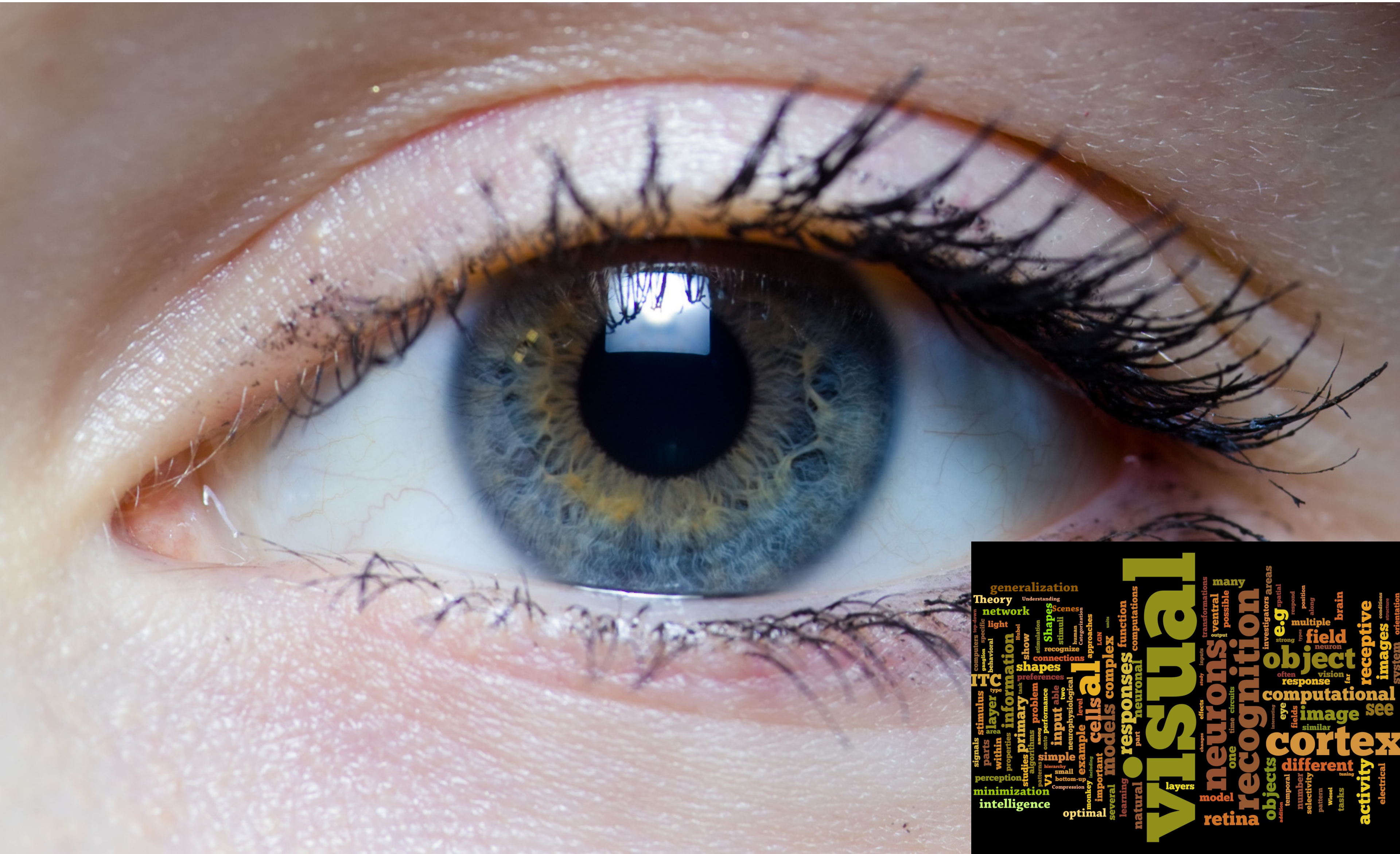
Visual Object Recognition
Computational Models and Neurophysiological Mechanisms

Neuro 130/230. Harvard College/GSAS 78454



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

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

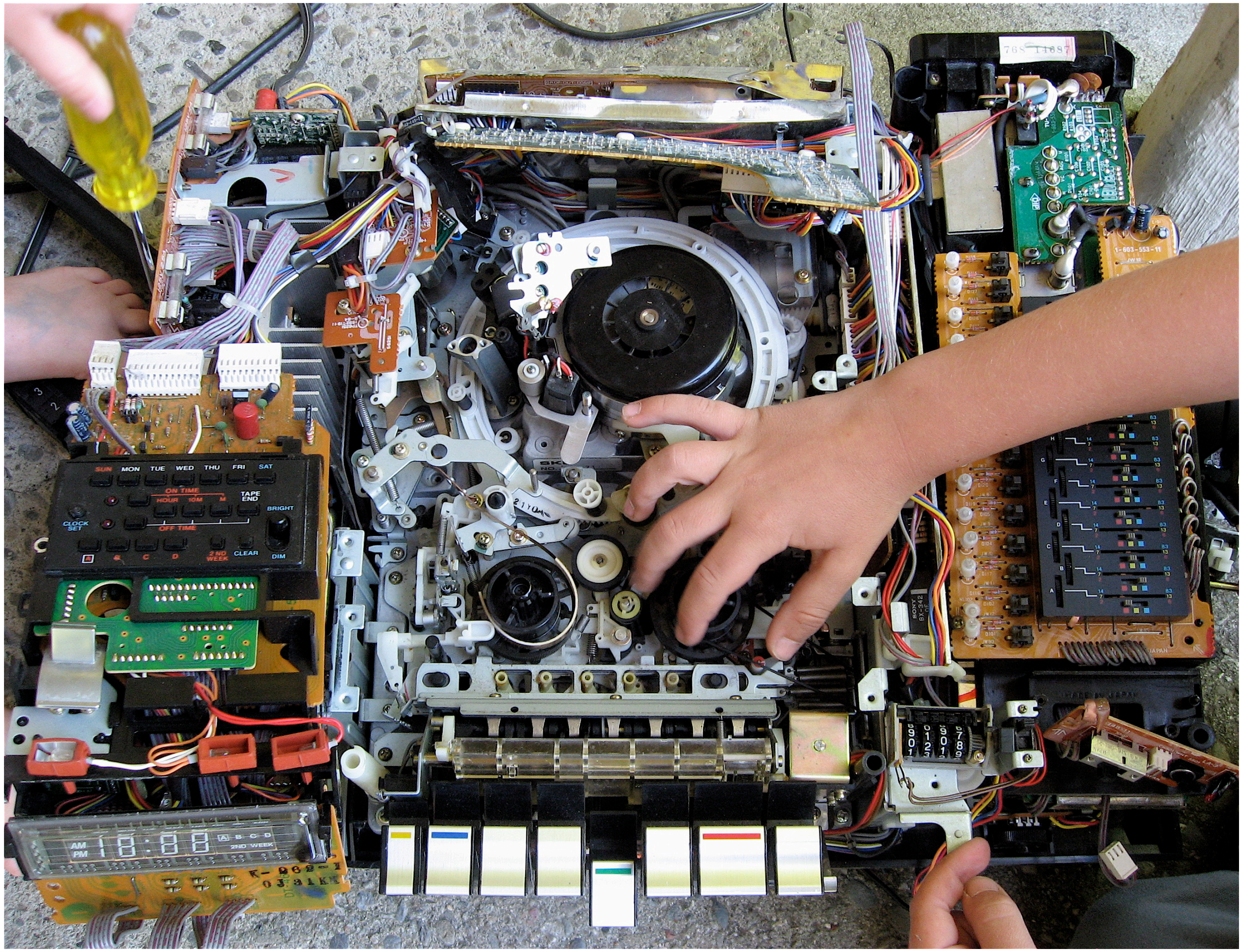
Class 10 [11/20/2023]. Computer Vision

Class 11 [11/27/2023]. Connecting Vision to the rest of Cognition [Dr. Will Xiao]

Class 12 [12/06/2023]. Visual Consciousness

FINAL EXAM, PAPER DUE 12/11/2023. No extensions.

Understanding function by taking things apart (and rebuilding them)



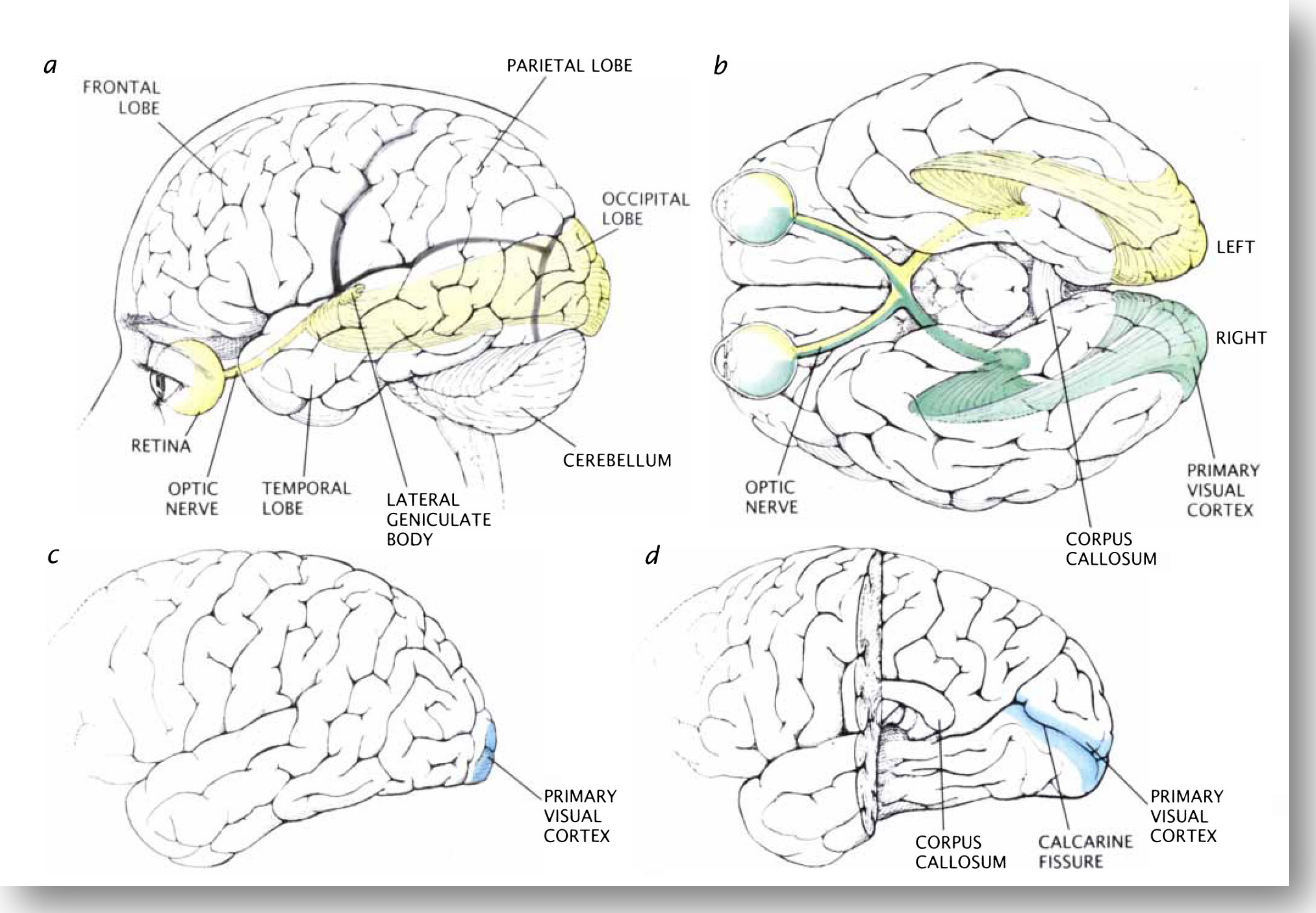
What I cannot create, I do not understand
Richard Feynman

The discovery of visual cortex

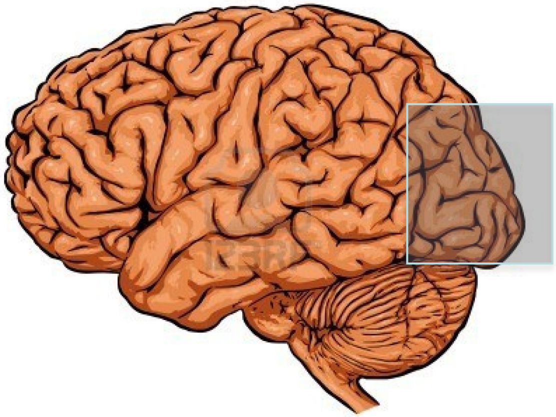
Primary visual cortex discovered by studying brain injuries sustained by soldiers during the Russia-Japanese War and First World War

Glickstein, The discovery of the visual cortex. Scientific American 1988
Holmes, Disturbances of visual orientation. British Journal of Ophthalmology 1918.

Basic path of visual signals from the eyes to primary visual cortex



V1 lesions lead to topographically specific scotomas



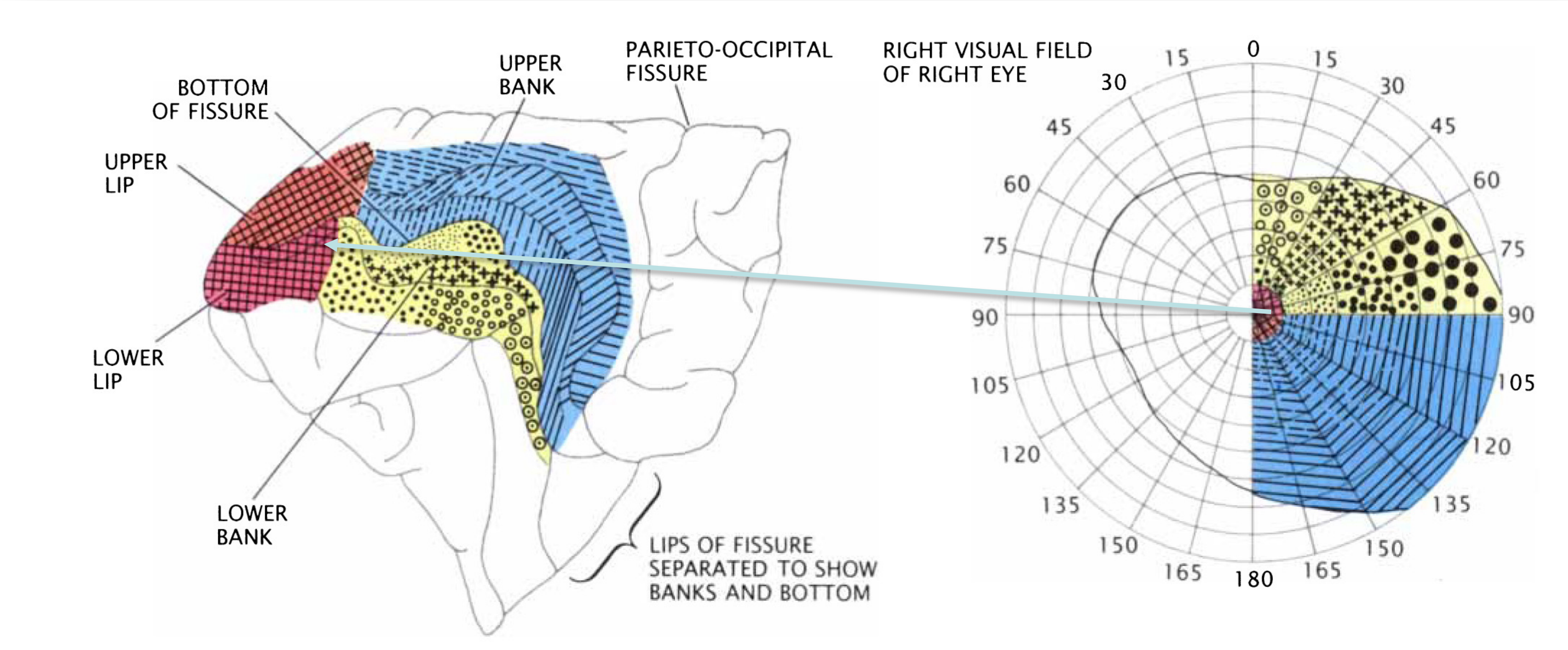
- Vascular damage, tumors, trauma studies of V1

- 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

Weiskrantz Curr Op. Neurobiol 1996; Farah Curr Op. Neurobiol 1994; Stoerig & Cowey, Brain 1997

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)

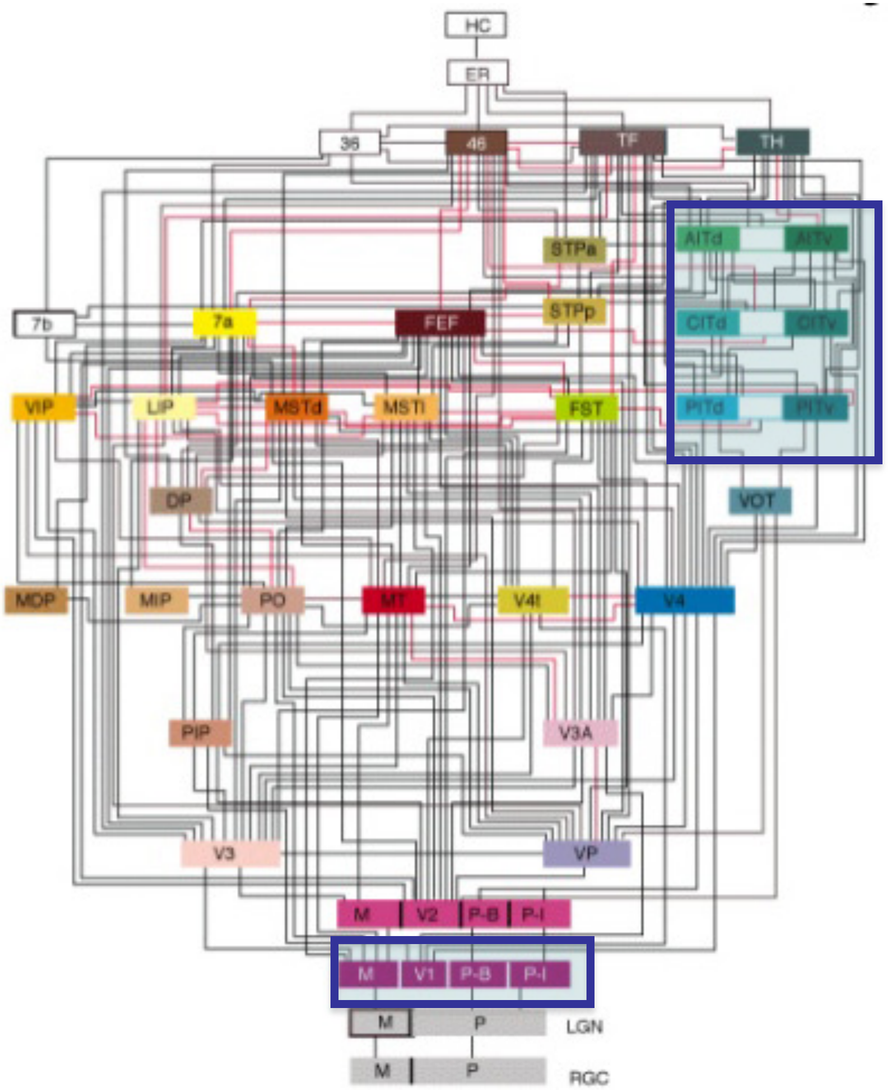
. . visual habits [illegible] cortex and upon no other part of the cerebral cortex. (Lashley, 1950)

Scientists are often terribly wrong!

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

As cited in Gross 1994. Cerebral Cortex **5**: 455-469

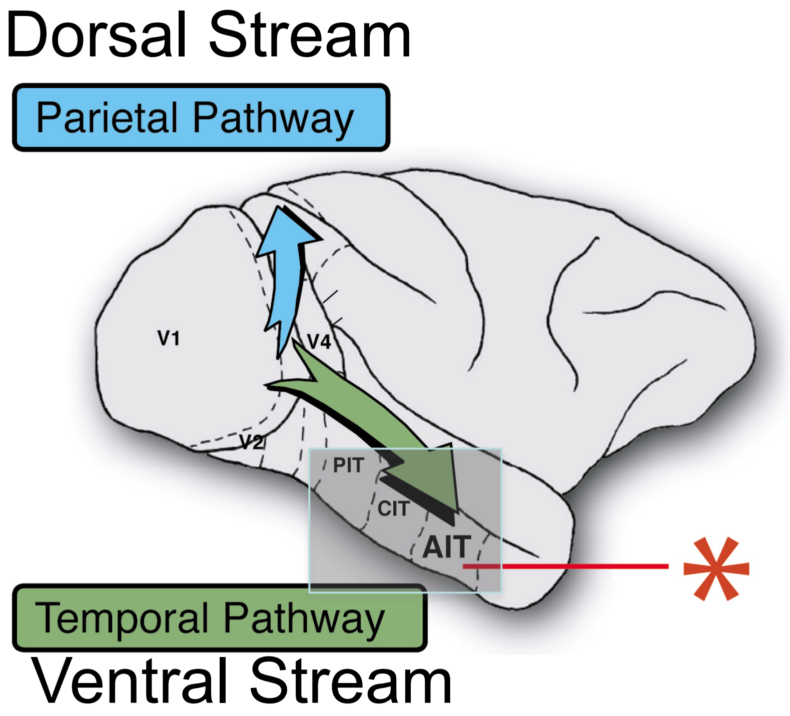
Visual system circuitry (macaque monkeys)



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



Dorsal Stream

Parietal Pathway

Temporal Pathway

Ventral Stream

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

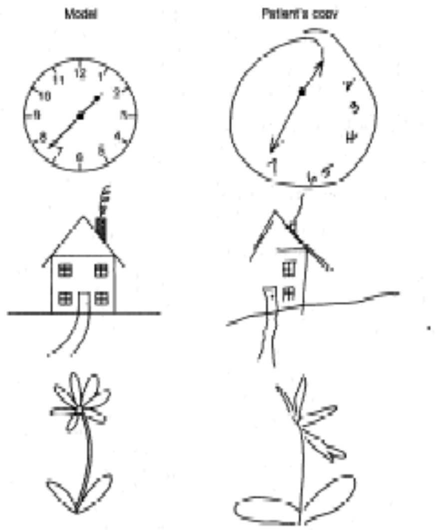
Akinetopsia – Specific inability to see motion

Zeki 1991 Brain 114: 811-824

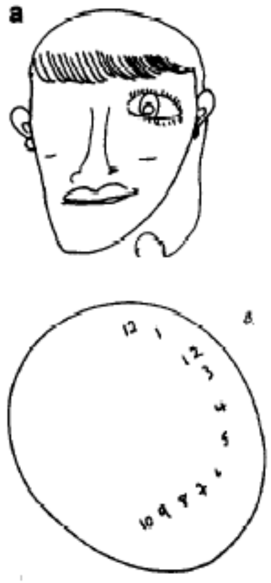
Cortical visual deficits in humans – dorsal stream
Hemineglect

Hemineglect – inability to attend to half of the visual field (or half of objects)

Copying:



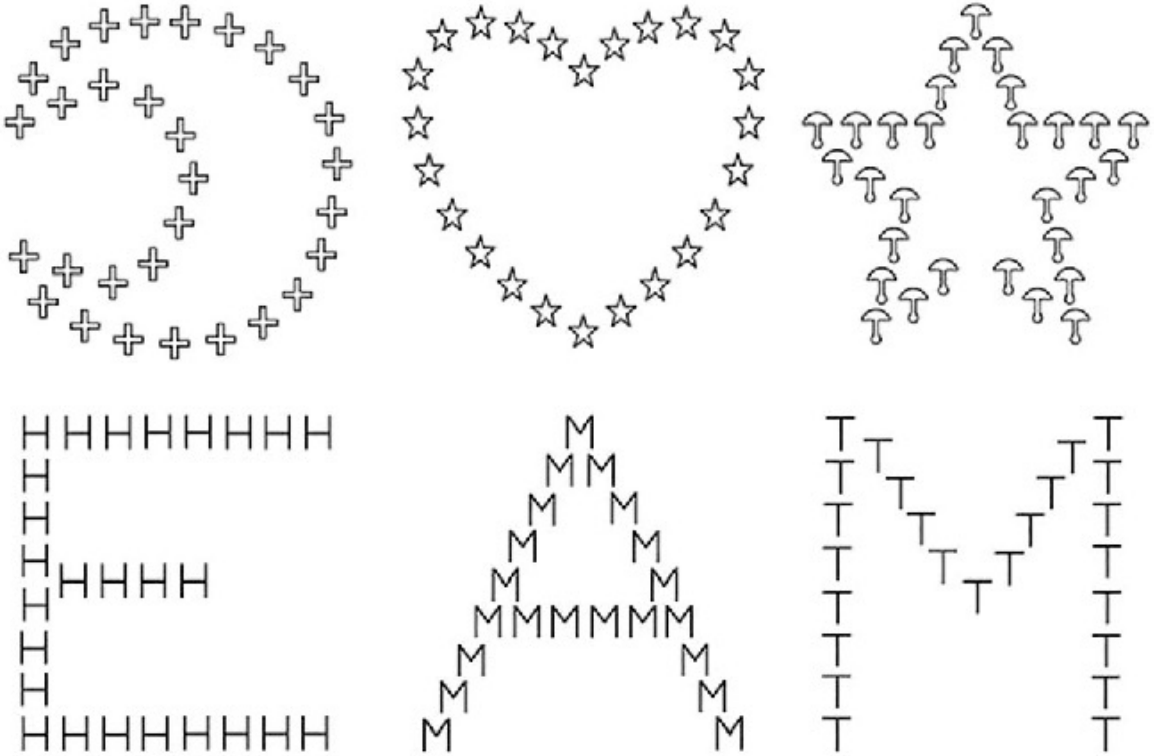
Spontaneous drawing:



Bisiach & Luzzatti 1978; Farah et al. 1990

Cortical visual deficits in humans – dorsal stream
Simultanagnosia

Simultanagnosia (Balint) – Inability to see more than one or two objects in a scene



Kinsbourne M, Warrington EK. A disorder of simultaneous form perception. Brain. 1962 Sep;85:461-86.

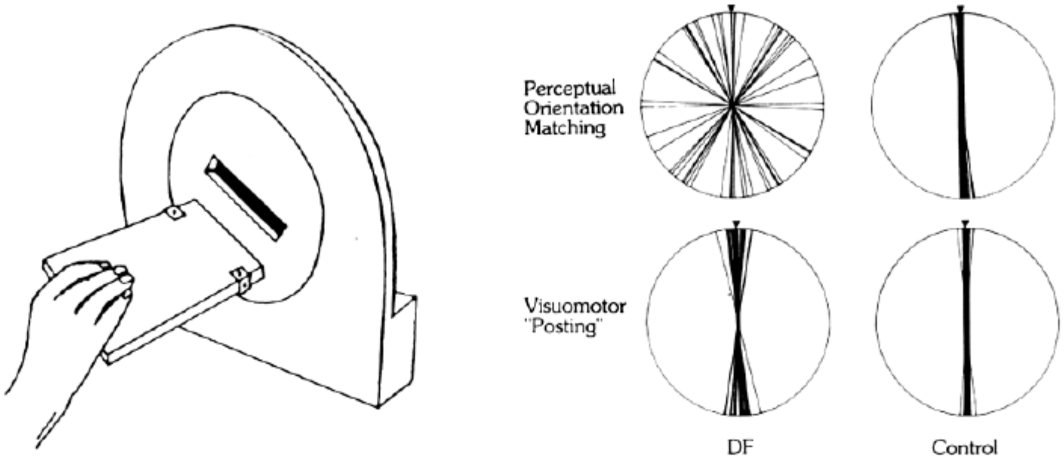
Cortical visual deficits in humans – dorsal stream
Optic ataxia

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

Damasio AR, Benton AL. Impairment of hand movements under visual guidance. *Neurology*. 1979;29:170-178

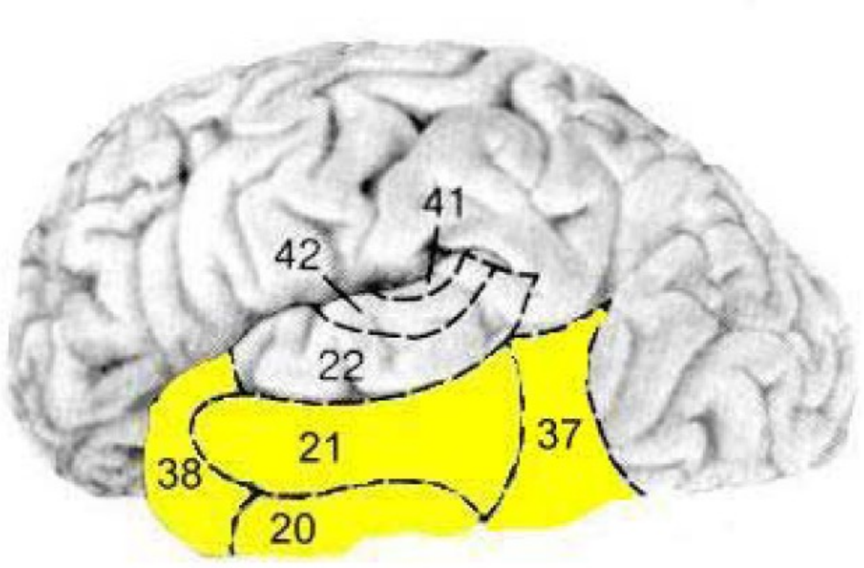
Vision for action can be dissociated from shape recognition

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



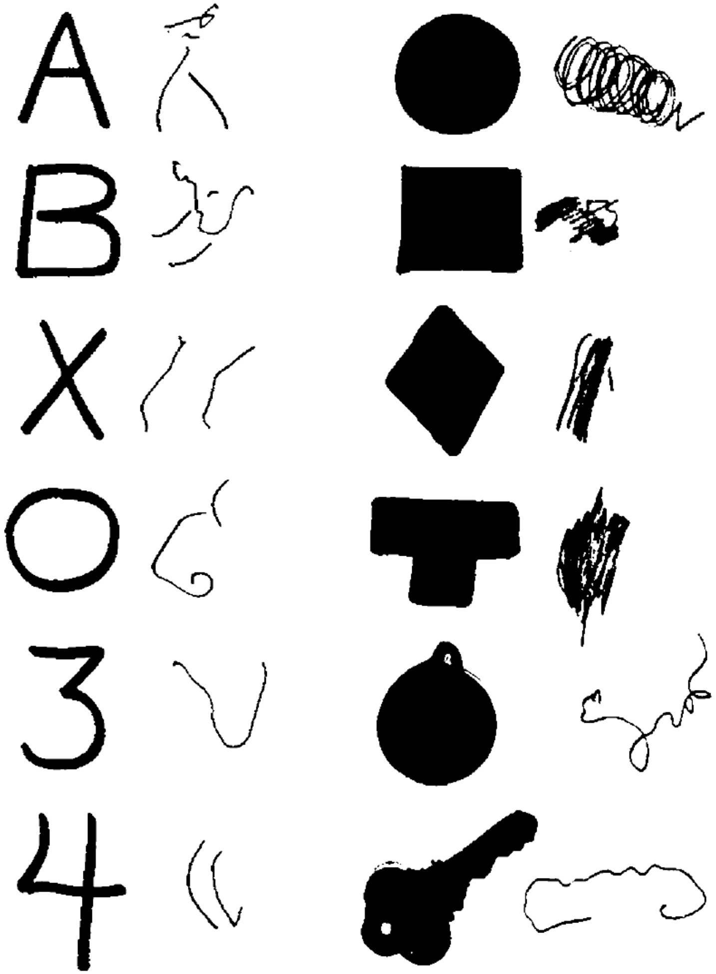
Goodale and Milner. Separate visual pathways for perception and action. Trends in Neurosciences. 1992 **15**:20-25

Cortical visual deficits in humans – ventral stream



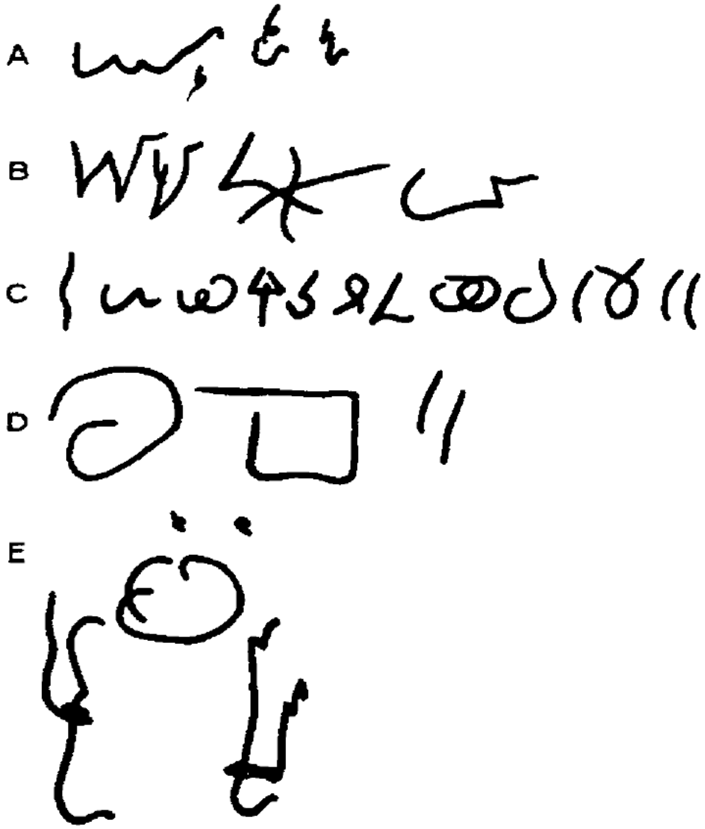
Areas typically affected in object agnosias

A patient who struggles to copy shapes



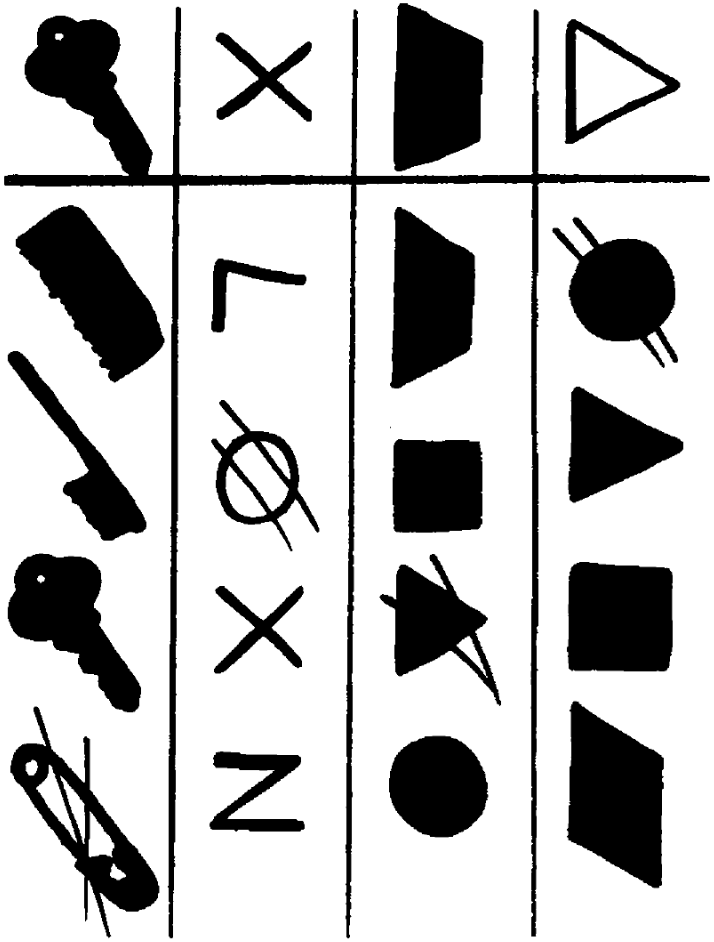
Benson 1969

The same patient cannot draw shapes



Warrington 1985

The same patient fails in a shape matching task



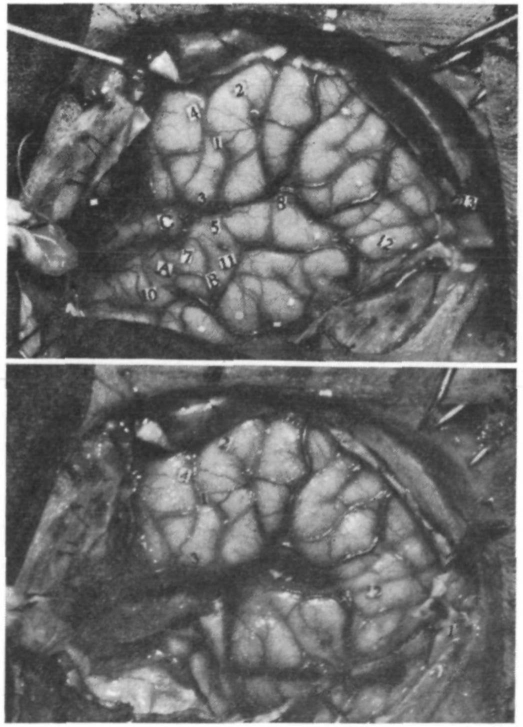
Warrington 1985

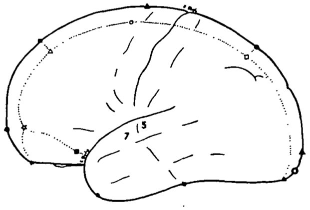
There are several claims about object-specific agnosias

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

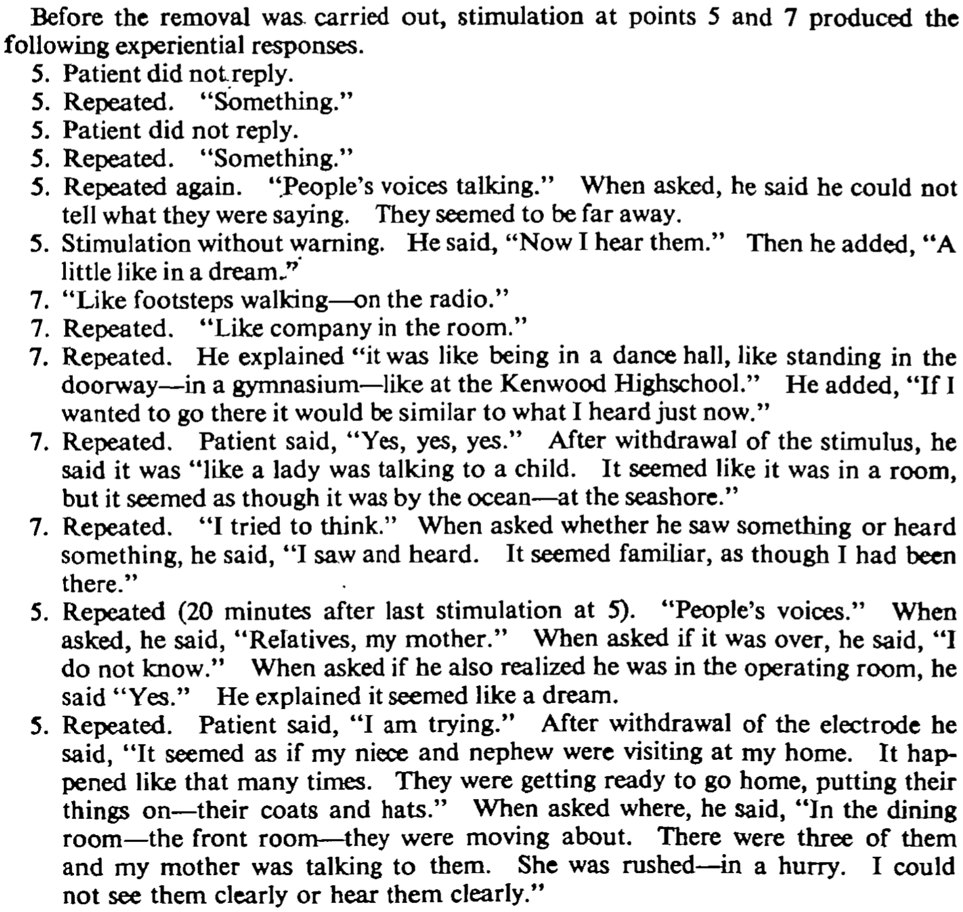
- “Face” versus ”non-face” objects
- “Inanimate” versus “animate” objects
- “Manipulable” versus “Non-manipulable” objects
- “Concrete” concepts versus “Abstract” concepts

Electrical stimulation in the human brain





CASE 2.—R. B.

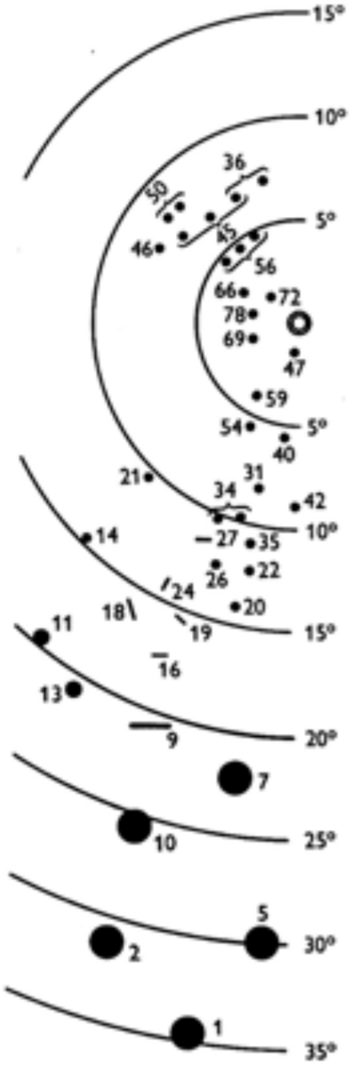


Before the removal was carried out, stimulation at points 5 and 7 produced the following experiential responses.

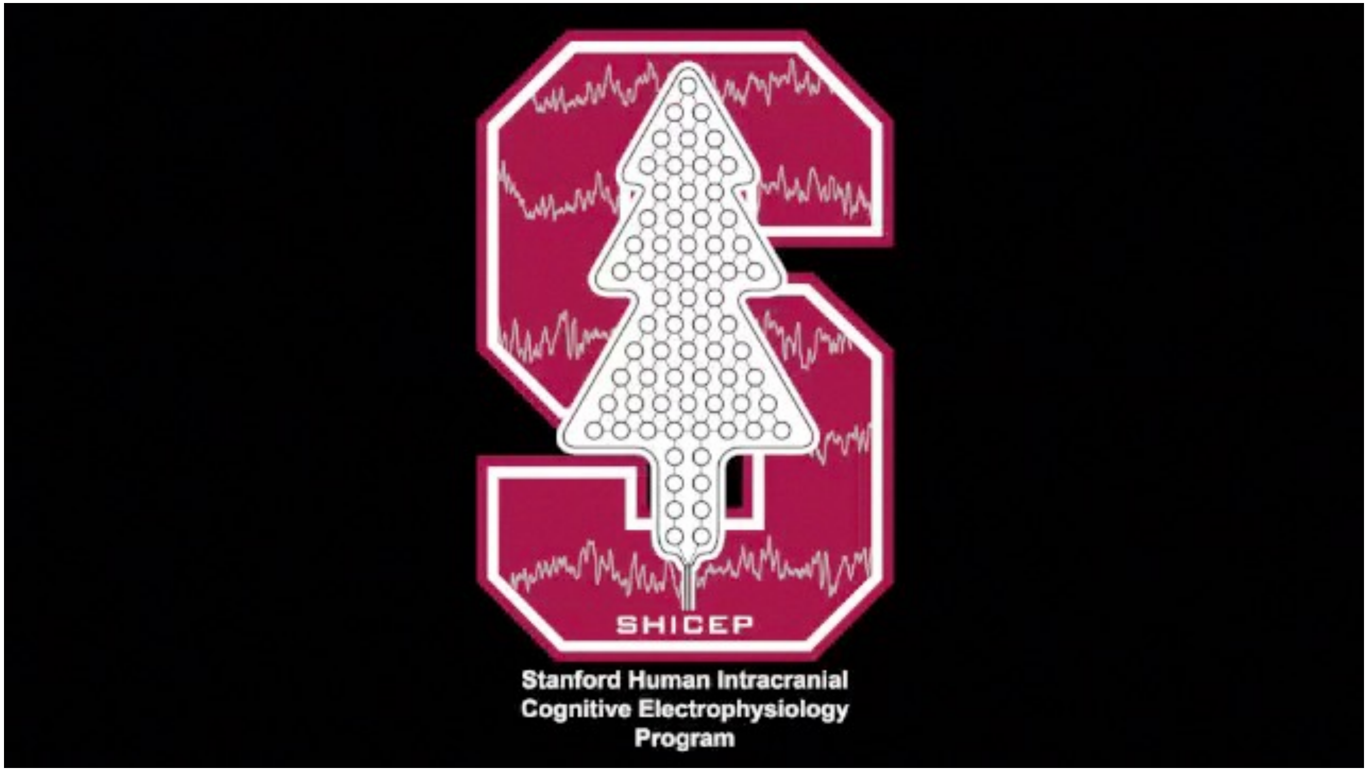
5. Patient did not reply.
5. Repeated. "Something."
5. Patient did not reply.
5. Repeated. "Something."
5. Repeated again. "People's voices talking." When asked, he said he could not tell what they were saying. They seemed to be far away.
5. Stimulation without warning. He said, "Now I hear them." Then he added, "A little like in a dream."
7. "Like footsteps walking—on the radio."
7. Repeated. "Like company in the room."
7. Repeated. He explained "it was like being in a dance hall, like standing in the doorway—in a gymnasium—like at the Kenwood Highschool." 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."
7. 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."
5. 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.
5. Repeated. Patient said, "I am trying." After withdrawal of the electrode 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."

Penfield & Perot. *The brain's record of auditory and visual experience. A final summary and discussion. Brain* (1963) **86**:595-696

Visual phosphenes triggered by electrical stimulation



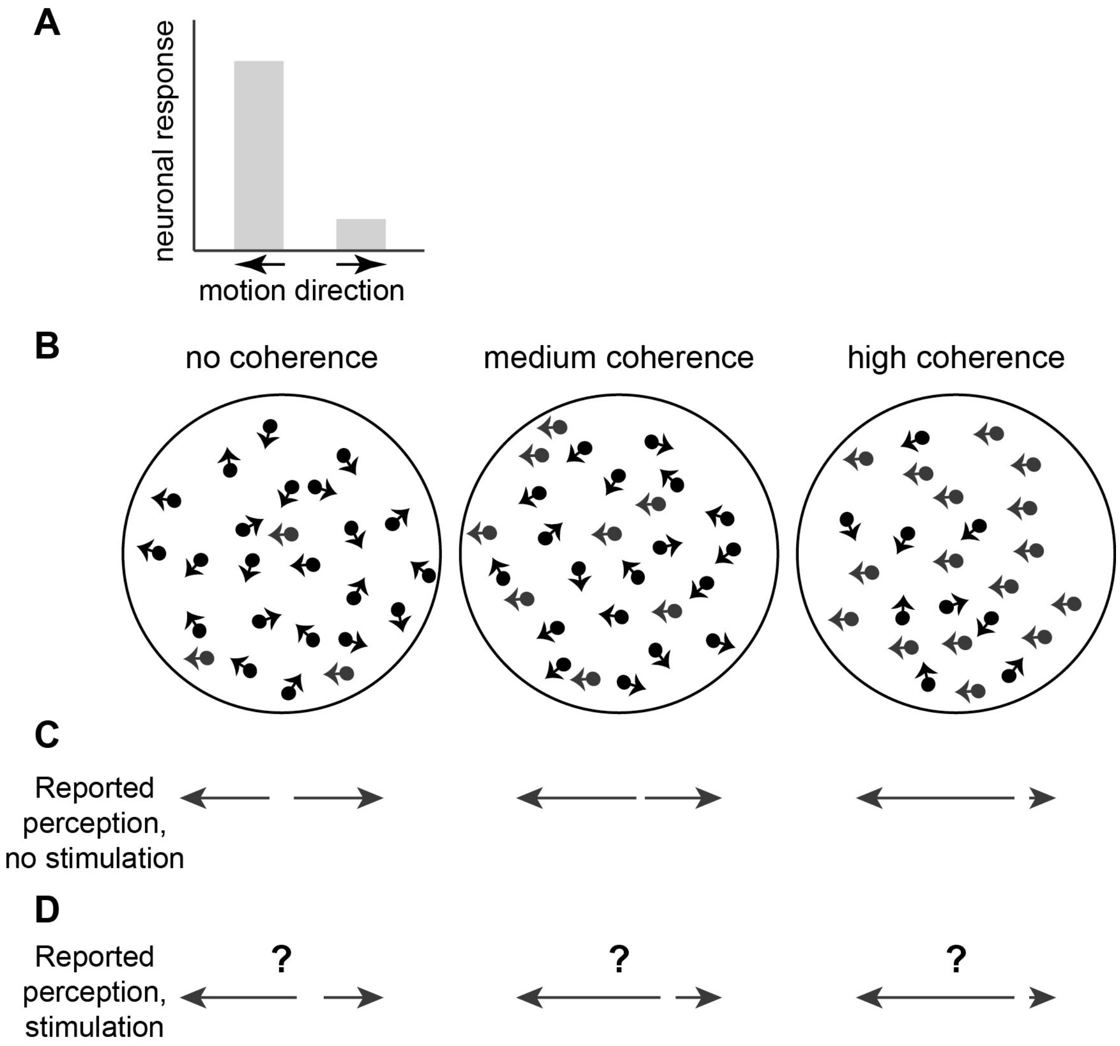
Electrical stimulation in face areas distorts face perception



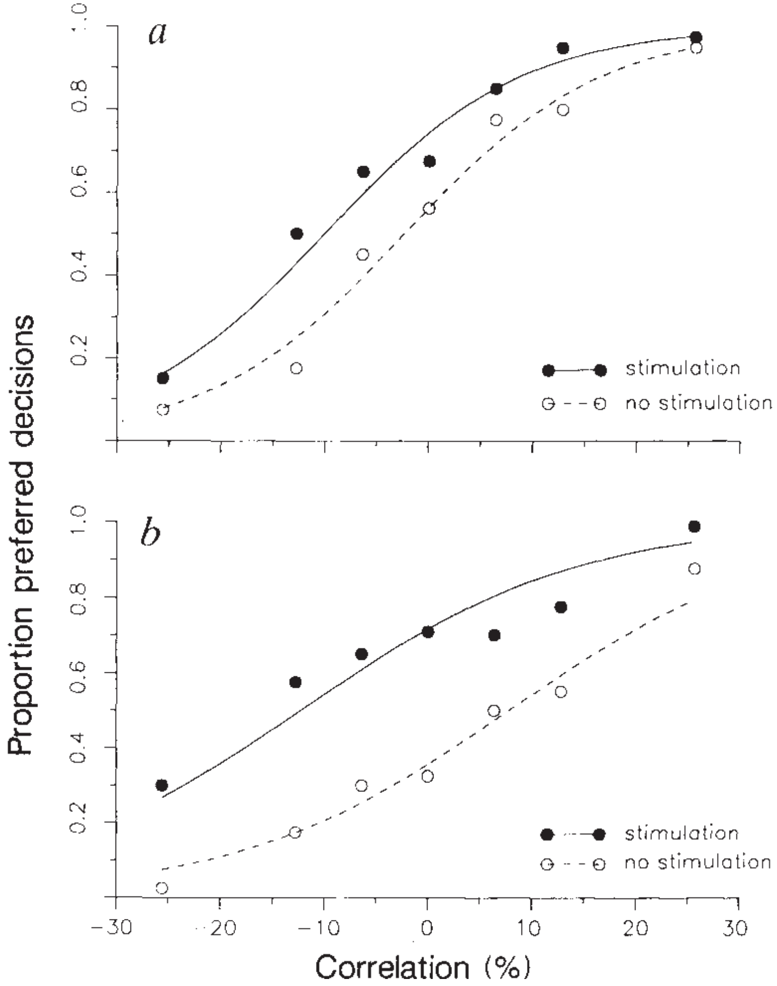
LINK TO MOVIE

Parvizi, J., Jacques, C., Foster, B. L., Withoft, N., Rangarajan, V., Weiner, K. S., et al. (2012). Electrical stimulation of human fusiform face-selective regions distorts face perception. J Neurosci, 32(43), 14915-14920.

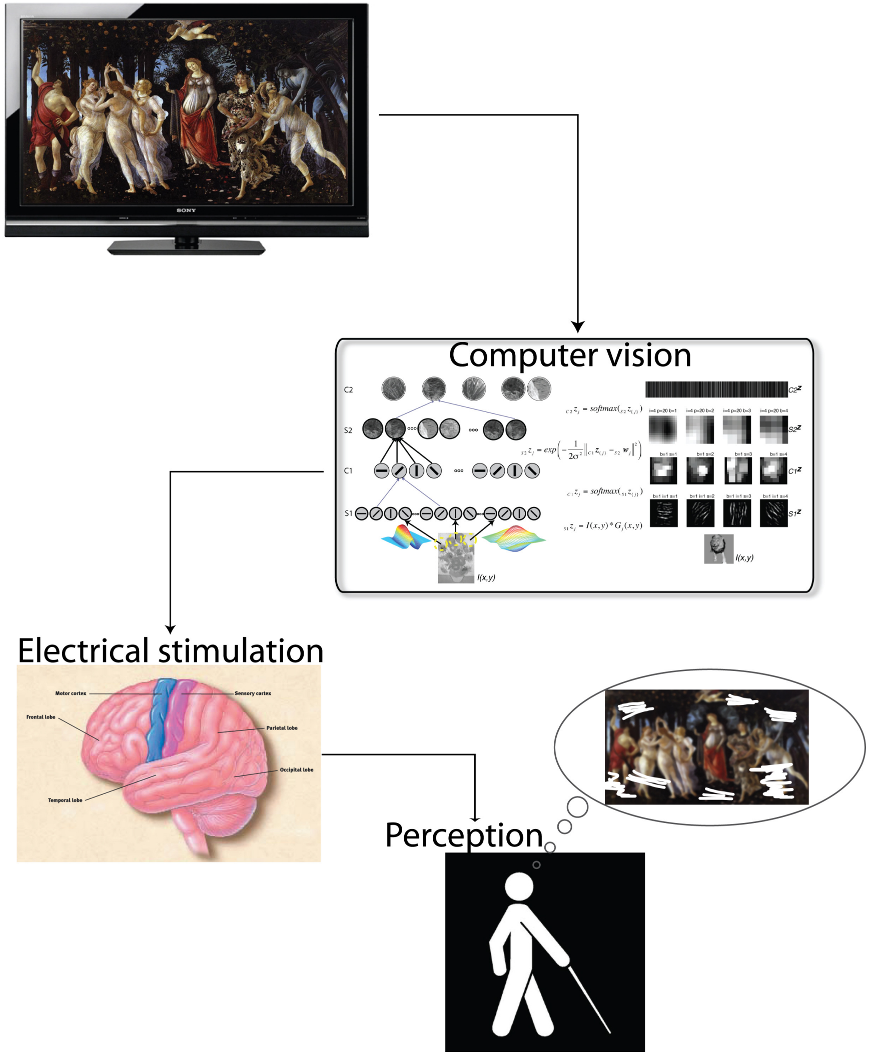
Electrical stimulation in macaque monkeys can bias perception in a specific manner



Electrical stimulation in macaque monkeys can bias perception in a specific manner



Towards prosthetic devices for the visually impaired



Computer vision

Electrical stimulation

Perception

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

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