Neuronal Implementation of the Jamming Avoidance Response (JAR)

Announcements

- Writing assignment due Monday (W22)
- Check links on website for lecture related supplements
- No discussion on Wed after fall break
- Wiki-titles due Monday, Oct. 3

Question: Does the fish compare the stimulus with its own pacemaker?

Answer: No! The JAR relies solely on sensory information

Question: Does the JAR depend on stimulus geometry?

Answer: Yes! The JAR only occurs under differential geometry

Walter Heiligenberg (1937-1994)
Minimal Stimulus Conditions for JAR

(1) Two signals: S1 + S2
(2) |Df| < 5 Hz
(3) Differential geometry

Two sine waves combine to produce a complex wave (amplitude modulation and phase modulation).

Relationship Between Amplitude and Phase Depends on the Sign of Df

Combining Two Periodic Signals Results in a Beat (Amplitude Modulation)

\[ S_1 = 300 \text{ Hz} \]

\[ S_2 = 302 \text{ Hz} \]

\[ S_1 = 298 \text{ Hz} \]

\[ +Df \]

Combined Signal is Also Modulated in Phase (Timing)

Fish’s own EOD
Neighbor’s EOD

Body area A
Body area B

Note: go to “links” page to see Flash Video of JAR
Peripheral Electroreceptors

**T-units**

Amplitude Increases / Phase Delays
Amplitude Decreases / Phase Advances

**P-units**

Amplitude Increases / Phase Advances
Amplitude Decreases / Phase Delays

Note: go to links page to download flash video of T-unit

Go to links page to download P-unit video
Together, T-units and P-units provide the necessary information for executing the JAR.

**Neuroanatomy of the JAR**

- T-units converge onto spherical cells
  - Combining inputs from several T-afferents results in even more precise action potential times

**Neuroanatomy of the ELL**

- T-units converge onto spherical cells
- P-units project to pyramidal cells
  - E-units respond to amplitude increases
  - I-units respond to amplitude decreases
Neuroanatomy of the JAR

The torus is a laminated structure

Spherical cells and pyramidal cells project to different laminae

- Pyramidal cells project to several laminae in the torus (3, 5, 7, and 8)
- Spherical cells project exclusively to lamina 6

Phase comparisons are made in lamina VI

1) Giant cells receive direct excitatory input from spherical cells
2) Spherical cells also send fibers to tiny dendrites of small cells
3) Small cells receive excitatory inputs from giant cells onto their soma
4) Small cells receive convergent timing input from different parts of the body surface
5) Small cells respond to differences in timing between different parts of the body surface

Convergence of amplitude and phase information within the torus

1) Small cells in layer 6 project to other layers of the torus
2) Phase sensitive neurons are found in layers 5, 7, 8a, 8b, 8c, and 9
3) E and I inputs from ELL project to layers 5, 7, 8a, and 8c
4) Phase and amplitude information converge in layers 5, 7, and 8

Responses of torus neurons to jamming stimuli

- Amplitude-sensitive cell (E-unit)
- Phase-sensitive cell (adv-unit)
- Sign-selective cell (E/adv-unit)
Model of a sign-selective cell

-Phase advance unit
- $E$ unit
- $I$ unit

-DF-selective neuron
- +DF-selective neuron

Neuroanatomy of the JAR

The African fish *Gymnarchus* also performs the JAR

The electroreception systems of *Gymnarchus* and *Eigenmannia* evolved independently

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Neuronal implementation of the JAR in Gymnarchus

- Like Eigenmannia, Gymnarchus does not have a corollary discharge
- Gymnarchus uses the same algorithm of combining information about amplitude and differential phase

Gymnarchus also has separate amplitude- and time-coding primary afferents

Amplitude-sensitive cell in ELL

- Gymnarchus has E-units and I-units in ELL, just like Eigenmannia

Phase-sensitive cell in ELL

- Eigenmannia calculates differential phase in the torus
- Gymnarchus calculates differential phase in ELL

Sign-selective cells in the torus

- Gymnarchus has sign-selective neurons in the torus, just like Eigenmannia

What have we learned from studying the JAR?

1) It is sometimes advantageous to study novel behaviors because they are well-suited to neurophysiological study.
2) Task-specific functions are encoded in separate, often parallel, channels. Time and amplitude channels serve specialized functions (similar to barn owl).
3) Recognition units emerge at higher levels in the sensory hierarchy. The complex recognition properties arise from successive analysis of features.
4) Recognition units may drive motor output.
5) Identical computational algorithms may evolve in unrelated species by convergent evolution.
6) Neuronal substrates for similar functions may involve very different neuronal subtypes.