Good Interaural Time Difference Sensitivity Despite Different Hearing Experience in Cochlear Implanted Rats

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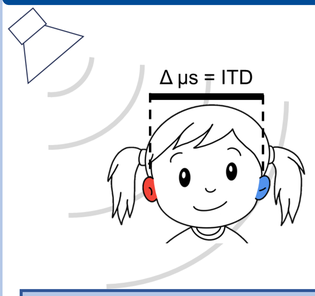
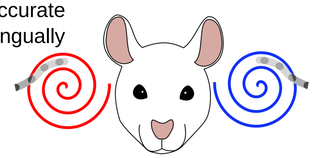
Background



- Normal hearing (NH) listeners localize sound sources using binaural cues such as interaural time differences (ITDs), that is, the difference in the arrival time of sound at the ears.
- Under optimized stimulation conditions providing temporally accurate binaural cues via bilateral cochlear implants (CIs), even a prelingually deafened auditory system can exhibit ITD sensitivity [1,2].
- Here, we investigate whether and to what extent prior acoustic hearing experience influences ITD sensitivity under these conditions.



Animal model: Rat with bilateral cochlear implants (CIs)

Research Question: **How does acoustic hearing experience prior to CI implantation affect the ITD sensitivity?**

Material and Methods

CI implantation:

- Eight neonatally deafened (ND) and six adultly deafened (AD) Wistar rats were bilaterally supplied with CIs in young adulthood.
- CIs were inserted via a cochleostomy into the middle turn of the cochlea (8-16 kHz) [1,2].

Behavioral training:

- AD and ND rats were trained for five weeks on an auditory lateralization task under accurate bilateral CI stimulation.

  Stimulation parameters:
  - Biphasic, bipolar pulses
  - Pulse rate: 900 pulses/s
  - ITDs in the range of ±{120, 100, 80, 60, 40} µs.
- NH rats were trained for two to three weeks under acoustic stimulation [3].

  Stimulation parameters:
  - Single pulse trains (delta function “click”)
  - Frequency: 50 Hz
  - ITDs in the range of ±{160, 140, 120, 100, 80, 60, 40} µs [4].

Testing and data analysis:

- After training, rats of all cohorts were tested on their ITD sensitivity.
- ITD sensitivity was verified using psychometric functions (Fig. 2) and the smallest perceivable ITD (JND) was taken as objective measure for ITD sensitivity (Fig. 2).

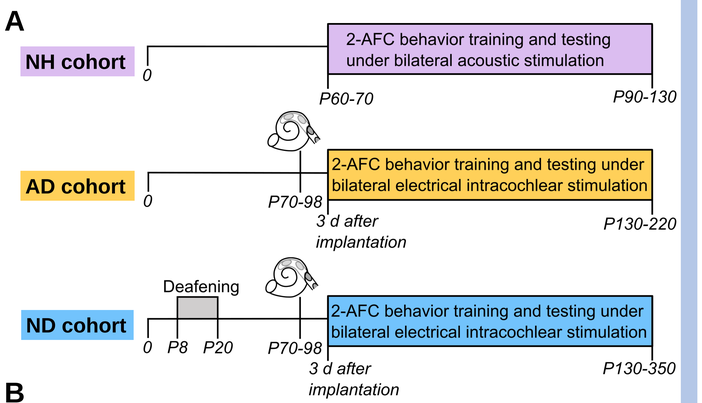


Figure 1: (A) Timetable of the experiments for the three experimental cohorts. Normal hearing **(NH)** rats (n = 5) were trained and tested acoustically. Four rats were acutely deafened during CI surgery in young adulthood **(AD)**. Eight rats were neonatally deafened **(ND)** and implanted with bilateral CIs in young adulthood. Both CI cohorts were trained and tested under CI stimulation. **(B)** Schematic of the two-alternative forced choice test (2-AFC). CI implanted rat performing the 2-AFC triggering the three water spouts, center (C), left (L) and right (R).

Results: ITD Sensitivity of Both biCI Cohorts is Comparable to That of Normal Hearing Rats

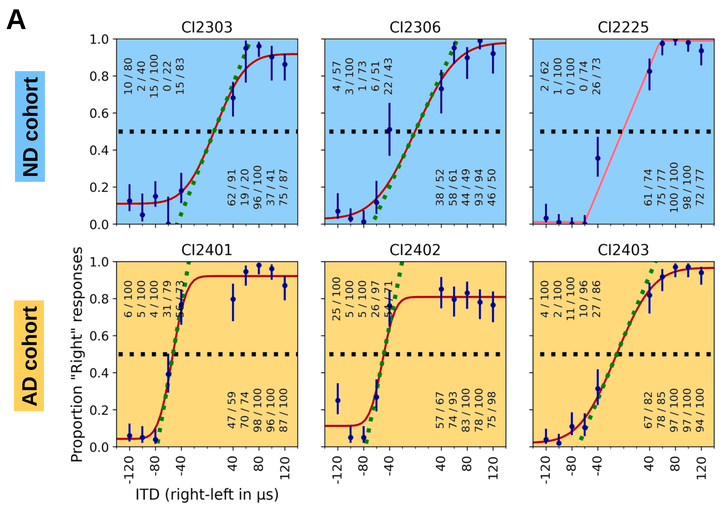
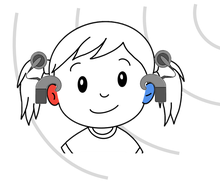


Figure 2: **(A)** Psychometric functions for ITD performance for three sample rats of the adult deafened **(AD)** cohort and three example rats of the neonatally deafened **(ND)** cohort. X-axes: stimulus ITD in µs. Negative values mean the stimulus in left ear is leading/louder. Y-axes: proportion of responses to the “right” spout. The fractions in small print show raw number of “right” responses/ total number of trials at the corresponding ITD value. Error bars: 95% Wilson confidence intervals for the underlying probability of choosing the “right” spout. Solid lines: fitted psychometric models. Different fits are shown in different shades of red. Green dotted diagonals: slopes of the fitted psychometric at ITD=0 µs**. (B)** ITD “just noticeable differences” (JNDs) in µs displayed on the y-axis. CI animal data was obtained at a typical clinical rate (900 pps), whereby NH data was obtained at the optimal frequency of 50 Hz [3]. The violet horizontal dashed line indicates the median JND of the five **NH** rats, and the violet shaded area represents the range between the 25th and 75th percentiles.

- All AD CI rats exhibited very good ITD sensitivity, with a **mean JND of 37.9 µs (n = 6)**.
- All ND CI rats also showed very good ITD sensitivity, comparable to that of the AD CI rats, with a **mean JND of 44.0 µs (n = 8)**.
- **No significant differences** were observed between the CI cohorts.
- Overall, the ITD sensitivity of CI rats was comparable to that of NH rats tested at 50 Hz.

Conclusion

Under optimized stimulation conditions, prior acoustic hearing experience before CI implantation does not significantly affect ITD sensitivity.



[1] Rosskothen-Kuhl, N.; Buck, A. N.; Li, K. and Schnupp, J. W. (2021). Microsecond interaural time difference discrimination restored by cochlear implants after neonatal deafness, eLife 10: e59300.

[2] Buck, A.N., Buchholz, S., Schnupp, J.W. et al. Interaural time difference sensitivity under binaural cochlear implant stimulation persists at high pulse rates up to 900 pps. Sci Rep 13, 3785 (2023).

***[3]** Li K., C. H. K. Chan, V. G. Rajendran, Q. Meng, N. Rosskothen-Kuhl, J. W. H. Schnupp (2019). Microsecond Sensitivity to Envelope Interaural Time Differences in Rats, JASA 145, Nr. 5, EL341–47*