What fraction of human cortex is devoted to processing visual information? Take a guess.
Note: no class on 09/04/2023 (Labor Day)
Class 1 [09/11/2023]. Introduction to Vision
Class 2 [09/18/2023]. The Phenomenology of Vision
Class 3 [09/25/2023]. Natural image statistics and the retina
Class 4 [10/02/2023]. Learning from Lesions
Note: no class on 10/09/2023 (Indigenous Day)
Class 5 [10/16/2023]. Primary Visual Cortex
Class 6 [10/23/2023]. Adventures into terra incognita
Class 7 [10/30/2023]. From the Highest Echelons of Visual Processing to Cognition
Class 8 [11/06/2023]. First Steps into in silico vision
Class 9 [11/13/2023]. Teaching Computers how to see
Class 10 [11/20/2023]. Computer Vision
Class 11 [11/27/2023]. Connecting Vision to the rest of Cognition [Dr. Will Xiao]
Class 12 [12/06/2023]. Visual Consciousness

How do we go from oriented lines to complex shapes?

Divide and conquer strategy: multiple small steps are required to solve a complex task.

Hubel and Wiesel (1959) *J. Physiol.* **148**: 574-591

Adventures into *terra incognita*

Felleman and Van Essen. *Cerebral Cortex* 1991
Response latency increases along the visual hierarchy

Each additional processing step takes ~15 ms

Schmolesky et al 1998
Receptive field size increases along the ventral visual stream
Responses to illusory contours in area V2

Neurons in V4 show color selectivity

The curse of dimensionality

Exhaustive exploration of the high dimensional image space is not possible with current techniques
Inferior temporal cortex is composed of many subareas

Logothetis and Sheinberg. Annual Review of Neuroscience 1996
Increase in “complexity” of feature preferences along the ventral visual stream

<table>
<thead>
<tr>
<th>V2</th>
<th>V4</th>
<th>posterior IT</th>
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</tr>
</tbody>
</table>

Increase in “complexity” of feature preferences along the ventral visual stream

\[ S_{\text{max}} = \text{maximum response to “simple stimulus”} \]
\[ \text{MAX} = \text{max response to all stimuli} \]
\[ S_{\text{max}}/\text{MAX} = 1 \rightarrow \text{“simple responses”} \]
\[ S_{\text{max}}/\text{MAX} = 0 \rightarrow \text{“complex responses”} \]

ITC neurons respond to a large variety of complex shapes

Selective responses to almost every kind of stimulus tried.

Desimone, Albright, Gross and Bruce

Connor and others

Kiani, Esteky, Mirpour and Tanaka

Logothetis, Pauls and Poggio

Tanaka, Saito, Fukada and Moriya

Hung, Kreiman, Poggio and DiCarlo
Neurophysiological recordings in the human brain

- Patients with pharmacologically intractable epilepsy
- Multiple electrodes implanted to localize seizure focus
- Targets typically include the temporal lobe (inferior temporal cortex, fusiform gyrus), medial temporal lobe (hippocampus, entorhinal cortex, amygdala and parahippocampal gyrus)
- Patients stay in the hospital for about 7-10 days
Shape selectivity in human extrastriate visual cortex

Liu et al. Neuron 2009
Position invariance in ITC

A
a 1  b 0.53  c 0.48  d 0.16  e 0.09  f 0.01

B

TJ1006.3

cont  ipsi

5°

C
center 1 0.71 0.43 0.13 0.05
left 0.65 0.66 0.32 0.04 0.09
right 0.49 0.47 0.34 0.07 0.10
upper 0.48 0.22 0.13 0.05 0.06
lower 0.99 0.43 0.40 0.11 0.05

30 l/s 1 s

Ito et al. J. Neurophys. 1995
Tolerance to image transformations
Tolerance to viewpoint changes

Logothetis et al 1995
Size invariance in ITC

Ito et al.
J. Neurophys. 1995

Logothetis et al. 1995

FIG. 4. Example of broadly tuned cells. A: optimal stimulus was a dome-shaped structure shown in a. B: recording site, the receptive field, and site of the stimulus presentation. C: responses to different sizes of the optimal stimulus. Comparably strong responses were evoked at a wide range of size (52.2–1.6° in height). D: magnitude of the responses normalized by that of the response to the stimulus 20.1° in size.

FIG. 5. Example of cells that maximally responded to the largest size of the optimal stimulus. A: optimal stimulus of the cell was a pair of white rings on a black base. B: recording site, the receptive field, and site of the stimulus presentation. C: responses to different sizes of the optimal stimulus. Comparably strong responses were evoked at a wide range of size (27.0–1.7° in height). D: magnitude of the responses normalized by that of the response to the stimulus 20.1° in size.
Rotation invariance in ITC

Logothetis and Sheinberg.
Annual Review of Neuroscience 1996
Cue invariance in the responses of ITC

![Diagram of cue invariance in the responses of ITC](Sary et al Science 1993)
Feature topography in ITC

Tanaka. Science 1993

Kreiman et al, Neuron 1996

A

B

C

D

Similarity of object preferences between pairs of sites

MUA

LFP

Site separation (μm) along same penetration

Site separation (mm) between penetrations
Machine learning 101: reading out neural activity
Summary

- Inferior temporal cortex (ITC) sits at the pinnacle of the visual cortical hierarchy, receiving strong inputs from both ventral and dorsal cortical areas and projecting widely to areas involved in episodic memory formation, decision making, and cognitive control.

- Monkey and human ITC neural responses are selective for a wide range of shapes, including abstract patterns and natural objects like chairs or faces.

- ITC neurons represent an overcomplete dictionary of features, are more concerned with shape rather than semantics,

- ITC neurons show invariance to image transformations.

- The activity of neural populations in ITC in single trials can be used to decode object information with linear classifiers.
Further reading


Original articles cited in class (see lecture notes for complete list)