Neural Coding in Moth Olfactory Responses


Action Potentials and Cell Communication
- Neurons communicate through action potentials (spikes) generated by electrochemical gradients of Na⁺, K⁺, and Cl⁻ ions.
- Produce characteristic spikes when introduced to stimuli
- Spikes are probabilistic in nature, therefore spikes vary when neurons are exposed to the same stimulus

Mathematical Expressions of Neural Coding
- Spike sequence can be represented in the form of Dirac delta functions

\[ \delta(x) = \begin{cases} +\infty, & x = 0 \\ 0, & x \neq 0 \end{cases} \]

Dirac Delta Function

Firing Rate
- Probability of a spike occurring within a certain time interval
- Determined over multiple trials

\[ r(t) = \frac{1}{t} \int_{t-T}^{t} dt \rho(t) \]

Neural Encoding in Moths
A moth’s olfactory encoding response to three different stimuli, cis (cis), cis-hexen-1-ol (hex), and linalool (lin), was observed and modeled. The moth was chosen because it represents a very simple physiology capable of an olfactory response.

Neural Encoding and Neural Decoding
Neural Encoding
- Looks at the spikes produced when a neuron is exposed to a stimulus

Neural Decoding
- Investigates a series of produced spikes and tries to understand the stimulus that created it

Neural Response Function
- Re-expresses sums over spikes as integrals over time

\[ \rho(t) = \sum_{i=1}^{n} \delta(t-t_i). \]

Spike-Count Rate
- Time average of neural response function over duration of a single trial

\[ r = \frac{n}{T} \int_{0}^{T} dt \rho(t) \]

Tuning Curves
- Compares differences in firing rate to variations in stimuli
- Shows “preference” towards stimuli
- Responses fit to appropriate tuning curve functions

Creation and propagation of an action potential through multiple neurons.

Figure 1. Neural spikes and interpretations
(a) example of a neural spike train.
(b-e) firing rate averaging through different methods.

Figure 2. Visual cortex neuron response to light. (a) firing rates of neurons in response to different angles of incoming light. (b) Gaussian tuning curve from firing rates.

Figure 3. (a) spike train response to cis, hex and lin. (b) average firing rates of neurons. (below) Information encoding and preference to stimuli.

Figure 4. Dirac delta function graph.

Figure 5. Mathematical expressions of neural coding.

References