Synergies for hearing instrument developments from cochlear implant research

Norbert Dillier

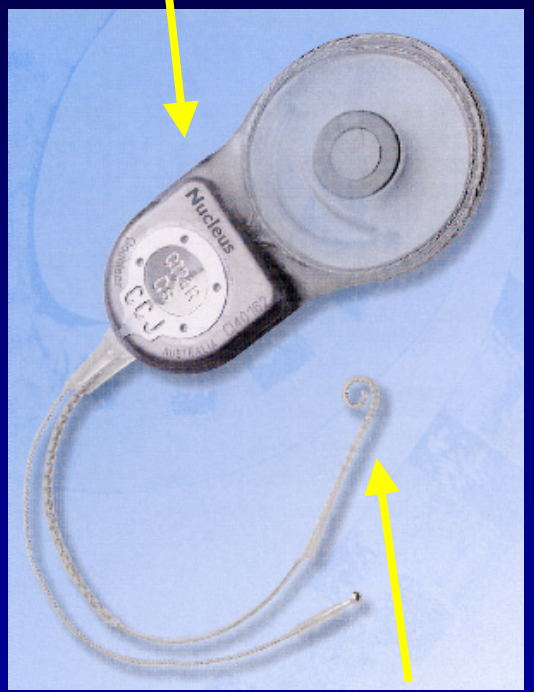
Laboratory of Experimental Audiology
ENT Department University Hospital Zürich

Hearing aid developers forum, Oldenburg, July 10-11, 2003

Challenges for improved performance with cochlear implants

- Selective stimulation of small groups of nerve fibers (with minimal channel interaction)
- Adequate and suitable signal processing strategies
- Appropriate mapping of signal parameters to patient-specific psycho-electrical stimulation conditions (loudness, pitch, timbre)

Components of a Cochlear Implant Systems



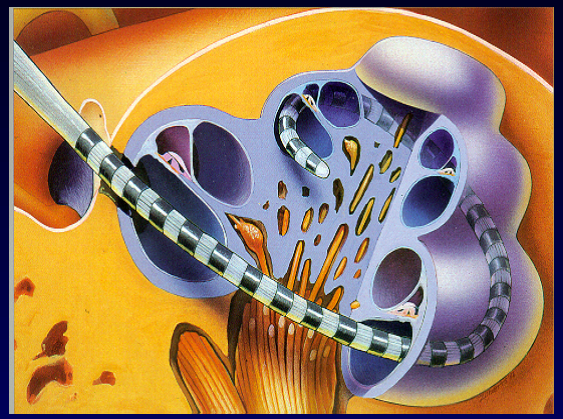
Implant

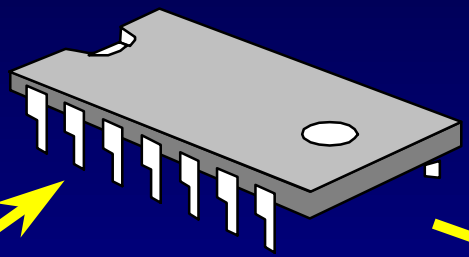
Cochlear Implant Research

- Electrodes, implanted electronics
- Speech coding strategies
- Fitting procedures
- Preprocessing, noise reduction
- Bilateral/bimodal stimulation

Speech coding strategy

signal processing





Number and type of electrodes

Analog preprocessing

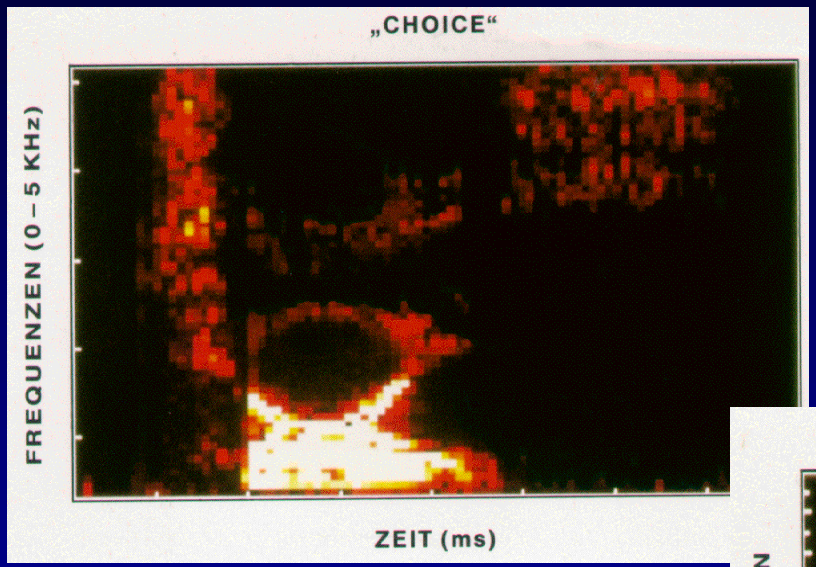
Microphone

Telemetry

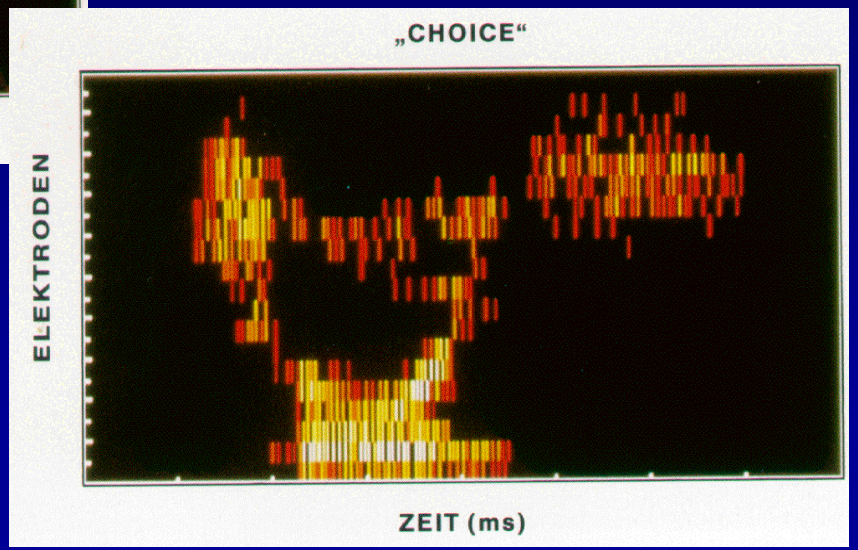
Implant characteristics

Radio frequency transmission

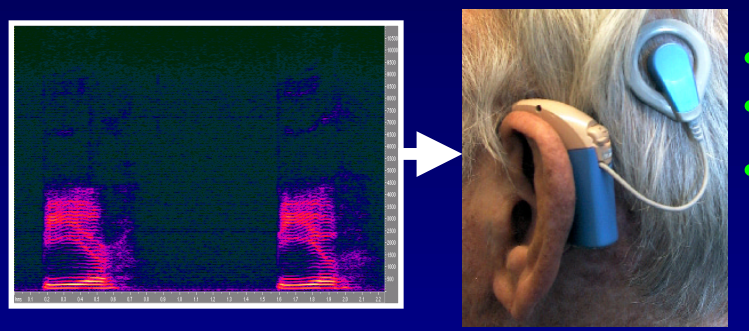
Sound pattern



is converted into a stimulation pattern



Specch coding strategies



- SPEAK

  Spectral Peak

  – Low pulse rate (250 pps) with 6 to 10 spektral maxima

- CIS

  Continuous Interleaved Sampling

  – High pulse rate (2000 pps) on fixed stimulation channels

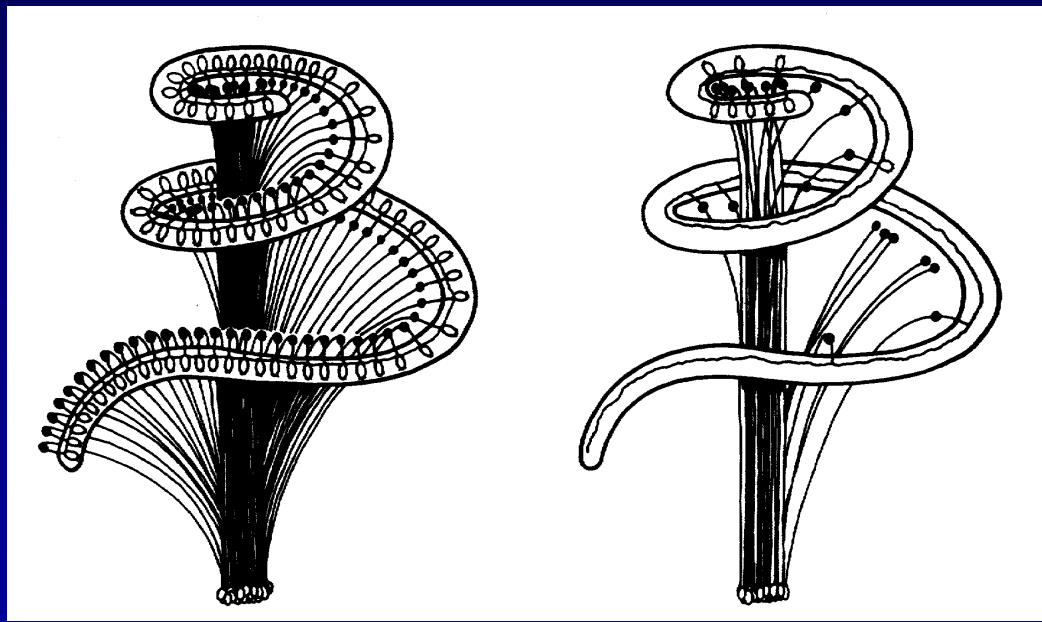
- ACE

  Advanced Combination Encoder

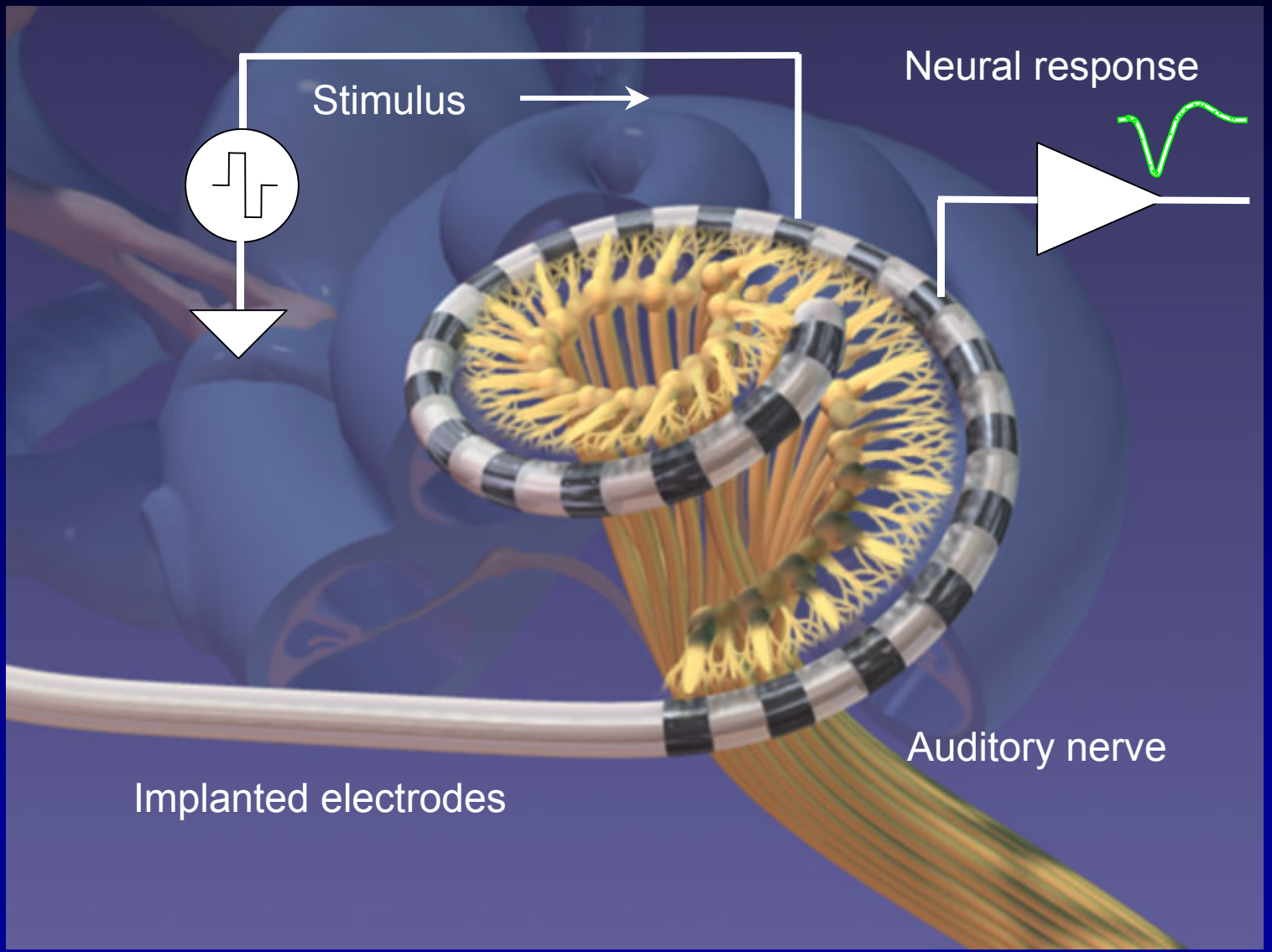
  – High pulse rate with many spectral maxima

Patient variables which may influence choice of coding strategy

- Aetiology
- Age, duration of deafness
- Habituation, training
- Distribution and condition of auditory nerve fibers



Intracochlear recordings of electrically evoked compound action potentials (ECAP)

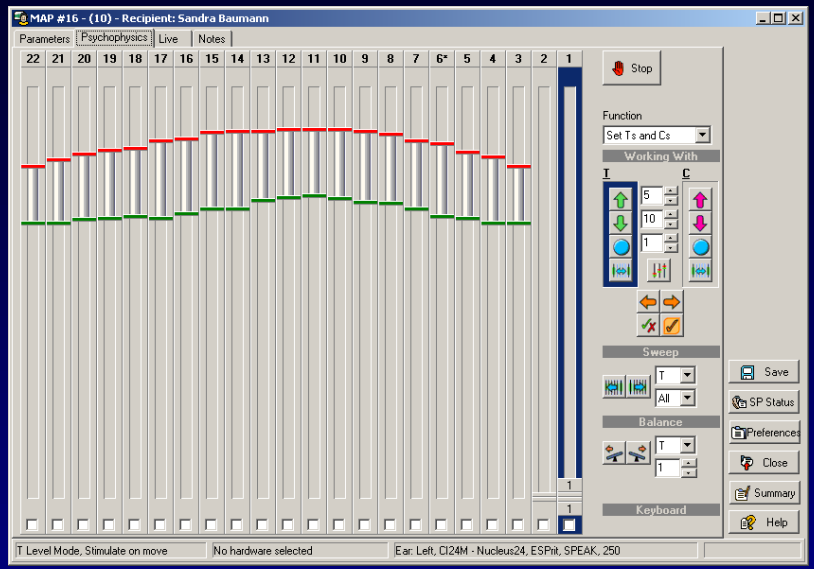


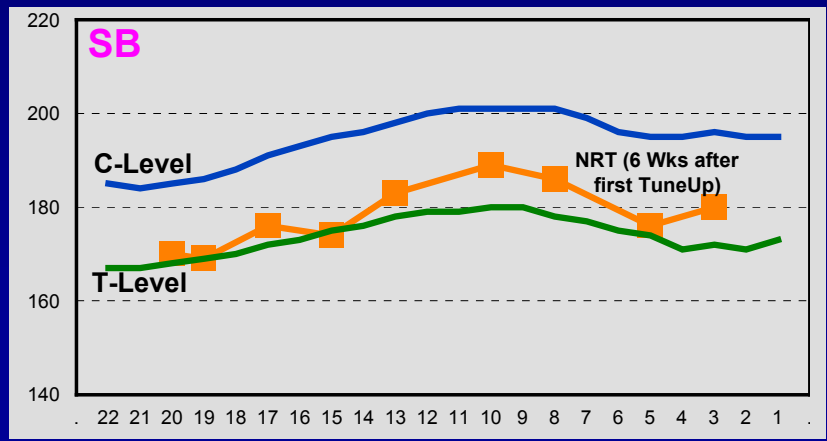
NRT recordings

- Assess peripheral function of auditory pathway (not central mechanisms!)
- Can be obtained intraoperatively
- Can be repeated any time even with uncooperative, sleeping or (hyper)active subjects
- Can be performed as a simple, semi-automatic procedure for routine clinical use or using more sophisticated, research-oriented paradigms

NRT Data and Speech Processor Maps

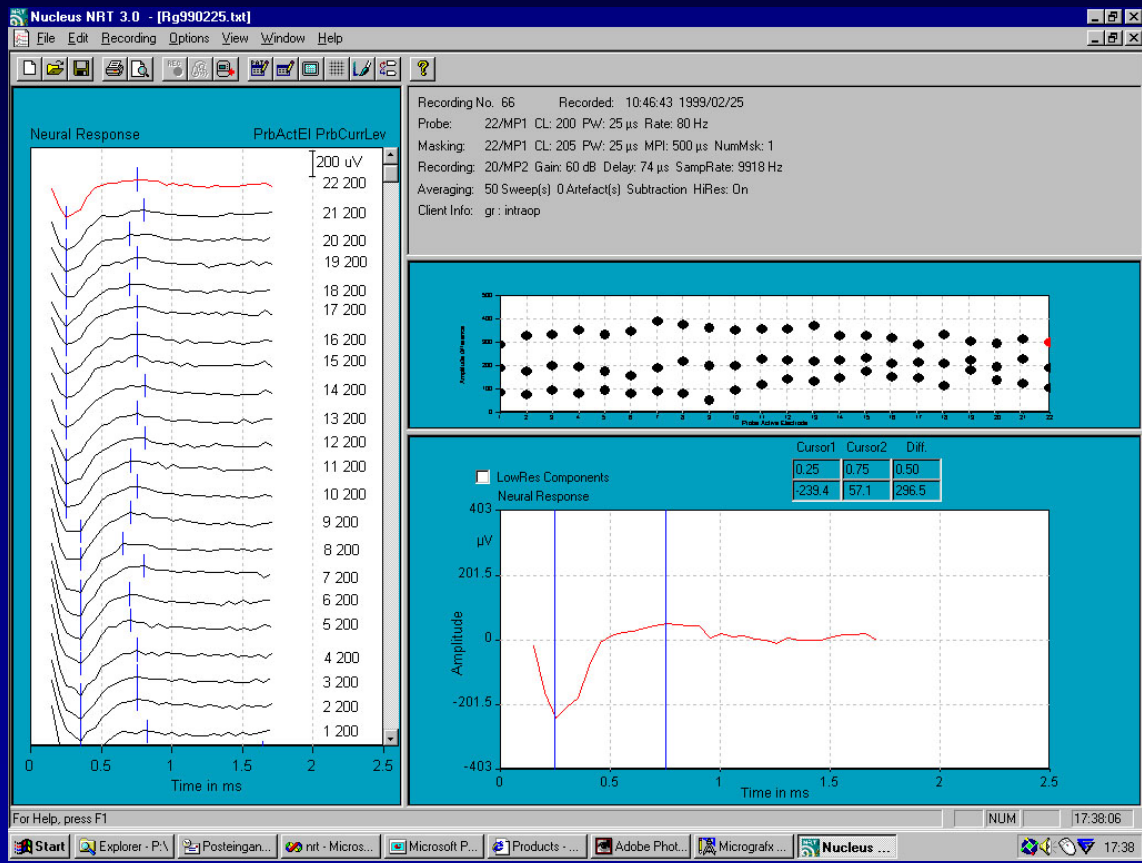
- Several studies have shown that the Neural Response threshold often lies within the T- and C-levels of the patient's Map
- The profile across the electrode array of the Neural Response thresholds are also often parallel to the profile across the array of the T- and C-levels of the Maps
- This may help us to
  - Locate the operating range of the Map quickly and
  - Set the Map profile across the array with only a small amount of data



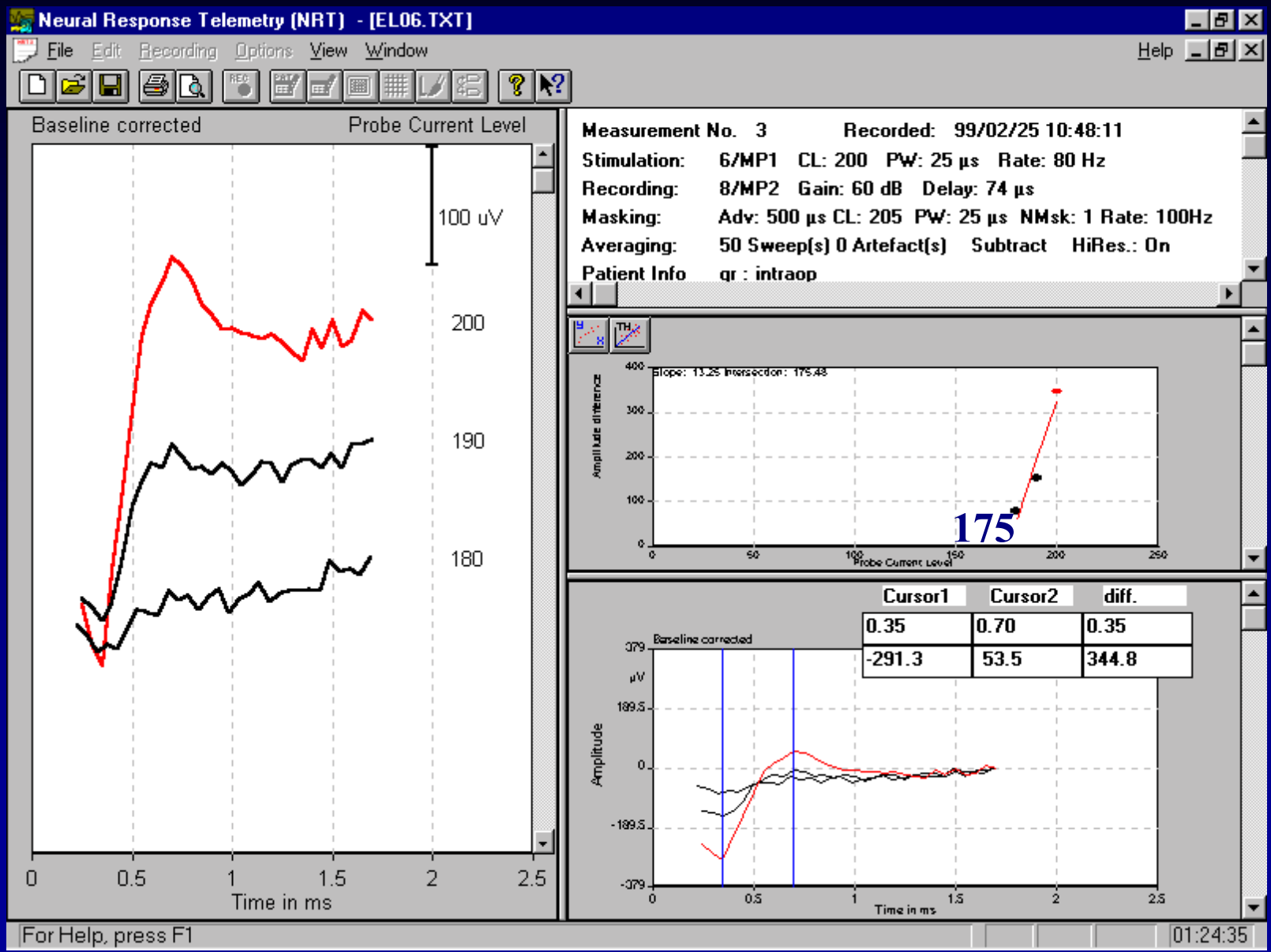


Benefits of performing intraoperative measurements

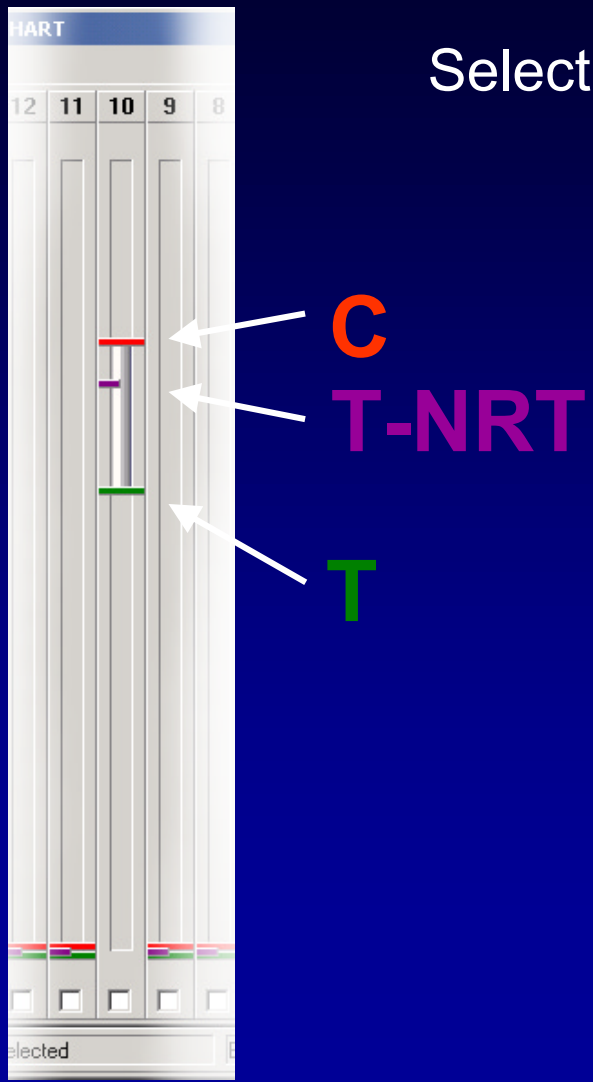
- NRT data is available prior to Speech Processor fitting
- NRT measurements can be made in the OR while the surgeon is finishing the operation
- Data for estimating the Neural Response threshold for all 22 intracochlear electrodes can be collected within less than 10 minutes in the Operating room using automated procedures



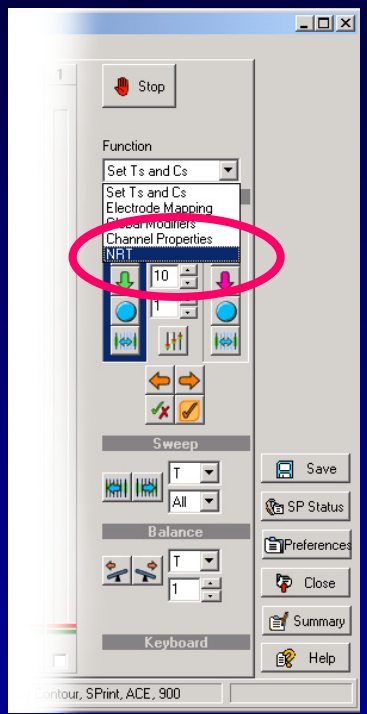
NRT threshold estimation



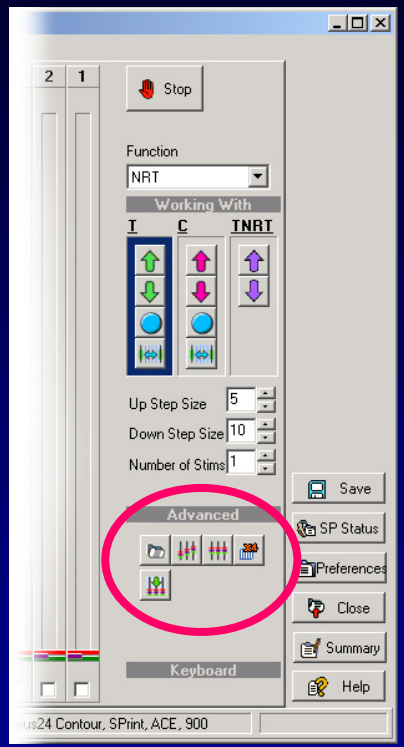
NRT Based Fitting (R126.V2)



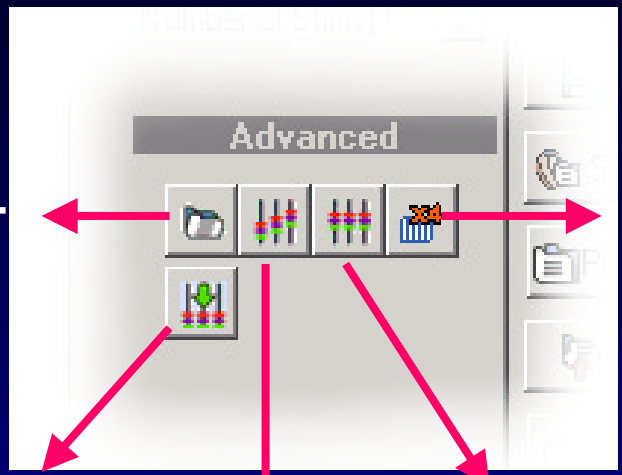
Select “NRT” in Psychophysics tab



Fitting options based on NRT-threshold profiles



Import an NRT file



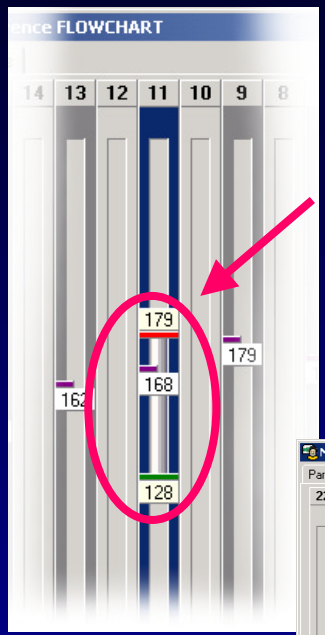
Progressive pre-set MAPs
(eg, Almqvist, Novy)

Reset TNRT levels to zero

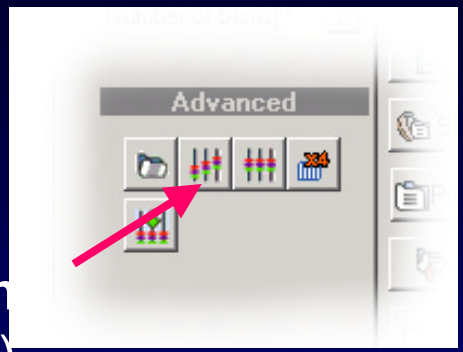
Parametric Shift/Tilt profile
(eg, Smoorenburg, Franck)

Determine T/C offset
(eg, Brown, Cooper & Craddock)

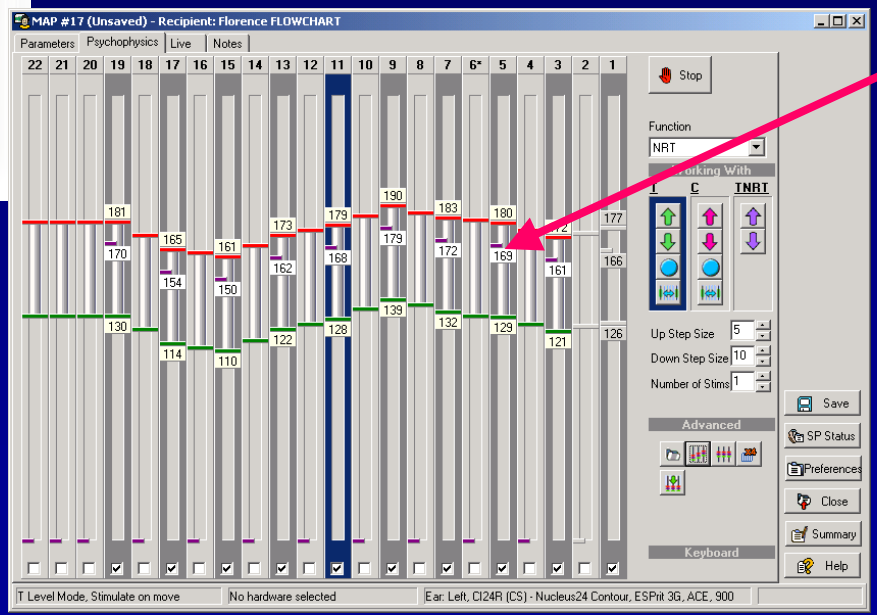
T/C Offset estimation (first suggested by Brown et al.)



1. Measure behavioural T/C levels on 1 channel

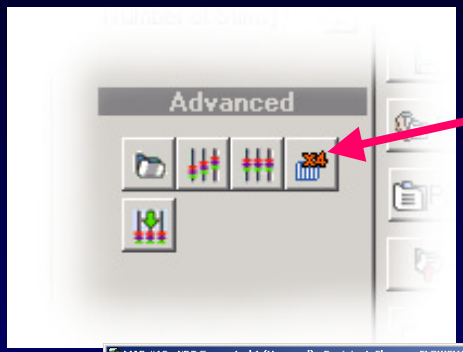


2. Click 'magic' button
("Determine T/C offset")



3. MAP is created

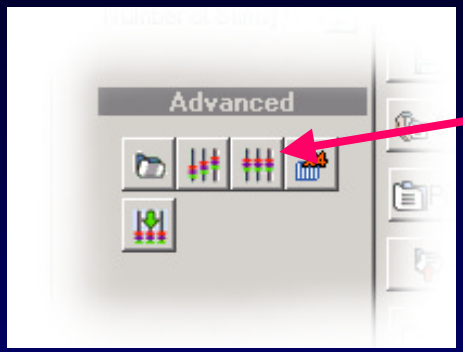
Progressive T/C Maps (suggested by Almqvist / Novy…)



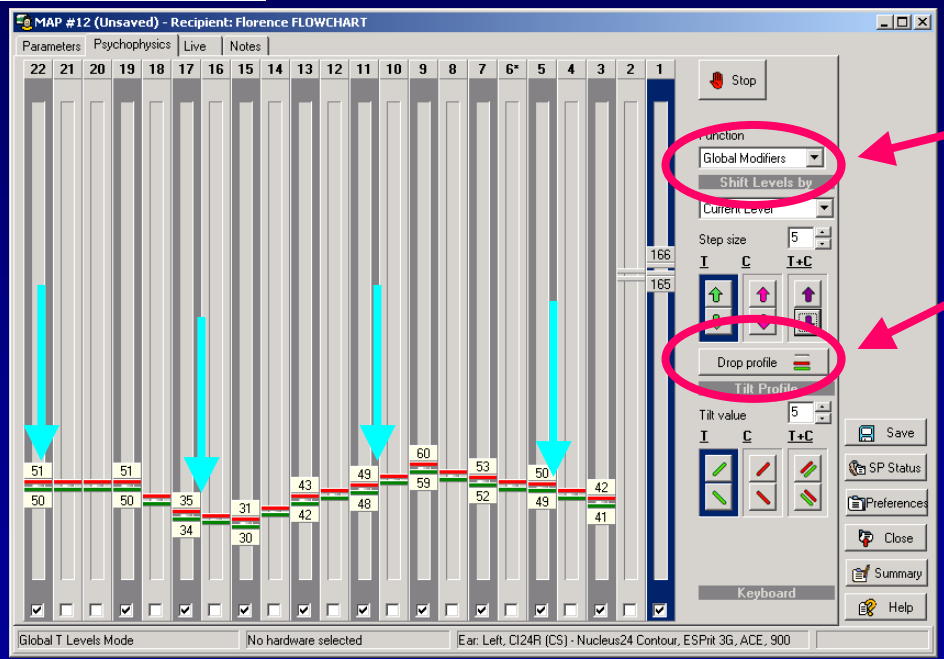
1. Click ‘magic’ button (Progressive pre-set MAPs)

2. Sequence of 4 MAPs created (place in P1 – P4 of SPrint)

Parametric Shift/Tilt (suggested by Smoorenburg et al.)

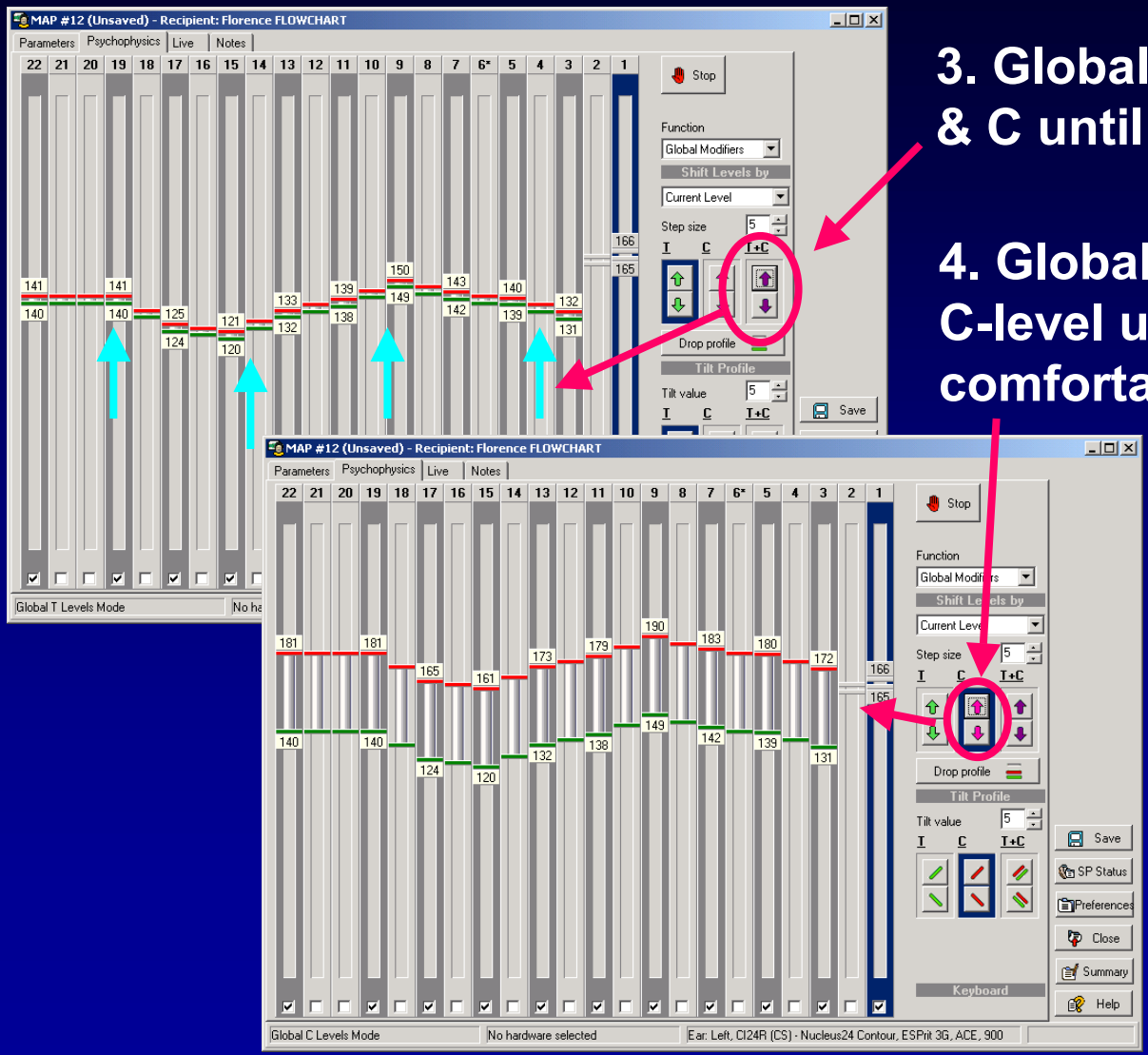


1. Click 'magic' button (Set T and C profile)



2. Select "Global Modifiers" and then "Drop Profile"

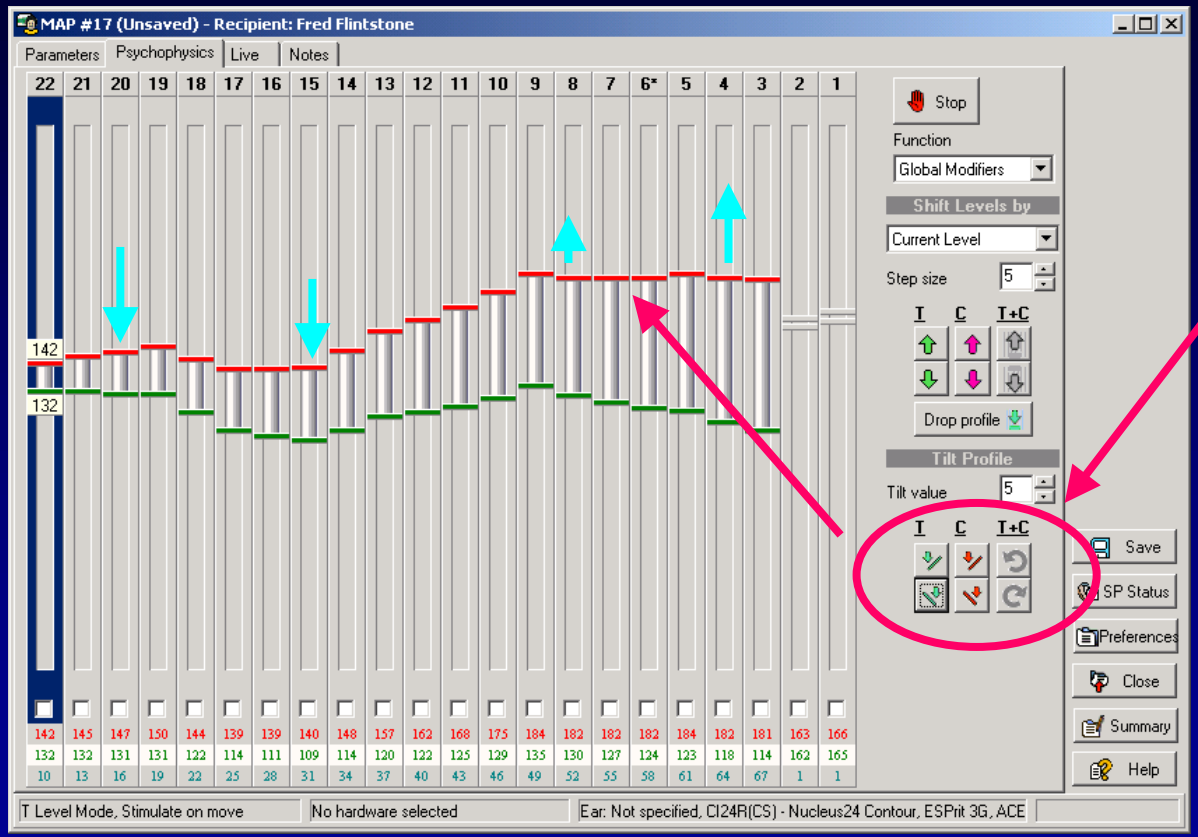
Parametric Shift/Tilt
(suggested by Smoorenburg et al.)



3. Globally increase T & C until just audible

4. Globally increase C-level until comfortable

Parametric Shift/Tilt (suggested by Smoorenburg et al.)



5. Apply tilt factors to T/C levels

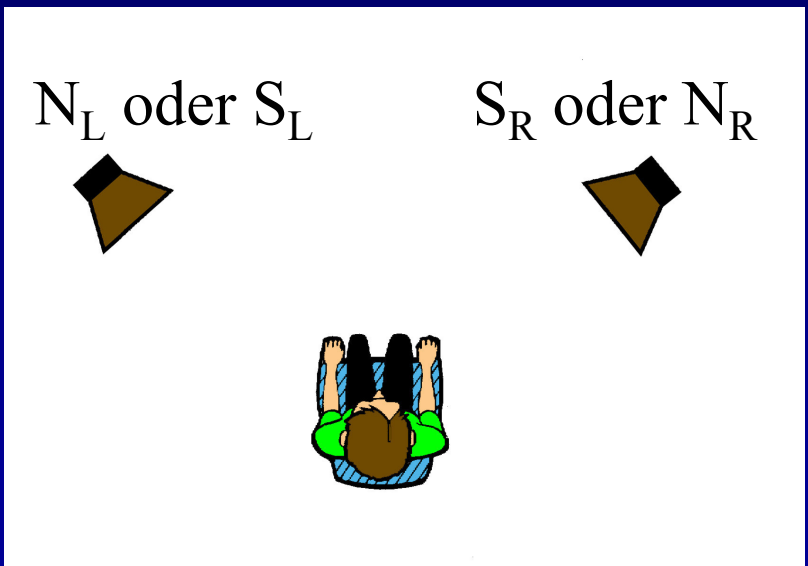
NOTE: In the Parametric Shift/Tilt technique, tilts are more typically applied when establishing a live MAP detection threshold using a MAP dynamic range of 1 CL.

NRT based processor fitting

- NRT measurements can provide valuable information for speech processor map generation
- Intraoperative NRT data does not always correspond exactly to postoperative conditions
- Changes in the NRT data are more likely to occur in the first 12 months postoperative
- Behavioral thresholds vary and change over time.
- Stimulation at higher rates may decrease NRT amplitudes and elevate NRT thresholds
- These factors need to be considered and further evaluated when fitting procedures based on NRT are introduced into clinical practice

Bilateral Head Shadow Benefit

- Benefit of bilateral stimulation by switching to the ear with the better signal to noise ration for spatially separated sound sources

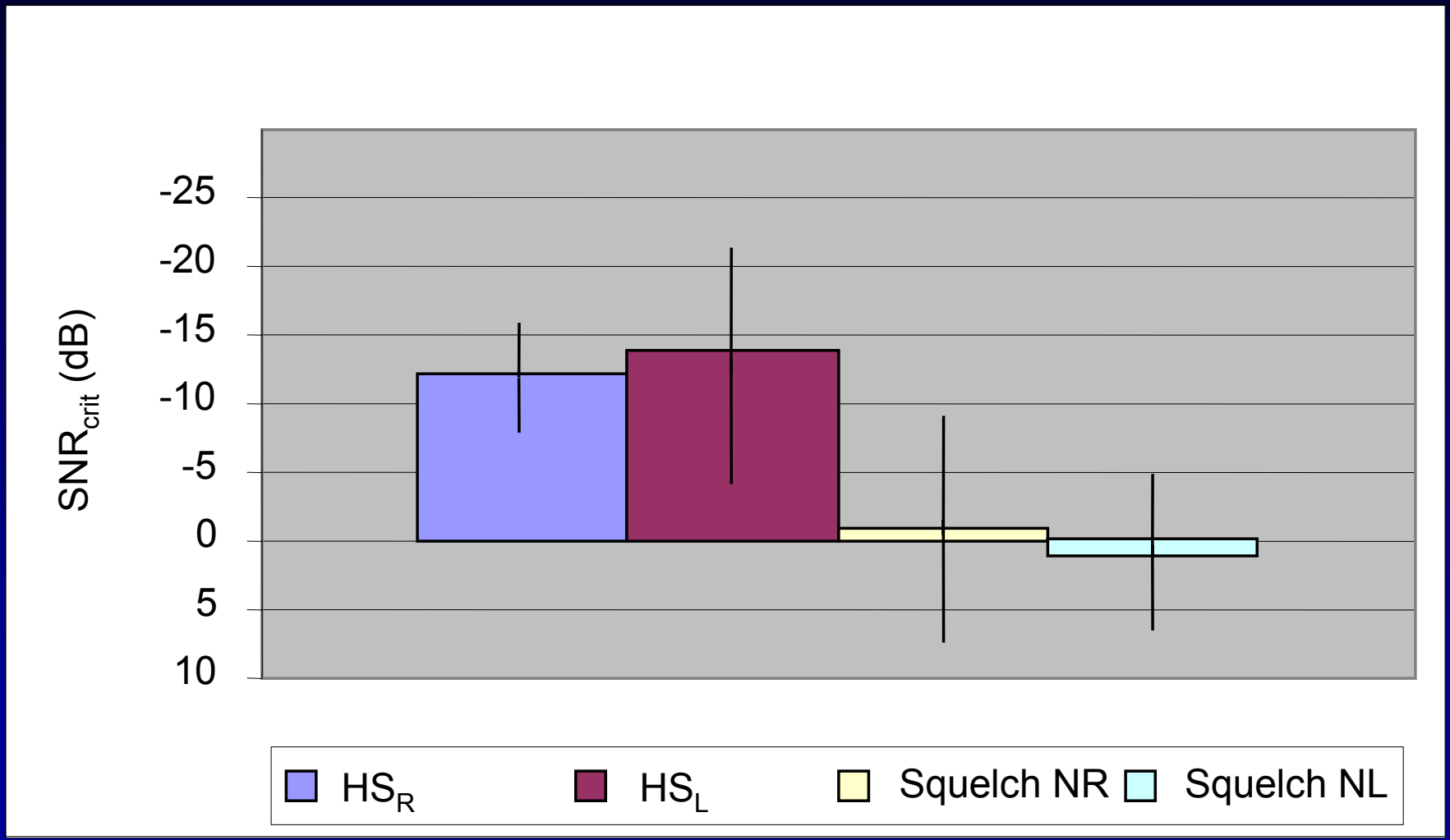


Difference between result in $S_R\&N_L$ and $N_R\&S_L$ condition for each ear:

$HS_R = S_R\&N_L - N_R\&S_L$

$HS_L = S_L\&N_R - N_L\&S_R$

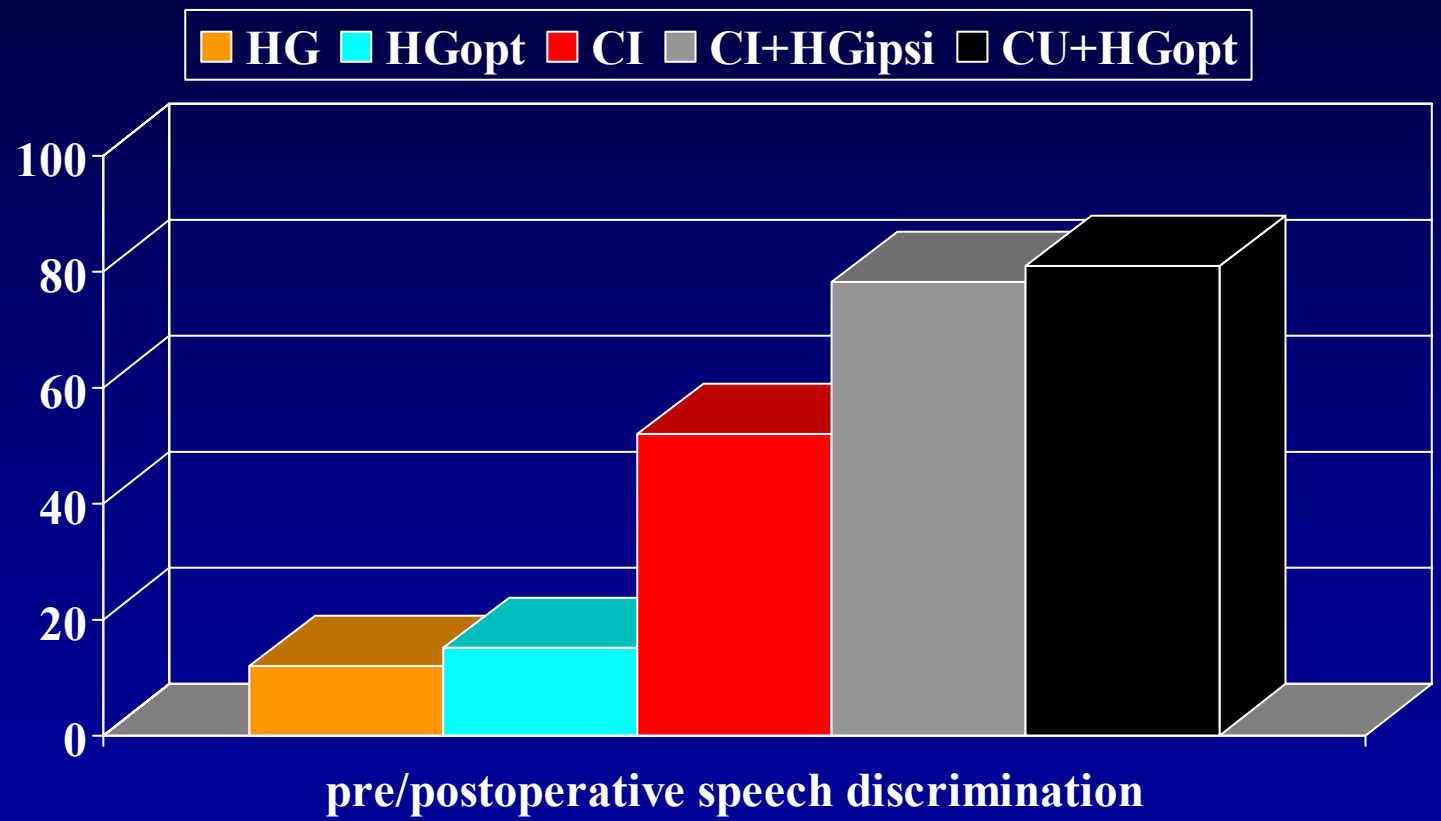
Head Shadow Benefit und Squelch: OLSA



Bimodal Stimulation

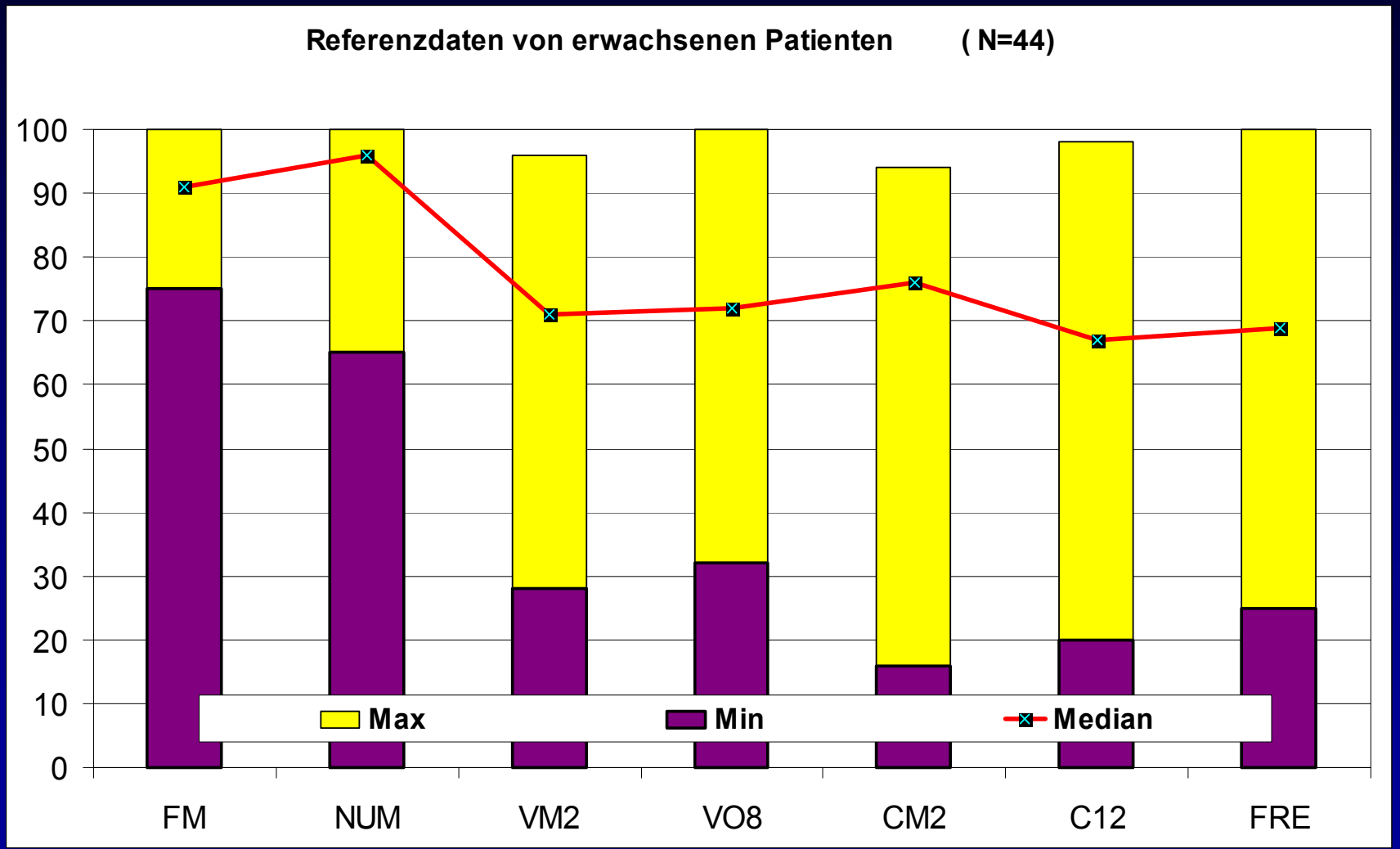
- CI on one side, hearing instrument on contralateral ear
  - Ear with CI may be completely deaf
  - Combination of auditory sensations in central auditory system
- CI and hearing instrument on the same ear
  - CI surgery should not impair the preoperative residual hearing (“safe surgery”)
  - Combination of auditory sensations may take place either peripherally or centrally

Example of electroacoustic synergy with bimodal fitting

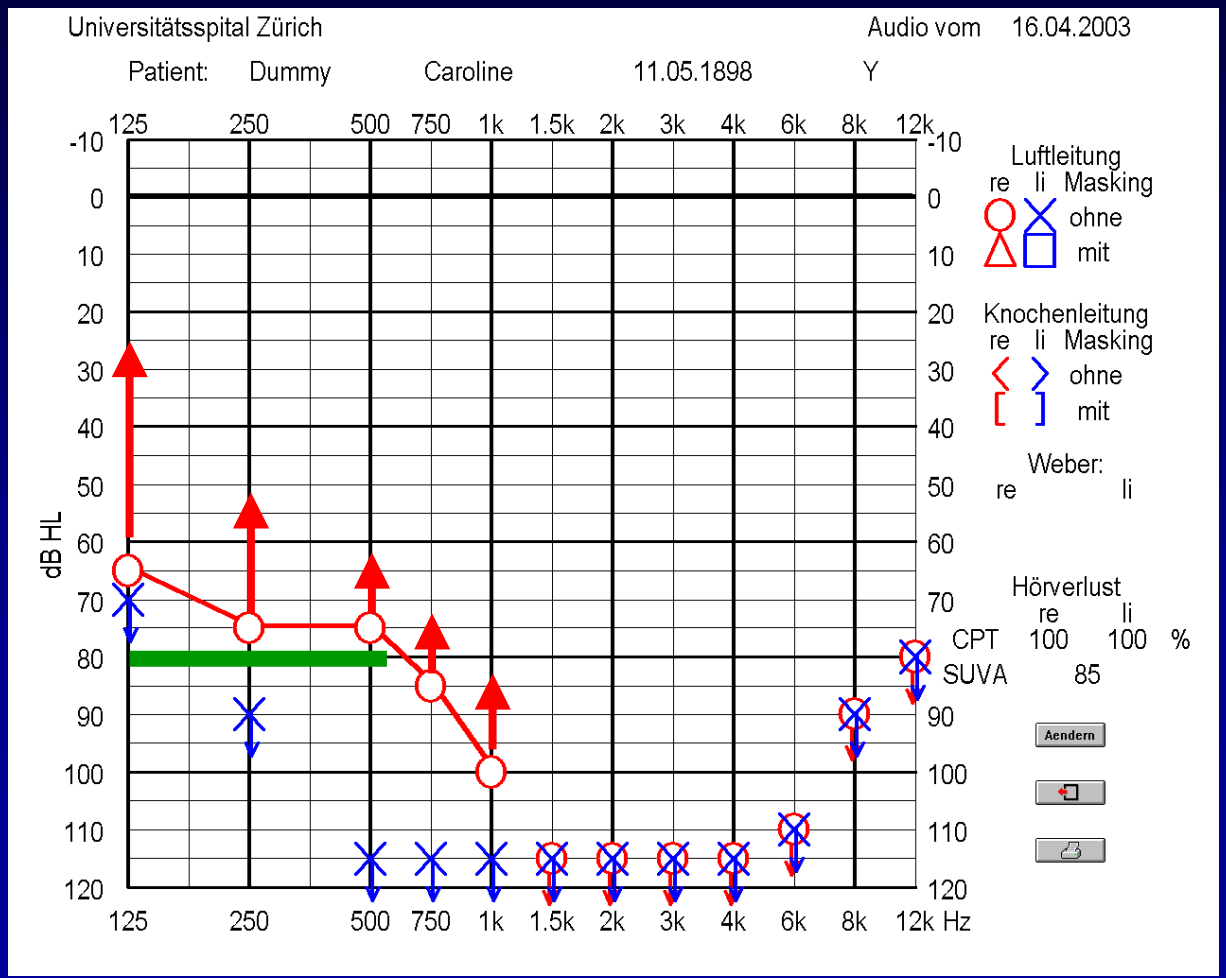


J.- Kiefer, HNO-Univ.Klinik Frankfurt, 2003

MAC - Results adult CI users



Sample audiogram for candidacy in electroacoustic study



Cochlear implants vs. Hearing instruments differences

Indication	Total deafness
Signal processing	Coding strategies
Fitting procedures	Objective measures (NRT based)
Evaluation	Psychoacoustic and electrophysiological procedures

Cochlear implants vs. Hearing instruments similarities

Indication	Profound deafness
Signal processing	Multichannel compression Loudness equalization
Fitting procedures	Software based Fitting rules
Evaluation	Free field measurements Speech recognition tests in quiet and noise