Coding of Communication Signals by Spike Synchrony and Asynchrony

Jan Benda$^{1,2}$ (j.benda@biologie.hu-berlin.de), André Longtin$^2$ & Len Maler$^1$

$^1$ Dept. of Cellular and Molecular Medicine, $^2$Dept. of Physics, University of Ottawa, ON Canada

International Conference of Neuroethology, Nyborg, 2004

1 Introduction / Summary

Synchronous spiking of neural populations is hypothesized to play important computational roles, like for example in solving the binding problem, attention, and cortical communication. We present an example where the opposite, i.e. the desynchronization of a neural population encodes a transient communication signal.

During male-female interaction of weakly electric fish the superposition of the electric fields results in an ongoing high frequency beat of about 100 to 300 Hz. Our in vivo recordings of P-unit electroreceptor afferents in Apteronotus leptorhynchus (single unit, dual, and whole nerve recordings) clearly show a highly synchronous response to such beats. However, whenever a male emits a courtship signal, a so-called type-I or large chirp, the beat is interrupted for about 25 ms and the response of the electroreceptor population becomes desynchronized. The mean firing rate during the synchronous and asynchronous response is approximately the same.

2 Stimulus

The weakly electric fish Apteronotus leptorhynchus produces a continuous quasi-sinusoidal electric field (EOD, 600 – 1100 Hz) which is used for both prey detection and communication.

The large type-I chirps are courtship signals emitted by males where the EOD frequency is raised by about 600 Hz during ~ 24 ms and the EOD amplitude is dropped by ~ 50 Hz.

In the presence of a second fish with EOD frequency $f_2$ a beat arises with frequency $\Delta f = f_2 - f_1$. During male-female interaction $\Delta f$ is as large as 100 to 300 Hz.

For the receiving fish the chirp results in a brief interruption of the beat.

3 Single Unit Recordings

In vivo recordings of electroreceptor fibers (P-units) with sharp electrodes.

$\Rightarrow$ Synchronous response to the fast beat
$\Rightarrow$ Asynchronous response during the chirp
4 Dual Unit Recordings

The probability of a coincident spike in the other trace within $\Delta t$ is larger during the beat:

$\Rightarrow$ Spikes during the beat are more synchronized than during a chirp on a $\sim 4$ ms timescale.

5 Trunk-Nerve Recordings

The population signal of all P-unit bers recorded with a pair of hook electrodes from the trunk nerve.

6 Behavior

As shown by a behavioral study (Bastian et. al (2001), J Exp Biol 204, 1909–1923) the probability of a fish emitting a large chirp (●) is highest for beat frequencies around 100 Hz.

This is nicely matched by the population synchrony (■) measured as the standard deviation of the nerve potential during the beat divided by the standard deviation during the chirp.

$\Rightarrow$ Degree of synchrony during beats matches behavior.

7 Conclusion

Desynchronization of the spike response can be as important as synchronous spikes. More generally:

any change of the degree of synchrony could code a signal.