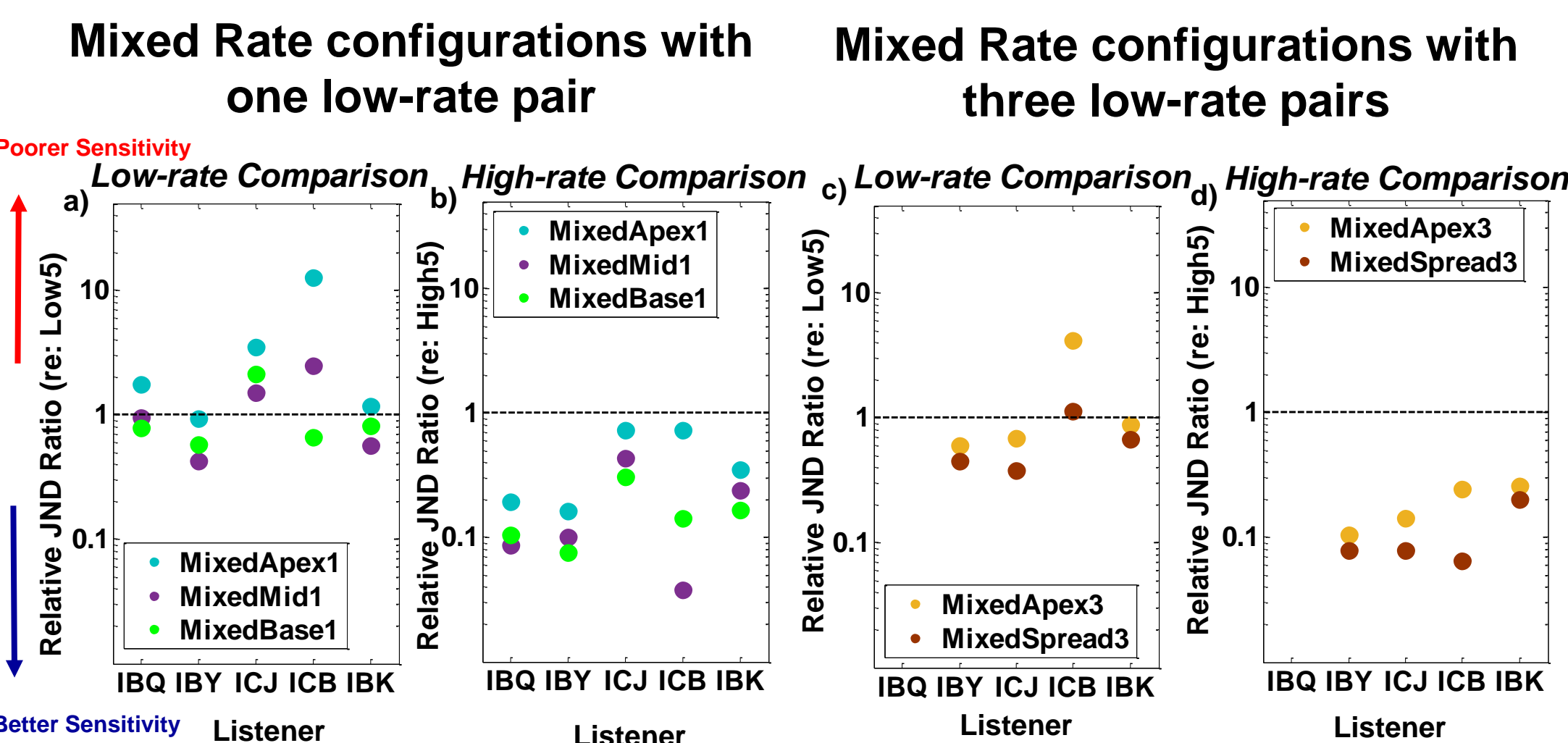


Figure 4: Relative JND ratios measure the relative difference (mixed-rate divided by same-rate) of JNDs between the mixed-rate conditions and either the low rates (panels a,c) or the high rates (panels b,d); JND ratios > 1 show a decrease in sensitivity with mixed rates in relation to either low rates or high rates (panels a,c and b,d, respectively), while ratios < 1 show an increase in sensitivity with the mixed-rate conditions. Ratios close to 1 indicate comparable performance between the mixed- and same-rate conditions.

CONCLUSIONS

1. The present data suggests that BiCI listeners presented with mixed-rate multi-electrode configurations can perceive ITDs comparable to low-rate conditions.
2. Individual differences in performance suggests that some BiCI listeners require a greater number of electrode pairs with low-rate stimulation than others to improve ITD sensitivity (see Fig. 4).

Given that high rate stimulation typically results in poor ITD sensitivity, introducing just a single channel of low rate stimulation can drastically improve ITD discrimination in the presence of high rate stimulation on near-by electrodes.

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