Tuned inhibition accounts for adaptation-induced tuning shifts in macaque V1 and V2

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Introduction and Motivation

The visual system utilizes inputs from the recent past to adjust its representations of the sensory world. This ubiquitous property of sensory systems - adaptation - influences neural response characteristics including gain, stimulus preference, and degree of selectivity. To identify the adaptation-induced alterations in tuning properties, we measured and modeled the effects of adaptation on excitatory and inhibitory neurons in V1 and V2 of the primates visual cortex.

Methods

We performed multi-tetrode single-unit recordings to measure neural responses to drifting sinusoidal gratings before and after 0.4 sec and 40 sec adaptation to preferred and non-preferred stimuli.

Physiological methods

Macaque V1 and V2

Anesthesia: sufentanil and propofol

Neuromuscular blockade: rocuronium

Adaptation Paradigms

Brief Adaptation

Prolonged Adaptation

For each recording site, two adaptation experiments are performed: brief adaptation (0.4 sec) and prolonged adaptation (40 sec). These paradigms are known to demonstrate adaptation-induced effects in V1 (Patterson et al., 2013).

Selection of Adaptation Parameters

Based on the tuning of the multiunit activity measured at 6 tetrodes, the adaptation orientations are chosen. In this example, neural activity at 3 of 6 tetrodes has peaks within 22.5 deg of a common direction. Here 90 deg (arrow) is chosen to be the adaptation orientation - it targets 3 of 6 tetrodes (grey, magenta, yellow) at the preferred orientation and the rest at a non-preferred orientation. Stimuli are presented at the spatial frequency that is optimal for at least one tetrode.

Extracellular Wave Shape Analysis

Single-Unit Responses

Population Responses

What accounts for the diversity of adaptation effects in V1?

1. Simple vs Complex? No

2. Granular vs Supragranular? No

3. Pinwheel vs Iso-Orientation? Partially

4. Adapting orientation - INHIBITORY cells

5. Pinwheel vs. Iso-Orientation ? Partially

Untuned V1 cells can become tuned

• The laminar position did not account for the diversity of adaptation effects to the orientation tuning. However there was a suggestion that, in layer 4, adaptation predominantly increases tuning bandwidth of cells, and not E cells.

• About 19% of untuned cells became tuned after adaptation. These cells (indicated by triangles) had a circular variance that were not significantly different from randomness under baseline conditions but showed significant tuning after adaptation. This phenomenon was present in both excitatory (blue) and inhibitory (red) cells.

• Diversity of adaptation-induced effects did not appear to be related to the excitatory vs inhibitory division, or to the simple vs complex distinction, or to the laminar location.

• The simple/complex distinction did not appear to account for the diversity of adaptation-induced tuning shifts and the attractiveness of the shifts. However, there was a significant attractiveness of pinwheel cells in both V1 and V2, with larger effects in V2, than in V1. This likely corresponds to the "indirect and "indirect" aftereffects observed in the classical psychophysical studies of Gibson and Radner (1937).

• Only models with pre-synaptic adaptation and tuned inhibition could account for the attractive shifts that are widespread in the data.

• Parameters within the physiological range accounted for the diversity of adaptation-induced tuning effects.

Summary and Conclusions

We found that adapted neurons adapted to an orientation - inhibitory cells

• Diversity of adaptation-induced effects did not appear to be related to the excitatory vs inhibitory division, or to the simple vs complex distinction, or to the laminar location.

• Location on the orientation map appeared to contribute to the nature of adaptation-induced tuning shifts: cells in pinwheel areas demonstrated larger changes than cells tuned to preadapted orientations.

• Adaptation-induced tuning in a subset of V1 neurons that were untuned under baseline conditions.

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References


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