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Effects of reduced device delay mismatch on precision and trueness of sound localization judgements in bimodal listeners

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Introduction

In bimodal users of cochlear implants (CI) in one ear and hearing aids (HA) in the contralateral ear, the different devices are typically not aligned in terms of signal processing delays. This so-called device delay mismatch ranges between 3 to 10 ms in users of a current MED-EL CI, with the electric stimulation of the acoustic nerve through the CI preceding the acoustic stimulation through the HA [1]. In recent work it has been shown that a reduction of the device delay mismatch by delaying the CI stimulation improves precision of sound localization judgements in bimodal listeners [2]. It is however still unclear if the trueness of sound localization judgements is affected by this measure and which delay is optimal for reducing the device delay mismatch.

Methods

- Subjects: 9 adult bimodal listeners provided with MED-EL CIs (age: 61.1 ± 6.9 years, min. 47 years, max. 71 years; 3 females, 6 males)
- CI stimulation was delayed by a programmable, portable delay line (DL) based on a microcontroller.
- Rms error (precision) and signed bias (trueness) of sound localization judgements were measured in an A-B-B-A paradigm in the frontal horizontal plane (Figure 1 & Figure 2)
- To determine which delay is optimal for device delay mismatch reduction the DL was programmed to the hearing aid delay τ_{HA} as well as τ_{HA} + 1 ms and τ_{HA} – 1 ms for acute testing in 7 out of 9 subjects.
- The delay that yielded the best results in acute testing was used for further testing

Figure 1: Loudspeaker setup used for sound localization testing

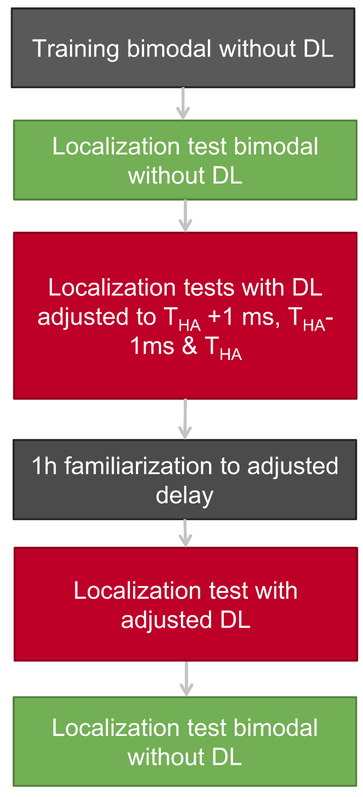

Figure 2: A-B-B-A test paradigm (A = green, B = red)

Results

- τ_{HA} + 1 ms seems suitable as a delay for the CI stimulation to reduce the device delay mismatch as it yielded the lowest rms errors and lowest absolute signed bias.
- Acute reduction of device delay mismatch (condition A vs B) led to a statistically significant improvement in rms error of 14.6 ± 5.8° ($p < 0.01$) and reduction of signed bias by 14.7 ± 9.2° ($p < 0.01$).
- After one hour of familiarization to the reduced device delay mismatch (condition B vs B) no significant change in rms error ($p = 0.3$) and signed bias ($p = 0.3$) could be observed.
- After setting the device delay mismatch back to its original mismatch (condition B vs A) a significant deterioration of rms error by 7.5 ± 6.4° ($p < 0.01$) and signed bias by 12.7 ± 8.1° ($p < 0.01$) could be observed.
- The two conditions without reduced device delay mismatch showed no significant difference in rms error ($p = 0.3$) and signed bias ($p = 0.7$) revealing no significant effects of procedural training throughout the measurements.

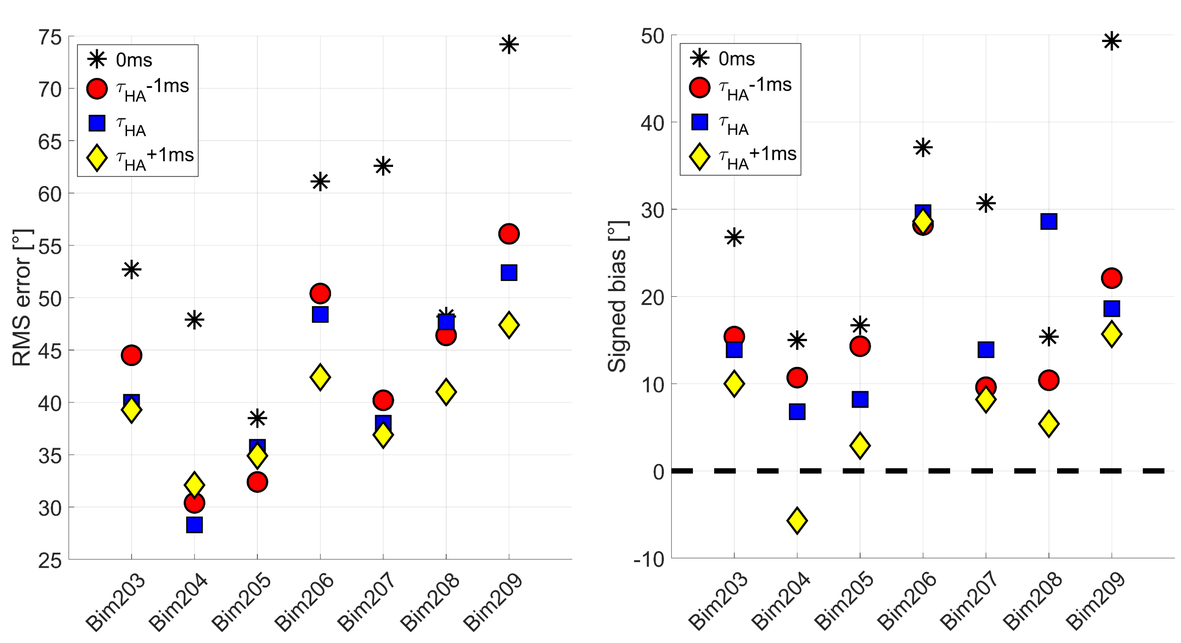

Figure 2: rms error and signed bias for three different delays to reduce the device mismatch in acute testing. For the signed bias data for participants wearing their CI on the left side was inverted that a positive value always corresponds to a bias towards the CI

Discussion

The results show that a device delay mismatch between CI and HA severely impairs sound source localization in bimodal CI/HA users. This impairment can partially be mitigated by applying an across frequency delay to the CI stimulation. Due to filterbank characteristics in the CI signal processing for MED-EL CI, a delay by τ_{HA} + 1 ms leads to a precise temporal alignment in the high frequency regions, thus facilitating the use of ILD, which are thought to be the predominant cue used by bimodal CI/HA users in sound localization [3]. Further work must be carried out to determine if longer familiarization periods lead to further improvement in sound source localization.

Conclusions

Reduction of device delay mismatch leads to a highly significant improvement in both precision and trueness of sound source localization judgements in bimodal CI/HA users. None of the subjects showed a deterioration of localization accuracy by the applied delay to the CI stimulation. We conclude that temporal alignment between CI and HA is a viable step to further improve bimodal provision.

Conflicts of interests

JA's, WH's and SZ's institutions have received research grants from MED-EL, a leading cochlear implant manufacturer.

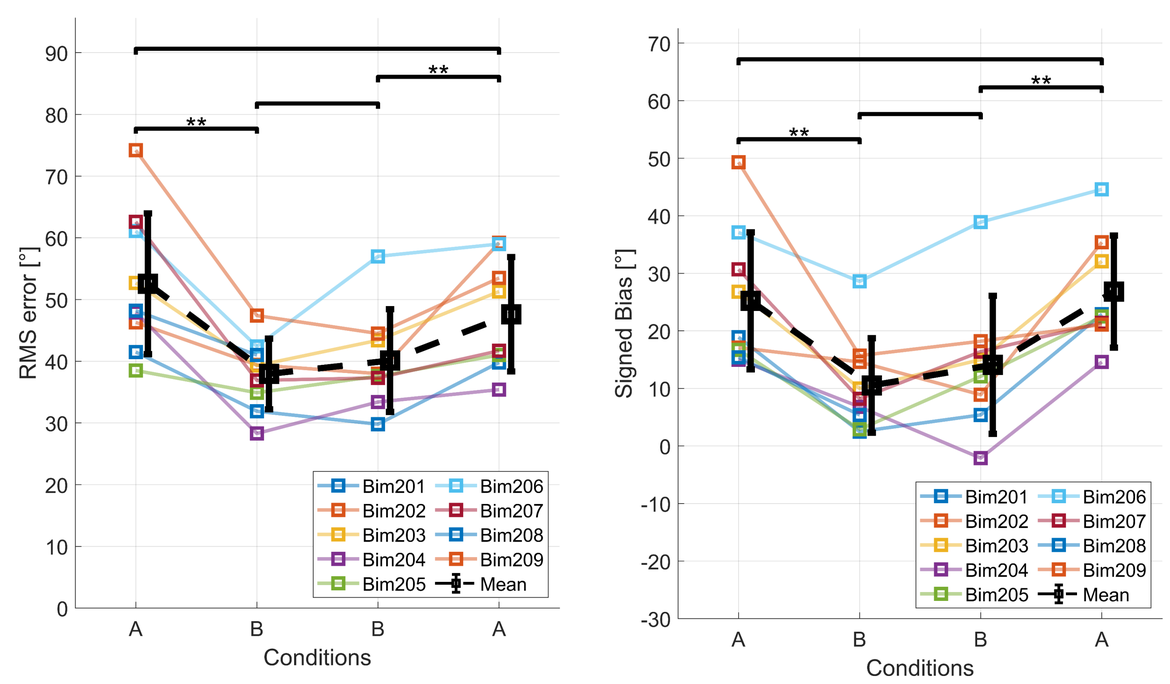

*Figure 3: rms error and signed bias for the A-B-B-A paradigm. The thick black line represents group mean and standard deviation (Significance levels: ** represents $p \leq 0.01$). For the signed bias data for participants wearing their CI on the left side was inverted that a positive value always corresponds to a bias towards the CI*

Sources:

[1] Zirn, S., Arndt, S., Aschendorff, A., & Wesarg, T. (2015). Interaural stimulation timing in single sided deaf cochlear implant users. *Hearing research*, *328*, 148-156.

[2] Zirn, S., Angermeier, J., Arndt, S., Aschendorff, A., & Wesarg,T. (2019). 'Reducing the Device Delay Mismatch Can Improve Sound Localization in Bimodal Cochlear Implant/Hearing-Aid Users'. Trends in Hearing 23:233121651984387. doi: 10.1177/2331216519843876.

[3] Seeber, Bernhard U., Uwe Baumann, and Hugo Fastl. 2004. 'Localization Ability with Bimodal Hearing Aids and Bilateral Cochlear Implants'. The Journal of the Acoustical Society of America 116(3):1698–1709. doi: 10.1121/1.1776192.

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