Visual Object Recognition

Neurobiology 230 – Harvard / GSAS 78454

**Today’s lecturer:** Leyla Isik (lisik@mit.edu)

**Web site:** [http://tinyurl.com/vision-class](http://tinyurl.com/vision-class)

**Dates:** Mondays

**Time:** 3:30 – 5:30 PM

**Location:** Biolabs 1075

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Outline

Stimulus-driven (bottom-up) inputs

Inferior temporal cortex

Cognition
Outline

- Probing high level neural responses
- Manipulating invariant Inferior Temporal Cortex (ITC) responses
- ITC responses match behavior
- ITC responses are modulated by cognition
- ITC neurons continue to respond in the absence of a stimulus
- Categorization and responses to non-metric stimulus properties
Probing high level neural responses

• “Feature reduction”
  - typically requires subjective decisions
  - local minima
• Parameterized shape space(s)
• Analysis of “natural stimuli” (e.g. movie clips) followed by quantitative models
• Approaches based on computational models
• Representational similarity – brain/behavior/model comparisons
Neuronal tuning for complex feature combinations could underlie shape recognition.

Superior temporal sulcus

Initial generation (random)

Partial examples across 4 generations

Top 10 stimuli (out of 500)

Using natural movies to probe neural visual responses

Huth et al., Neuron 2012
Using natural movies to probe neural visual responses
Using natural movies to probe neural visual responses

<table>
<thead>
<tr>
<th>trial</th>
<th>stimulus</th>
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<tr>
<td>n</td>
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</tr>
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5 min video presentations

McMahon et al., J. Neurosci 2015
Using natural movies to probe neural visual responses

McMahon et al., J. Neurosci 2015
Analyzing neural responses with computational models

Yamins et al., 2014
Analyzing neural responses with computational models

• Model matching as a tool to interpret neural responses.
Analyzing neural responses with computational models
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Training can rapidly alter neuronal responses

Neural responses can be stable over days

Figure 1. Single unit responses in area TE. Data are shown from two neurons from monkey N97. The two neurons were recorded on two different microwires (channels of electrodes bundle marked as I1 and I8) and during two different time periods. Directly below each image, the action potential responses are shown over a period of several days, with each background color corresponding to data collected from a different session. The diverse responses appear to be stable over the recording periods. At the bottom are the corresponding peristimulus time histograms for the two neurons.

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Matching category responses of man and monkey
IT population activity accurately predicts human object recognition performance

Majaj et al., J. Neurosci., 2015
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Response latencies depend on stimuli/questions

Sugase et al. Nature 1999
Neuronal activity in ITC can be modulated by tasks

Sigala et al 2002
Neuronal activity in ITC can be modulated by tasks

**FIG. 1.** Stimulus sequences for representative trials in the task with 2-stimulus arrays, with the array confined to the hemifield contralateral to the recording site.
Neural responses can reflect perception

Here, shown with binocular rivalry and flash suppression

Sheinberg DL and Logothetis NK, PNAS 94:3409-3413, 1997
As some weak and nonsignificant changes in activity associated with experimental conditions were present in these control ROIs, we explicitly tested whether the activity differences we observed in localizer ROIs were significantly different from control ROIs. Critically, the interaction between condition (visible, invisible, absent) and region (localizer, control) was significant in V1 and trended toward significance in V2, $F(2,14) = 9.510, p = .003$ and $F(2,14) = 3.582, p = .087$ for V1 and V2, respectively. Hence, MIB-associated modulation of activity in Figure 2.

Neural responses can reflect perception
Clutter reduces neural responses

Fig. 3 The neuronal firing rate of one cell when an effective stimulus was present parafoveally and an ineffective stimulus for that cell was present at the fovea. Fixation was always at the point shown by a dot in the center of the upper right quadrant. Left, the neuron had a large firing rate when the effective stimulus was shown parafoveally. Middle, the neuron did not respond when the non-effective stimulus was present at the fovea. Right, the neuron had only a small firing rate to the parafoveal effective stimulus if a non-effective stimulus was present at the fovea. The means and standard errors of the firing rate are shown. The mean spontaneous rate of the cell was 10 spikes/s.
And yet the problem of clutter can be resolved at the population level
Target detection modulates responses in human ventral visual system
Attentional modulation in ITC

Zhang et al 2011
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Neuronal responses in ITC persist during DMTS task

"Target-Present" Trial
Saccade to the good stimulus in the array

"Target-Present" Trial
Saccade to the poor stimulus in the array

"Target-Absent" Trial
No saccade

FIG. 1. Stimulus sequences for representative trials in the task with 2-stimulus arrays, with the array confined to the hemifield contralateral to the recording site.

Selective responses during visual imagery in the human brain

Kreiman et al. Nature 2000
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Selectivity and tolerance beyond ITC in humans

Quian Quiroga et al 2005
Selectivity and tolerance beyond ITC in humans

Microwire location:
right amygdala

Figure 2 shows another single unit located in the right anterior hippocampus of a different patient. This unit was selectively activated by pictures of the actress Halle Berry as well as by a drawing of her (but not by other drawings; for example, picture no. 87). This unit was also activated by several pictures of Halle Berry dressed as Catwoman, her character in a recent film, but not by other images of Catwoman that were not her (data not shown). Notably, the unit was selectively activated by the letter string 'Halle Berry'. Such an invariant pattern of activation goes beyond common visual features of the different stimuli. As with the previous unit, the responses were mainly localized between 300 and 600 ms after stimulus onset.
Categorical responses in the macaque pre-frontal cortex

Caveat: human and monkey brains differ
Cited works


• Rolls, E. T., & Tovee, M. J. (1995). The responses of single neurons in the temporal visual cortical areas of the macaque when more than one stimulus is present in the receptive field. Experimental Brain Research, 103(3), 409-420.


Noticing Familiar Objects in Real World Scenes: The Role of Temporal Cortical Neurons in Natural Vision

David L. Sheinberg and Nikos K. Logothetis

Journal of Neuroscience 15 February 2001, 21 (4) 1340-1350