Primary Afferent Responses to Naturalistic Signals and Backgrounds in Weakly Electric Fish

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Introduction

Sensory systems are specialized for selectively extracting information from the environment that is relevant to an animal's behavioral goals, while suppressing background noise that tends to obscure behaviorally important signals. Considering the amazing ability of many sensory systems to extract weak signals from background noise, it is expected that sensory filtering mechanisms should be adapted to the statistical properties of natural sensory stimuli. Understanding the functional consequences of sensory filtering can best be assessed using stimuli consistent with the characteristics of the natural environment.

Sensory Processing in Weakly Electric Fish

The electrosensory system of weakly electric fish is a model for studying neural filtering of weak signals. These fish detect prey-induced perturbations in a dipole-like electric field surrounding their body generated by continuous, high-frequency electric organ discharges. Electroreceptors in the skin encode electric field amplitude by measuring the potential difference across the skin of the fish. This transdermal potential is typically in the range of a few millivolts (Bastian, 1981; personal observations). The perturbations induced by prey are several orders of magnitude smaller than the baseline amplitude of the electric field (Nelson and MacIver, 1999; MacIver *et al*., 2001).

Electrosensory Environmental Characterization

We developed techniques for recording the voltage perturbations of the transdermal potential at select locations on the fish body while the animal was allowed to swim freely in a large tank. Fish movement and location relative to environmental landmarks were reconstructed in three dimensions from video records. This allowed us to correlate the statistical properties of the electrosensory input signal with fish movement. Preliminary results suggest the power spectrum of the sensory input falls off with the inverse of frequency. Additionally, the amplitude of self-generated or external noise can be at least an order of magnitude larger than actual prey signals at detection threshold and the spectra of noise and prey signals strongly overlap. Therefore, the detection of prey-like signals appears to be a particularly difficult task for the central nervous system.

Primary Sensory Filtering

As an initial step in investigating this problem, we recorded from primary electroreceptor afferents exposed to simulated prey-like signals, background noise, and signal-plus-noise. Primary afferents responded to signals in an amplitude and frequency dependent manner. The response to naturalistic background was a "whitening" of the stimulus power spectrum through high-pass neural filtering. The signal-plus-noise stimuli caused a peak in the power spectrum of the neural response that was absent in the noise-only condition.

References

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