Assessment of binaural interaction in SSD CI users from auditory brainstem responses

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Introduction

In a study by Bernstein et al. (2021), single sided deaf cochlear implant users (SSD-CI) with a normally hearing (NH) contralateral ear exhibited a relatively large interaural mismatch between intracochlear positions for electrical and acoustic stimulation. To improve binaural processing, the study proposed reducing this mismatch.
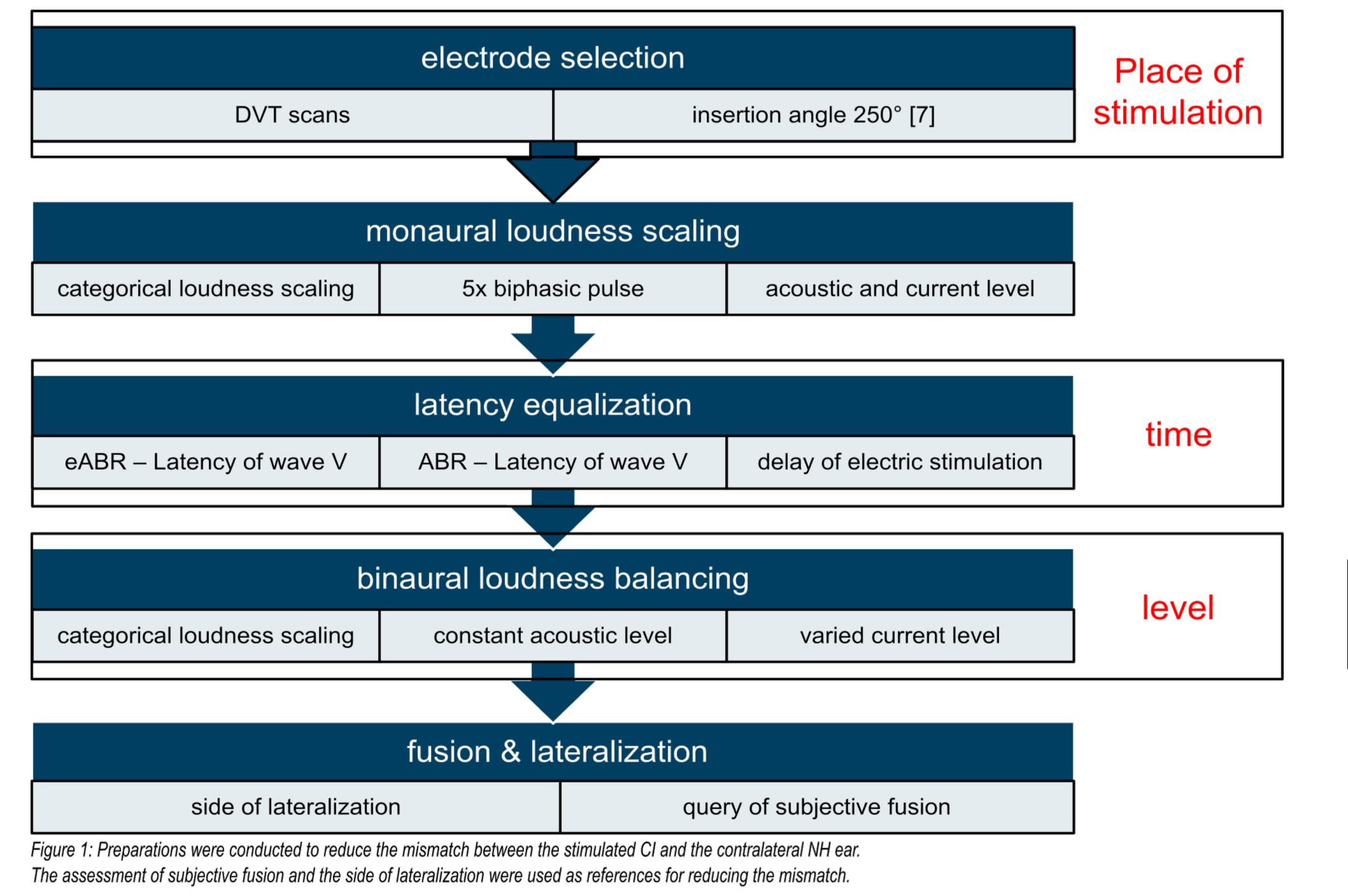
The auditory brainstem response (ABR) reflects the synchronous neural activity of neurons in the brainstem following a transient acoustic stimulus. Binaural processing can be investigated using the binaural interaction component (BIC) derived from the ABR. The BIC is calculated as the difference between the sum of the monaural left and right ABR and the binaural ABR (Dobie & Berlin, 1979). The main potential (DN1) of the BIC is a negative deflection around the latency of wave V and its roll-off. DN1 is often used as an objective marker for binaural processing in research and varies with interaural time difference (ITD) and interaural level difference (ILD) (Riedel & Kollmeier, 2002). Additionally, variations in interaural frequency matching have been shown in chinchillas (Brown et al., 2019). Obtaining reproducible results in human subjects, even in those with normal hearing, is challenging (Sammeth et al., 2021).

In contrast, the electrically evoked ABR (eABR) derived from a CI is highly reproducible. It has been shown that the BIC calculated from the eABR could be a potential method for interaural electrode matching in bilateral cochlear implant users (Hu & Dietz, 2015).

Methods

- Subjects: 9 adult SSD-CI users provided with Cochlear CI (age: 50.1 ± 13.3 years, min 20 years, max 62 years; 5 females, 4 males). One SSD-CI user was excluded because no wave V could be measured in the NH ear.
- The interaural 2 kHz frequency-matched neurons of the spiral ganglion using correction from the Stakhovskaya et al. (2007) to the greenwood map. Existing digital volume tomography (DVT) scans were used to analyze intracochlear electrode positions to find electrode/frequency pairs that would allow for a reduction of place of stimulation mismatch. The selected electrode and subsequent electrodes with increasing intracochlear distance in steps of two were measured. Loudness and latency preparation measurements were conducted prior to the experiment. The acoustic level was varied only between 60 and 70 dB nHL (Figure 1).
- For the monaural ABR, 8000+ sweeps were averaged, and for the monaural eABR and binaural (e)ABR, 4000 sweeps were averaged. The three measurements were performed with each electrode (Figure 2).
- The standard error of the BIC was calculated as the square root of the summed variances of both monaural and binaural (e)ABR in the prestimulus interval (Riedel & Kollmeier, 2006).
- The monaural ABR, eABR, and binaural (e)ABR were filtered using a bandpass Butterworth filter (order: 2, lower cutoff frequency: 100 Hz, upper cutoff frequency: 1500 Hz) (Sammeth et al., 2021; Granzow et al., 2001). Zero-phase digital filtering was performed using the filtfilt function.

Preparations

electrode selection		Place of stimulation
DVT scans	insertion angle 250° [7]	

monaural loudness scaling		
categorical loudness scaling	5x biphasic pulse	acoustic and current level

latency equalization		time
eABR – Latency of wave V	ABR – Latency of wave V	delay of electric stimulation

binaural loudness balancing		level
categorical loudness scaling	constant acoustic level	varied current level

fusion & lateralization	
side of lateralization	query of subjective fusion

Figure 1: Preparations were conducted to reduce the mismatch between the stimulated CI and the contralateral NH ear. The assessment of subjective fusion and the side of lateralization were used as references for reducing the mismatch.

Experimental procedure

$$BIC = binaural - sum_{CI+NH}$$

Figure 2: Experimental procedure for calculating the BIC: The monaural ABR and eABR, as well as the binaural (e)ABR, were derived from the selected electrode and the subsequent electrodes. The lower plot provides an overview of the monaural sum, binaural, and BIC recordings.
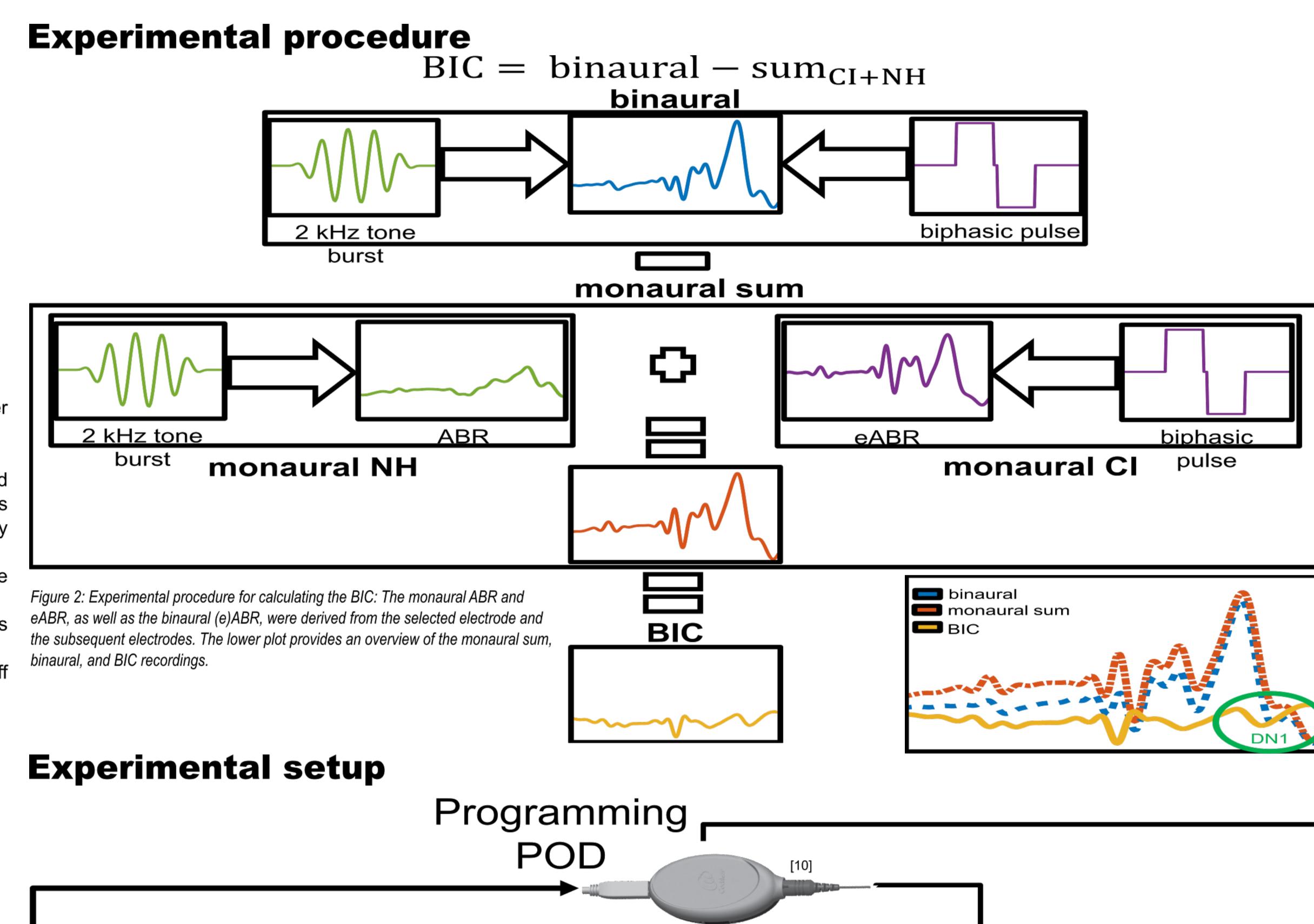
Experimental setup

Figure 3: The experimental setup for measuring ABR and eABR involved the use of a programming pod to trigger the Eclipse, starting EEG recording and playback of the acoustic stimulus through headphones. The electrical stimulus was transmitted from the programming pod to a CP910 Cochlear Sound Processor with a delay. EEG electrodes were attached to the upper forehead (+), the neck (-), and the lower forehead (ground).

Results

For six out of eight SSD-CI users, the amplitude of DN1 with the latency of wave V exceeds the background noise at a minimum of one of the measured electrodes. Therefore, DN1 surpasses twice the standard deviation of the prestimulus interval. A DN1 is detected with a 95% confidence level assuming a normally distributed measurement error. A reproducible DN1 across multiple electrodes could only be detected in 2 out of the 8 SSD-CI users.

SSD01 and SSD08 exhibited changes in DN1 with increasing intracochlea distance between the electrodes.

Three SSD-CI users reported subjective fusion, but only one SSD-CI user confirmed the perception of centralization.
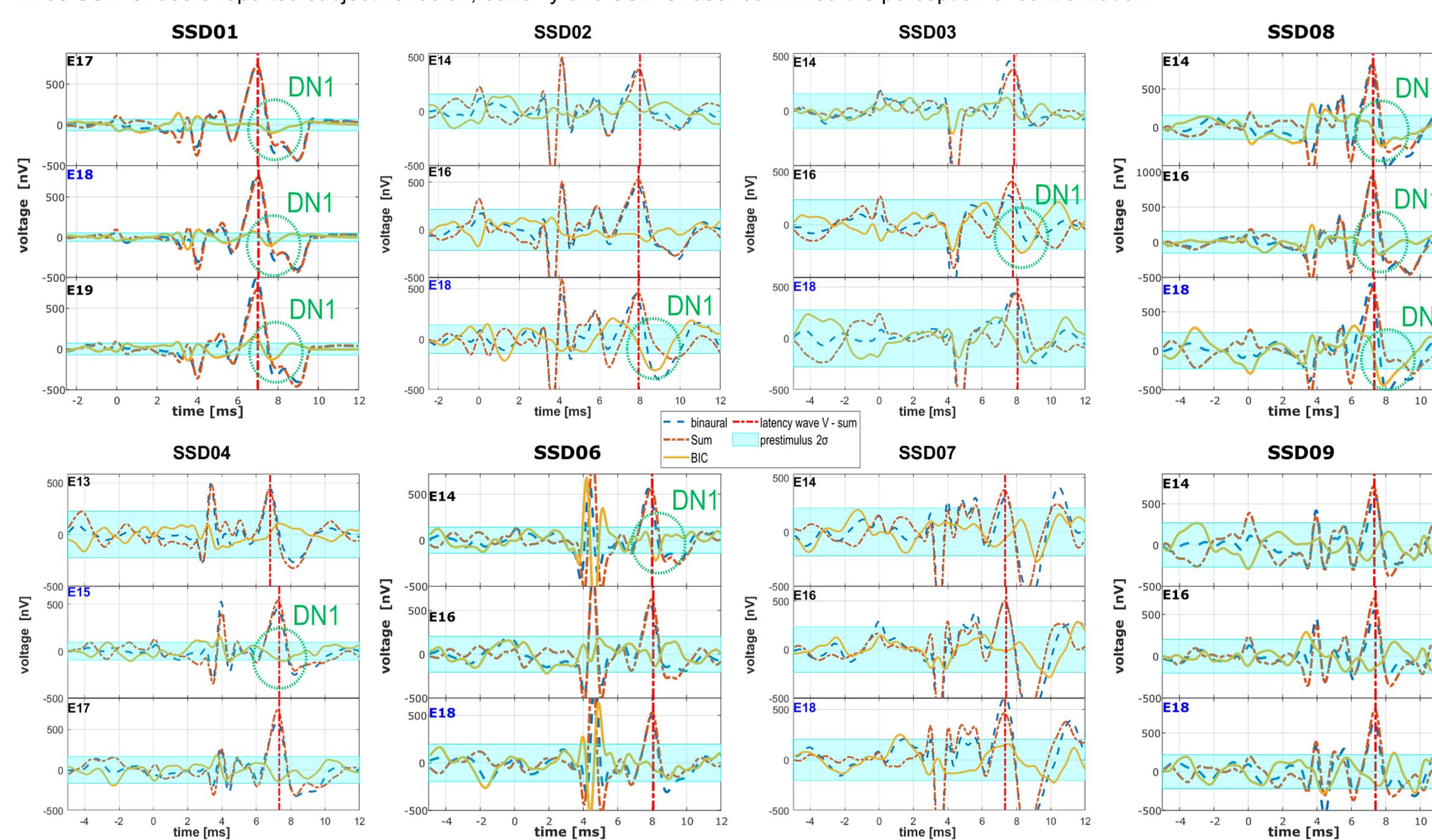

Figure 5: The monaural sum, binaural (e)ABR, and BIC for three different electrodes are displayed for the eight SSD-CI users. An existing DN1 is indicated with a green circle if it exceeds twice the standard error of the prestimulus interval. The red dashed line represents the peak of the monaural sum as a latency reference. The transparent cyan-colored area represents twice the standard deviation of the prestimulus interval of the EEG as an amplitude reference. The blue number indicates the electrode for the place of stimulation matched electrode.

Summary

In summary, the DN1 is measurable as a marker for binaural processing in a subset of SSD-CI users. Among the only two SSD-CI users with a detectable DN1 across multiple electrodes, the amplitude of the DN1 decreased with a larger distance between the stimulation electrode and the tonotopic intracochlear region.

Given the high level of residual noise in many recordings, no reliable conclusion can be drawn regarding the suitability of the BIC as a tool for investigating binaural processing in SSD-CI users. More participants need to be included, and further improvements are needed to reduce the

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