Selectivity of Responses to Natural Vocalizations in the Mouse Dorsal Cochlear Nucleus

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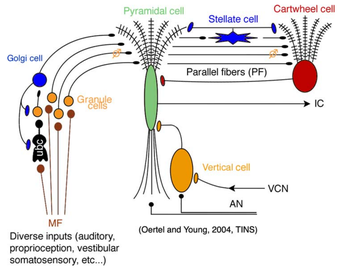
Introduction

The dorsal cochlear nucleus (DCN) is a cerebellum-like structure that integrates direct auditory nerve input with multimodal inputs. Although responses in the inferior colliculus are known to be selective for different vocalizations, it was not yet know whether selectivity could arise in the brainstem DCN and project to the midbrain. The purpose of this study was to investigate whether responses in DCN are selective to different natural vocalizations that share similar frequency spectra.



Methods

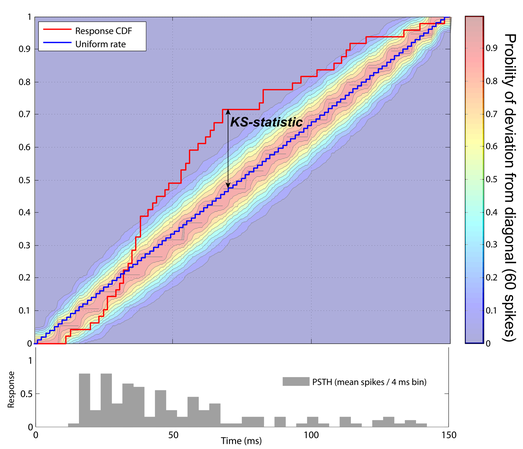
We recorded auditory response properties of single DCN units in the awake mouse, and used data from frequency tuning curves and broad band noise stimuli to identify physiological response types. We then presented a suite of 49 synthesized vocalizations that were noise-free replicas of the timing and frequency of natural vocalizations.

We accessed the DCN using a dorsal approach through the cerebellum. We have recorded responses in 58 well-isolated single units.

Statistical determination of significant responses:

Neurons of the DCN are often spontaneously active, and stimuli may affect the spike pattern without affecting the average spike rate. Therefore, we determined responses using a Kolmogorov-Smirnov (KS) test between the peristimulus time histogram (PSTH) and a histogram that would have been generated by a uniform spike rate. The KS-test provides a statistical measure of goodness-of-fit between these two histograms to determine if the spike pattern was due to a stimulation or chance. We used 0.20 for the significance level.

In the graph below, the blue trace is the cumulative distribution function (CDF) based on a constant rate, and the color background shows the probability of CDFs generated by spike trains with Poisson intervals. The red trace is CDF generated by the spike times of the PSTH below the graph. When the maximum difference between the two curves (KS-statistic) is greater than 0.20 probability, the response is significant.



Results

I*n vitro* and *in vivo* experiments in DCN have established that particular cell types respond to sound in specific manners (Young, 2002, Portfors & Roberts, 2006). Based on responses to tone & BBN stimuli, DCN neurons have been classified into physiological types for identifying cell types *in vivo*.

DCN cells were classified into 3 types: fusiform cells, vertical cells, and cartwheel cells.

- Fusiform cells: short latency, low thresholds to both pure tones and BBN and narrowly tuned.
- Vertical cells: short latency, higher threshold to BBN than to pure tones, and narrowly tuned.
- Cartwheel cells: long latency, broadly/multiply tuned, identifiable complex and simple spikes.

Fusiform Cells

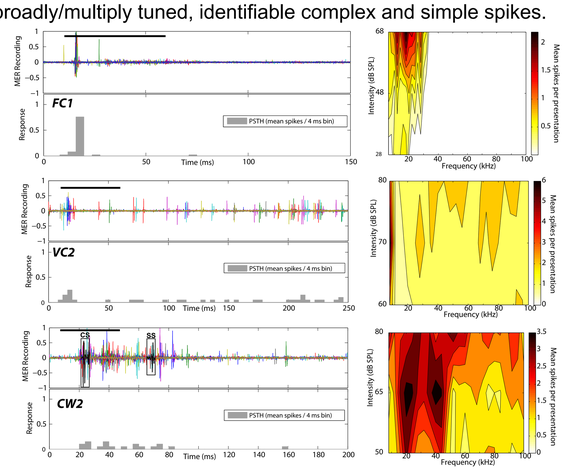
36 cells were identified as fusiform cells by latency <11ms, BBN threshold <20dB of tone, no identifiable complex spikes.

Vertical Cells

10 cells were identified as vertical cells by latency<11ms, BBN threshold >20dB of tone, no identifiable complex spikes.

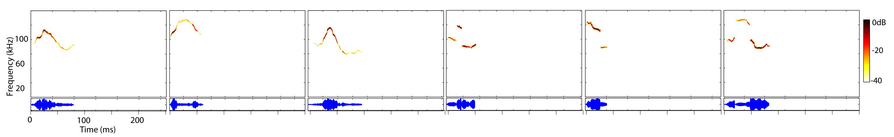
Cartwheel Cells

11 cells were identified as vertical cells by latency>11ms, BBN threshold <20dB of tone, identifiable complex spikes.

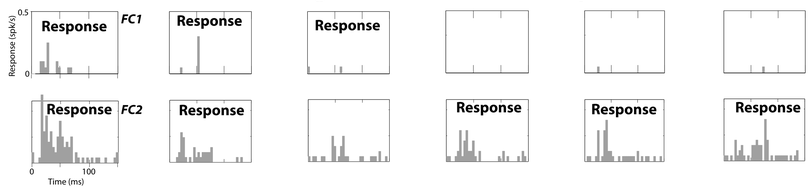


Responses to vocalizations are heterogeneous

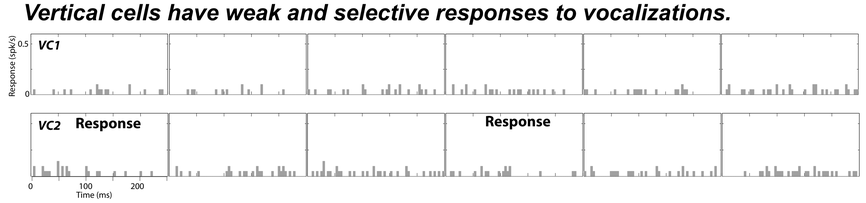
A suite of 49 vocalizations were presented (attn. 15 dB) to each isolated single unit.



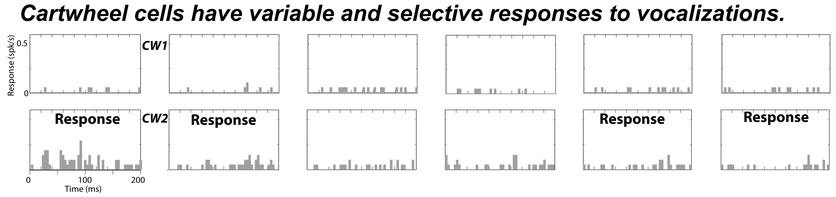
Fusiform cells often have vigorous and selective responses to vocalizations.



Vertical cells have weak and selective responses to vocalizations.

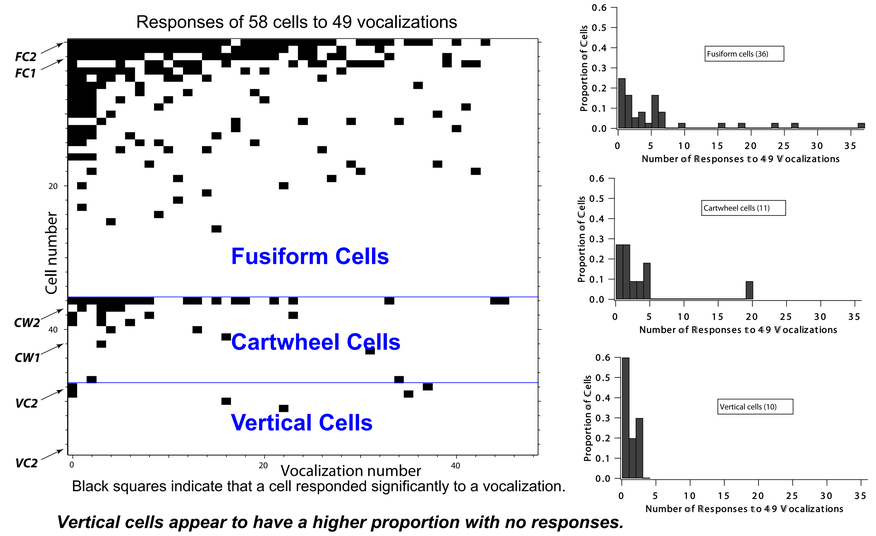


Cartwheel cells have variable and selective responses to vocalizations.



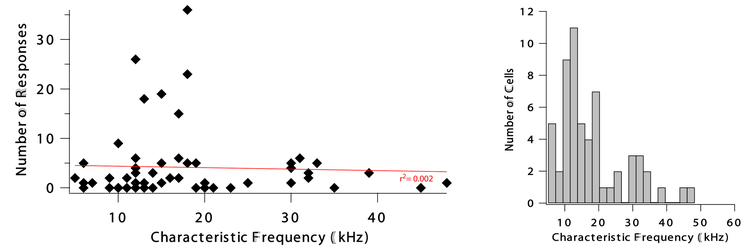
Responses of all units to all vocalizations

The identified physiological response type was found to respond selectivity to a subset of vocalizations, and individual units responded to different vocalizations of the suite.

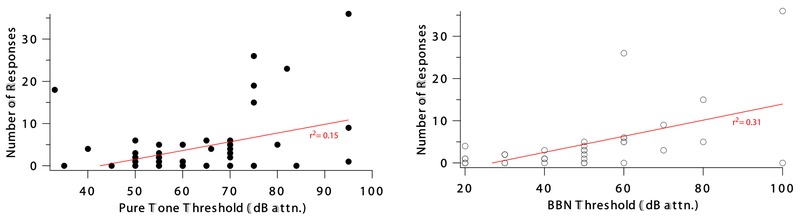


Vertical cells appear to have a higher proportion with no responses.

The tuning curves of neurons were usually not congruent with the spectral content of the vocalizations, and the responses were uncorrelated with the characteristic frequency.



A better correlation is found with the response threshold for pure tones, and particularly the response threshold for broad band noise. The correlation of responses with broad band noise could explain the lack of responses in vertical cells.



Conclusions

1. Selectivity to natural sounds can arise in the brainstem at the first site of central processing of auditory signals.

2. The different cell types in DCN respond differently to vocalizations.