Fundamentals of area V1
Part 1: Receptive fields and maps

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Receptive fields in area V1

Hubel and Wiesel, circa 1969 (from Nicholls et al., 1992)
Responses of a V1 neuron

Hubel and Wiesel, 1959
Artificial early visual system

www.ini.unizh.ch/~tobi/friend/chip/

Delbruck & Liu, 2004
Responses of artificial simple cell

Tuning curve

Receptive field

Delbruck & Liu, 2004
Receptive field of a V1 simple cell

DeAngelis, Ohzawa & Freeman, 1995
Receptive field of a V1 simple cell

DeAngelis, Ohzawa & Freeman, 1995
Selectivity for orientation

The diagram illustrates the response of neurons to different orientations over time. The left side shows a series of responses to varying orientations, with a peak response for a specific orientation. The right side shows a more gradual response pattern, indicating a different mechanism or sensitivity to orientation changes.
Stimuli and receptive fields in space-time

Adelson & Bergen, 1985

Carandini, Heeger & Movshon, 1999
Separability and direction selectivity

Separable, not direction selective

Inseparable, direction selective
Space-time receptive fields

DeAngelis, Ohzawa & Freeman, 1995
V1 simple cell, separable
V1 simple cell, inseparable
How are V1 receptive fields obtained?

DeAngelis, Ohzawa & Freeman, 1995
Assembly of receptive fields in the artificial visual system

ON center ganglion cell
(Vm: 2, R: 3)

OFF center ganglion cell
(R: 4)

ODD simple cell
(Vm: 5, R: 7)

EVEN simple cell
(Vm: 6, R: 8)

Delbruck & Liu, 2004
H & W’s feedforward model of simple cells

Hubel & Wiesel, 1963
Receptive field of a V1 complex cell

DeAngelis, Ohzawa & Freeman, 1995
Receptive field of a V1 complex cell

DeAngelis, Ohzawa & Freeman, 1995
H & W’s feedforward model of complex cells

Hubel & Wiesel, 1963
Simple cell responses to a drifting grating
Responses to a drifting grating
Responses to a drifting grating

Carandini & Ferster, 2000
Dichotomy of simple and complex cells

Complex

Simple

Cat

Monkey

F1/F0

Skottun, DeValois, Grosof, Movshon, Albrecht & Bonds, 1991
Responses to a drifting grating

Carandini & Ferster, 2000
Dichotomy is created by threshold

Priebe, Mechler, Carandini & Ferster, 2004

Priebe, Mechler, Carandini & Ferster, 2004
Feedforward model of complex cells
Complex cells as networked simple cells

Low gain

Chance, Nelson & Abbott, 1999
Complex cells as networked simple cells

Chance, Nelson & Abbott, 1999
Complex cells as networked simple cells

- Simple
- Intermediate
- Complex

Gain = 1
Gain = 5
Gain = 20

Chance, Nelson & Abbott, 1999
Maps
Cortical representation measured with 2-deoxy-glucose

Tootell et al. (1988)
Complex-log model

Schwartz et al. (1988)
Frederick and Schwartz (1990)
If your eyes see this...

Schwartz et al. (1988)
Frederick and Schwartz (1990)
...your brain maps it to this

Schwartz et al. (1988)
Frederick and Schwartz (1990)
Retinotopy is very precise

Map of ocular dominance measured with radioactive proline

LeVay, Hubel and Wiesel (1975) in Nicholls et al. (1992)
Optical imaging

- Intrinsic signals
- Voltage-sensitive dye
Map of ocular dominance measured with optical imaging

Bonhoeffer & Grinvald (1991) in Nicholls et al. (1992)
Map of orientation preference measured with optical imaging

Bonhoeffer and Grinvald (1991) in Nicholls et al. (1992)
Relationship between ocular dominance and orientation preference

Obermayer & Blasdel (1993)
Connections from LGN may constrain the map of orientation preference
Preliminary evidence from tree shrew V1

The retinal mosaic may determine orientation preference

Retinal mosaic, X cells

Ringach, 2004
The retinal mosaic may constrain the map of orientation preference.

Retinal mosaic, X cells

Ringach, 2004
Summary

• V1 receptive fields in space-time
• Wiring of simple cells and complex cells
• Maps of selectivity
• Constraints on orientation map
Power law creates dichotomy

Priebe, Mechler, Carandini & Ferster, 2004