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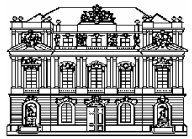
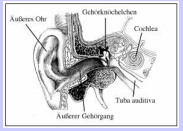


Acoustics Research Institute
Austrian Academy of Sciences

Interaural time differences in temporal fine structure, onset, and offset in bilateral electrical hearing

B. Laback, P. Majdak
Acoustics Research Institute, Vienna, Austria

W. D. Baumgartner
ENT-Department, Vienna University Hospital, Austria



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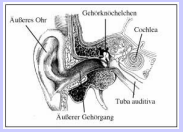
Many thanks to

Med-El company for providing equipment for direct binaural electrical stimulation

The Cochlear Implant users for participating in our time-consuming experiments



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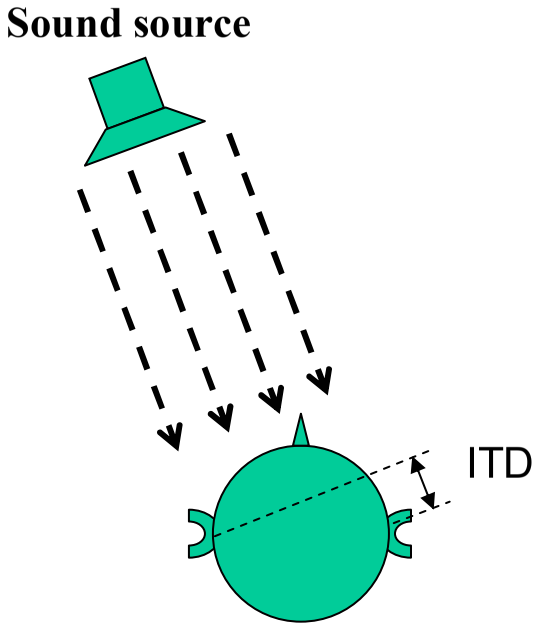
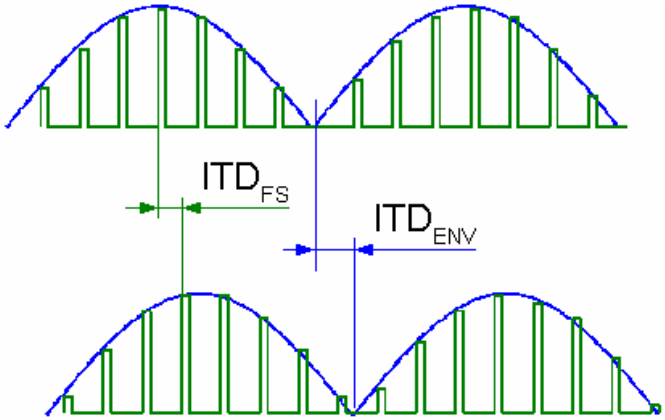
Interaural time differences



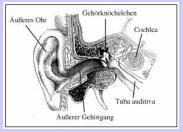


Interaural time differences (ITD) occur in

- temporal fine structure
- temporal envelope

ITD relevant for

- Localization of sound sources (left/right dimension)
- Speech understanding in noise (binaural unmasking)
- *Auditory Scene Analysis (separation of multiple sources, acoustic orientation etc)*



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ITD in bilateral electrical hearing

Compared to normal hearing (NH) listeners, cochlear implant (CI) listeners often show Ö

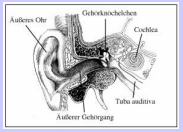
- Higher JNDs (just noticeable differences) for ITD
- Higher inter-individual variability in ITD-JNDs
- Highly elevated ITD-JNDs for pulse rates exceeding 200 pulses per second (pps)
- Amplitude modulation improves performance at higher rates

[e.g., van Hoesel and Tyler, 2003; Lawson et al., 1998; Laback et al., 2004]

Current clinical CI systems

- Uncontrolled offset of stimulation timing between the two ears causes uncontrolled ITD in the fine structure

➔ Are CI listeners sensitive to ITD in fine structure?



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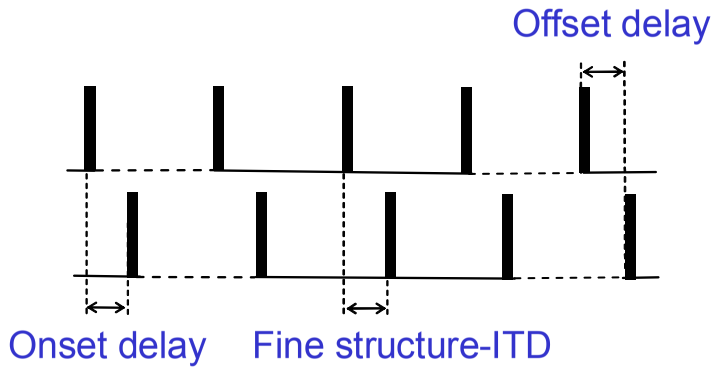
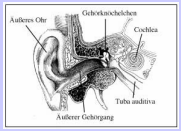
Motivation

Stimulus often used for ITD-experiments (unmodulated pulse train)



Unknowns

- Are CI listeners sensitive to ITD in the fine structure only (without onset and offset ITD cues)?
- What is the relative contribution of ITD in the fine structure and in the gating portions (onset and offset)?
- How does this depend on the pulse rate?



➔Important for interpreting ITD data involving amplitude modulation (next talk by Majdak, Laback and Baumgartner)

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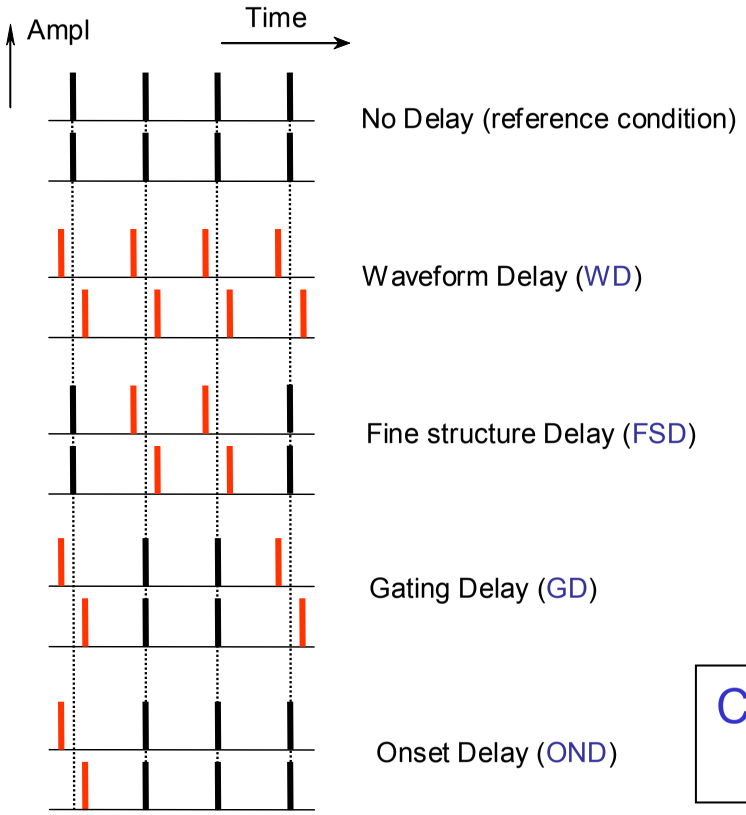
Test stimulus

ITD types:

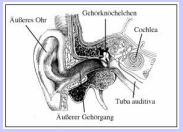


Constant amplitude at different rates

Advantage of 4-pulse-stimulus with constant amplitude at varying pulse rates

Equal number of information units carrying fine structure delay (FSD) and gating delay (GD)

➔ Avoid interfering effect of pulse amplitude across rates on relative potency of FSD and GD. Stimuli with constant duration across pulse rates would require amplitude adjustment to provide constant energy (or loudness)



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Experimental design I

Electrical stimulation

- Pitch-matched interaural electrode pair; loudness balanced levels
- Direct stimulation via *Research Interface Boxes* (interaural accuracy: 2.5 µs)

Acoustical stimulation (simulation of electrical stimulation)

- Filtered clicks (3900-5400 Hz); Background (pink) noise
- Presentation via headphones

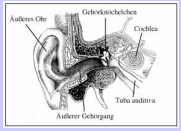
Independent variables

- ITD type
- Pulse rate (100, 200, 400 and 800 pps)

Procedure

- *Lateralization discrimination* (2AFC)
- Method of *Constant Stimuli*
- Response feedback

Subjects



- 5 bilateral CI listeners (*Med-El Combi40+/40+*)
  - postlingually deafened
- 4 Normal Hearing (NH) listeners

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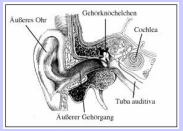
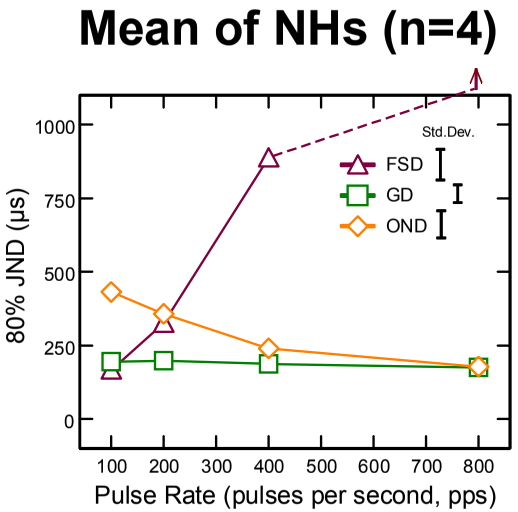
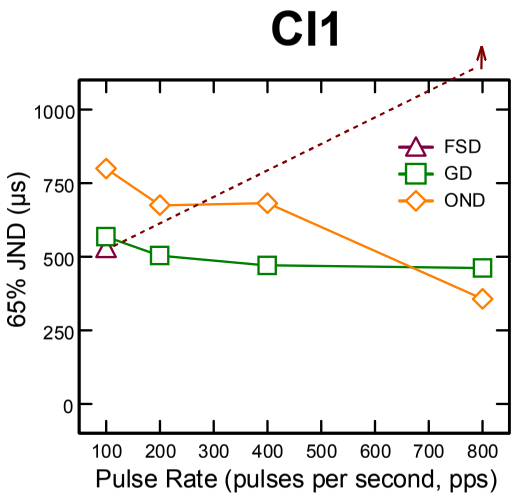
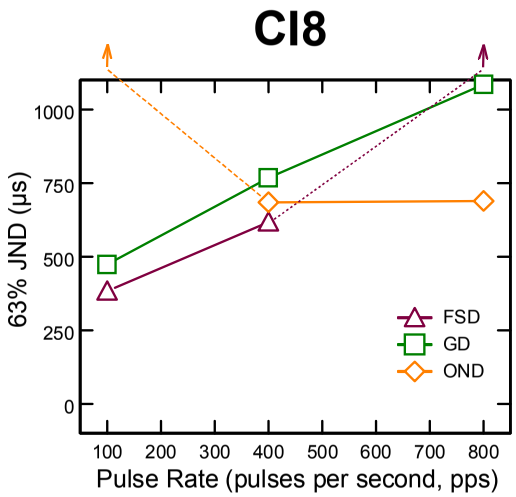
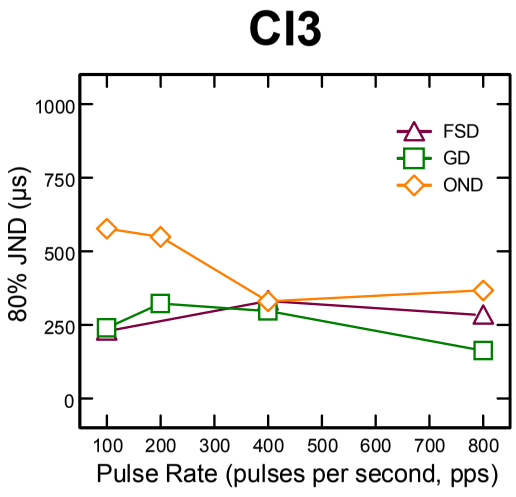
JNDs of NH listeners (mean) and 3 CI listeners











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Monaural experiment

Clarification if monaural cues were used by the listeners when performing the lateralization discrimination task (e.g., periodicity pitch)

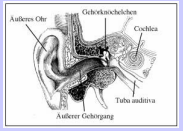
Design

- *Detection Task* (3AFC, ìoddity taskî)
- All ITD conditions (except WD); ITD values corresponding to the JNDs
- Monaural presentation
- Response feedback

Results

All subjects performed at chance level for all conditions tested

➔ Lateralization performance in previous experiment was NOT based on monaural cues



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Summary of results

- CI listeners lateralize upon ITD in the fine structure only (without influence of onset/offset cue or ongoing envelope cues)
- For one CI user, the sensitivity to fine structure ITD exceeds even that of normal hearing listeners [duration of deafness: 4 weeks; testing time: 6 weeks after implantation, that is 1 week after activation of the system]
- Wide range of upper rate limit for perception of fine structure ITD:
CI1: 100pps; CI8: 400 pps; CI3 > 800 pps
- Onset/offset ITD appears to be a lateralization cue at all pulse rates tested

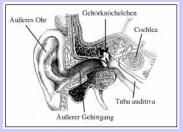
Open question

Do these results are valid for more practical situation: a constant stimulus duration instead of a constant number of pulses (at different pulse rates)

Hypothesis

The advantage of a larger number of pulses at higher rates (temporal integration) is compensated by the lower pulse amplitude, necessary to achieve constant energy (≅ loudness)

➔ Confirmed by experiment applying constant stimulus duration across rates



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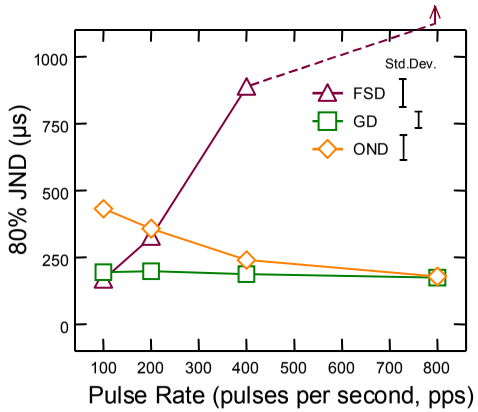
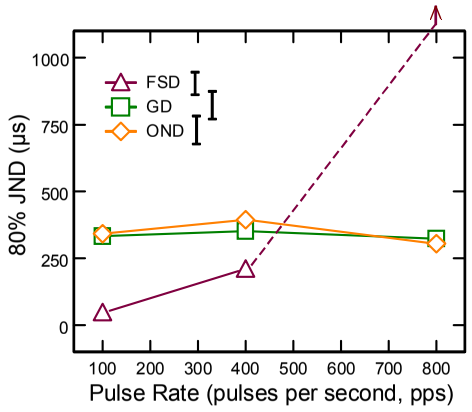
Comparison between 4 pulse stimulus and constant duration stimulus (300 ms)

4 pulses (replotted)

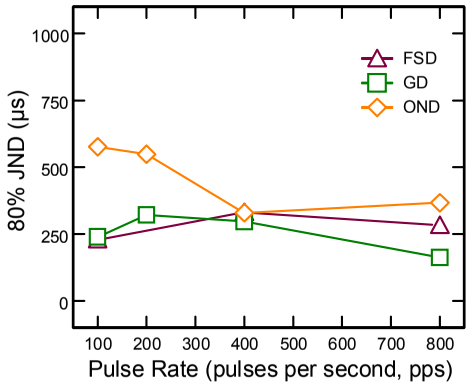
300 ms

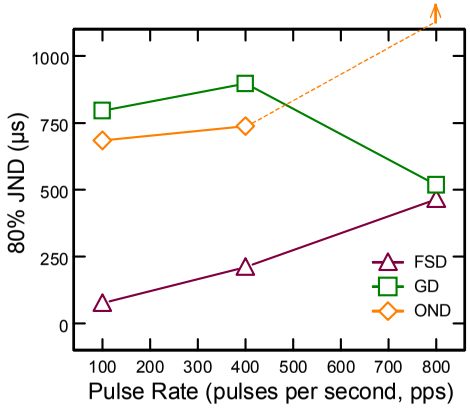
mean of NH (n=3)

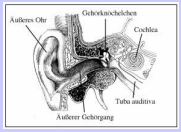




CI3







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Extended Results

- The relative potency of fine structure and onset/offset ITD at different rates determined with the 4 pulse stimuli corresponds roughly to that determined using stimuli with constant duration across pulse rates (300 ms)
- The relative effect of gating ITD tends to decrease with increasing stimulus duration (at all rates tested)

- The observed sensitivity of CI listeners to fine structure ITD suggests the importance of encoding stimulus fine structure in future stimulation strategies
- Further data on the interaction between fine structure and ongoing envelope ITD will be presented in the next talk (Majdak, Laback, and Baumgartner)