Poster # M14

Binaural Unmasking with Fine Structure in Cochlear Implant Listeners

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Binaural Hearing and Speech Laboratory

Conference on Implantable Auditory Prostheses, 2013

INTRODUCTION

- Binaural hearing provides a benefit for speech perception and signal detection in noisy environments when there is spatial separation between sources, but this benefit is severely limited for listeners with bilateral cochlear implants (CIs; Van Hoesel et al., 2008).
- Using direct electrical stimulation, listeners with CIs have shown binaural unmasking for signal detection (Long, Carlyon, Litovsky, & Downs, 2006; Lu, Litovsky, & Zeng, 2010), but binaural benefits have been limited compared to those in normally hearing listeners (Lu et al., 2010; Goupell, 2012).
  - Electrical stimuli used in previous experiments contained interaural differences in the temporal envelope but no information in the temporal fine structure.
- The **present study** examined whether maintaining the interaural timing differences of the acoustic fine structure in the electrical temporal fine structure would improve binaural unmasking for CI listeners. It was hypothesized that the aperiodic nature of the fine structure (due to the noise masker) would facilitate listeners' use of interaural timing delays in the electrical fine structure (Laback & Majdak, 2008).

GENERAL METHODS

Stimuli

- Masker: 400 ms noise
  - 50 or 125 Hz bandwidth (BW)
  - Interaurally in-phase **(N0)**
- Target: 300 ms tone centered in the noise masker
  - Interaurally in-phase **(S0)** or out-of-phase **(Sπ)**
- Signal-to-noise ratio (SNR; between target tone and noise masker) varied
- Hilbert envelope and phase were calculated
- Conditions
  - Envelope (ENV): The Hilbert envelope was presented with a interaurally synchronized, steady-rate pulse train. The pulse rate was equal to the noise center frequency.
  - Envelope + Fine Structure (ENV+FS): The Hilbert envelope was presented with pulse trains timed to the zeros in the Hilbert phase.

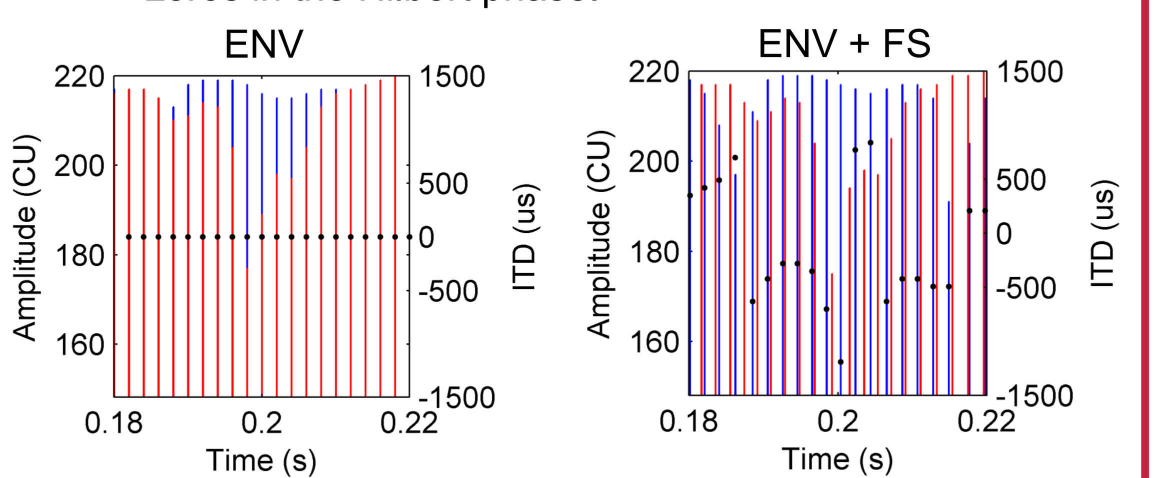

Fig 1. An N0Sπ stimulus in the ENV (left panel) and ENV+FS (right panel) conditions at 0 dB signal-to-noise ratio. Blue indicates the left ear and red indicates the right. Black dots show **interaural time differences** (ITDs) between pulses. The noise had a 500 Hz center frequency and a 125 Hz bandwidth.

Procedure

- 3 interval, 2-AFC
  - Target interval was N0S0 or N0Sπ
  - Non-target interval was N0
- Signal-to-noise ratio (SNR) varied adaptively (2 down 1 up)
  - 3-5 tracks per condition

EXPERIMENT 1: CI listeners

- Participants: 4 listeners with bilateral cochlear implants (CIs)
  - Implanted with Cochlear devices
  - Sensitive to interaural time differences (ITDs): single electrode-pair ITD thresholds < 400 µs at 100 pulses per second

Subject	Age (yrs)	CI exp (yrs)	BiCI exp (yrs)	ITD JND (µs)
IAJ	67	16	9	352
IBN	66	13	3	380
ICB	62	10	7	384
ICD	55	10	4	114

- Equipment: Stimuli presented with the Nucleus Implant Communicator and L34 processors
- Stimuli: Noise center frequency: 500, 750, 1000 Hz
  - Temporal envelope was compressed between each listeners threshold and maximum comfort levels using a nonlinear compression (Long et al., 2006).
  - ENV, ENV+FS conditions
  - Stimuli were presented to single pair of interaurally pitch-matched electrodes

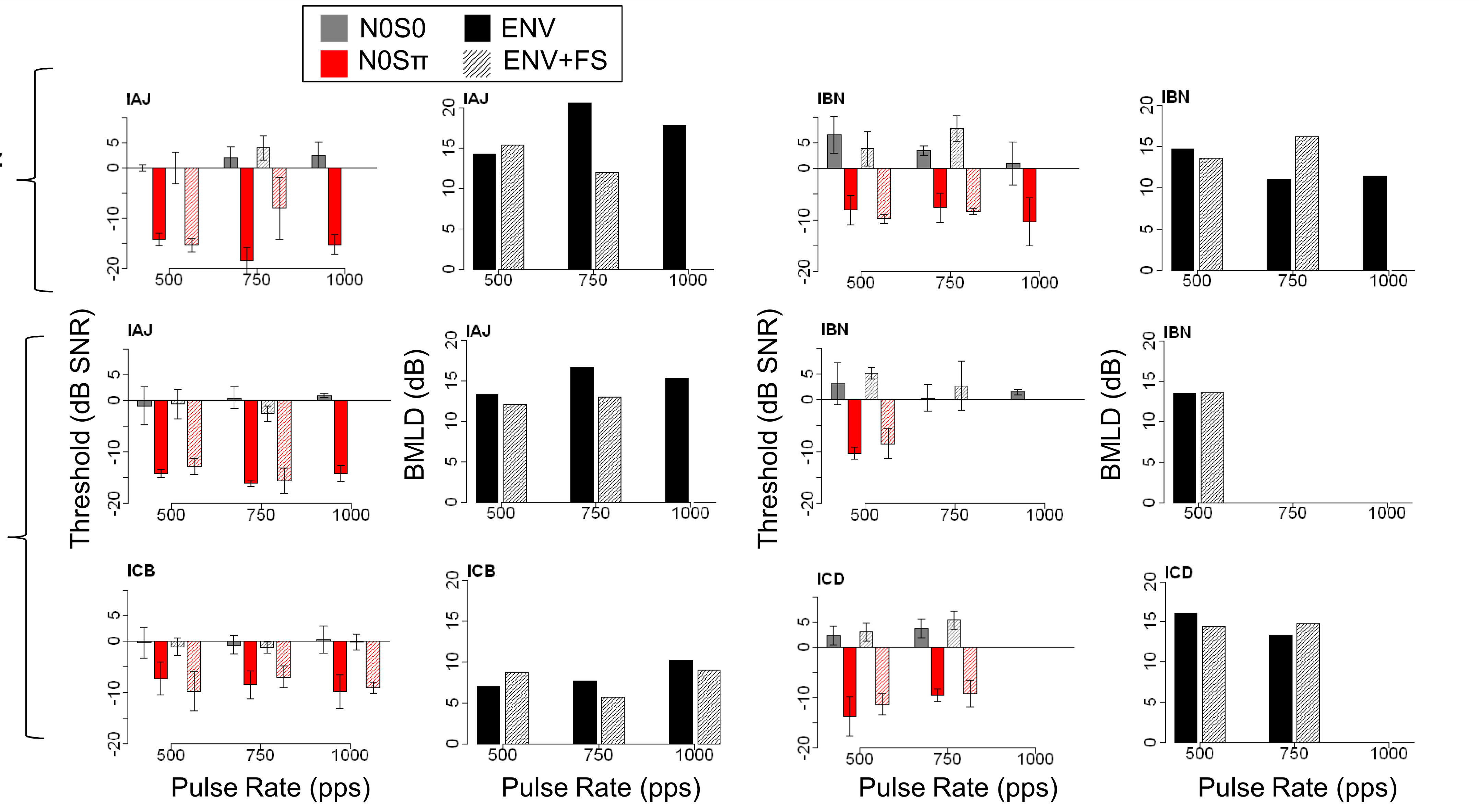

Fig 2. Panels with red bars show the signal detection thresholds (dB) for individuals with cochlear implants as a function of the nominal pulse rate. Bars show the mean threshold over multiple tracks. Error bars show 95% confidence intervals. Panels with black bars show the corresponding binaural masking level differences (BMLD = N0S0 threshold – N0Sπ threshold).

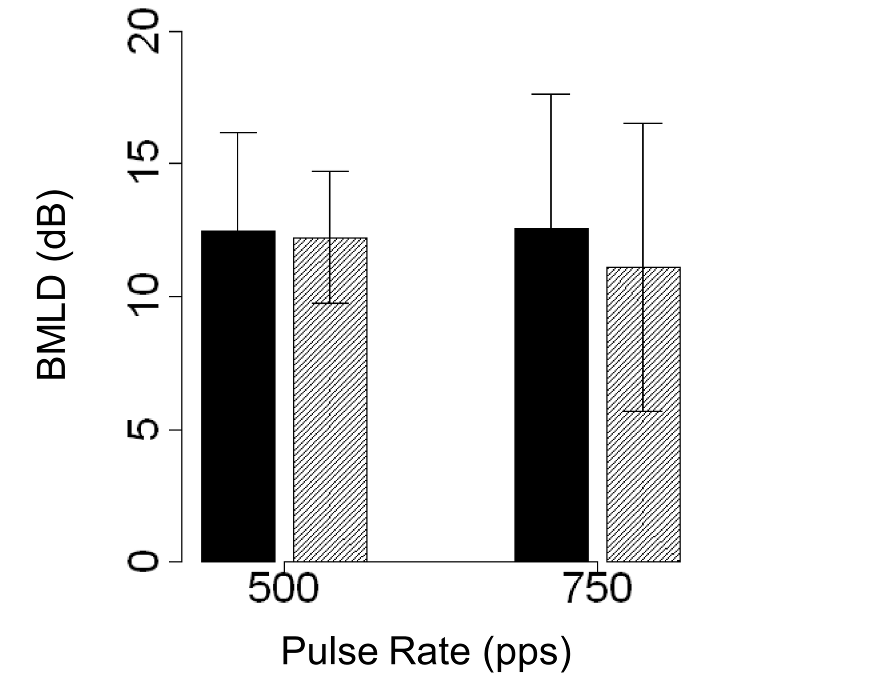

Fig 3. Average binaural masking level differences (BMLD = N0S0 threshold – N0Sπ threshold) for the 125 Hz bandwidth noise. Error bars show 95 % confidence intervals.

- The binaural masking level difference (BMLD = N0S0 threshold – N0Sπ threshold) was 13 dB on average which was similar to that found by Long, Carlyon, and, Litovsky (2007).
- Thresholds did not improve with fine structure (ENV+FS) at the pulse rates examined.

EXPERIMENT 2: NH listeners

- Participants: 8 listeners with normal hearing (NH; 19-32 yrs old)
  - Pure tone thresholds within 20 dB HL at 8000 Hz
- Equipment: Stimuli presented using ER-2 insert earphones
- Stimuli: Noise center frequency: 125, 250, 500 Hz
  - Single channel Gaussian-enveloped tone vocoder
  - 9.2 kHz carrier
  - -3 dB bandwidth was 1660 Hz
  - ENV, ENV+FS, FS conditions
    - Fine Structure (FS): The Hilbert envelope from one side was presented to both sides with pulse trains timed to zeros in the Hilbert phase
  - Uncorrelated pink-noise background from DC to 20 kHz

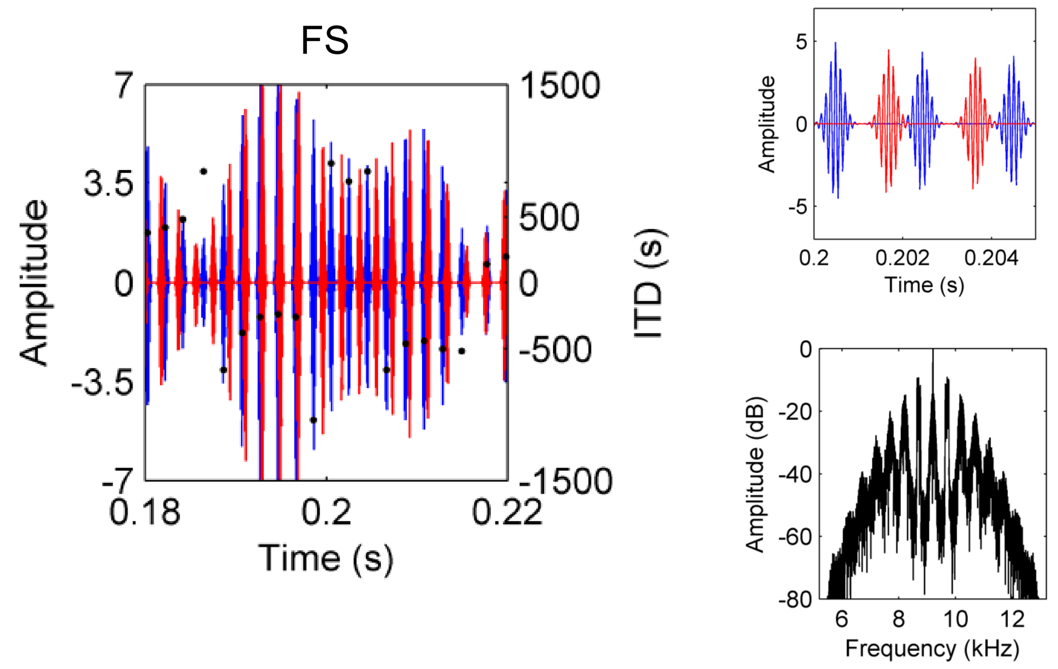

Fig 4. An FS stimulus in the N0Sπ condition at 0 dB signal-to-noise ratio. Blue indicates the left ear and red indicates the right. Black dots (left panel) show **interaural time differences** (ITDs) between pulses. The noise had a 500 Hz center frequency and a 125 Hz bandwidth.

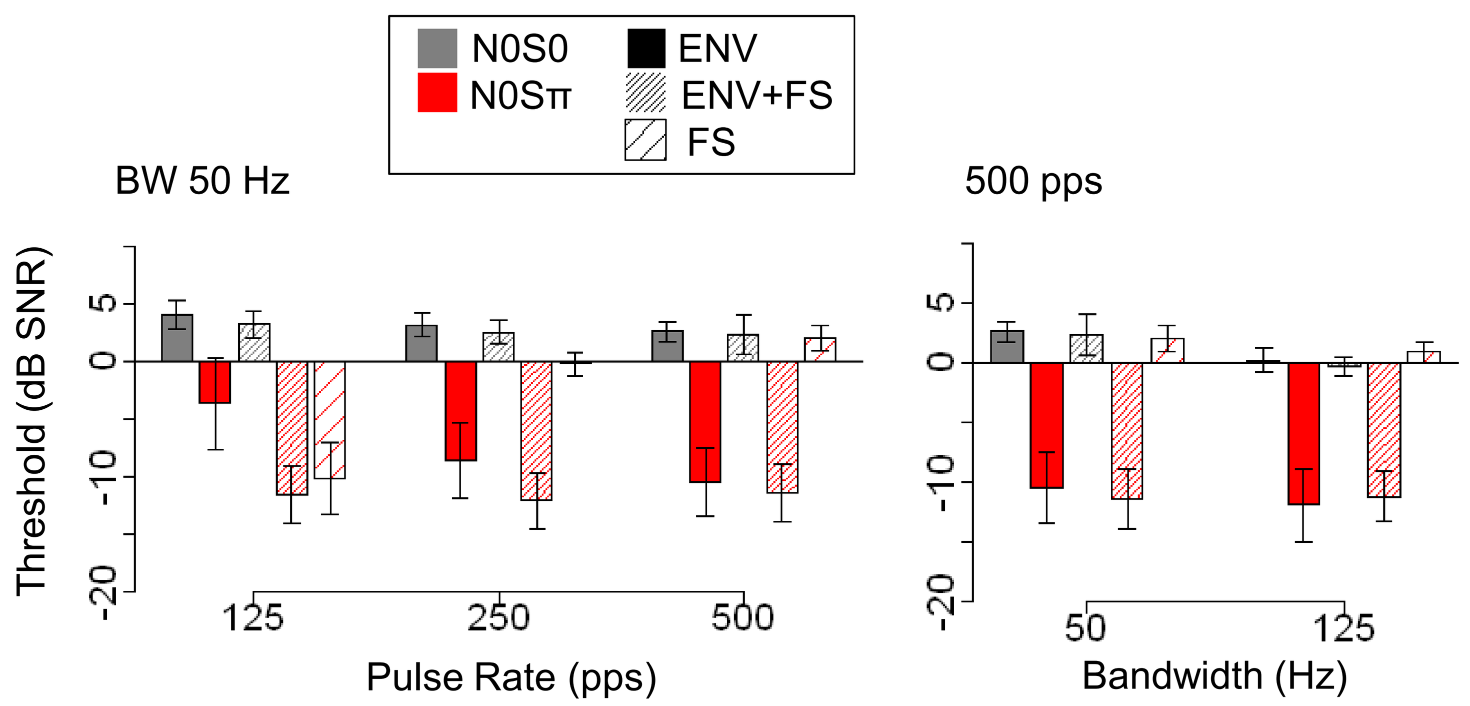

Fig 5. Mean signal detection thresholds for 8 listeners with normal hearing. The left panel shows thresholds as a function of the nominal pulse rate for noise with a 50 Hz bandwidth. The right panel shows thresholds as a function of bandwidth for stimuli at the nominal rate of 500 pulses per second. Error bars show 95% confidence intervals.

- The inclusion of 'fine structure' (i.e., the pulse timing for ENV+FS) resulted in improved N0Sπ thresholds for the lower pulse rates (125, 250 pps; p<.01). This was due to poor N0Sπ thresholds at these pulse rates without 'fine structure' (ENV).
- Lower pulse rates led to poorer N0Sπ thresholds without 'fine structure' (ENV; p<.001), but not with 'fine structure' (ENV+FS).
- FS resulted in binaural unmasking only at lower pulse rates (125, 250 pps; p<.01).
- The inclusion of 'fine structure' (ENV+FS) did not improve thresholds for either bandwidth at 500 pps.

SUMMARY & CONCLUSIONS

- Previous studies have found that listeners with CIs can show binaural unmasking for signal detection. This study examined whether this binaural benefit could be improved from the inclusion of interaural time differences in the electrical fine structure (i.e., pulse timing).
- The listeners with CIs examined did not show an improvement in binaural unmasking from information in the pulse timing. The pulse rates used were likely too high for the listeners to use interaural timing delays and the amount of jitter in the pulse timing was likely too low (i.e., at the most, jitter was such that ~90% of interpulse intervals were within ± 20% of the nominal interpulse interval).
- NH listeners were able to use information in the pulse timing to improve binaural unmasking at lower pulse rates, but performance did not exceed that of performance at steady pulse rates at the highest rate tested.
- For the NH listeners as a group, pulse timing information eliminated the detrimental effect of lower pulse rates on thresholds for binaural signal detection.
- Further research is needed to determine whether listeners with CIs can benefit from pulse timing information at lower pulse rates for binaural signal detection.

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ACKNOWLEDGEMENTS

Support provided by NIH-NIDCD R01 DC003083 (Litovsky), NIH-NIDCD R00 DC010206 (Goupell), and in part by a core grant to the Waisman Center, NIH-NICHD P30 HD03352. Thanks go to Alan Kan for helpful discussions on the project.