Effects of adaptation on orientation tuning in excitatory and inhibitory neurons in macaque V1 and V2

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Introduction and Motivation

Historically, adaptation devices were used to display images with distorted visual features to examine the adaption process in the visual cortex. In this study, we investigate the effect of orientation tuning in functionally diverse cell categories (excitatory vs. inhibitory) in V1 and V2 of the macaque.

Methods

We performed multi-unit extracellular single-unit recordings to measure neural responses to drifting sinusoidal gratings before and after adaptation to preferred and non-preferred orientations.

Adaptation Paradigms

In this study, two adaptation experiments are performed, one at 0.5° and another at 60° spatial deflections. These are chosen to demonstrate qualitative differences in the effects of adaptation in V1 (Pepperberg et al., 2013).

Selection of Adaptation Parameters

Based on online analysis of tuning measured at six sites, the adapting orientations are chosen to be 0°, 45°, and 90°, respectively. Neural activity at three of these six sites have peaks within 2.5° of a common direction. Orientations of 0° and 112.5° (indicated by vertical bars) are therefore selected for the appropriate stimulation. Sites are presented at the spatial center and are repeated for at least one of the six sites.

Single-unit Responses

V1 Supragranular Layer

Peak Shifts

Bandwidth Changes

Population Responses

V1 Granular Layer

V1 Layers Combined

Conclusions

- Excitatory and inhibitory neurons both show adaptive shifts of their orientation tuning curve, for brief and prolonged presentations of the adapting stimulus.
- In the granular layer of V1, brief adaptation of inhibitory cells types mostly broadens tuning bandwidth while prolonged adaptation narrows it.
- In V2, adaptation mostly induces narrowing of orientation tuning in excitatory cells, but increase or decrease the bandwidth of inhibitory cells. Both repulsive and attractive shifts in tuning are observed in V2.
- Both pre-synaptic adaptation and tuned inhibition are required to account for both repulsive and attractive shifts in tuning, as observed in the data.

Adaptation-induced tuning shifts in models of orientation selectivity

Model Characteristics

- Common to all Models
  - Feedforward architecture
  - 80% excitatory neurons
  - 20% inhibitory neurons
  - Orientation tuning modeled with sine Mersenne functions
  - Tuning parameters drawn from our norm data
  - Output neuron modeled as Poison spike train

Adaptation Rules

- Post-synaptic adaptation influence strength changes of all inputs by a common factor, determined by post-synaptic neuron
- Pre-synaptic adaptation influences changes proportional to the pre-synaptic unadapted response

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References