Differences in binaural interaction between normal hearing and asymmetric hearing loss measured by the auditory brainstem response

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MULTISENSORY SPACE LAB

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BACKGROUND

- Sound localization can be accomplished by using, among others, interaural level differences (ILD)[1,2] and is distorted by asymmetrical hearing loss (AHL)[3].
- A way to measure the amount of binaural cues and their integration is by recording an auditory brainstem response (ABR). The ABR is a response in brain activity to the presentation of sounds and can be recorded with EEG[4].
- The binaural interaction component (BIC) reflects the amount of binaural interaction in the brainstem and indirectly relates to sound localization[5].

Aim: To quantify the impact of AHL on binaural interactions in the human brainstem.

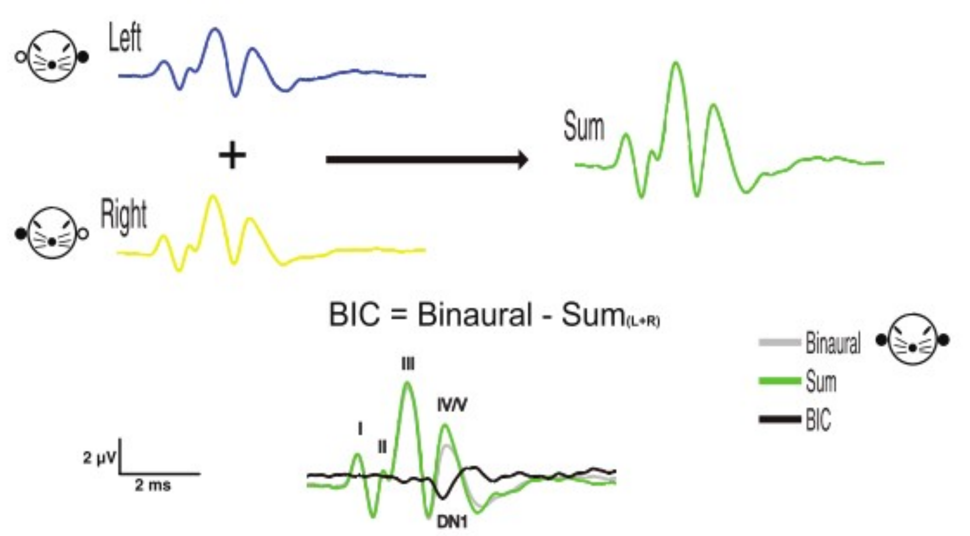

Fig. 1.: Left and right ABR waveforms (violet and yellow, respectively) are summed (green) and subtracted from the binaural ABR (grey). The subtraction results in the BIC (black). From Laumen, Ferber, Klump & Tollin, (2016)[6].

METHODS

Participants
- 10 normal-hearing participants

Hearing loss
- 32dB AHL simulated with a soft earplug

Hearing tests
- Audiogram
- Equal loudness test
- ILD test

ABR measurement
- EEG: One electrode on the forehead, one on each mastoid

Stimuli
- 100 μs clicks at ~90 dB(A) at 37 Hz through TDH-39 headphones
- ILDs: -32, -16, -8, -4, -2, 0, 2, 4, 8, 16
- In simulated AHL: all ILDs + 32 dB

Task
- Relax and listen to the sounds

RESULTS: How do we localize sounds in the brainstem with and without AHL

Binaural ABR for perceived ILD = 0

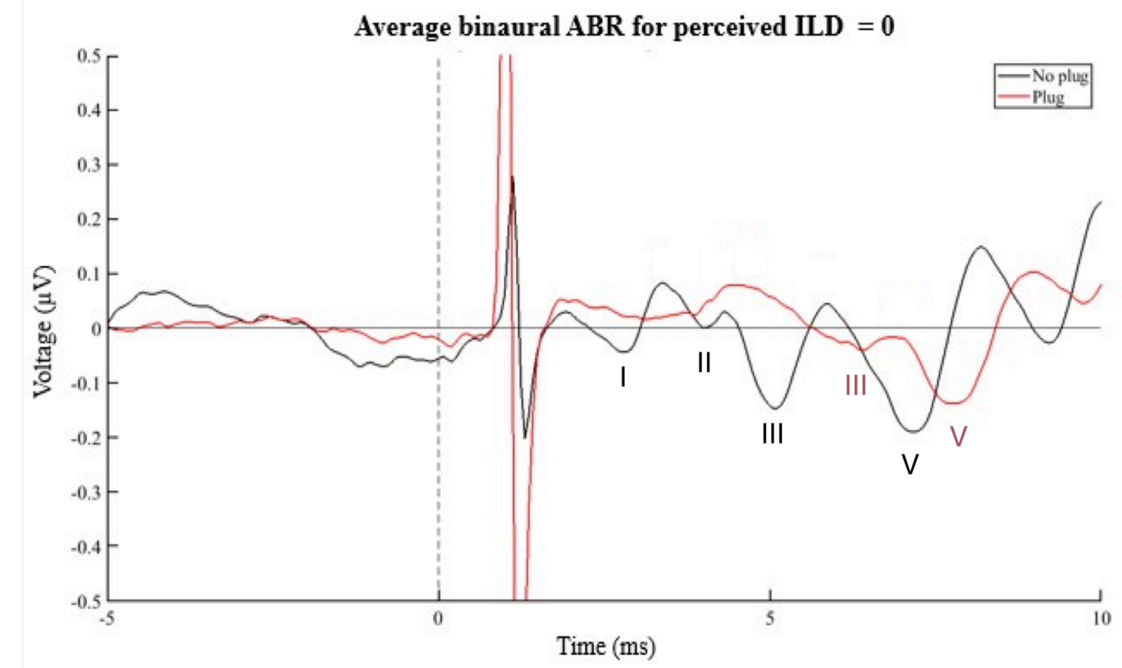

Fig. 2: The group average ABR for the binaural stimulation at a perceived ILD level of 0 dB. The black graph shows the ABR for normal hearing (ILD = 0 dB), while the red graph shows the ABR for simulated asymmetrical hearing loss (ILD = 32 dB). The x-axis represents the time in ms and the y-axis represents the voltage of the response in μV. The wave classification is also indicated.

Binaural interaction component for perceived ILD N = 1

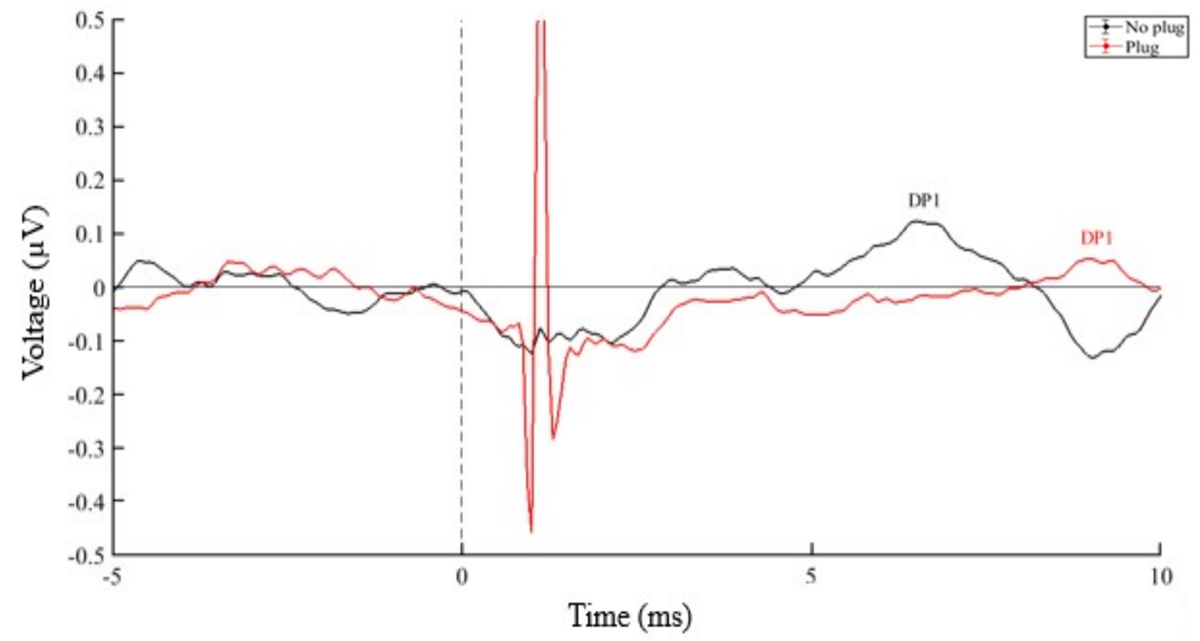

Fig. 3: The average BIC for the perceived ILD of 0 dB for a single participant. For normal hearing, the ILD of 0 dB is shown. For asymmetrical hearing loss, an ILD of 32 dB is shown, as this ILD level is perceived as an ILD of 0 dB with hearing loss. The x-axis represents the time in ms and the y-axis represents the voltage in μV. The click artefact is clearly visible at 1 ms.

Average change in binaural interaction per ILD condition *N* = 9

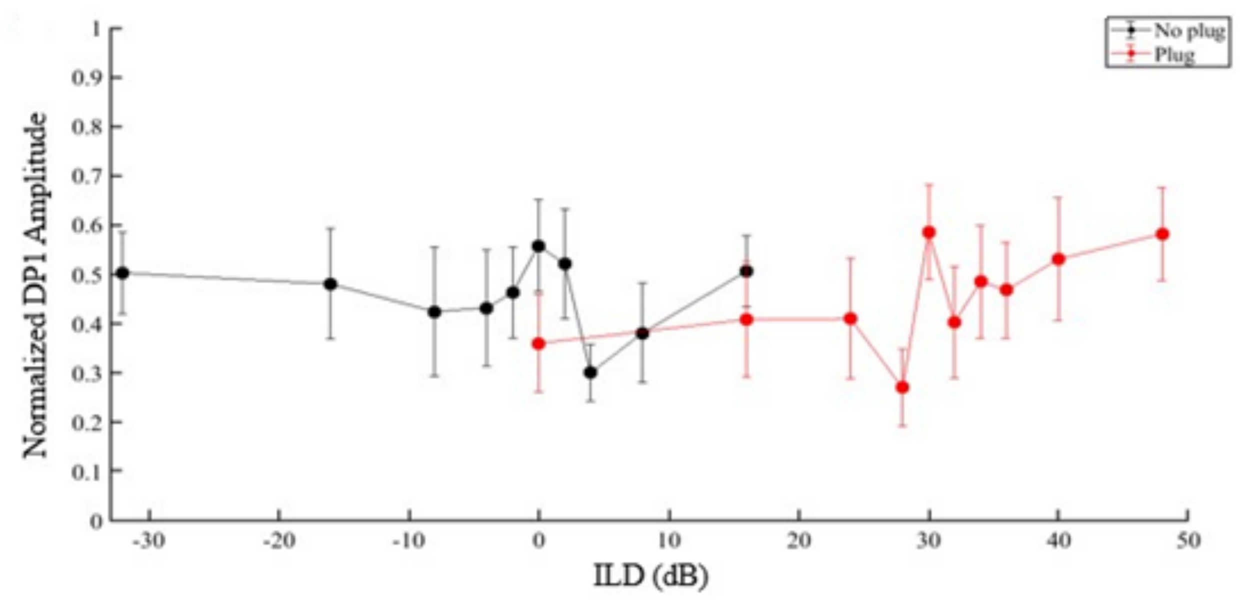

Fig. 4: The group average change in binaural interaction/DP1 amplitude per ILD condition for each participant. The x-axis represents the ILDs in dB and the y-axis represents the normalized DP1 amplitudes. The black graph represents normal hearing, while the red graph represents simulated asymmetrical hearing loss.

RESULTS: Sound localization in brainstem: normal hearing vs AHL

Average change in binaural interaction component

Average max. binaural interaction

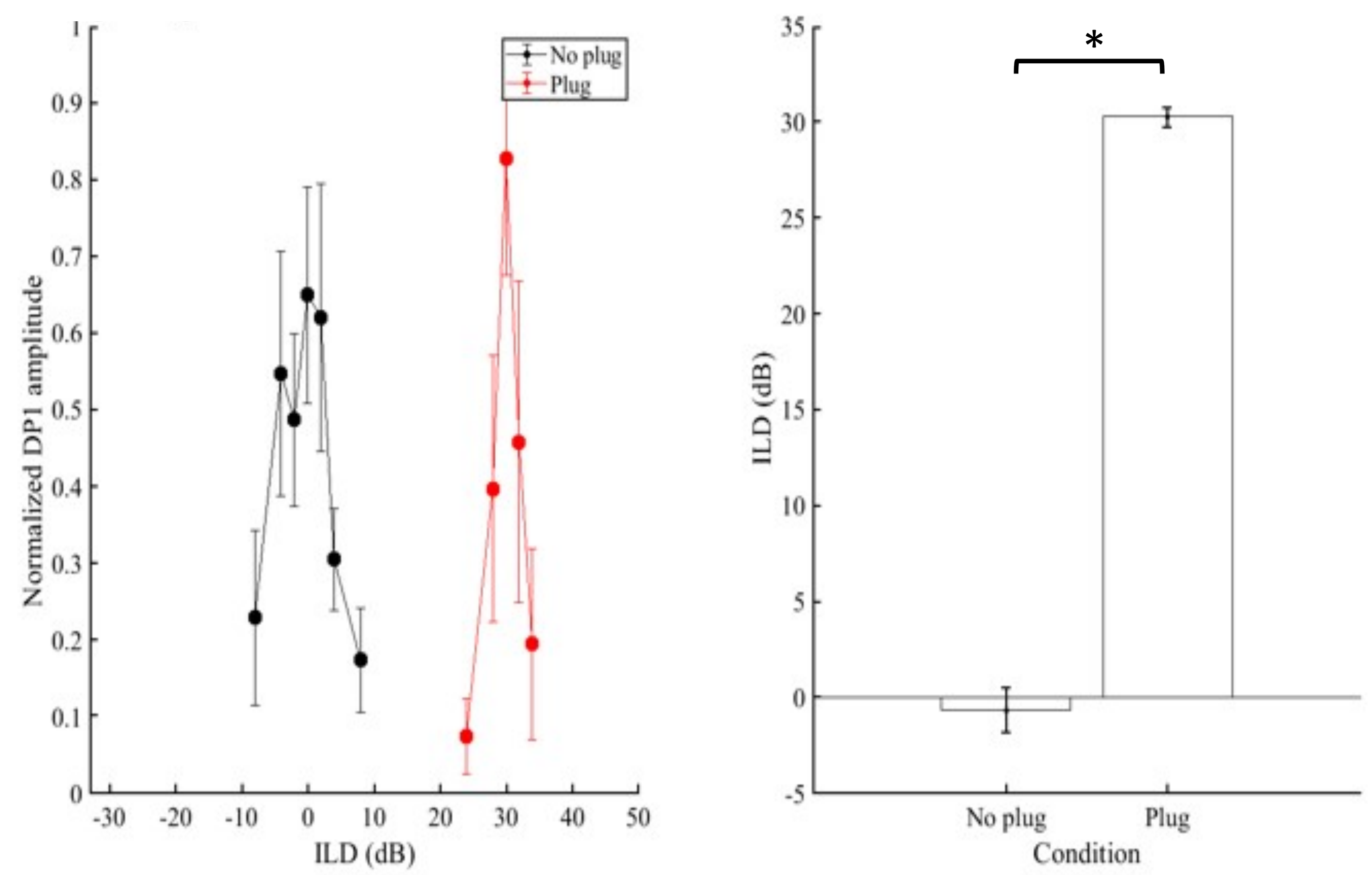

Fig. 5: The average change in binaural interaction for participants 1, 2, 4, 6 and 7 (clear binaural interaction). The x-axis represents the ILDs in dB and the y-axis represents the normalized amplitudes of the DP1 peak. For the normal hearing condition, only the ILD values of -8, -4, -2, 0, 2, 4 and 8 dB are shown. For the plugged condition, only the ILD values of 24, 28, 30, 32 and 34 dB are shown. The black graph shows the changes in binaural interaction for normal hearing, while the red graph shows these changes for simulated asymmetrical hearing loss. The right graph shows at what ILD level the binaural interaction is the greatest. The x-axis shows the condition, which is either with or without a plug, and the y-axis shows the ILDs in dB. This difference was significant, ($t(4) = -31.44$, $p < 0.001$).

CONCLUSIONS

Normal hearing:

- Binaural interaction is dependent on ILD and starts around 5 ms after sound onset
- Binaural interaction is strongest for sounds located at the midline of the head and weakest for sound in the periphery.

Acute conductive asymmetrical hearing loss:

- Impairs auditory localization at the brainstem level
- Delays auditory brainstem responses
- Shifts binaural interaction to larger ILDs in line with the amount of hearing loss

After asymmetric hearing loss, binaural interactions due to naturally occurring ILDs are greatly reduced at the brainstem level, explaining poor sound localization for high frequency sounds.

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