Envelope vs. Fine Structure in Bilateral Hearing

Bernhard Laback[1], Piotr Majdak[1], and Wolf-Dieter Baumgartner[2]

[1] Acoustics Research Institute, Austrian Academy of Sciences

[2] ENT-department, Vienna University Hospital

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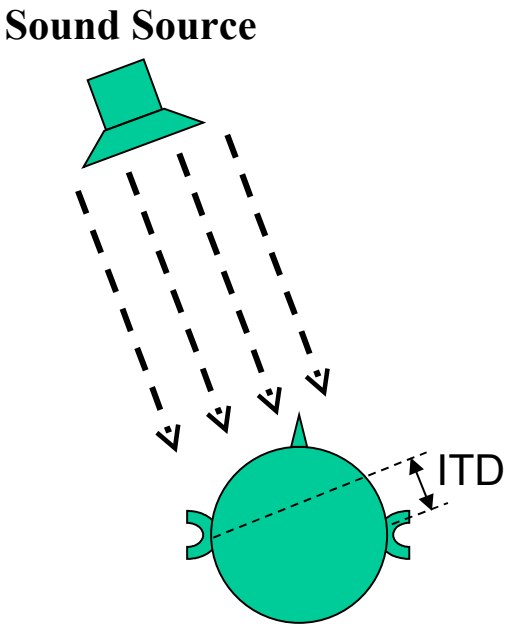
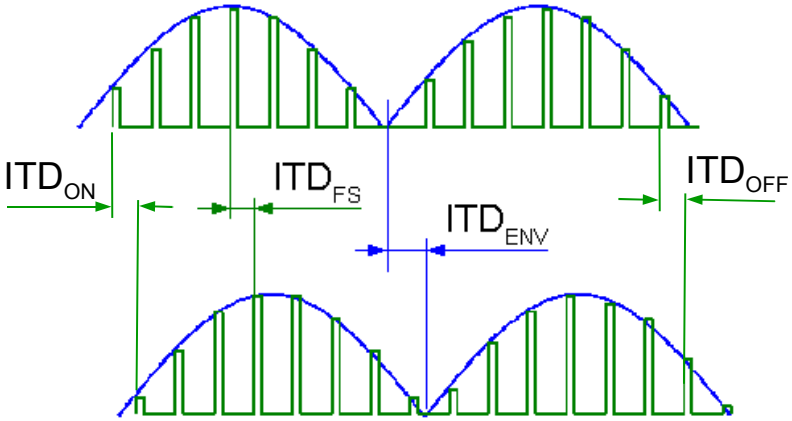
http://www.kfs.oeaw.ac.at
Bernhard.Laback@oeaw.ac.at

Interaural Time Difference (ITD)





Interaural Time Differences (ITDs) occur in

- Gating portions (ITD_{ON}/ITD_{OFF})
- Temporal fine structure (ITD_{FS})
- Ongoing envelope (ITD_{ENV})

Motivation for study

- Fine structure ITD is important for
  - Lateralizing sound sources (Wightman and Kistler, 1992; Smith et al., 2002) and for
  - Speech understanding in noise (Nie et. al., 2005; Zeng et al., 2005)
- CI listeners are often sensitive to ITD (e.g. van Hoesel and Tyler, 2003)
- Open Questions:
  - Are bilateral CI listeners sensitive to ITD in the fine structure?
  - What is the contribution of gating ITD and ongoing envelope ITD?

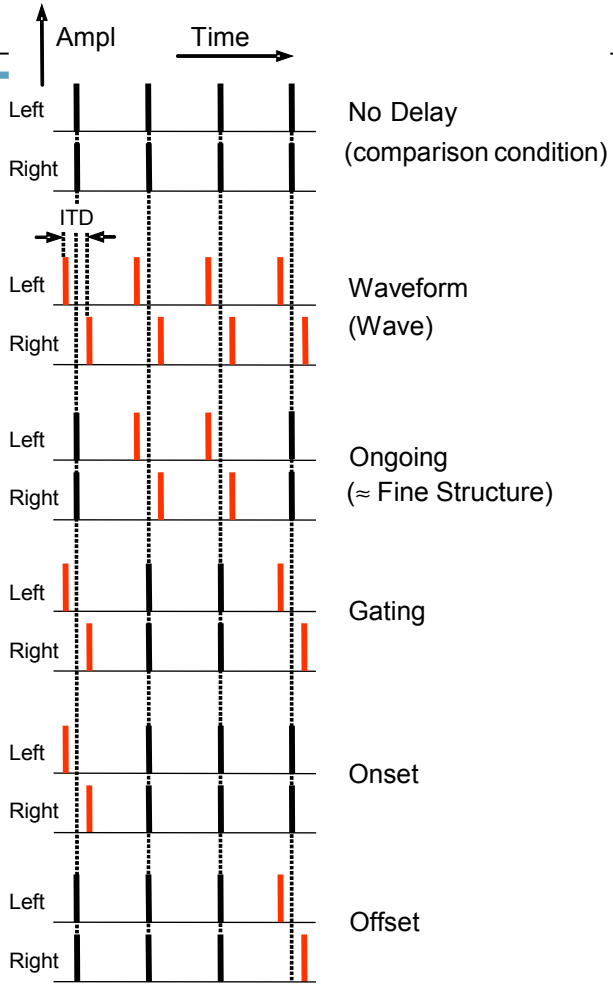
Study I

Lateralization Discrimination of ITD in Fine Structure, Onset, and Offset: Four-Pulse Sequences

Laback, Majdak, and Baumgartner (2007) JASA 121 (April)

Methods I

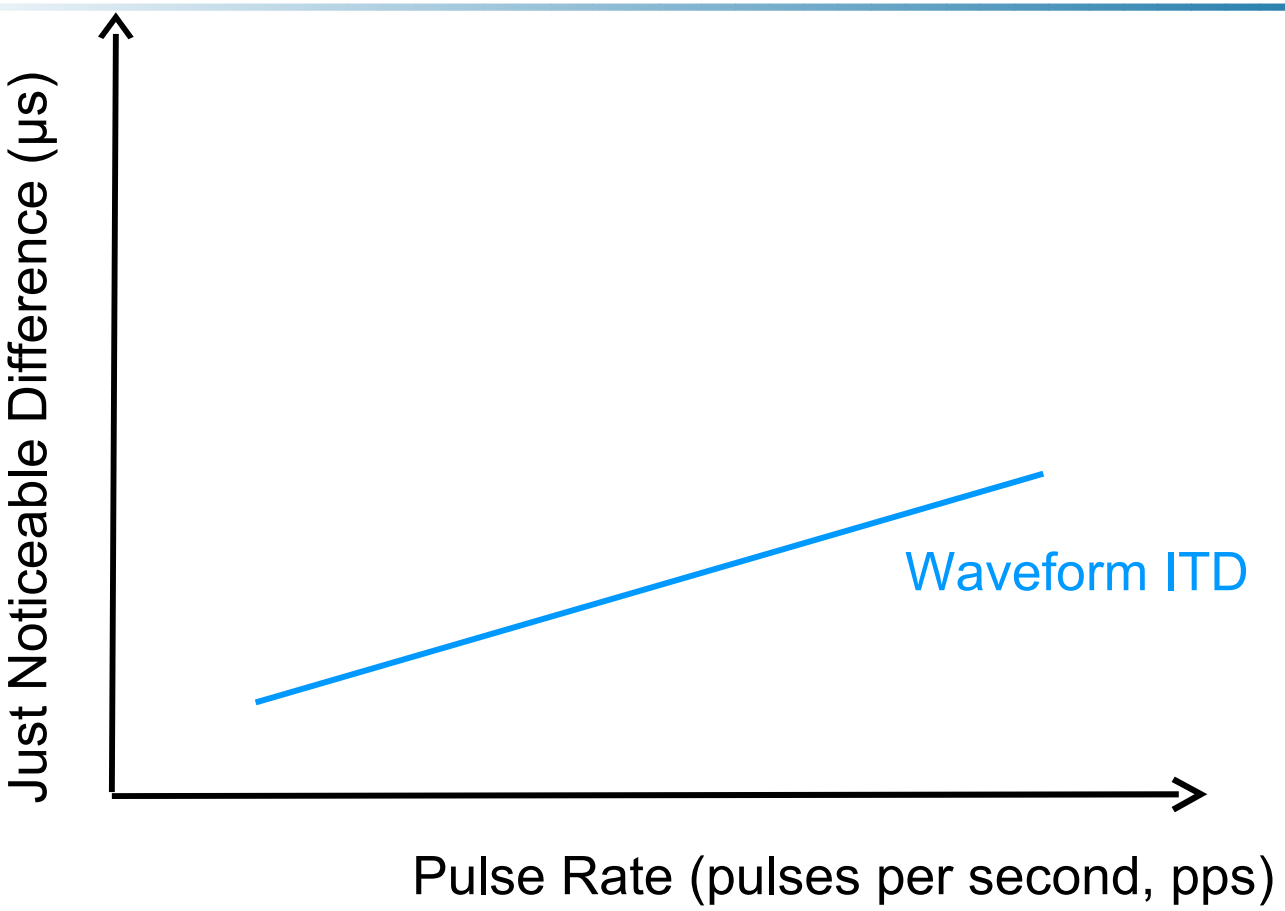
- Electric stimuli
  - Biphasic pulse trains (4 pulses) presented
    - at interaurally pitch-matched and loudness-balanced electrode pair (selected in pretests)
    - via Research Interface (*RIB*) with interaural accurracy of 2.5 *µs*
- ITD conditions (see right side)



Methods II

- JNDs for Left/Right Discrimination
- Subjects
  - Four CI listeners (*C40+*, *MED-EL*), postlingually deafened, selected based upon minimum ITD sensitivity criterion
  - Five NH listeners (listening to CI simulation)
- Independent Variables
  - ITD condition
  - Pulse Rate

Expectations



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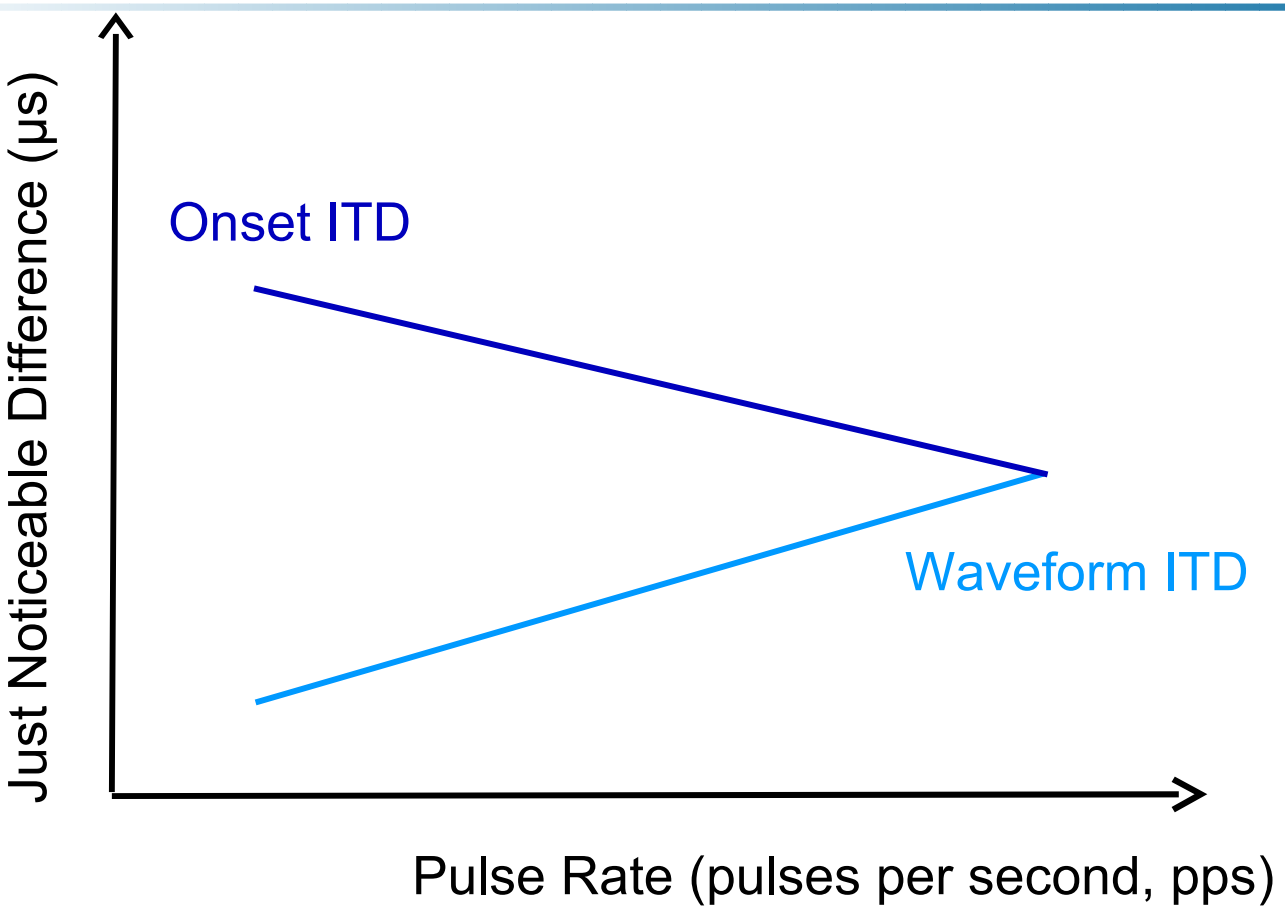
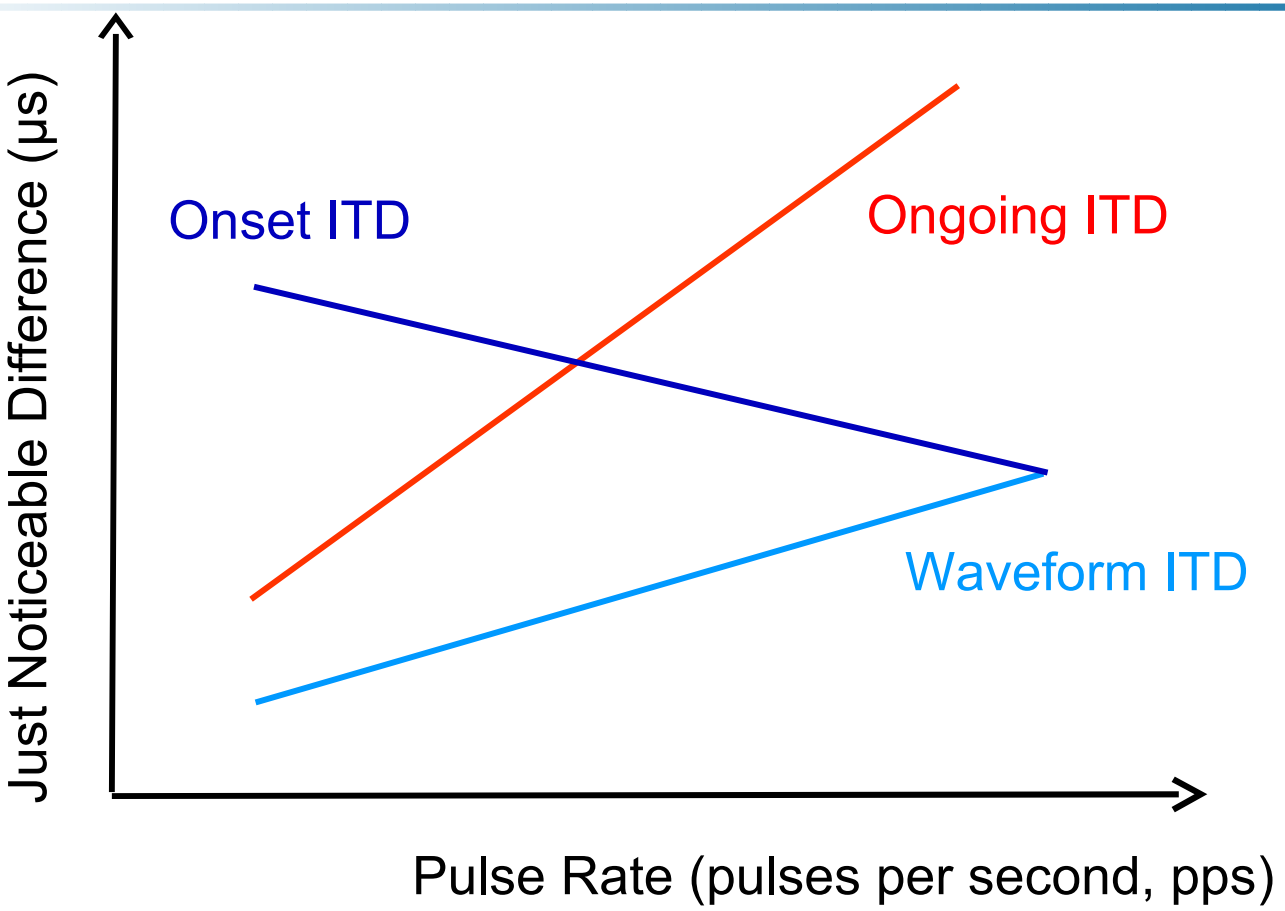
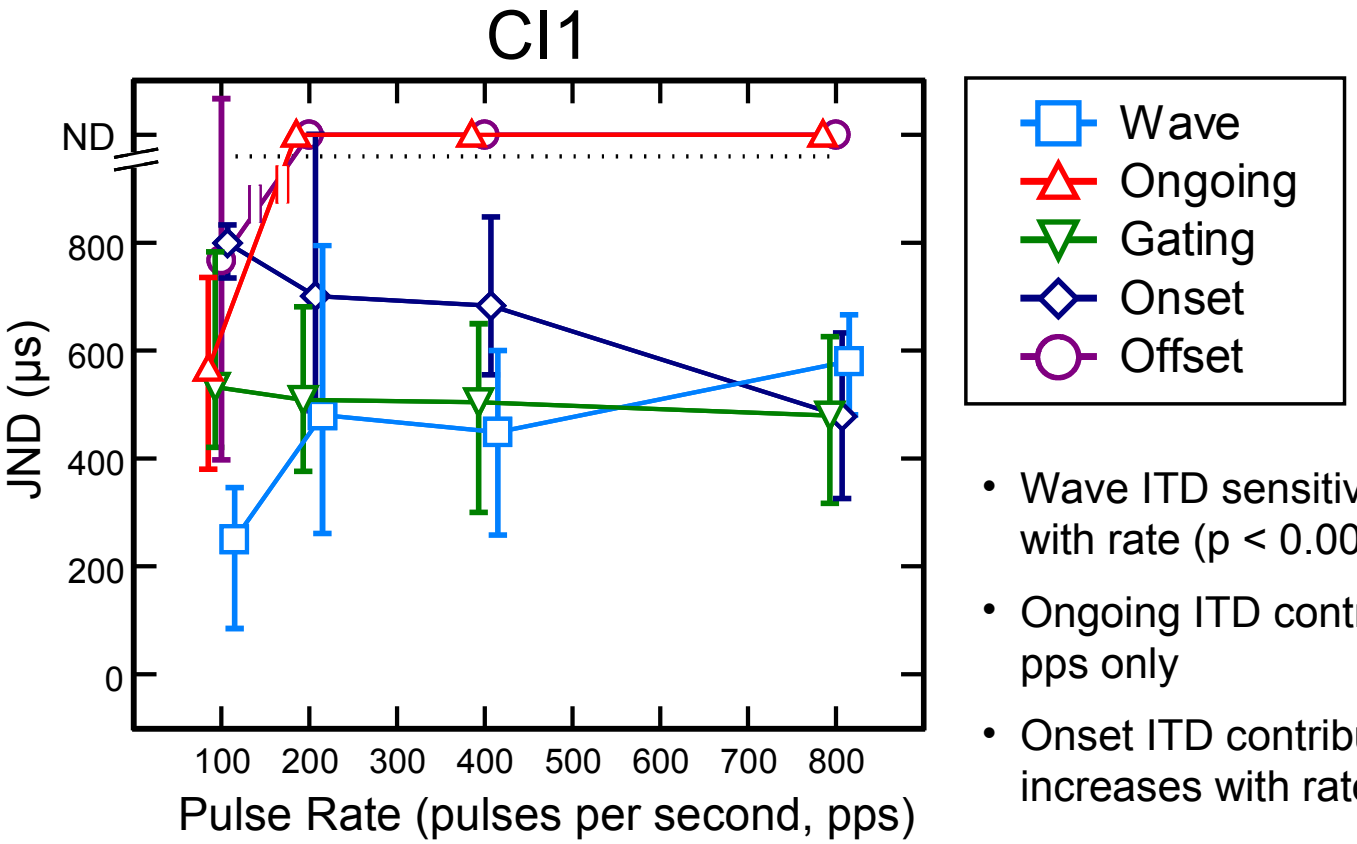


Expectations

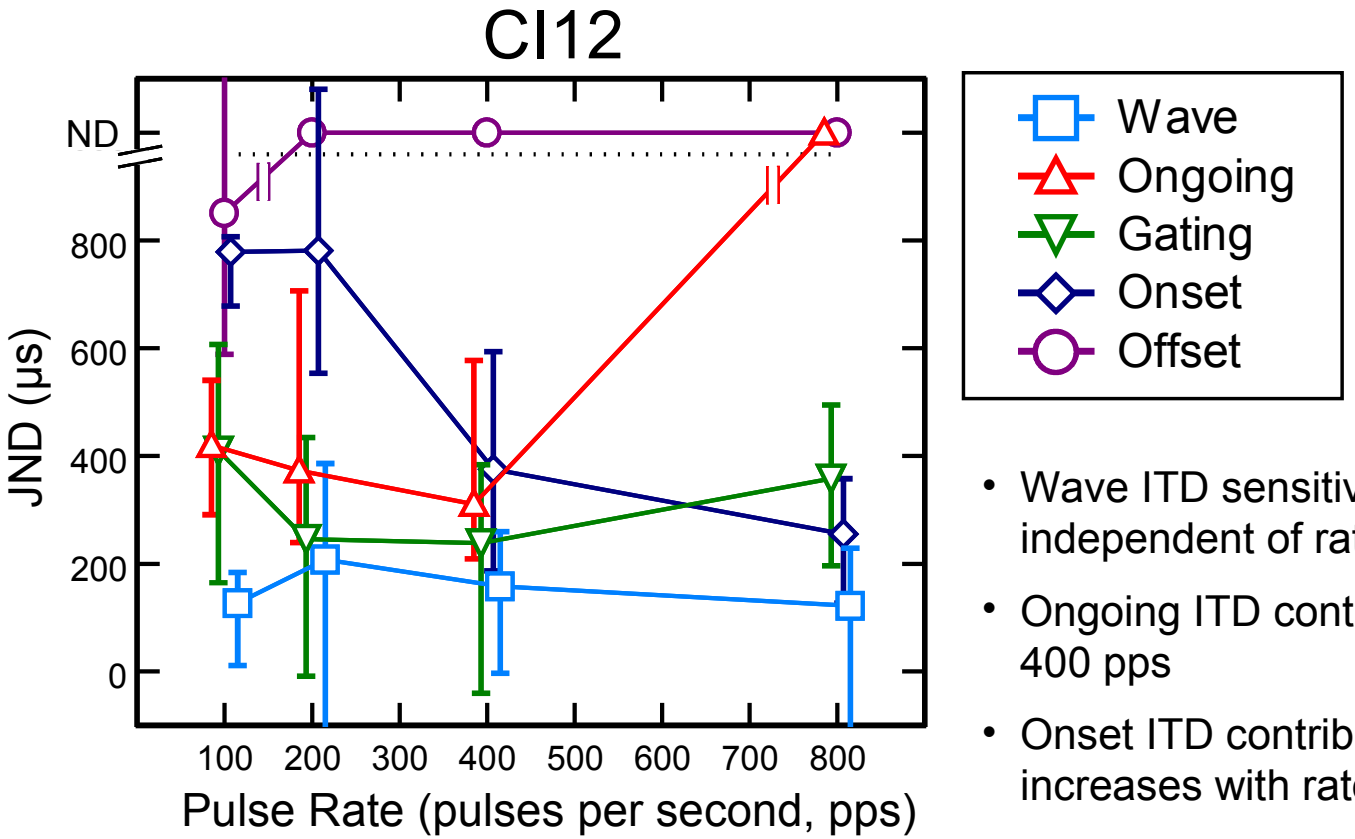


Results for CI listeners: CI1



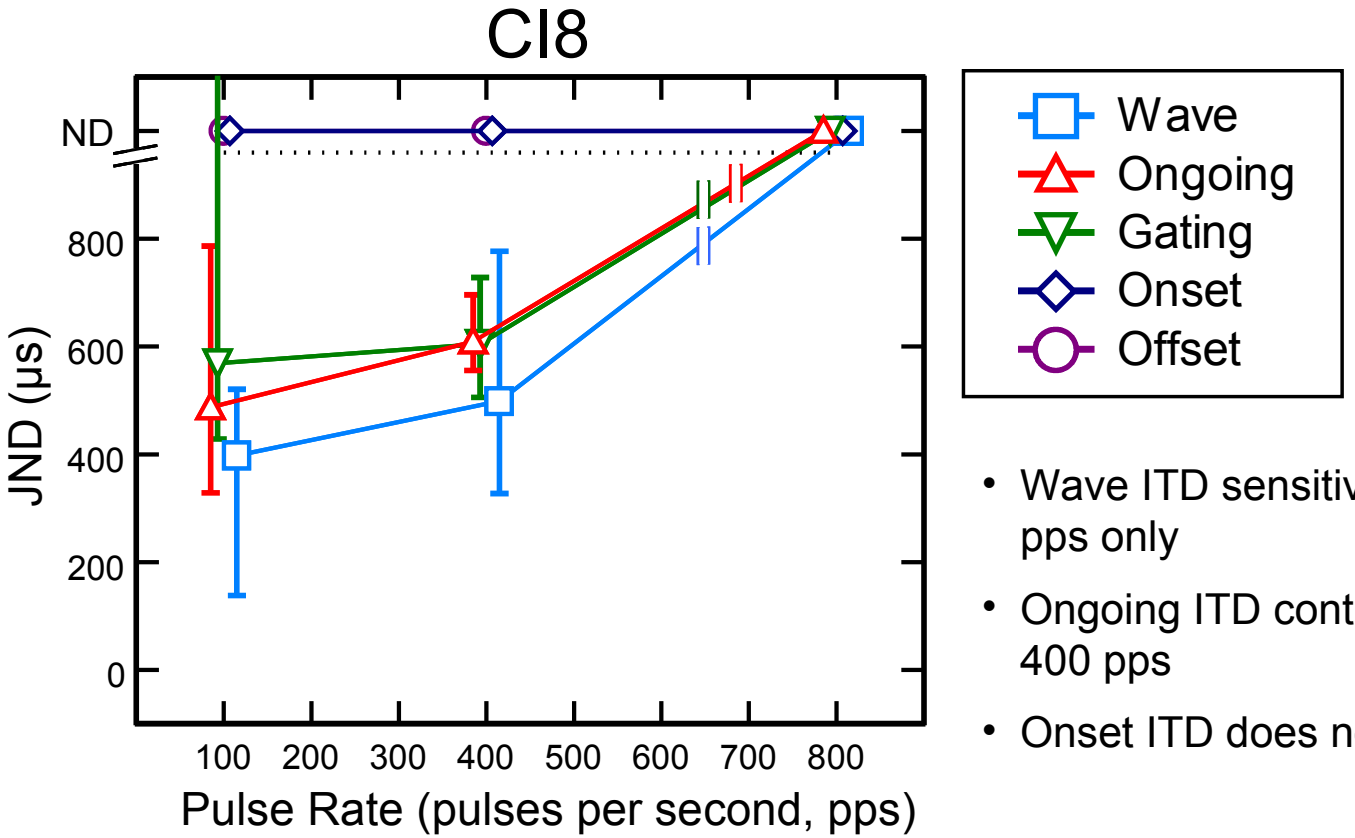
- Wave ITD sensitivity decreases with rate ($p < 0.003$)
- Ongoing ITD contributes at 100 pps only
- Onset ITD contribution increases with rate ($p < 0.0001$)

Results for CI listeners: CI12



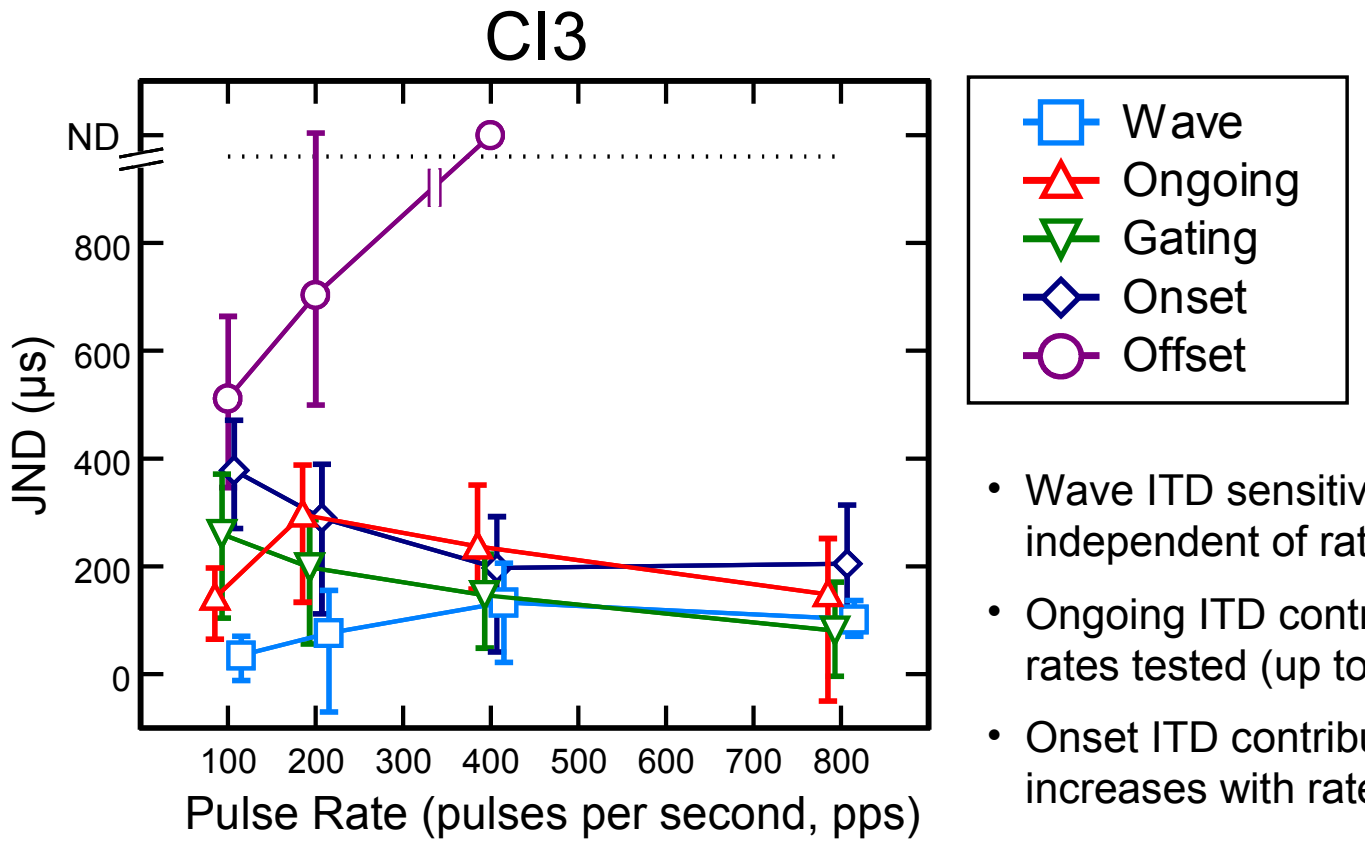
- Wave ITD sensitivity independent of rate
- Ongoing ITD contributes up to 400 pps
- Onset ITD contribution increases with rate ($p < 0.034$)

Results for CI listeners: CI8



- Wave ITD sensitivity up to 400 pps only
- Ongoing ITD contributes up to 400 pps
- Onset ITD does not contribute

Results for CI listeners: CI3



- Wave ITD sensitivity independent of rate
- Ongoing ITD contributes at all rates tested (up to 800 pps)
- Onset ITD contribution increases with rate ($p < 0.04$)

Conclusions of Study I

- CI listeners are sensitive to ongoing ITD in four-pulse sequences, thus to “pure” fine structure ITD
- Highest rate showing fine structure ITD sensitivity varies from 100 to 800 pps
- Contribution of onset ITD increases with pulse rate (in three out of four subjects)

Study I

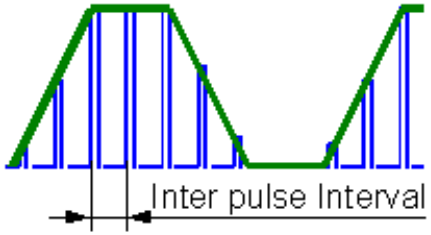
Lateralization Discrimination of ITD in Fine Structure and Ongoing Envelope: Modulated pulse trains

Majdak, Laback, and Baumgartner (2006) JASA 120, 2190-2201

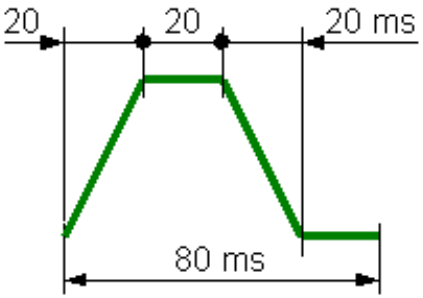
Methods

- **Stimuli**
  - Amplitude modulated pulse trains (300 ms)

    (F_{mod} = 13 Hz)

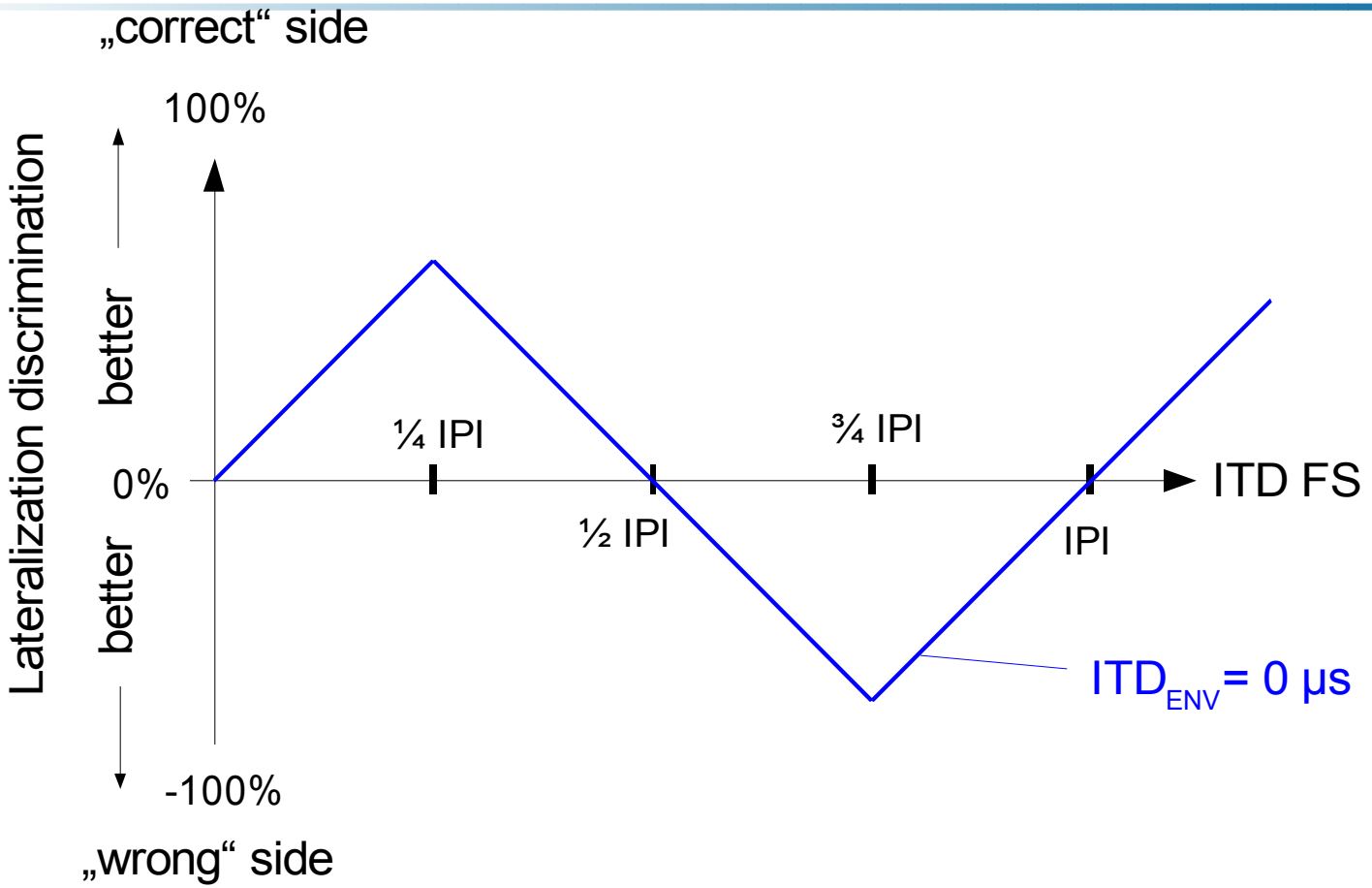


- **Independent variables**
  - ITD_{FS}: 0…IPI (inter-pulse interval)
  - ITD_{ENV}: 0…800µs
  - Pulse rate: 100 … 1600 pps



- **Subjects**
  - 4 CI listeners (postlingually deafened)
  - 4 NH listeners (listening to CI simulation)

Expectations



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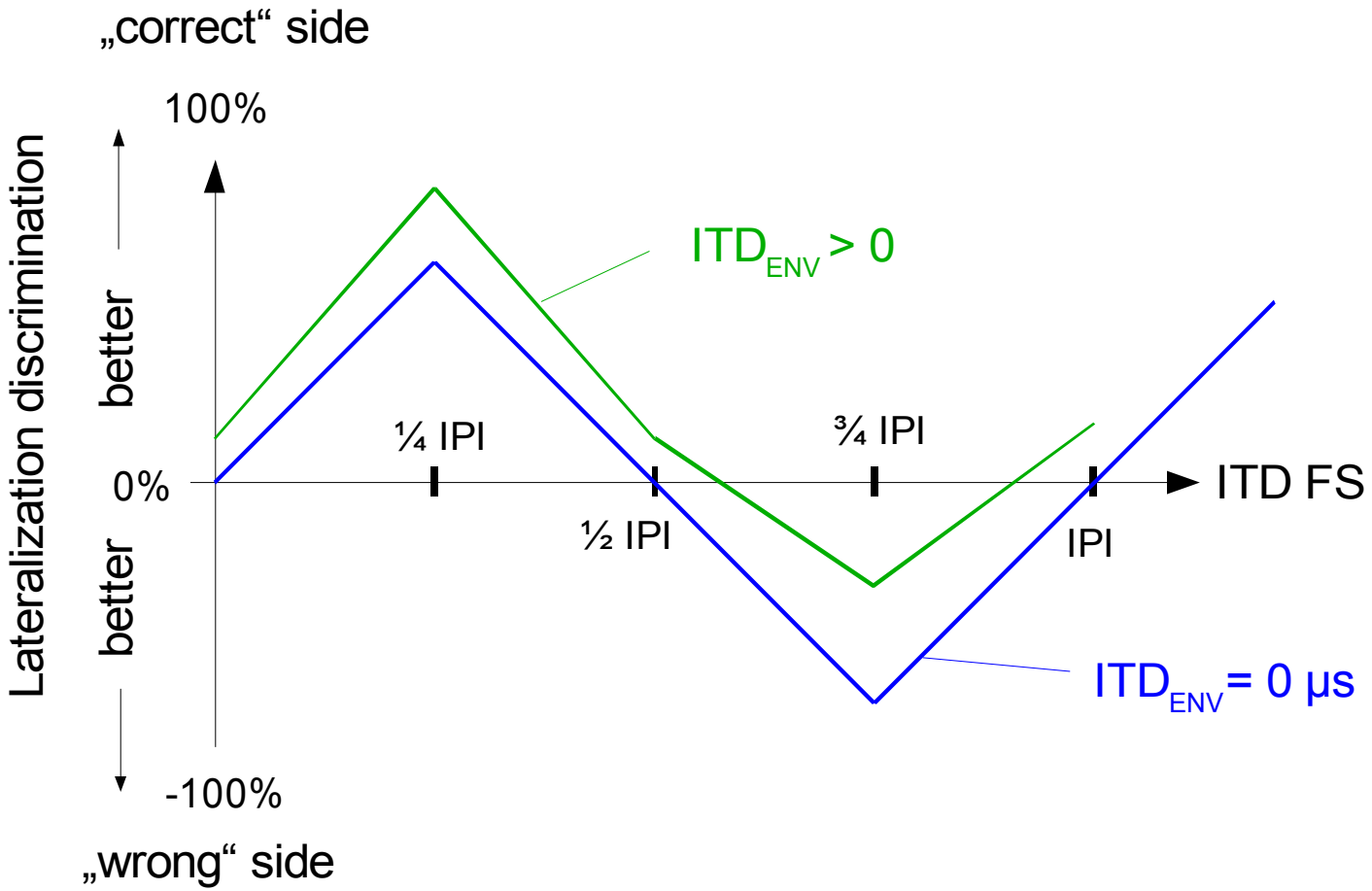
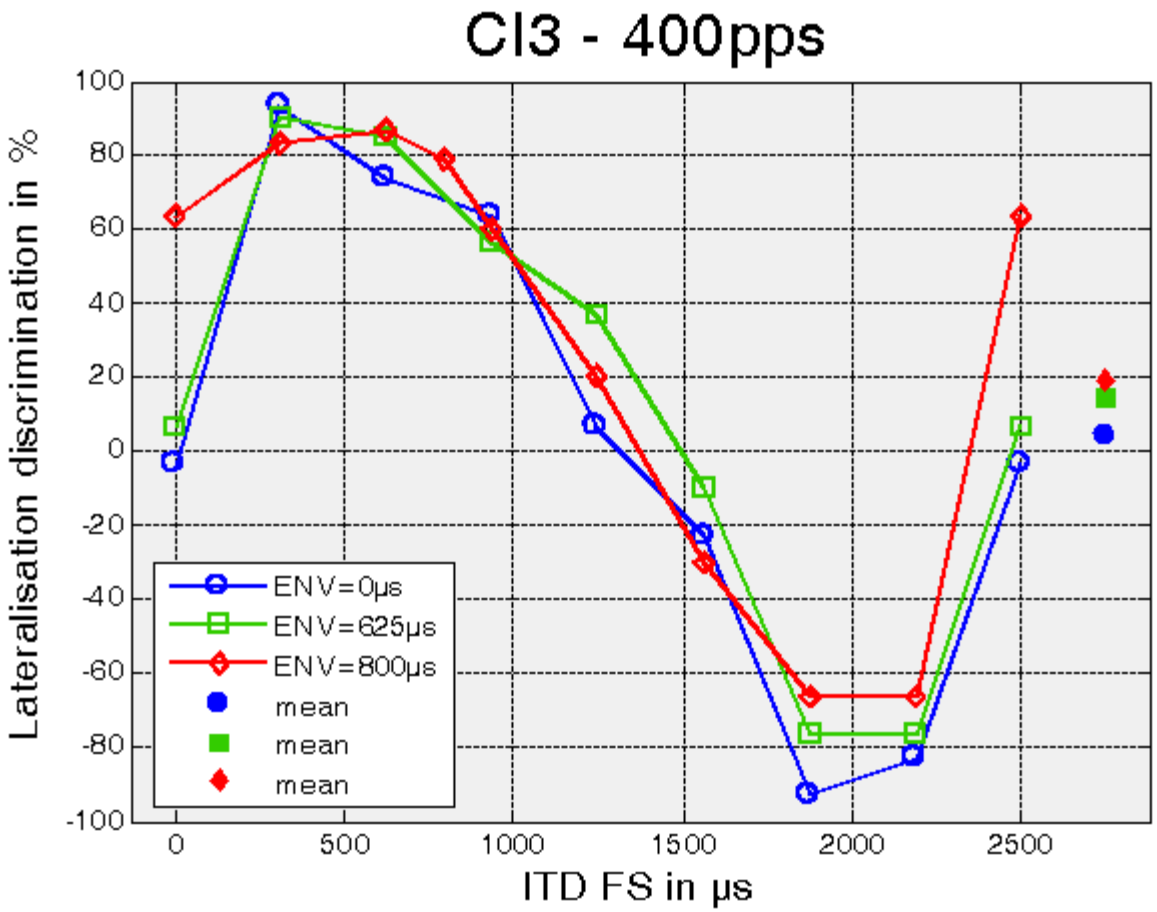


Results for Lower Pulse Rates



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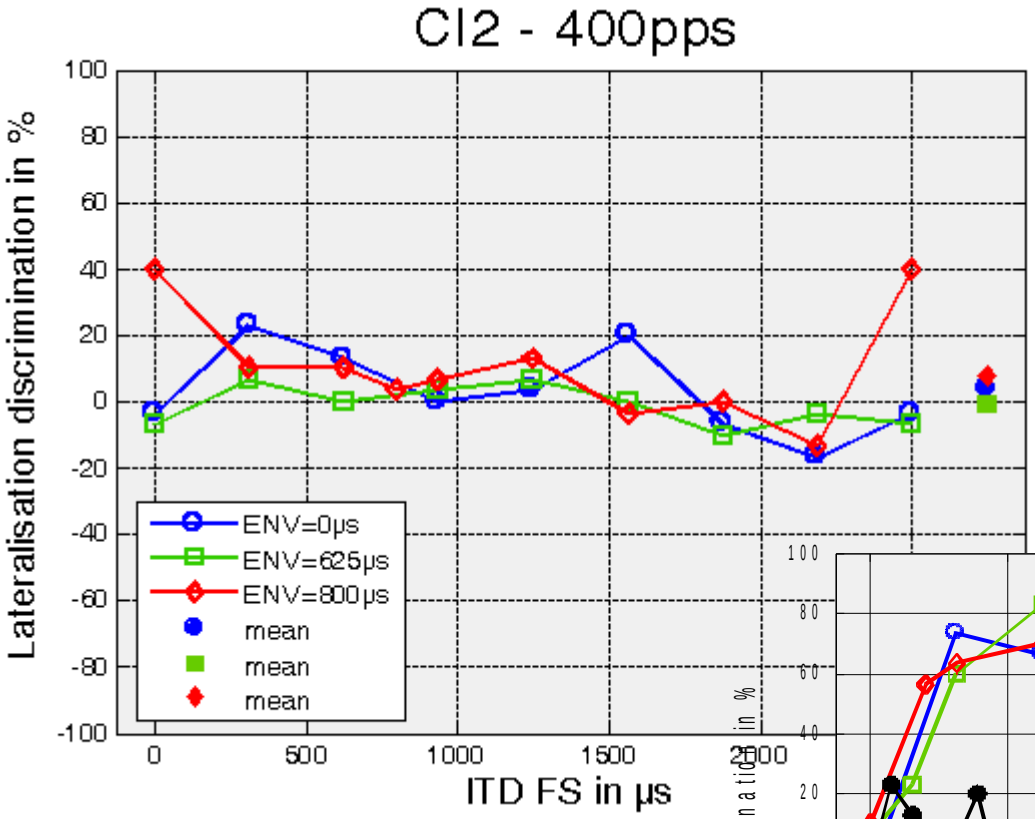
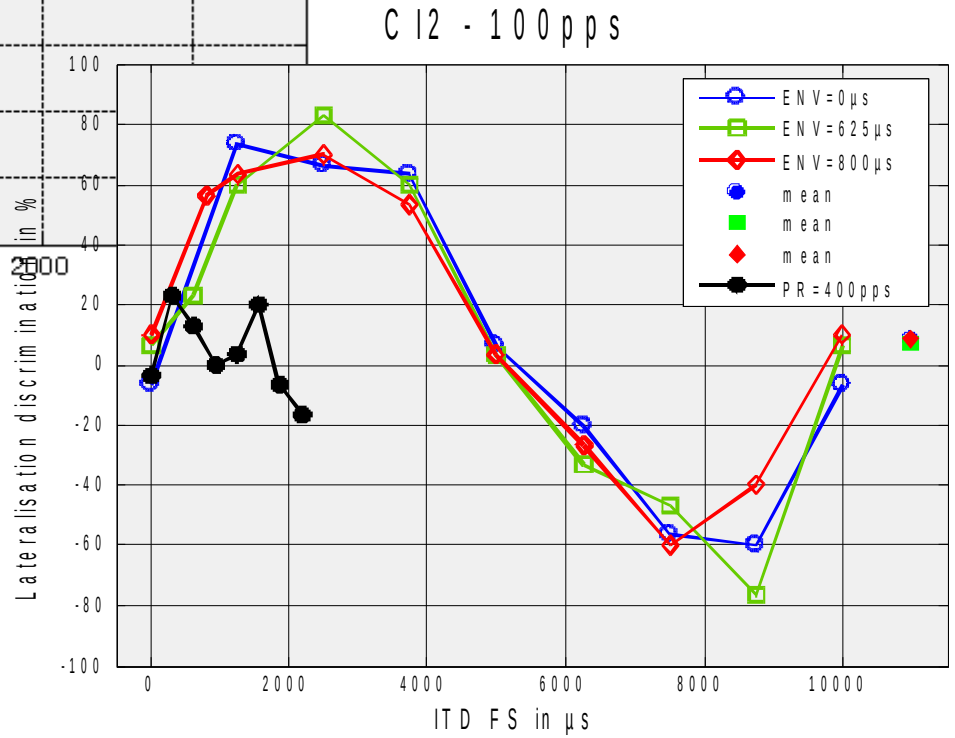
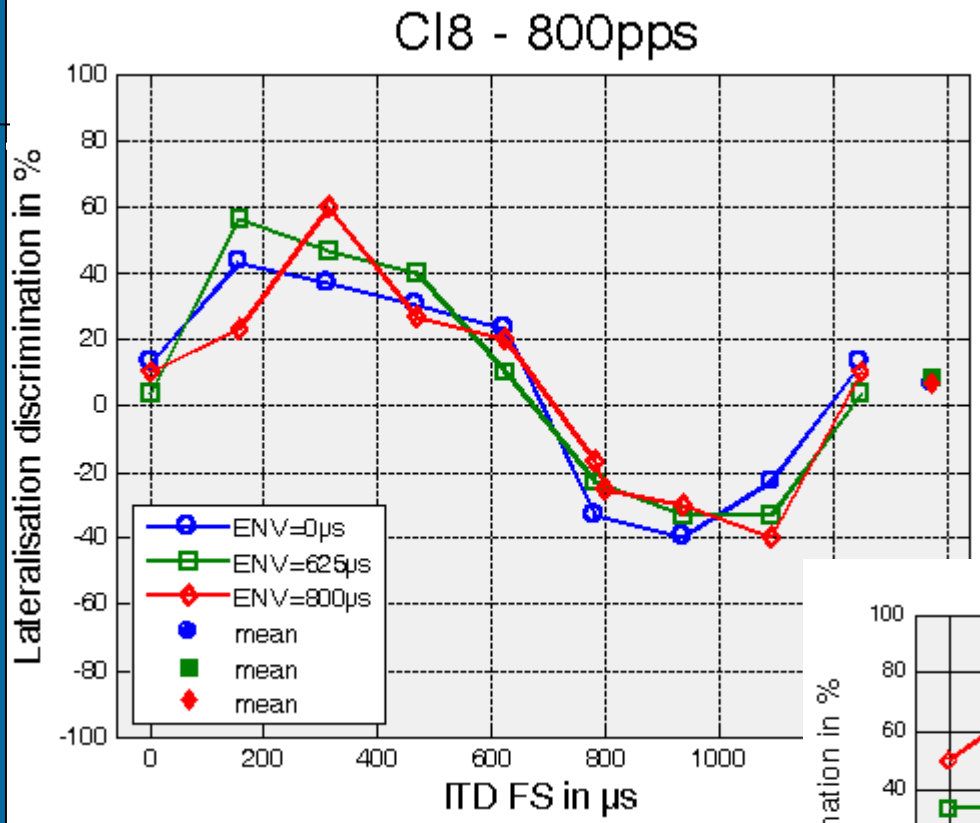
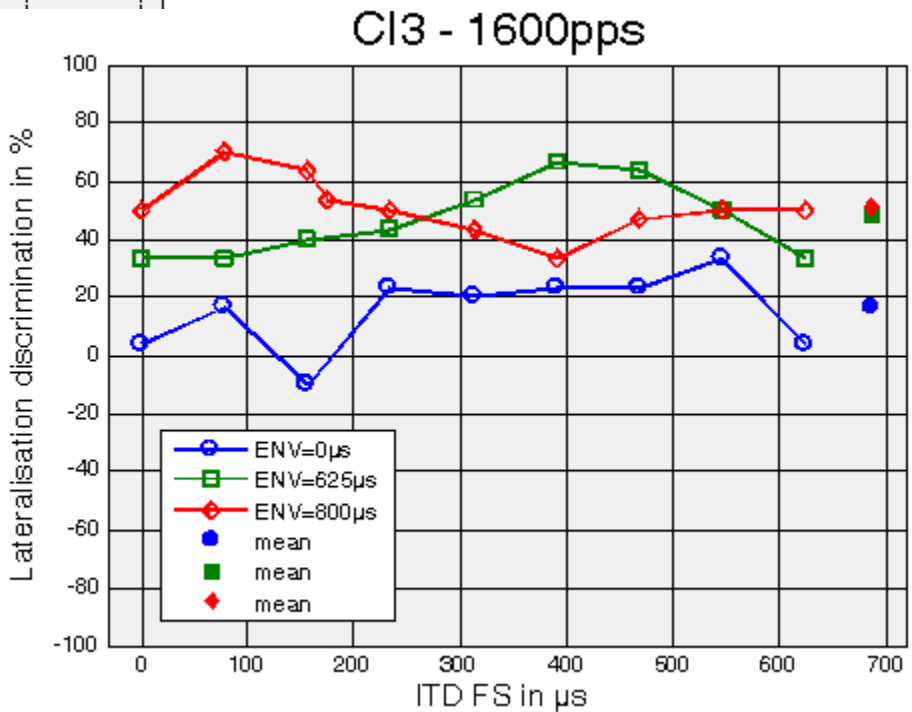




Results for Higher Pulse Rates





Sensitivity to Fine Structure ITD

Pulse rate	CI1	CI2	CI3	CI8	NHs
100		< 0.001	-	-	-
150		< 0.001	-	-	-
200	< 0.001	0.01	-	-	-
400	0.75	0.21	< 0.001	< 0.001	< 0.001
600	-	-	-	-	< 0.001
800	-	-	<0.001	<0.001	< 0.139
938	-	-	-	0.45	< 0.712
1600	0.46	-	0.11	-	-

Conclusions of Study II

- High sensitivity to ITD_{FS} (in 2/4 subjects up to 800 pps)
- Low sensitivity to ITD_{ENV} (low modulation rate)
- High inter-subject variability of performance

Overall Conclusions

- CI listeners are likely to benefit from encoding fine structure ITD at lower rates in CI systems
- The highest rate providing fine structure ITD cues is lower than in acoustic hearing with sinusoids (up to 1500 Hz)