Two Coding Strategies for Communication Signals in a Population Rate Code

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1 Introduction

It is generally believed that encoding of stimuli in the firing rate of single neurons strongly limits a rapid read-out by higher-order neurons. A rate code, however, that makes use of a whole population of neurons is much better suited for high speed processing. Here we present an example where different mechanisms are employed to encode two types of communication signals in a population rate depending on the time scale of the signal.

The weakly electric fish \textit{Apteronotus leptorhychus} generates a quasi sinusoidal electric field (EOD) of about 800 Hz that is used for both prey detection and communication. During male-male interaction the superposition of the EODs results in a beat of upto 60 Hz whereas during male-female interaction higher beat frequencies between 100 and 300 Hz occur. The fish produce two types of chirps, brief (15 – 25 ms) rises of their EOD frequency, for communication. We performed single unit, dual unit, and whole nerve recordings of P-unit electroreceptor afferents to investigate the encoding strategies that are used for the two types of chirps.

2 Small chirps

2.1 Stimulus

Small (type II) chirps that are emitted during antagonistic male-male interaction result in a phase shift of the beat by about 0.5 to 1.5 cycles. This generates short transients that interrupt the periodic beat pattern.

The high-pass properties of the cells induced by spike-frequency adaptation strongly enhance the firing frequency response to the chirps compared to the response to low (less than 30 Hz) beat frequencies (Benda, Longtin, et al., 2005).

2.2 Single unit response

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Maler (2005), J. Neurosci.).

2.3 Single trial rate

![Graph: Firing rate vs Time (ms)]

⇒ Single-trial rate similar to average.

2.4 Population response

![Graph: Nerve Voltage vs Time (ms)]

⇒ Summed activity of the whole population of P-units similar to single-trial rate.

3 Large chirps

3.1 Stimulus

During large (type I) chirps that males emit in the presence of females, the high frequency beat is interrupted by a short period of essentially constant EOD amplitude.

EOD Fish 1 (female) + EOD Fish 2 (male)

![Graph: EOD Amplitude Modulation Fish 1]

⇒ Single-trial rate differs from average.

3.2 Single unit response

![Graph: Beat and Chirp Activity]

Spike response is phase locked to the fast beat, and synchronized among each other. During the chirp, however, the response is desynchronized.

3.3 Single trial rate

![Graph: Firing rate vs Time (ms)]

⇒ Single-trial rate differs from average.

3.4 Population response

![Graph: Nerve Voltage vs Time (ms)]

⇒ Population response differs from single-trial rate.

4 Summary

In summary, two different coding mechanisms result in a clear change in the population activity in response to the chirps:
⇒ For the small chirps it is just the sum of an enhanced firing rate response that is already visible in a single cell
⇒ The encoding of the large chirps requires the whole population to translate the change from synchrony to asynchrony into an interruption of the oscillation of the population rate
How higher order neurons read out this code remains to be explored.