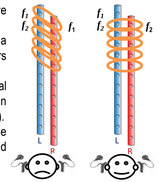
Comparison of Interaural Electrode Pairing Methods: Pitch matching, ITD Sensitivity, and Binaural Interaction Component

Hongmei Hu, Mathias Dietz
Medizinische Physik, Universität Oldenburg and Cluster of Excellence "Hearing4All", Germany
Email: hongmei.hu@uni-oldenburg.de, mathias.dietz@uni-oldenburg.de

Introduction

- Compensation for mismatched place-of stimulation is critical for bilateral cochlear implants (CIs) to have better speech perception, localization, sound image fusion and so on.
- Pelizzone (1990) suggested that the binaural interaction component (BIC), **BIC= B-(L+ R)**, could be a potential way to pair cochlear implant electrodes. If two implants are placed to stimulate auditory-nerve fibers from comparable regions in the two ears, the BIC amplitude is larger.
- It has been shown in animal experiments that the magnitude of the BIC decreases for increasing interaural place of stimulation mismatch (Smith and Delgutte 2007). However, a replication of these results in human subjects resulted in a less clear place dependence of the BIC amplitude (He et al. 2010, Gordon et al. 2012).
- In this study, we assess and compare three interaural electrode pairing (IEP) methods collected from the same subjects: (1) BIC amplitudes (an objective measure), (2) ITD sensitivity (psychoacoustic), and (3) interaural pitch comparison (psychoacoustic).



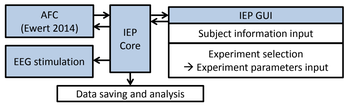
Methods

Subjects: Seven MED-EL Bilateral CIs.

ID	Sex	Age	Etiology	yrs exp HA L/R	yrs exp CIs L/R	Implant Type L/R	Reference EL /processor EL	Probe electrodes	Polarity in EEG
S1	F	27	progressive hearing loss	12/13	3/2	Sonata (EAS)/ Concerto	L4/R7	R1-7,R12	anodic first
S2	M	78	unknown	3/8	9/4	Sonata/ Sonata	L5/R5	R1-6, R9, R12	anodic first
S3	M	48	unknown	unknown	7/2	Sonata/ Concerto	L4/R4	R1-7, R12	anodic first
S4	M	55	noise	17/20	10/7	Pulsar/ Sonata	L4/R4	R1-7, R12	alternating
S5	F	59	sudden hearing loss	Na /2	5/4	Sonata/ Sonata	L4/R4	R1-7, R12	anodic first
S6	F	47	sudden hearing loss	15/22	7/0.8	Sonata/ Sonata	L4/R4	R1-12	alternating
S7	F	57	measles	16/12	9/13	Pulsar/ Pulsar	L4/R4	R1-12	alternating

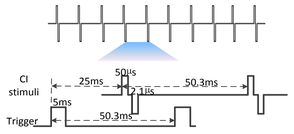
Equipment and Procedure : (Hu et al. 2014)

- Pretest: comfortable level (MCL), hearing threshold level (HL), interaural loudness balanced, centralization
- Interaural pairwise pitch comparison
- IPTD sensitivity testing
- electrically evoked auditory brainstem response (eABR) recording

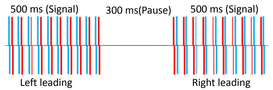


Stimuli:

- Biphasic pulse chain
- Pulse rate 19.9 pps
- Phase duration 50-60 µs
- phase gap 2.1 µs
- Monopolar stimulation mode

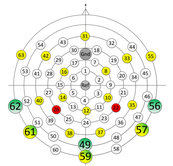


IPTD task stimuli

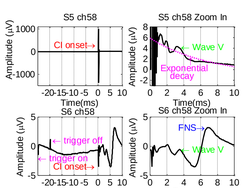


EABR recording configuration:

- Stimulation level: 65% value of the subject's dynamic range (He et al. 2010)
- 61 channels, with FPz as the ground and Cz as the reference
- 20 kHz sampling rate
- 8 kHz lowpass antialiasing filter
- 3000 pulses per condition.



Interpretation of eABR and BIC Data



Artifact detection and reduction	
Trigger on/off artifact	**Cut out**
CI onset artifact	**Linear interpolation**
Exponential decay	**Exponential fitting and / or alternating polarity stimulation**
FNS artifact	**PCA**
Signal enhancement	
Wave V and BIC	**Band pass filter and weighted average**

Figure 1 (Hu et al. 2015) The top panel and the bottom panels are eABR recordings from channel 56 (right mastoid) of subject S5 and S6, respectively. The right panels are zoomed in versions of the corresponding panel on the left hand side. The y-axis is the recorded amplitude in µV. Note the very different amplitude scales for the two subjects in the left panels. Wave eV is visible at approximately 3.6 ms.

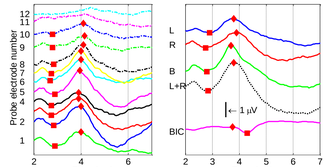


Figure 2 EABRs and the BICs of subject S6: (left) Results of the eABR at 12 probe electrodes. (right) Exemplary EABRs of L4 and R3, of the binaural stimulation (L4+R3), of the monaural sum L+R, and of the BIC. The ordinate is their amplitude values in µV. The electric artifact was lined out, wave eV and BIC are visible at approximately 3.6 and 4.1 ms, respectively.

Discussions and Conclusions

- **Place Pitch Comparison**: Most subjects showed a $\Delta E_{pitch} \leq 1$, the two exceptions being S1 with an EAS on the left side, and S6 who had only 9 months experience of listening with bilateral CIs. The data further support the hypothesis that the pitch perception adapts to the clinical processor mapping.
- **Interaural Pulse Time Differences**: Although one specific electrode pair with significantly better IPTD sensitivity than any other IEP was identified in 4 of our subjects, the pairing of the remaining 3 subjects spanned several electrodes (e.g., S5).
- **Electrically Evoked Auditory Brainstem Responses**: Clear monaural and binaural eABRs and BICs can be obtained in most of the subjects. Most subjects' data revealed a specific electrode pair that generated the largest BIC amplitude and a gradual reduction in the amplitude for those probe electrodes to either side of this
- **Comparison of Pairing Methods**: Focus is on the 4 subjects that have two regular CIs since at least 2 years and pairs could be determined (S2, S3, S5, S7). The sign of ΔE is the same for all three methods. However, the average deviation from the processor-paired electrode was 1.7 electrodes for IPTD and BIC, while just 0.3 electrodes for pitch.
- **Conclusions**: The most common interaural electrode pairing method -pitch comparison - is misleading. IPTD and BIC based pairing are arguably the better choice for subjects that have used their generic frequency map for many months or years.

Results

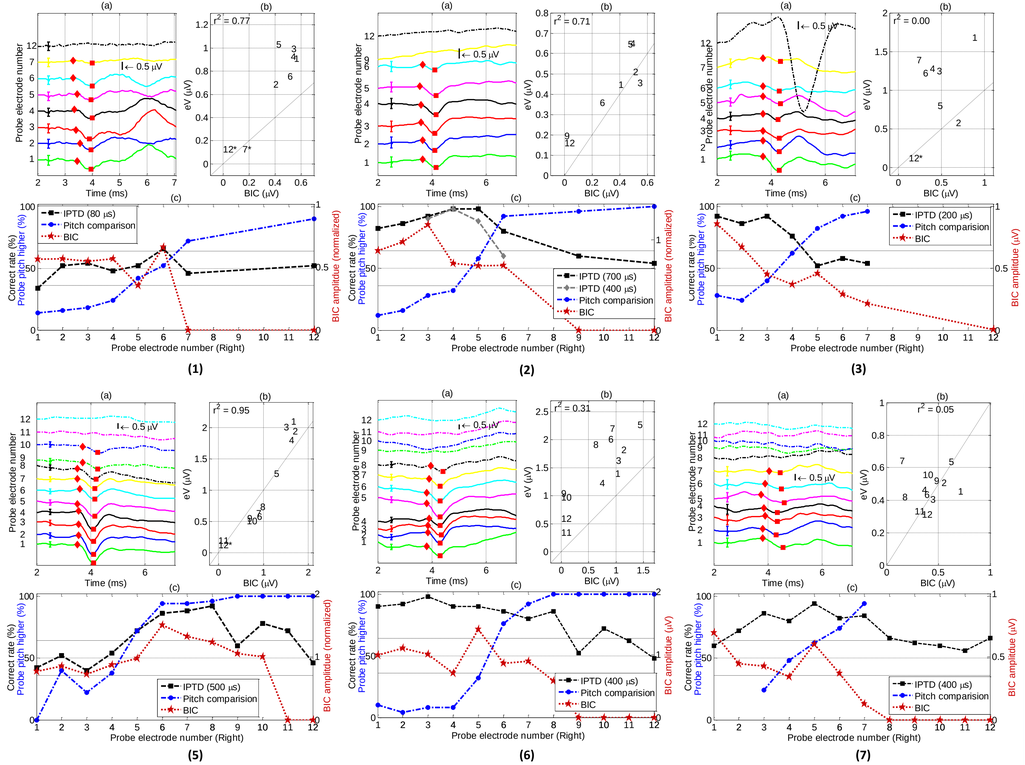


Figure 3 (1)-(7) Results of S1-S7 with reference electrode L4 (S2: reference L5): (a) BIC traces for all probe electrode pairs. The peak and the trough of each BIC are marked with diamonds and squares respectively. The error bar shows the standard deviation of the BIC which was estimated as the square root of the summed variance of the three measurements; (b) scatter plot of the wave eV and BIC amplitudes with the number referring to the probe electrode number. The ordinate and the abscissa are the amplitudes of eV and BIC in µV. The r^2 value denotes the correlation coefficient between the eV amplitude and the BIC amplitude; (c) results of the three IEP methods. The left ordinate is the percentage (%) and the right ordinate is the BIC amplitude. The line 50% indicates chance level for both the pitch and the IPTD task. Lines at 36% and 64% mark the respective 95% confidence intervals.

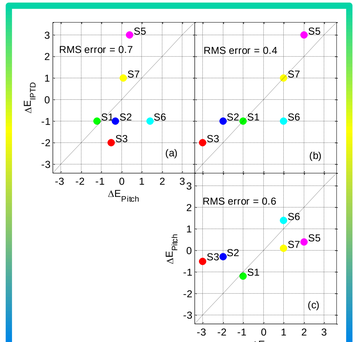


Figure 4 Three pairwise method comparisons: (a) pitch vs. IPTD, (b) BIC vs. IPTD, and (c) BIC vs. pitch. The abscissa and ordinate are the electrode offsets ΔE, i.e., the difference between processor pair and method specific pair: offset for best IPTD performance (ΔE_{IPTD}), pitch comparison (ΔE_{pitch}), and largest BIC amplitude (ΔE_{BIC}).

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