The neurophonic potential in nucleus laminaris of birds

Nico Lautemann[1*], Paula T. Kuokkanen[2], Richard Kempter[2,3], Hermann Wagner[1]

1 Institute for Biology II, RWTH Aachen, Germany
2 Institute for Theoretical Biology, HU Berlin, Germany
3 Bernstein Center for Computational Neuroscience, Berlin, Germany
* Corresponding author. E-mail address: nico@bio2.rwth-aachen.de

The auditory system of birds can be used as a model system for signal processing in the sub-microsecond time range. In nucleus laminaris (NL), the interaural time differences are detected and a neurophonic potential with a high signal-to-noise ratio can be measured. We use microelectrode arrays to analyse the neurophonic potential as well as to measure the delay lines proposed by an early model by Jeffress. Here we present the first direct evidence of delay lines in the barn owl.

Introduction

Although action potentials in the nervous system have typical durations of at least 1 ms, events can be encoded in the sub-microsecond range, for example in the auditory system.

To subserve the detection of interaural time difference, which is used to localize the azimuthal position of a sound source, the Jeffress-model [1] has suggested three levels of processing: frequency specificity, delay lines and coincidence detection.

This system is realized in birds in the third-order nucleus laminaris, the first nucleus where binaural signals are processed and coincidence detection takes place.

We use the auditory system of birds (chicken, barn owl) to study the neurophonic potential (NP), a frequency-following potential with a temporal precision of some 10 μs, occurring in the network formed by nucleus magnocellularis (NM) and nucleus laminaris in the brainstem. Through our studies, we expect to find out more about the origin of the NP (Fig. 1). We hypothesise that NM axons are the origin of the high-frequency component of the NP, whereas the spike-activity of NL neurons is the source of the low-frequency component.

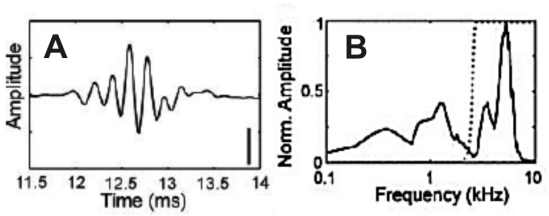

Fig. 1: Neurophonic potential (mean of n=128 trials) evoked by an acoustic click stimulus applied at 10 ms (A, scale bar: 2,5 mV) and the normalized amplitude of the Fourier transform showing 3 major peaks (B) [2]. The question is whether those peaks can be correlated to the different field sources (axons, synapses, somata).

Materials and Methods

Acute coronal slices of the brainstem (300 µm thick) were prepared from barn owls (*Tyto alba*, P2-P8). Recordings were made on perforated 8x8 MEAs (Multichannel Systems, Reutlingen, Germany) while stimulating extracellularly at different loci (Fig.2). The latencies of the averaged response (n=20) were determined by calculating the time difference between corresponding extrema to show the progression of the signals within NL (Fig. 3 B). TTX was used to show the neuronal origin of the response.

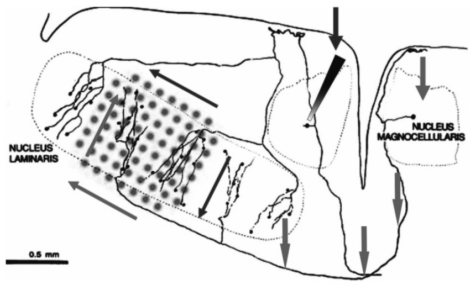

Fig. 2: Schematic drawing of the recording situation (anatomy: [3]): Acute slices of the brainstem are placed on the MEA as shown. This orientation allows the recording along the projections from NM while stimulating with tungsten electrodes (3-5 MΩ, bipolar pulses, 100-4000 mV) at different positions (vertical arrows). With this arrangement, the delay lines proposed by the Jeffress-model can be measured.

Results

Latencies changed within the NL of the barn owl from medial to lateral as well as in the dorso-ventral direction in response to contralateral stimulation. Averaged signal amplitudes ranged from 10 to 50 µV. Latencies between two neighbouring electrodes (interelectrode distance: 200 µm) were about 34 to 250 µs corresponding to

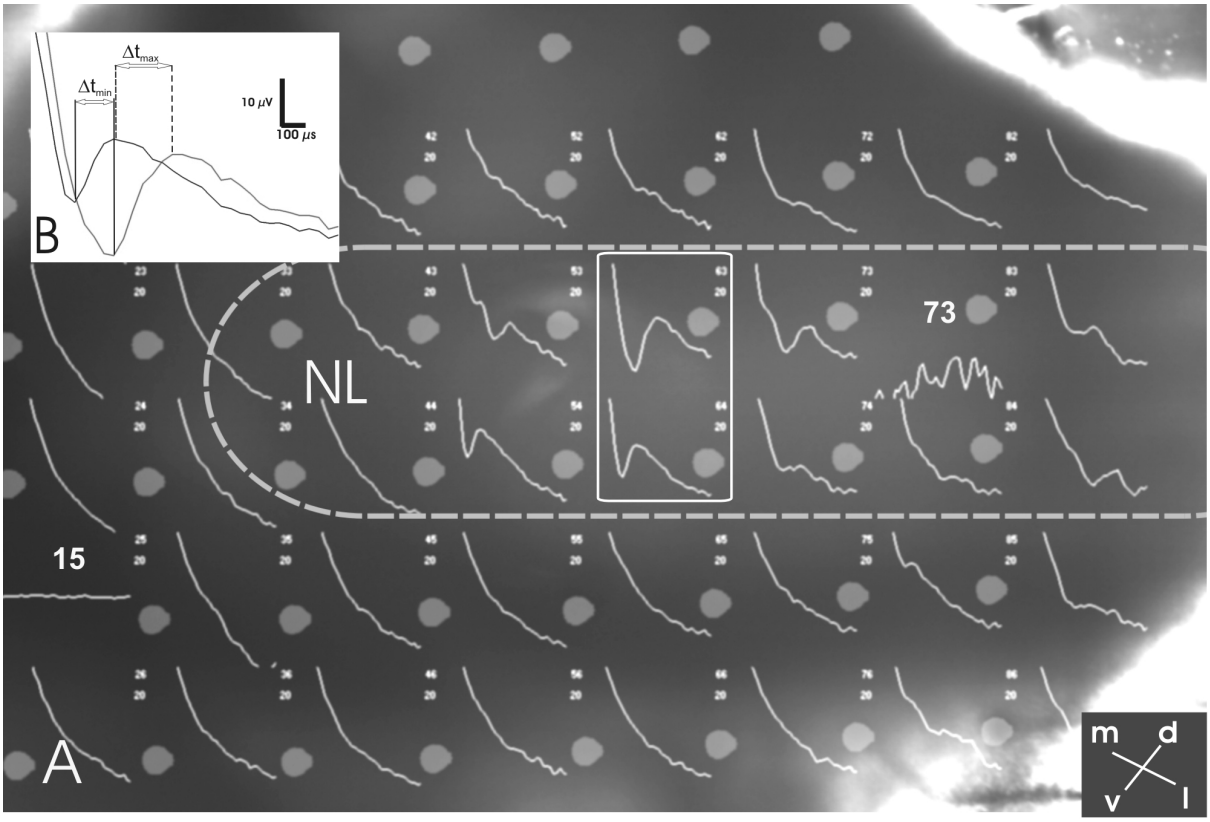

Fig. 3: **A** Cutout (5x8 electrodes) of the averaged (n=20) stimulus-triggered response in the NL of the barn owl (orientation is indicated by the crosshairs). Here, bipolar stimulation pulses (100 μs, ± 2400 mV) were used and applied in the medial region (on the left side, not shown). The projections of the contralateral NM run from medial to lateral outside of NL (border indicated by dashed line), and within the NL from ventral to dorsal (see also Fig. 2). Accordingly, the latencies of the response increase from medial to lateral and from ventral to dorsal. Electrode 73 is defective, electrode 15 is the internal ground electrode. **B** shows a superposition of the responses of the marked electrodes in (A). The time differences between the extrema indicate the latencies along the dorso-ventral extension of the NL.

propagation velocities between 0,8 – 5,9 m/s at 35 °C (Fig.3 A). The responses vanished after application of TTX.

Summary

Because MEAs allow the simultaneous measurement of the neuronal response with a high temporal and spatial resolution, the signal propagation within NL can be accessed. Our data provide direct evidence for delay lines in NL thereby indicating the realisation of the Jeffress-model. In future experiments, we will use Ca-free medium to separate axonal (pro-jections from NM) from somatic responses. These data will be used to simulate the NP.

Acknowledgements

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