Neural mechanisms of novelty detection

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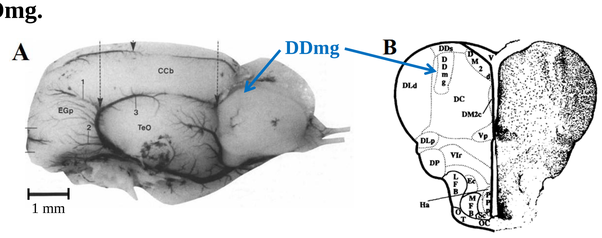
Introduction

The weakly electric fish *Apteronotus leptorhynchus* recognizes and communicates with members of its own species through its electric organ discharge (EOD)[1]. It has previously been shown in songbirds that regions in the forebrain are involved in habituation to novel intraspecific communication signals[2]. Expression of the Egr-1 (early growth response-1) gene in these regions has been shown, via knockout experiments in mammals, to be essential for consolidation of long-term memories[3].

A recent study[4] has shown that expression of the Apteronotid homolog of the Egr-1 gene in dorsal forebrain regions of *A. leptorhynchus* is correlated with habituation to novel communication stimuli. Specifically, mRNA expression of this Egr-1 homolog increased most significantly in the dorsal magnocellular region of the telencephalon (DDmg) when the fish were exposed to novel communication signals.

Figure 1. Brain of *Apteronotus leptorhynchus* showing location of DDmg.



Images from Maler et al (1991)

A, Lateral view of brain, with forebrain aimed towards the right. Arrow points to the left dorsal magnocellular region of the dorsal telencephalon (DDmg).
B, Transverse section of forebrain stained with cresyl violet.

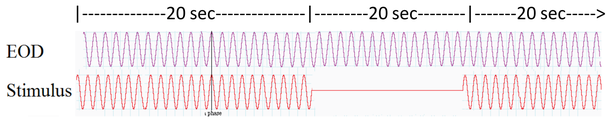
Objective

The goal of the present study is to determine whether neurons in the DDmg region of the telencephalon of *A. leptorhynchus* respond selectively to unfamiliar communication signals, which would indicate that neurons in this area may be involved in the process of recognition or consolidation of novel stimuli.

Methods

- Fish were anaesthetized and forebrain was exposed
- Pancuronium was used to immobilize fish
- Fish were placed in stimulating tank, artificially respirated
- Electrodes at head and tail recorded fish's EOD
- Novel stimulus was presented in the form of an artificial EOD for 20 minutes (see Fig. 2), maintaining a constant frequency difference with the fish's own EOD
- Electrophysiological recordings were performed on neurons in DDmg region with metal or glass electrode

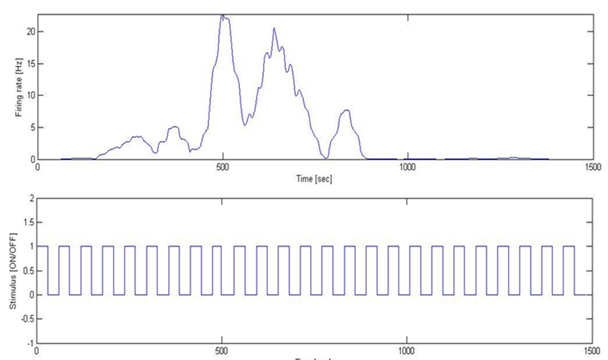
Figure 2. Sinusoidal stimulus EOD mimics the presence of another fish.



Stimulus consisted of 30 presentations of artificial EOD (with frequency close to fish's own EOD) for 20 seconds on, 20 seconds off.

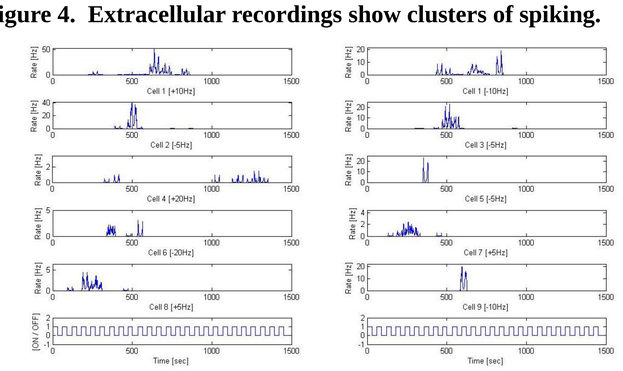
Results

Figure 3. Spiking frequency in DDmg increases during presentation of novel stimulus.



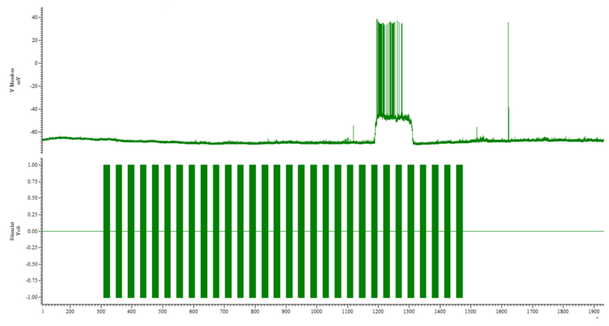
Extracellular recordings showed an increase in spiking activity following onset of stimulation. A latency of approximately 4 minutes from the beginning of the stimulus can be seen (top panel).

Figure 4. Extracellular recordings show clusters of spiking.



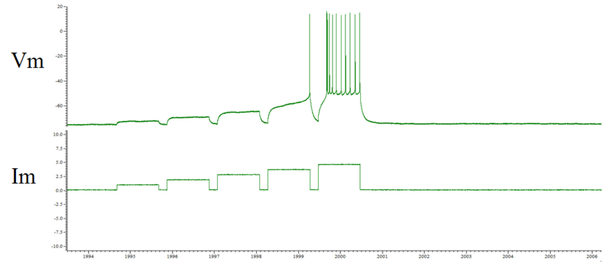
Recordings from 10 stimulus sets with stimulus EOD frequency differences of ±5 Hz, ±10 Hz, and ±20 Hz show localized clusters of spiking activity after the beginning of stimulation.

Figure 5. Intracellular (whole-cell) recording of neuronal membrane potential showing Up state during stimulation.



Up states are identified when two stable, alternating levels of neuronal activity can be distinguished[5]. The Up state is the more depolarized state, during which spiking occurs more readily. The latency for this Up state was 15 minutes from onset of stimulation.

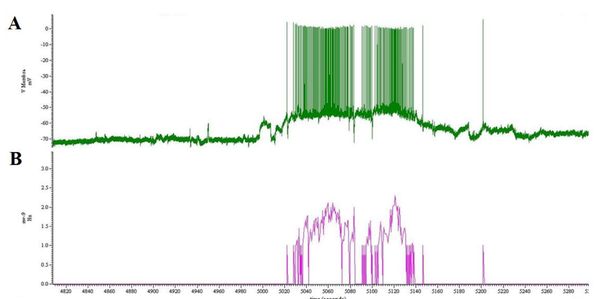
Figure 6. Injection of current fails to produce persistent activity.



Depolarization by current injection causes cell to spike, but is not sufficient to produce an Up state response.

Results

Figure 7. Up state observed with intracellular recording.



A, Intracellular (whole-cell) recording of neuronal membrane potential from neuron in DDmg region of telencephalon following novel stimulation, showing Up state response. The duration of this Up state was approximately 2 minutes.
B, Rate of spiking. Note the absence of activity prior to and following the Up state.

Conclusions

- Stimuli mimicking intraspecific communication signals initiate response in DDmg cells if the stimulus is novel, indicating that this region of the telencephalon is associated with recognition or consolidation of novel stimuli
- The role of Up states may be to maintain neural networks in a state of sustained activation[6], thereby allowing for more efficient processing of sensory information

References

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Further information

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