Pulse timing interval sensitivity in the inferior colliculus of cochlear implanted rats

Fei Peng, Shiyi Fang, Muhammad Zeeshan, Bruno Castellaro, Qinjie Zhang, Jan W.H. Schnupp
Department of Neuroscience, City University of Hong Kong

BACKGROUND

Temporal coding plays an important role in pitch perception for normal hearing. However, **temporal fine structure coding is largely or entirely lacking for cochlear implant (CI) users.**
Previous studies from our lab[1,2] have shown that neonatally deafened rats have much better ITD discrimination than human CI users. If these rats are better at binaural timing task, are they also better in monaural task? It could be that the constant-rate stimulation may desensitize human CI users to precise pulse timing information.

Research question:
Is the sensitivity to pulse timing interval in the CI rats smaller than that seen in a previous psychoacoustic study[3] on human CI users?

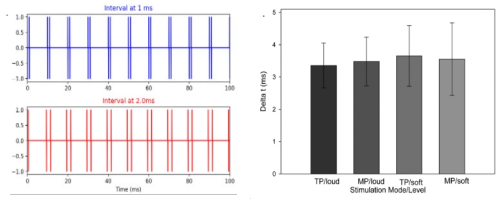

Figure 1 The paired-pulses stimulus diagram **(A)** and the discrimination threshold of the dual-pulse interval from a previous psychoacoustic study [3] **(B)**.

METHODS

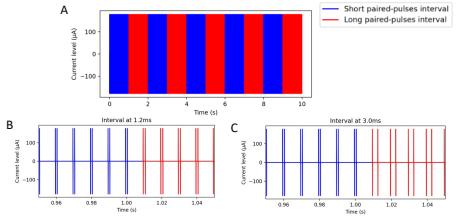

Figure 2 (A) Stimulus paradigm: the paired-pulse interval changed each second. Blue: short paired-pulse interval at 1 ms. Red: long paired-pulse interval. **(B), (C)** Stimulus waveforms with the long paired-pulses intervals 1.2 ms and 3 ms, respectively.
Dual pulse rate: 100 Hz.

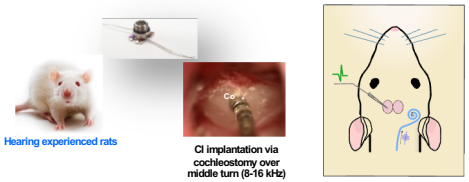

Figure 3 Rats were implanted via cochleostomy over middle turn. Neural responses were collected with a 32-channel Atlas probe in the contralateral inferior colliculus (IC) of anesthetized rats.

METHODS (continued)

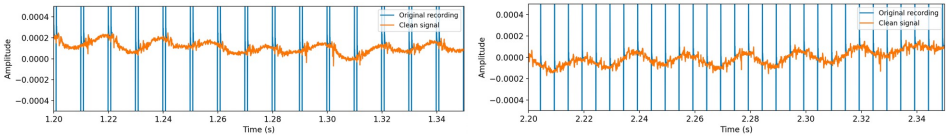

Figure 4 Example raw recording signals (blue) and clean signals (orange) after the artifact removal [4]. Examples with paired-pulse intervals at 1 ms and 5 ms are shown.

RESULTS

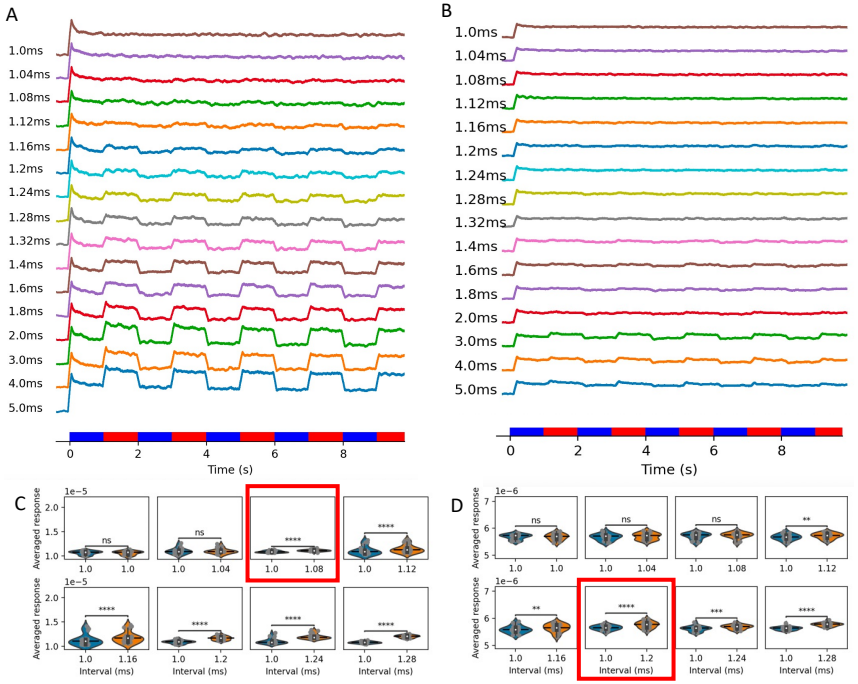

Figure 5 (A), (B): Neural responses of two representative example units. Different colors represent the neural responses at different long paired-pulse intervals indicated at the left, the short paired-pulse interval was constant at 1 ms.
(C), (D): Comparisons of response amplitude across trials for each of the different paired-pulse intervals for the units shown in (A) and (B), respectively. Each grey dot represent the average neural response for one trial. The threshold for each unit was defined as the minimum long paired-pulse interval which showed a significant difference. *P* values were corrected by Bonferroni correction ($p < 0.05/16$). The threshold of these two units was indicated by the red rectangular box.

RESULTS (continued)

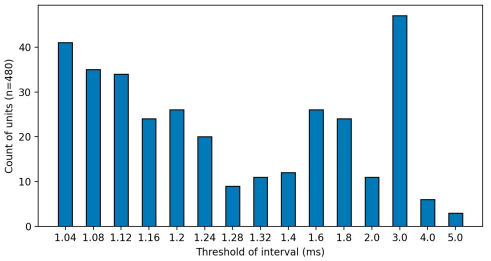

Figure 6 The distribution of threshold intervals observed across a dataset of 480 multiunits recorded in 6 animals.

SUMMARY

- The minimum threshold of the paired-pulse interval was as small as 40 μs.
- We found the threshold of 83% of units was smaller than 3 ms, which was previously reported as a psychoacoustic threshold in human CI users [3].
- Our results suggest that much better temporal fine structure sensitivity might be achievable in CI patients with better signal processing and treatment strategies.

REFERENCES

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

[2] Buck, A. N., Rosskothen-Kuhl, N., & Schnupp, J. W. (2021). Sensitivity to interaural time differences in the inferior colliculus of cochlear implanted rats with or without hearing experience. *Hearing research*, *408*, 108305.

[3] Fielden, C. A., Kluk, K., & McKay, C. M. (2014). Interpulse interval discrimination within and across channels: comparison of monopolar and tripolar mode of stimulation. *The Journal of the Acoustical Society of America*, *135*(5), 2913-2922.

[4] Najafabadi MS, Longtu C, Dutta K, Norris A, Feng B, Schnupp JW, Rosskothen-Kuhl N, Read H, Escabi M. Optimal Multichannel Artifact Prediction and Removal for Neural Stimulation and Brain Machine Interface. Front. Neurosci. https://doi.org/10.3389/fnins.2020.00709

URL: auditoryneuroscience.org/CIAP2023_Fei