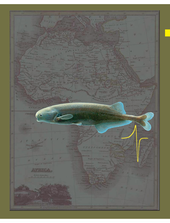

Temporal coding and the electric organ discharge: mormyrid fish as a model system

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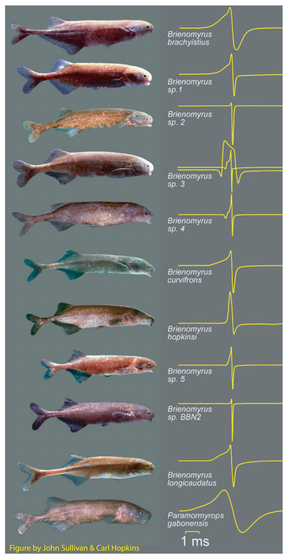
Introduction

1 The temporal features of an EOD are used for social recognition

Weakly-electric African mormyrid fishes use the timing information in an electric organ discharge (EOD) waveform to identify sex and species of other mormyrids[1].

2 Timing of EOD waveforms, encoded by Knollenorgan electroreceptors, is re-encoded by small cells in midbrain nucleus, ELa



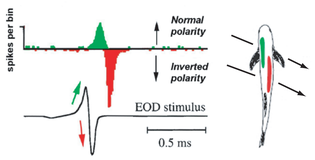
Knollenorgan electroreceptors phase-lock to an EOD

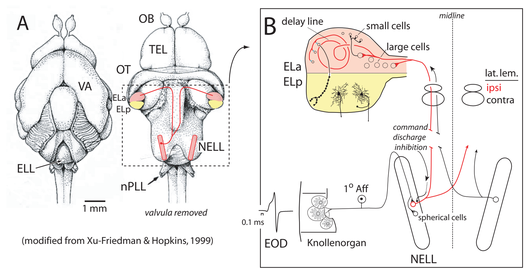
These receptors in the skin are stimulated by the positive-going voltage transient of an EOD, therefore, sensory inputs from different areas of the body are required to encode the entire EOD waveform--**"two-spike code"**[1]

Temporal processing in brainstem, ELa

In midbrain toral nucleus exterolateralis pars anterior (ELa, pink), 'small cells' compare arrival times of spikes from the periphery. ELa small cells output timing information exclusively to ELp (nucleus exterolateralis pars posterior, yellow).

"Two-spike code"

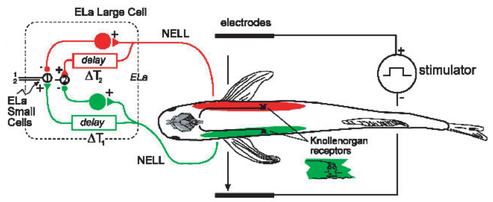


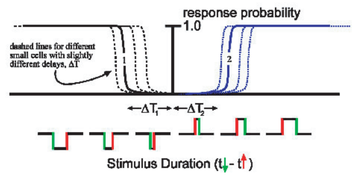


(modified from Xu-Friedman & Hopkins, 1999)

3 Re-encoding by relative timing of excitation and inhibition: delay-line 'anticoincidence' model of EOD waveform processing in ELa

Inhibition is hypothesized to arrive in advance of excitation at ELa small cell 'anti-coincidence' detectors.[2,3] Stimulus-evoked spikes from different body regions arrive at small cells, through either a delayed excitatory pathway or non-delayed inhibitory path. Only stimulus durations exceeding axonal delays excite small cells (i.e., excitation from pulse onset arrives at small cell before inhibition from pulse offset, small cell '2'). We predict uniform geometry stimulation will activate inhibitory inputs in advance of excitation, preventing ELa small cells from firing.





(modified from Xu-Friedman and Hopkins, 1999)

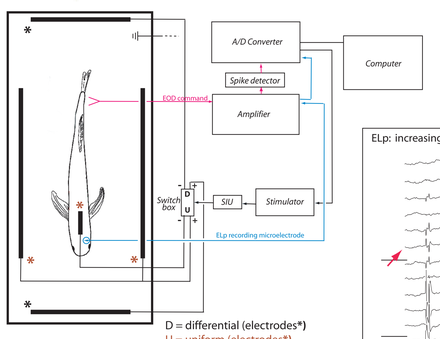
Methods

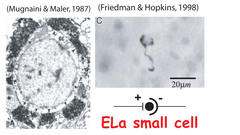
1 Stimulate fish with either uniform or differential electric field geometry

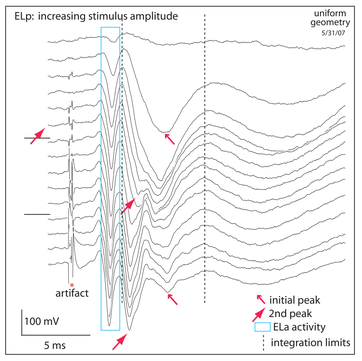
2 Record evoked potentials from ELp

Small cell size and large presynaptic terminals precludes intracellular recording (antomy, upper right), so we recorded local field potentials from ELp under different electric field geometries (uniform, differential), and stimulus amplitudes and durations.

3 Quantify the evoked potential using the integral method





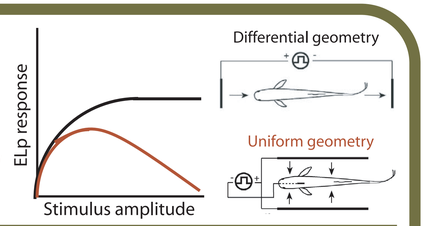


We measured the evoked potential by integrating the area under the curve, in the time interval delimited by the dashed lines. Since the large majority of the evoked potential was negative, we considered only the negative values.

Predictions of the model

If excitation is always delayed relative to inhibition, then

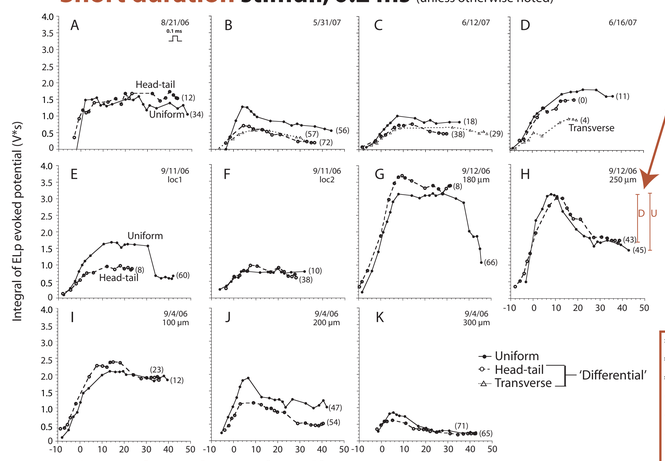
1) ***Uniform geometry**: ELp evoked potential will be **eliminated***
2) ***Differential geometry**: ELp evoked potential will **reach a plateau***



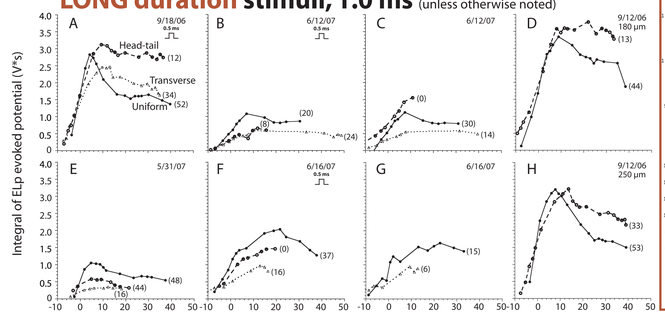
Results

1 Experimental: evoked potentials

Short duration stimuli, 0.2 ms (unless otherwise noted)



LONG duration stimuli, 1.0 ms (unless otherwise noted)

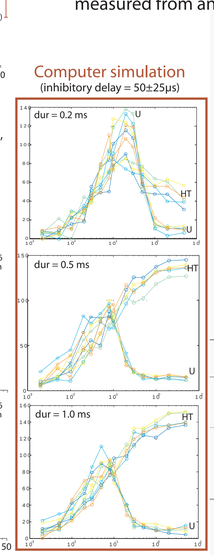


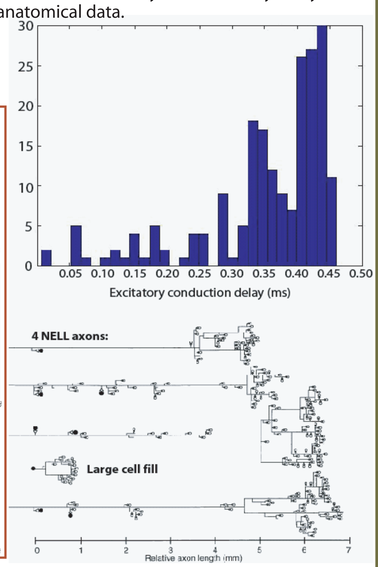
% Decrease in excitation *Ratio of integral at highest stimulus amplitude compared to the peak integral of that stimulus geometry*

D_{short} = 32.0±23.8%	D_{long} = 20.0±12.2%
U_{short} = 39.1±23.2%	U_{long} = 37.3±14.6%

2 Computer simulations

We modeled the Knollenorgan pathway to see the effects of inhibitory and excitatory delay lines on small cell activity as a function of stimulus durations. Inhibitory and excitatory delays were measured from anatomical data.





Discussion

i. **Uniform geometry: evoked potentials *not* abolished (more than 60% excitation "getting through")**

ii. **Differential geometry: evoked potentials tend to reach a plateau at long stimulus durations, but not always**

iii. **Small duration effect (ca. 18% difference) on geometry: inhibition is greater in uniform than in differential**

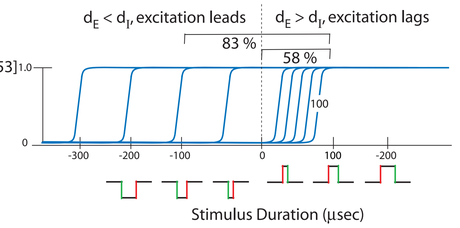
(Is small cell activity being inhibited at high stimulus amplitudes, or is ELp firing more synchronously? ELp units with "closed tuning?")

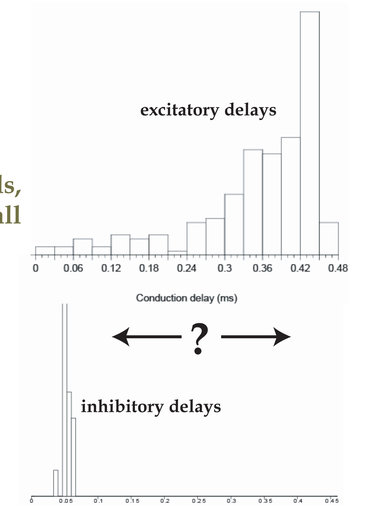
Excitation arrives ahead of inhibition for some ELa small cells

Future directions...

MORE COMPUTER SIMULATIONS, varying relative delays, thresholds, additional excitatory inputs (NOTE: the inhibitory synapse at the small cell is a *chemical synapse* with an estimated delay of *300 ms*)

Using excitatory conduction delays from anatomical studies, and a fixed inhibitory delay of 360 μs--overlapping distributions--, the majority of ELa small cell tuning would fall within a 100 μs stimulus duration range.





Acknowledgements

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