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Shall We Even Understand the Fly’s Brain?
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Living organisms share a common evolutionary heritage.

↓

Much can be learned about complex systems by studying simpler ones.
Integrative neuroscience is an odd biological science.

"When it comes to computation, integrative principles, or "cognitive" issues such as perception, however, most neuroscientists act as if King Cortex appeared one bright morning out of nowhere, ..."
Why This Obsession with Cortex?

We are still much too attached to empirical descriptions, names, molecular details
1. We should identify the underlying functional principles
2. We should be open to the possibility that such principle may be at work equally in small and large brains.

1. Small systems seem to use mechanisms and strategies that are not unique to them.
2. Small systems are not at all that “simple”;

Olfactory Systems
The Olfactory Brain as a System to Identify Rules of Potentially General Relevance

Identification of odors

Some are relatively simple.
- “labeled lines”

Some are more complex.
- Mixture of multi-molecular odors
- Qualitatively / Quantitatively identification
- Fluctuations due to noise, oxidation, or volatile components.

→ The olfactory system recognizes odors as patterns.
OB and AL are highly interconnected circuits with wide-spread inhibition.

Mitra cells (MCs, output of OB) and Projection neurons (PNs, output of AL): many forms of temporal patterning of activity.
The OB and AL are “encoding machines”.
- actively transform a distributed, multidimensional input to encoded output
- to enable the formation of compact and easily recalled memories.

Due to complexity, brain exploits circuit dynamics to accomplish 2 objectives:
1. To create a very large coding space through spatiotemporal patterns
2. To use distributed dynamics to confer stability and to optimize the filling of the representation space.
The OB and AL as Decorrelators

Slow patterns

Temporal Patterning
- Odor responses in PNs are not static.
- The population representation is dynamic
- Both neuron- and odor-specific

Perez-Orive et al. 2002
Spatiotemporal patterning results in a rapid decorrelation of odor representations
- Odor classification during early epochs
- Precise stimulus identification during later ones
The OB and AL as Decorrelators

Mechanisms and Possible Formal Principles

The mechanisms involve at least interactions within the OB (or AL)

Slow synaptic dynamics and distributed lateral connections responsible for such spatiotemporal patterning.
Oscillatory Synchronization and Sparse Representations

Oscillatory synchronization

Oscillatory synchronization arises through the action of local inhibitory neurons (LNs) with widespread output to other LNs and to the PNs.
Decoding

- Sparse representation is used.
- Neurons can act as coincidence detectors.
- Oscillatory synchronization play a critical role.
Sparsening has many advantages
- Reducing overlap
- Facilitate storage (fewer synapses need modifying)
- Facilitate pattern matching (fewer elements need to be compared)
- Facilitate pattern association

Significance

Bazhenov et al. 2001
Are Slow Dynamical Patterns Features of a Code?

Slow dynamics might appear irrelevant for these reasons:
1. Decoding of the AL output by KCs seems to make no explicit use of the dynamical features of PN responses.
2. Each KC selectively assesses the state of a small part of the PN assembly.

The author still believe them to be essential:
1. Sequence decoding could be accomplished downstream of KCs
2. The relevance of slow dynamics in the AL might be implicit in the KC responses
3. Dynamics are critical for optimization of the code but need not be the code itself
   (1) Spread out the representations in a larger coding space
   (2) Facilitate decoding
4. Dynamics may be useful not only for representation but also for recognition
The Problem with Noise

Require mechanisms that can discriminate noisy from meaningful differences.

Possible noise-reduction mechanisms:

1. The convergence of ORNs and the distributed sprinkling of these ORNs, limiting the probability of correlate noise, could allow the averaging necessary to increase signal-to-noise ratios.

2. AL circuits might operate at low detection threshold at “rest” but immediately “focus” on a signal once it has been detected.

3. Network mechanisms could play a critical role in ensuring stability in the collective output.

Carey et al. 2011
The Problem with Decorrelation and Perceptual Clusters

**Problems:**

1. Perceptual relatedness between odors may be lost.

2. Individual odors at different concentrations usually retain, at least over some range. But if the patterns are different, decorrelation would possibly preclude their perceptual grouping.

**Possible Solutions:**

1. Perceptual grouping could be a high-level property

2. Decorrelation is a temporal process

3. Network dynamics and sparsening never completely orthogonalize representations
General Conclusion

- Much integrative work is needed to understand the computational organization of olfactory systems.
- A system perspective that is based on experimentation with small olfactory brains.
- Circuit dynamics over multiple timescales and correlation rules play an integral role in optimizing stimulus representation.
- How a neuron behaves may be relevant not as a response per se but as part of a transformation to help further processing in the area in which the neuron lies or in “target” circuits.