Cochlear implant use causes changes in the auditory cortex

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Summary

The tuning of sites within the auditory cortex changes within the first three months of cochlear implant use.

Introduction

We have previously shown that neonatal profound deafness results in a loss of the normal cochleotopic organization of the primary auditory cortex, but that environmentally-relevant chronic electrical stimulation via a multi-channel cochlear implant can restore that organization[1]. To explore the time course of this re-establishment of cochleotopy, we obtained chronic recordings of multi- and single-unit responses from the auditory cortex of cats throughout the course of the stimulation program.

Method

Neonatal cats (n=5) were deafened with daily subcutaneous injections of neomyacin sulfate (60 mg/kg)[2]. At two months of age, animals were implanted with a 14-ring scala tympani electrode array and lead-wire assembly[3]. At seven months of age, animals were implanted in putative primary auditory cortex with a 6 x 10 planar silicon electrode array (Blackrock Microsystems, Salt Lake City, Utah) under sterile conditions (Figure 1). Initial recordings from the arrays were made approximately 4 weeks post-surgery and subsequent recordings at approximately 4-week intervals, with the cats anesthetized with xylazil (2mg/kg, s.c.) and ketamine (20mg/kg, i.m.), for up to 6 months. After the inital recording session, environmentally-relevant chronic electrical stimulation was provide from a modified cochlear implant[1]. An additional two normal hearing animals were also implanted with the cortical recording arrays to serve as controls.

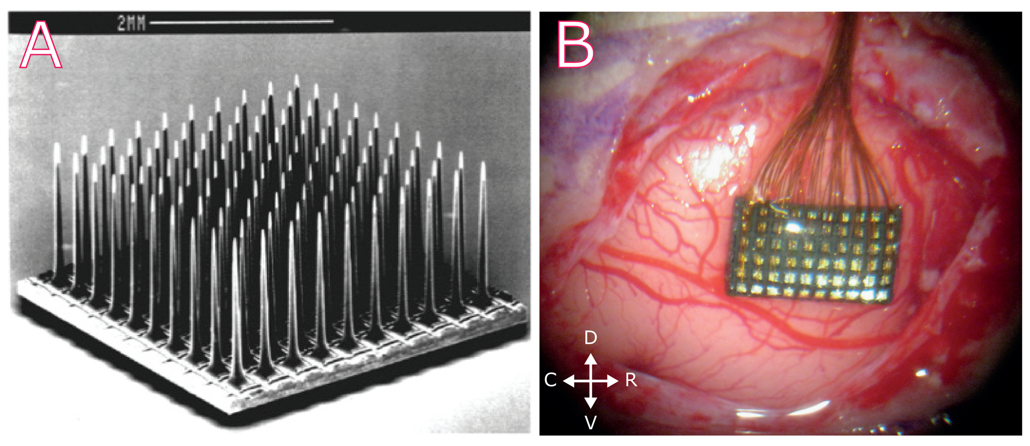

Figure 1. (A) An image of a 10x10 planar silicon electrode array with the Platinum tips clearly visible. The spacing between the electrode tips is 400 μm. (B) A 6x10 planar silicon electrode array has been implanted in putative primary auditory cortex. D = Dorsal; R = Rostral; V = Ventral; C = Caudal

Results - Normal Hearing

Responses to tonal stimuli (Figure 2) were observed on 80 of 120 channels tested (66%) in the initial recording sessions and on 63 of the 120 channels (52%) in the final recording session 6 - 8 months later.

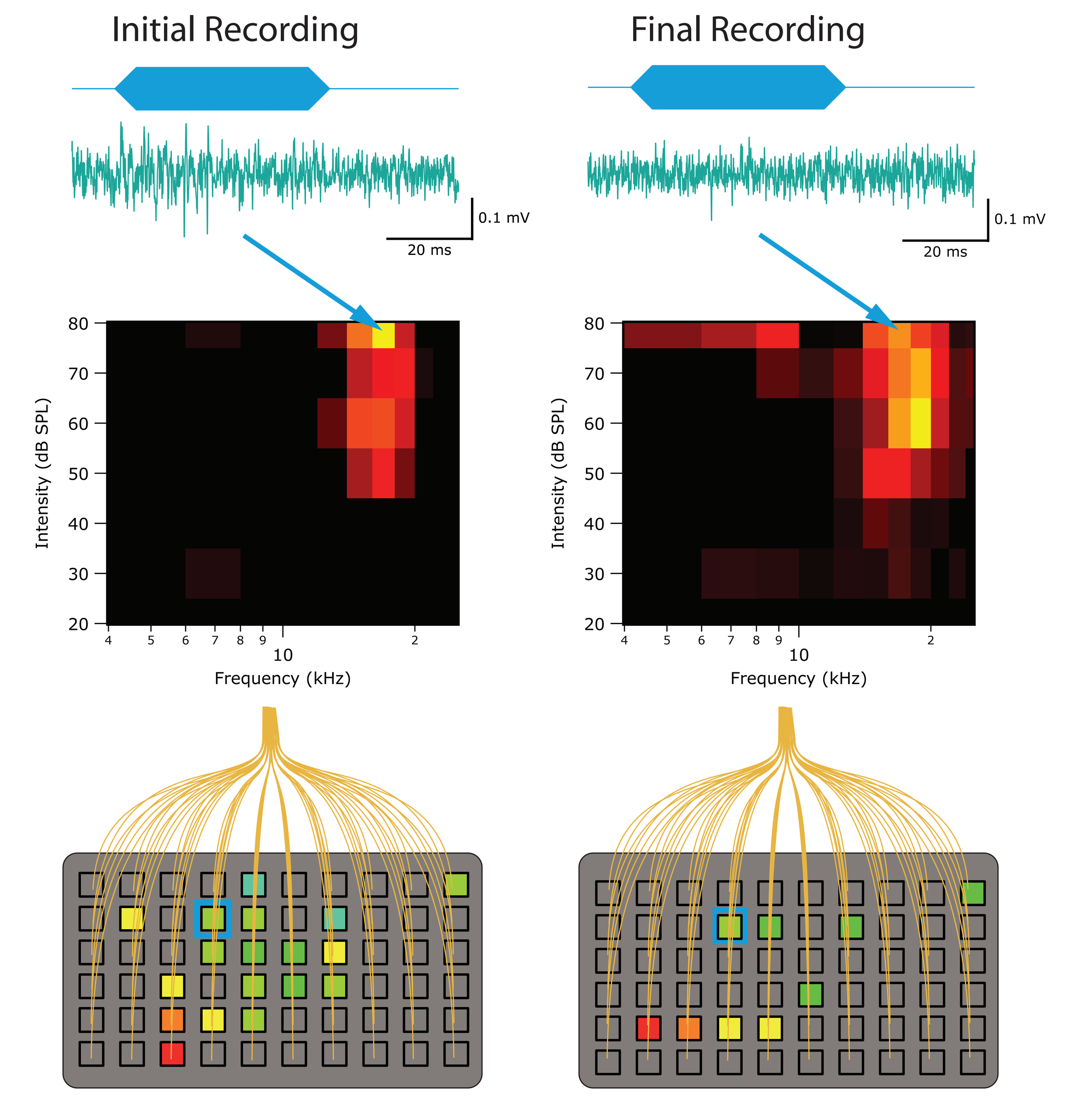

Figure 2. Example neural response (top row) to acoustic stimulation (18 kHz tone-pip @ 80 dB SPL) recorded four weeks post-implantation (Initial Recording) and six months later (Final Recording). Acoustic response areas (middle row, responses normalized to maximum response (yellow) and spontaneous rate (black)) exhibited compact regions of excitation with well defined thresholds and characteristic frequencies. The bottom row illustrates the distribution of recording sites responsive to tonal stimuli (filled, colour represents characteristic frequency, red/yellow lower frequencies, blue/purple higher frequencies) or unresponsive sites (open) at both the initial recording session and six months later. The blue square indicates recording location illustrated in middle and top rows.

There was no significant difference in either threshold or characteristic frequency for either animal over the 6 month recording period (paired-T tests; p-values > 0.1).

Results - Deaf Implanted

Responses to electrical stimuli (Figure 3) were observed on 94 of 300 channels tested (31%) in the initial recording sessions and on 196 of the 300 channels (65%) in the final recording session 6 - 8 months later.

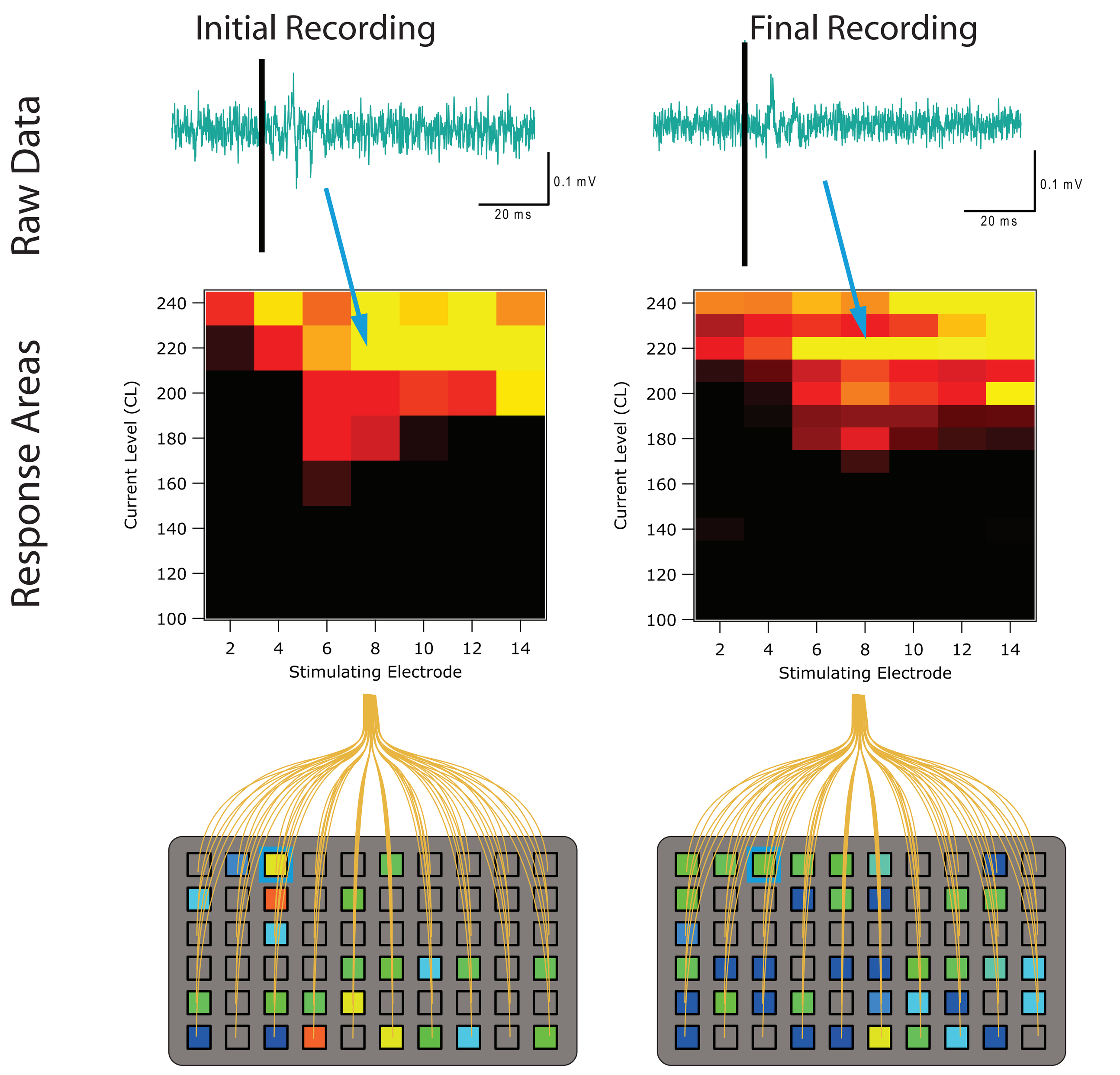

Figure 3. Example of neural response (top row) to intracochlear electrical stimulation (Electrode 8 @ 220 CL, black bar = stimulus) recorded prior to any chronic stimulation (Initial Recording) and after six months of chronic cochlear implant use (Final Recording). Electrical response areas (middle row, responses normalized to maximum response (yellow) and spontaneous rate (black)) exhibited broad regions of excitation, but with well defined thresholds and best electrodes. The bottom row illustrates the distribution of recording sites responsive to electrical stimuli (filled, colour represents best stimulating electrode, yellow more apical electrodes, blue/purple more basal electrodes) or unresponsive sites (open) at both the initial recording session and one month later. The blue square indicates recording location illustrated in middle and top rows.

There was a significant changes in best electrode within three months for all five animals (paired-T tests; p-values < 0.05).

Discussion and conclusion

These results demonstrate that our recordings from auditory cortex are stable over a six month period in normal hearing animals. Therefore, the changes in best electrode seen within three months in the deaf-implanted animals are a result of the chronic cochlear implant use. The increase in the number of responsive recording sites also suggests that chronic cochlear implant use may increase cortical responsiveness compared to the deaf unstimulated condition.

References

[1] Fallon, et al. 2009, J Comp Neurol 512: 101-114.
[2] Leake, et al. 1991, Hear Res 54, 251-71.
[3] Shepherd, et al. 2011, Hear Res 277, 20-27.

Acknowledgments

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