Visual Object Recognition
Computational Models and Neurophysiological Mechanisms
Neuro 130/230. Harvard College/GSAS 78454

Web site: http://tinyurl.com/visionclass

Class notes, Class slides, Readings, Assignments

Location: Biolabs 2062

Time: Mondays 03:00 – 05:00

Lectures: Faculty: Gabriel Kreiman (and invited guests)

TA: Will Xiao

Contact information: Gabriel Kreiman
xiaow@fas.harvard.edu
617-919-2530

Office Hours: Before class (Mondays 2pm), after class (Mondays 5pm). By appointment
Visual Object Recognition
Computational Models and Neurophysiological Mechanisms
Neurobiology 230. Harvard College/GSAS 78454

Class 1 [09/01/2021]. Introduction to Vision
Note: no class on 09/06/2021
Class 2 [09/13/2021]. Natural image statistics and the retina
Class 3 [09/20/2021]. The Phenomenology of Vision
Class 4 [09/27/2021]. Learning from Lesions
Class 5 [10/04/2021]. Primary Visual Cortex
Note: no class on 10/11/2021
Class 6 [10/18/2021]. Adventures into terra incognita
Class 7 [10/25/2021]. From the Highest Echelons of Visual Processing to Cognition
Class 8 [11/01/2021]. First Steps into in silico vision [Will Xiao]
Class 9 [11/08/2021]. Teaching Computers how to see
Class 10 [11/15/2021]. Computer Vision
Class 11 [11/22/2021]. Connecting Vision to the rest of Cognition

FINAL EXAM, PAPER DUE 12/14/2021. No extensions.
Understanding function by taking things apart (and rebuilding them)

What I cannot create, I do not understand

Richard Feynman
The discovery of visual cortex

Primary visual cortex discovered by studying brain injuries sustained by soldiers during the Russia-Japanese War and First World War

Basic path of visual signals from the eyes to primary visual cortex
V1 lesions lead to topographically specific scotomas

- Vascular damage, tumors, trauma studies of V1
- Visual field deficits contralateral to the lesion
- Shape and color discrimination are typically absent

Holmes. British Journal of Ophthalmology, 1918
Riddoch, Brain 1917
How the visual field maps onto the visual cortex

Note the disproportionately large representation of the fovea
Blindsight: persistent visual function in the hemianopic field

- Detection of presence/absence of light
- Some subjects can localize light
- Some subjects can discriminate orientation, color and direction of motion

- There may be intact islands within the blind field
- LGN-extrastriate pathways can subserve visual function
- Subcortical pathways could be responsible

Is there any visual function beyond V1?

In human subjects there is no evidence that any area of the cortex other than the visual area 17 is important in the primary capacity to see patterns. . . . Whenever the question has been tested in animals the story has been the same. (Morgan and Stellar, 1950)

Scientists are often terribly wrong!

. . . visual habits are dependent upon the striate cortex and upon no other part of the cerebral cortex. (Lashley, 1950)

. . . image formation and recognition is all in area 17 and is entirely intrinsic. . . . the connections of area 17 are minimal. (Krieg, 1975)
Visual system circuitry (macaque monkeys)

Felleman and Van Essen. *Cerebral Cortex* 1991
Lesions in macaque monkey IT cortex

- Bilateral removal of IT cortex
- Impaired learning of visual discriminations
- Impaired retaining of discriminations learned before lesion
- Objects, patterns, orientation, size, color
- Severity correlated with task difficulty
- Defect is long-lasting
- Deficit restricted to vision

Dean 1976; Holmes and Gross 1984; Mishkin and Pribram 1954
“Natural” lesions in the human brain

- Carbon monoxide poisoning
- Bullets and other weapons
- Viral infections
- Bumps
- Partial asphyxia (particularly during the first weeks of life)
- Tumors
- Hydrocephalus
- Stroke
Cortical visual deficits in humans – dorsal stream

Akinetopsia – Specific inability to see motion

Zeki 1991 Brain 114: 811-824
Hemineglect – inability to attend to half of the visual field (or half of objects)

Bisiach & Luzzatti 1978; Farah et al. 1990
Simultanagnosia (Balint) – Inability to see more than one or two objects in a scene

Cortical visual deficits in humans – dorsal stream

Optic ataxia

Optic ataxia (Balint) – Inability to make visually guided movements

Vision for action can be dissociated from shape recognition

Subject with temporal lobe damage
Severely impaired shape recognition
Yet, appropriate reach response!

Cortical visual deficits in humans – ventral stream

Areas typically affected in object agnosias
A patient who struggles to copy shapes

Benson 1969
The same patient cannot draw shapes

A
B
C
D
E

Warrington 1985
The same patient fails in a shape matching task
There are several claims about object-specific agnosias

Visual agnosias for objects, topography, body parts, faces, animals, letters and numbers:

- “Face” versus “non-face” objects
- “Inanimate” versus “animate” objects
- “Manipulable” versus “Non-manipulable” objects
- “Concrete” concepts versus “Abstract” concepts
Before the removal was carried out, stimulation at points 5 and 7 produced the following experiential responses.
1. Patient did not reply.
2. Repeated. “I heard voices talking.” When asked what it was, he said he could not tell what they were saying. They seemed to be far away.
3. Stimulation without warning. He said, “Now I hear them.” Then he added, “A little like in a dream.”
4. “Like footsteps walking—on the radio.”
5. Repeated. “Like company in the room.”
6. Repeated. He explained “it was like being in a dance hall, like standing in a doorway—in a gymnasium—like at the Kenwood High School.” He added, “If I wanted to go there it would be similar to what I heard just now.”
7. Repeated. Patient said, “Yes, yes, yes.” After withdrawal of the stimulus, he said it was “like a lady was talking to a child. It seemed like it was in a room, but it seemed as though it was by the ocean—at the seashore.”
8. Repeated. “I tried to think.” When asked whether he saw something or heard something, he said, “I saw and heard. It seemed familiar, as though I had been there.”
9. Repeated (20 minutes after last stimulation at 5). “People’s voices.” When asked, he said, “Relatives, my mother.” When asked if it was over, he said, “I do not know.” When asked if he also realized he was in the operating room, he said “Yes.” He explained it seemed like a dream.
10. Repeated. Patient said, “I am trying.” After withdrawal of the stimulus he said, “It seemed as if my niece and nephew were visiting at my home. It happened like that many times. They were getting ready to go home, putting their things on—their coats and hats.” When asked where, he said, “In the dining room—the front room—they were moving about. There were three of them and my mother was talking to them. She was rushed—in a hurry. I could not see them clearly or hear them clearly.”
Visual phosphenes triggered by electrical stimulation
Electrical stimulation in face areas distorts face perception

LINK TO MOVIE

Electrical stimulation in macaque monkeys can bias perception in a specific manner.
Electrical stimulation in macaque monkeys can bias perception in a specific manner
Towards prosthetic devices for the visually impaired
Summary

• Inactivating visual cortex --> specific visual deficits from localized scotomas (primary visual cortex) to recognition impairment (inferior temporal cortex)

• Without the primary visual cortex, subjects are essentially blind

• Lesion studies have delineated two main processing streams: (1) a dorsal/where/action path and (2) a ventral/what path

• Several cases have been reported of agnosias where subjects have specific visual discrimination challenges while maintaining otherwise normal vision

• Electrical stimulation in visual cortex leads to phosphenes (topographically)

• Microstimulation experiments in monkeys have shown that it is possible to specifically bias the animal’s visual behavior
• Afraz et al. PNAS (2015):112:6730-6735
• Klur H, Bucy PC (1939) Preliminary analysis of the functions of the temporal lobes in monkeys. Archives of Neurology and Psychiatry 42:979-1000.