Vision in Human and Machine

Part 5
Principles of Object Representation in the Brain

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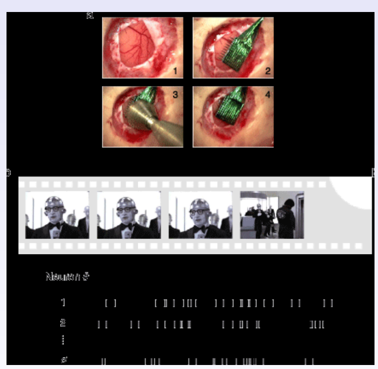
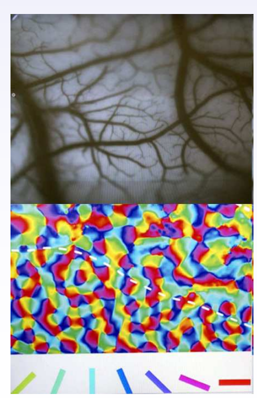
Experimental techniques

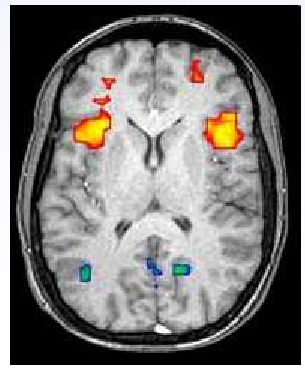
- Invasive
  - Lesion studies
  - Single-cell recording
  - Multi-electrode arrays
  - Optical imaging



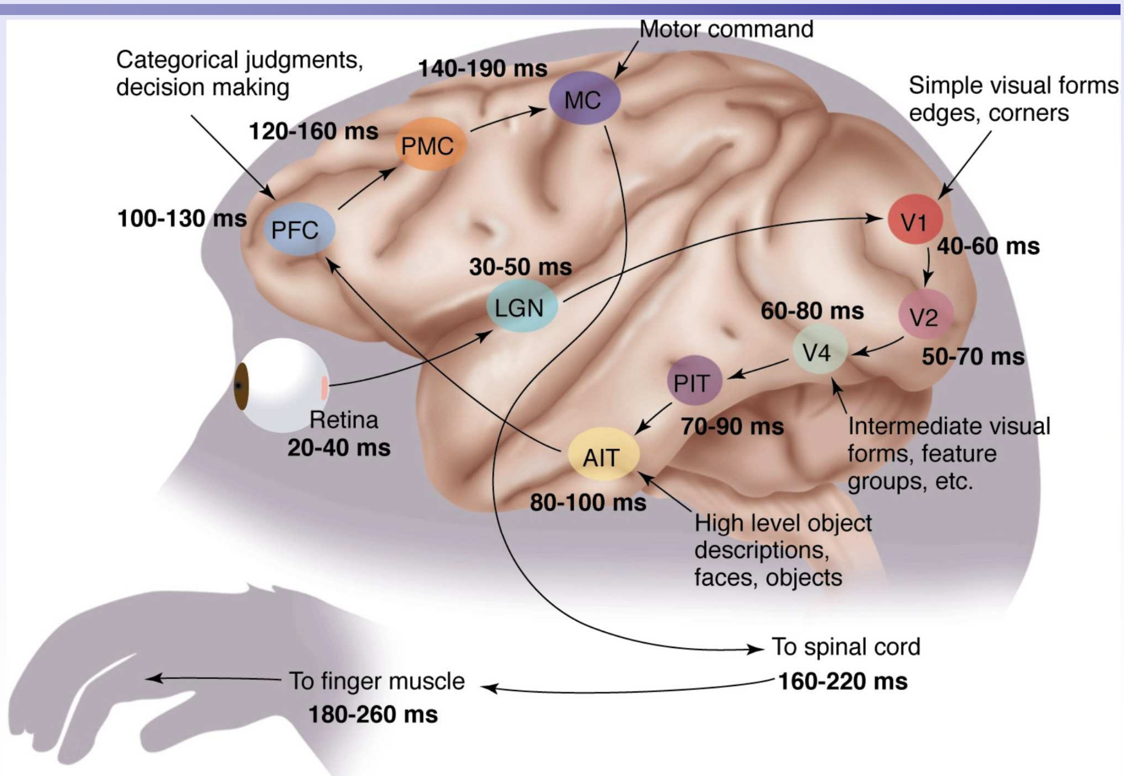


Experimental techniques

- Non-invasive
  - Computer tomography (CT)
    - Density computation based on several X-ray scan slices
  - Positron emission tomography (PET)
    - Radiactive isotope is taken up after injection
    - Positron emissions are registered → Measure of local neural activity
  - Functional magnetic resonance imagery (FMRI)
    - Spin polarization in strong magnetic field
    - Fine spatial resolution
    - Low temporal resolution



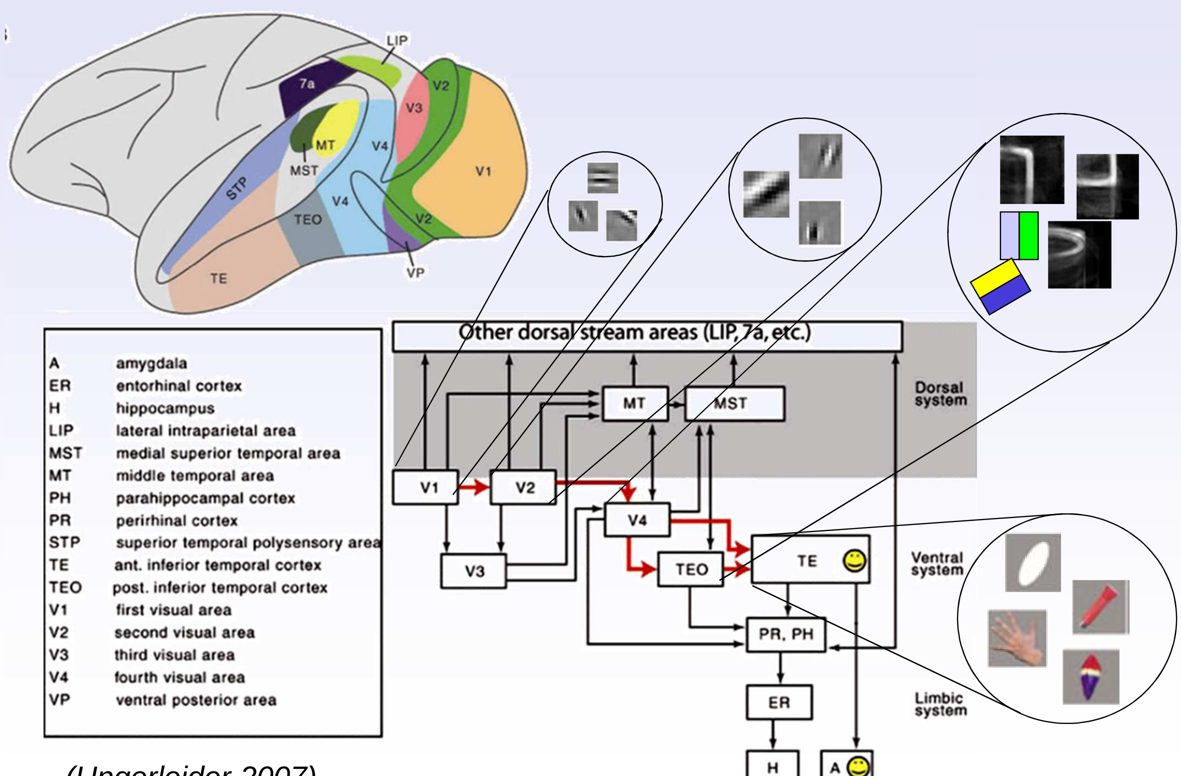
Time course of visual object processing



Properties of Human Object Perception

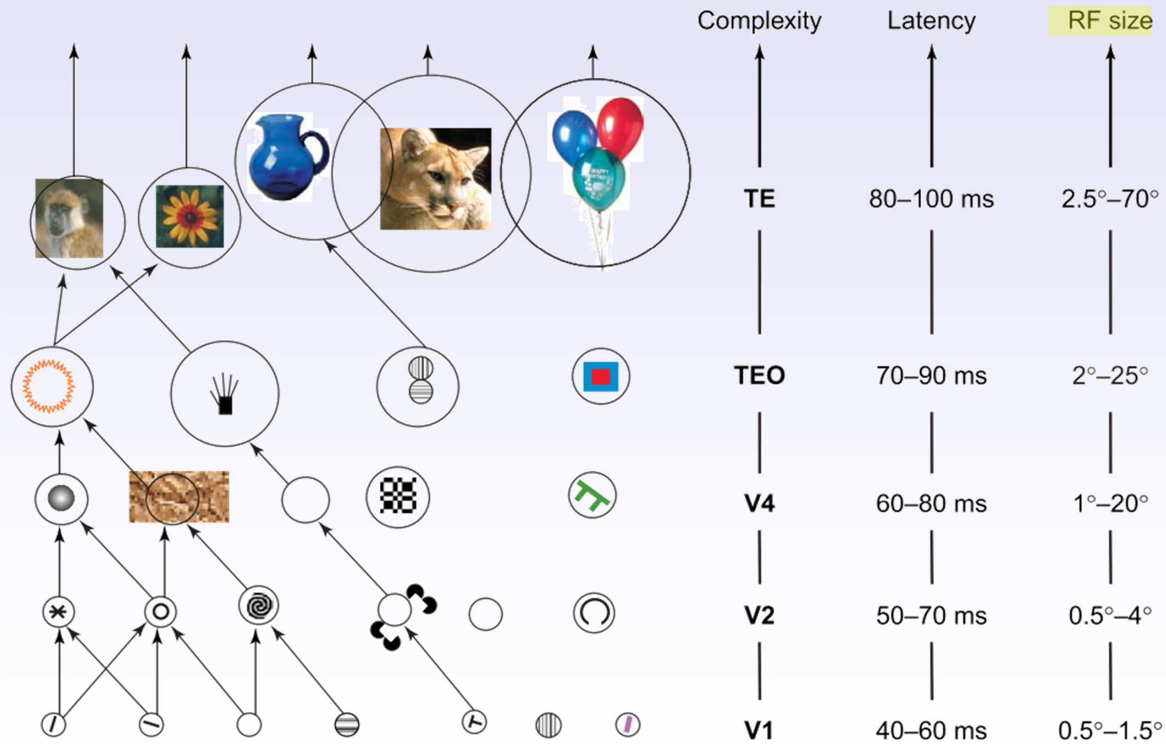
- Recognition is fast

Visual Areas in the Macaque Brain

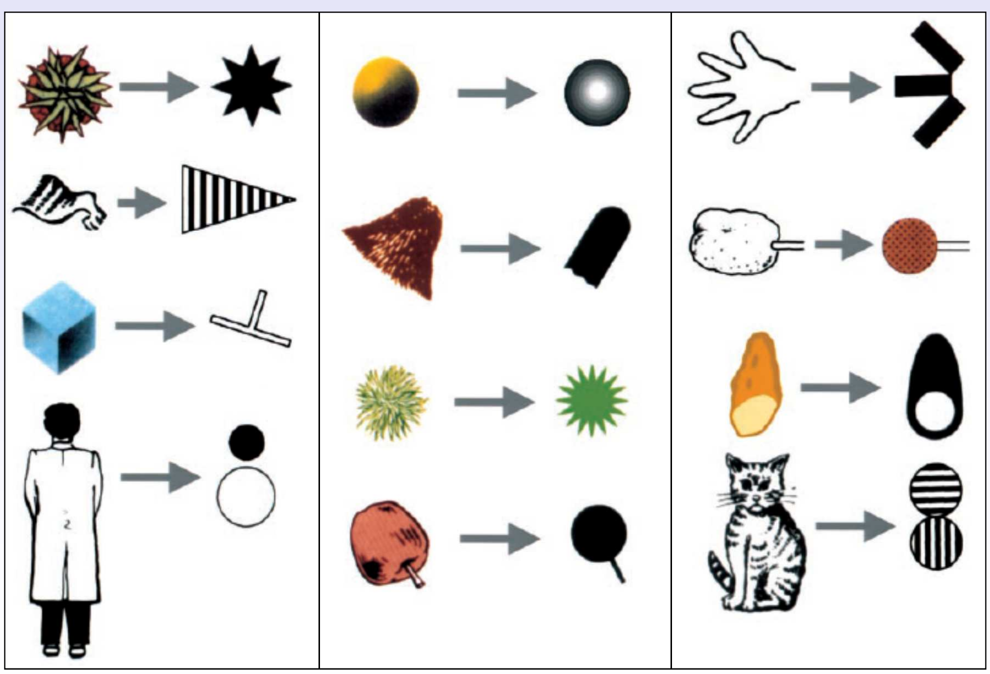


(Ungerleider 2007)

Processing hierarchy in the ventral pathway

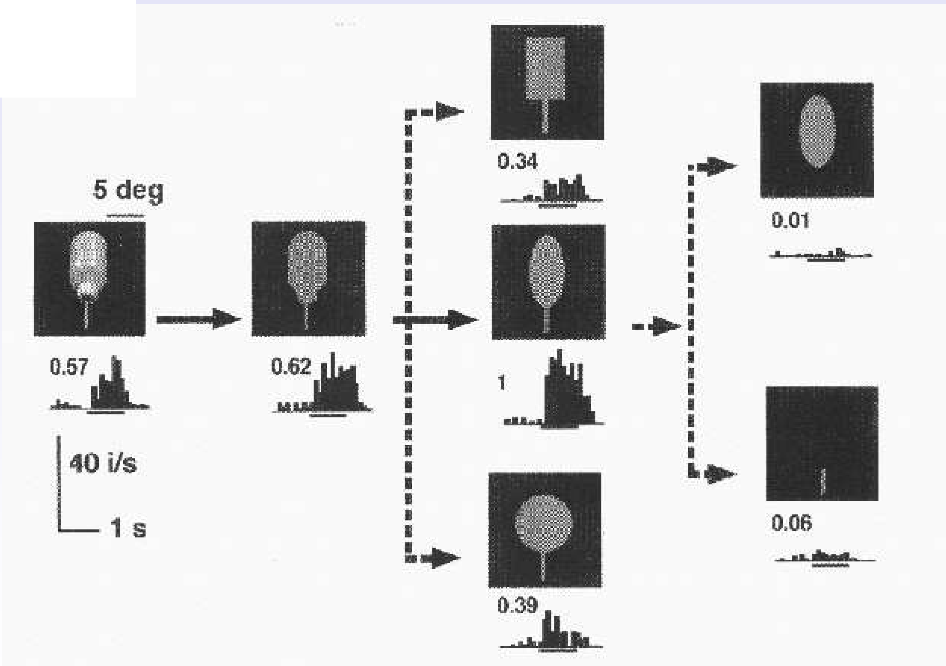


Optimal Features in Area TE



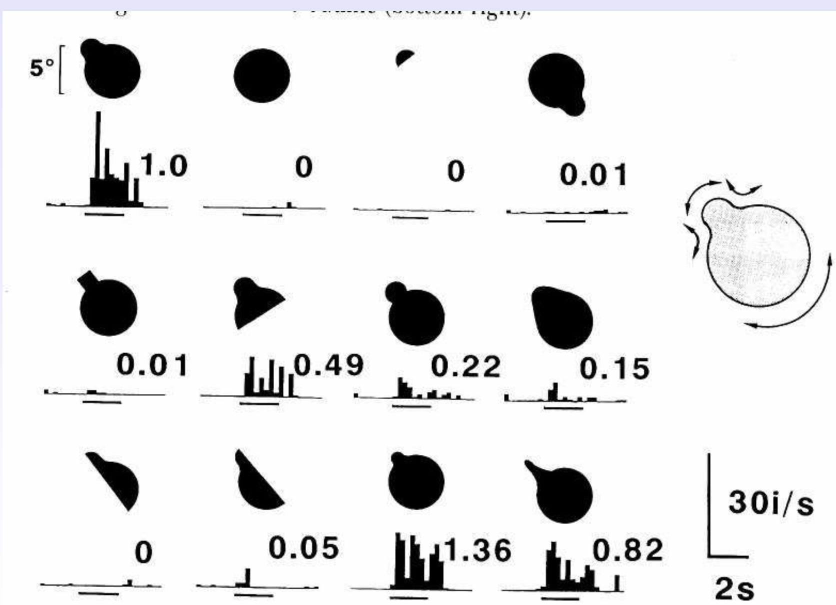
Simplification procedure for optimal features (Tanaka 1990)

Features in IT (and V4)



Response to simplified stimuli (Kobatake and Tanaka 1994)

Features in IT - Pattern Specifity



Features in IT - Orientation Selectivity

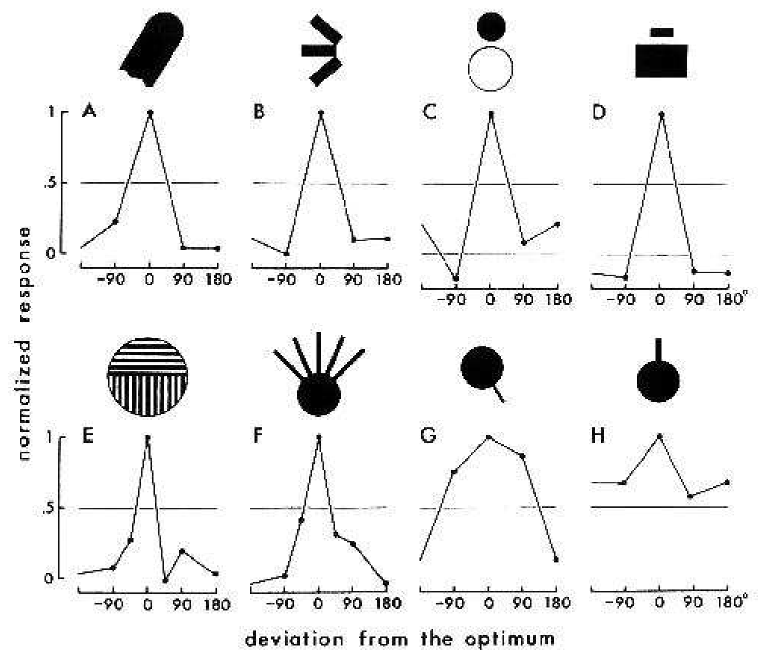


Figure 5. Tuning of responses of eight TE cells for the stimulus orientation.

Features in IT - Size Tuning

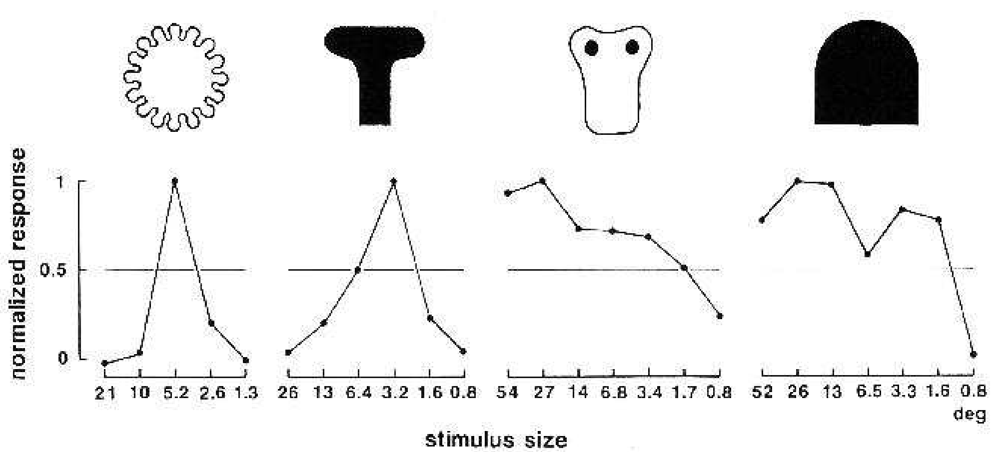
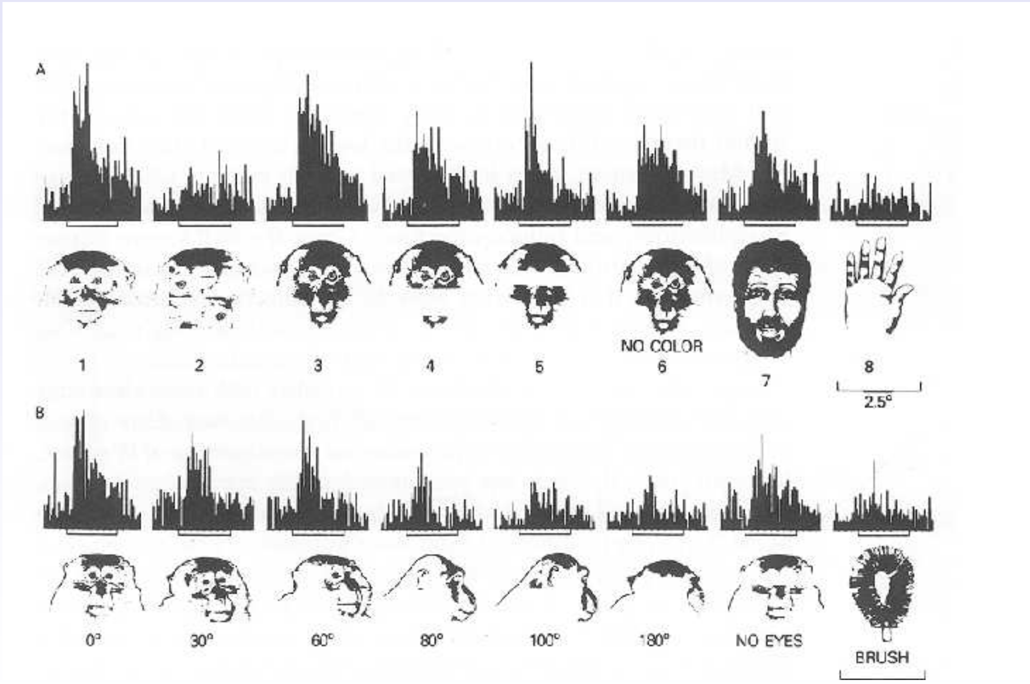
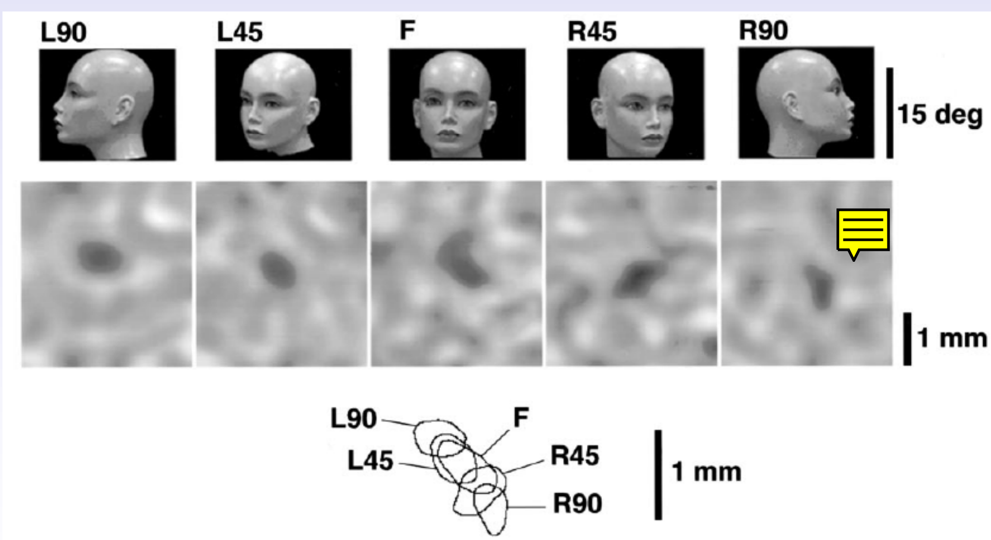


Figure 6. Tuning of responses of four TE cells for the stimulus size.

Face cells

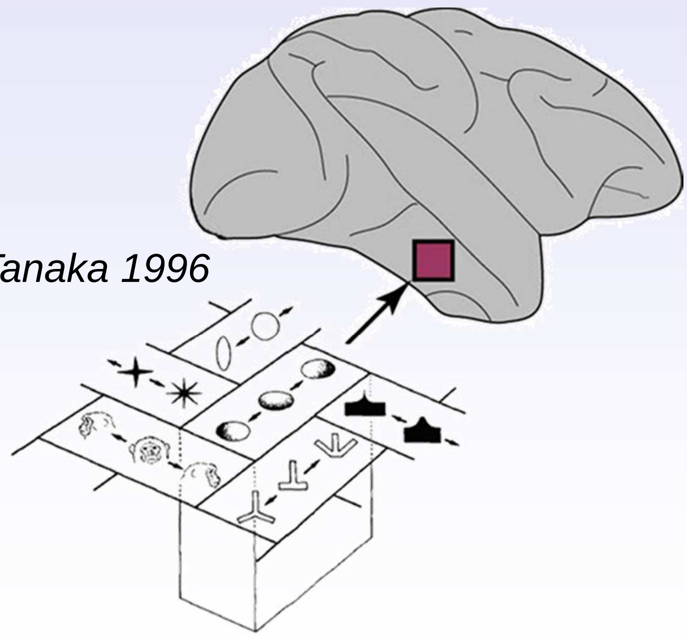


Columnar Tuning in Area TE



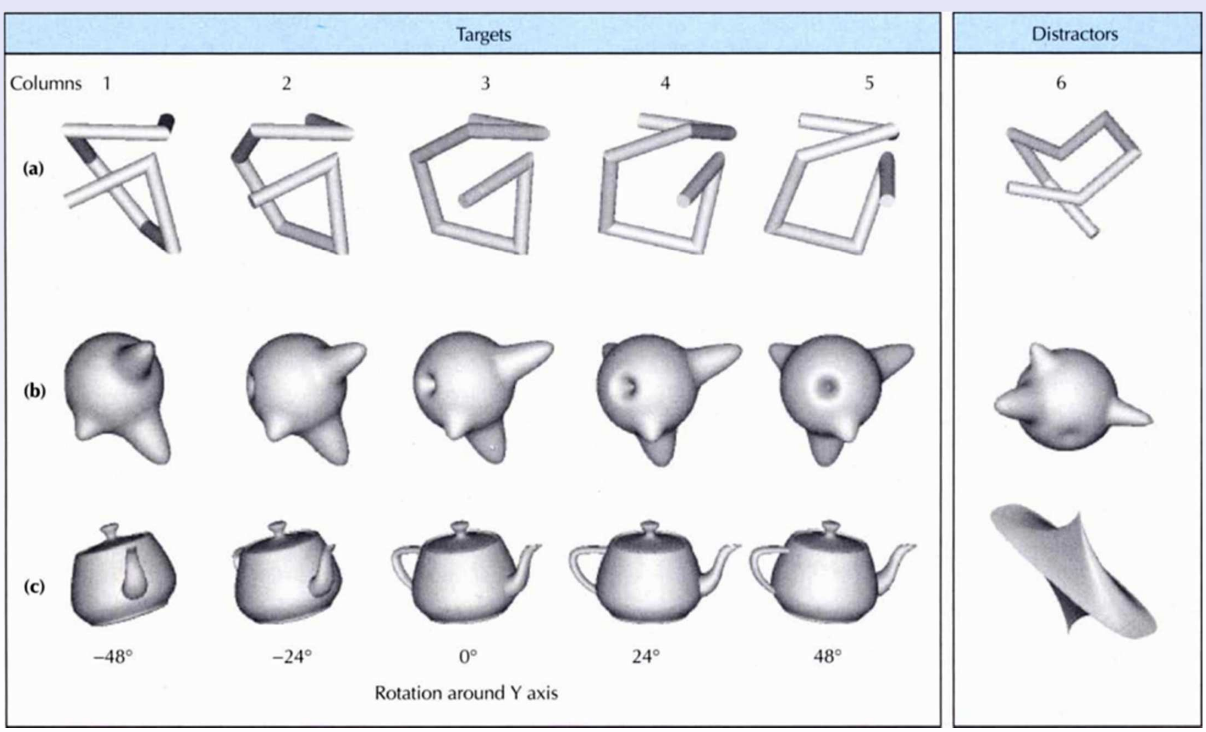
Wang, Tanaka, & Tanifuji (1996)

Overall Columnar Organization in Area TE



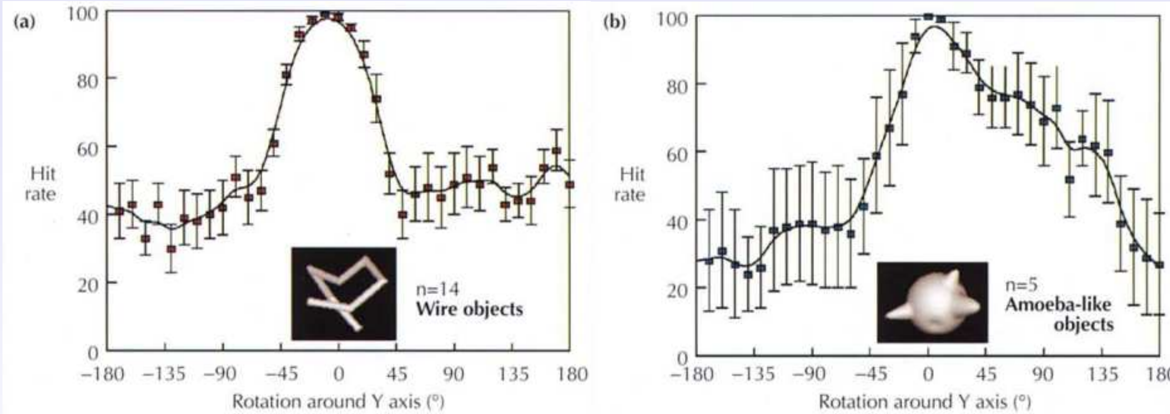
Tanaka 1996

Psychophysical evidence for view-based object representation

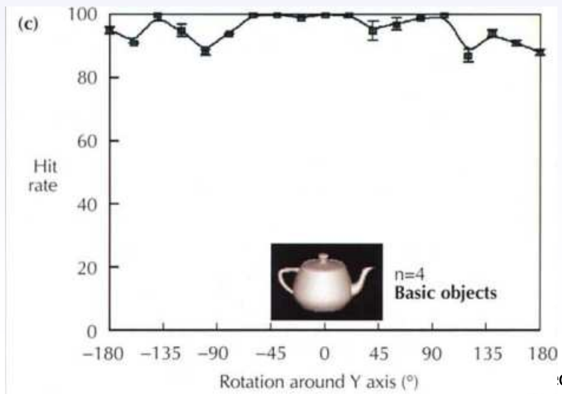


Logothetis, Pauls, Buelthoff, & Poggio (1994)

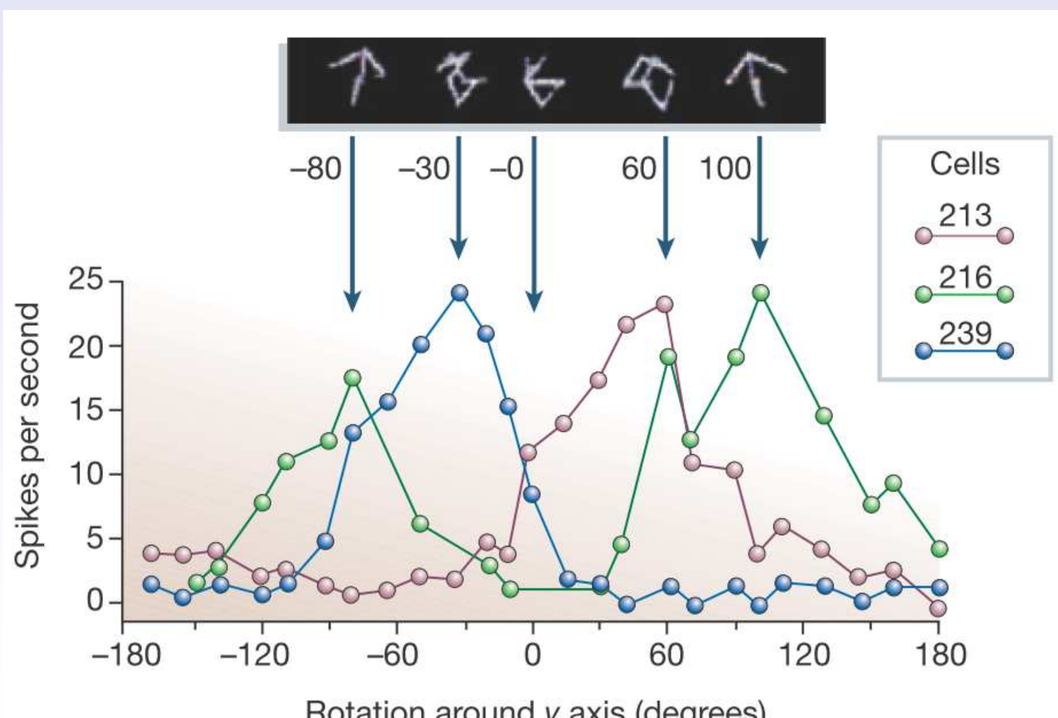
Psychophysical evidence for view-based object representation



Logothetis, Pauls, Buelthoff,
& Poggio (1994)



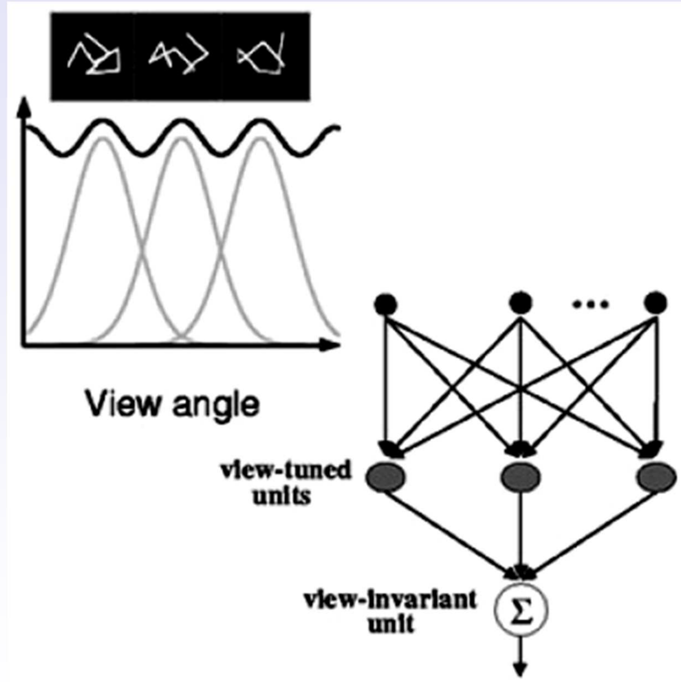
Responses of IT neurons



Logothetis, Pauls, & Poggio (1995)

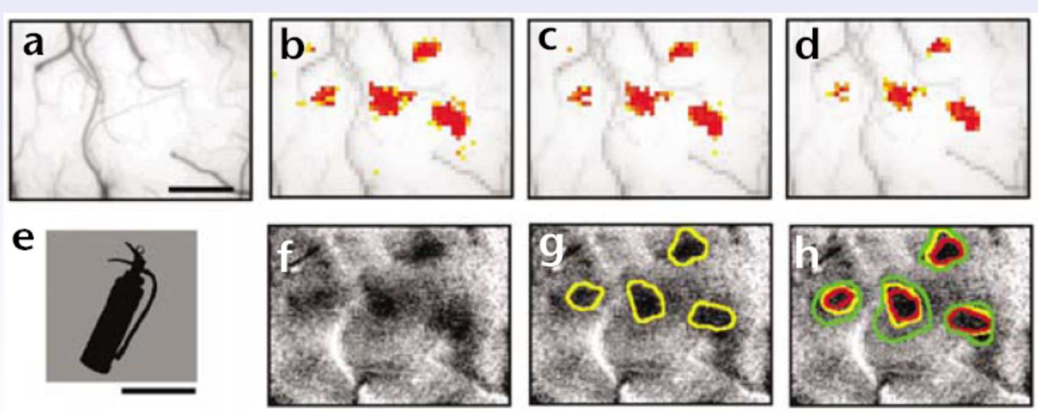
Generating an invariant representation

- Summation over view-tuned neurons



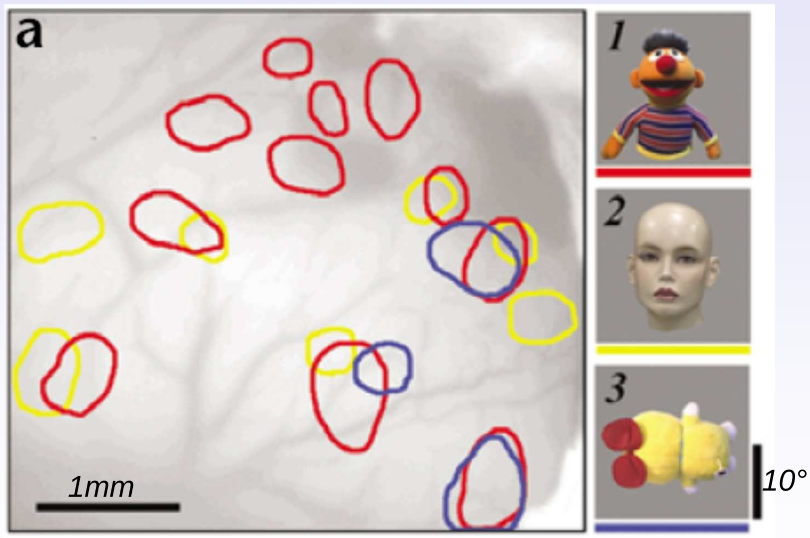
Columnar representation

Complex objects are represented in macaque inferotemporal cortex by the combination of feature columns.
Tsunoda,Yamane, Nishizaki, and Tanifuji. Nature Neuroscience (2001)

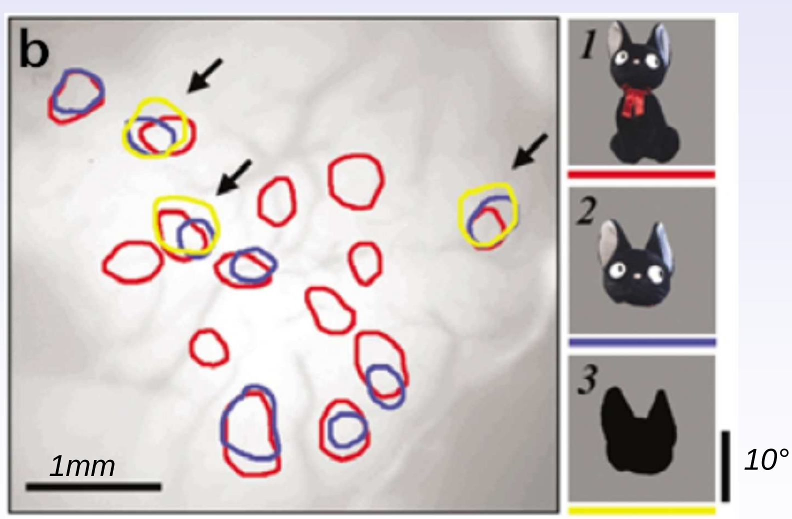


Light absorption imaging technique

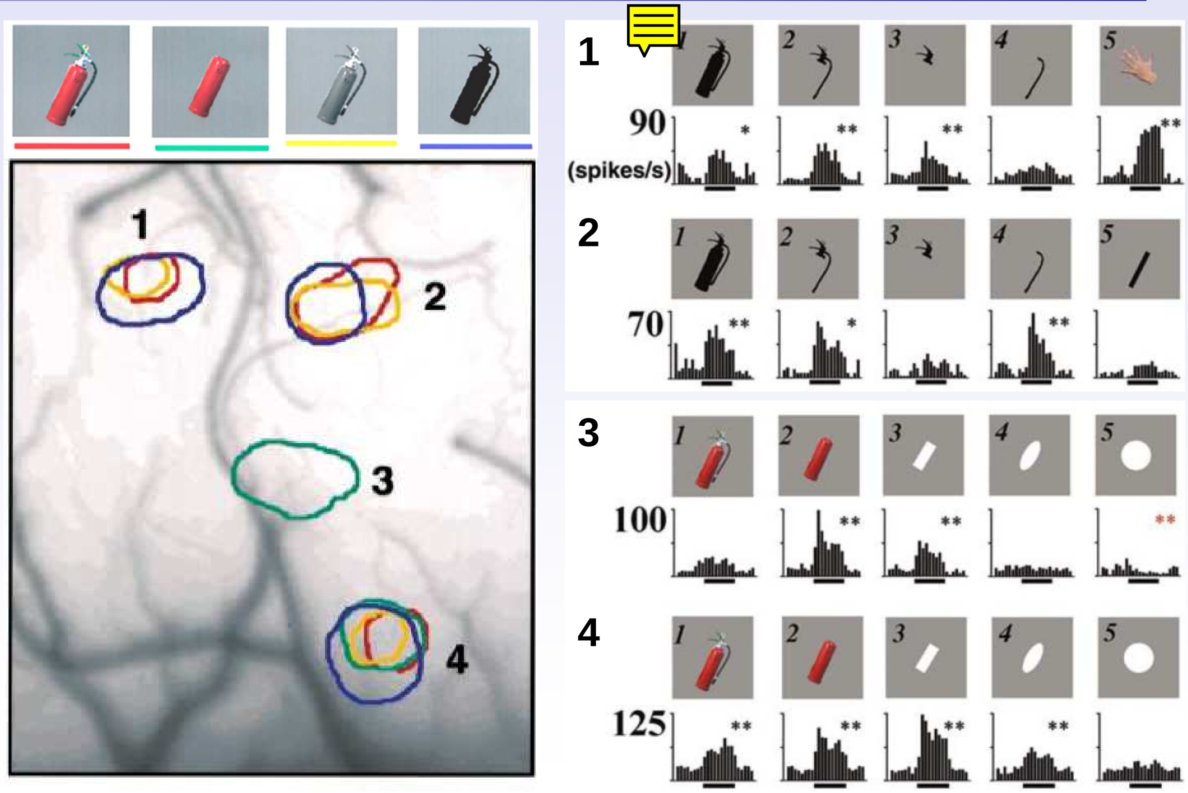
Stimulus Examples



Compositionality



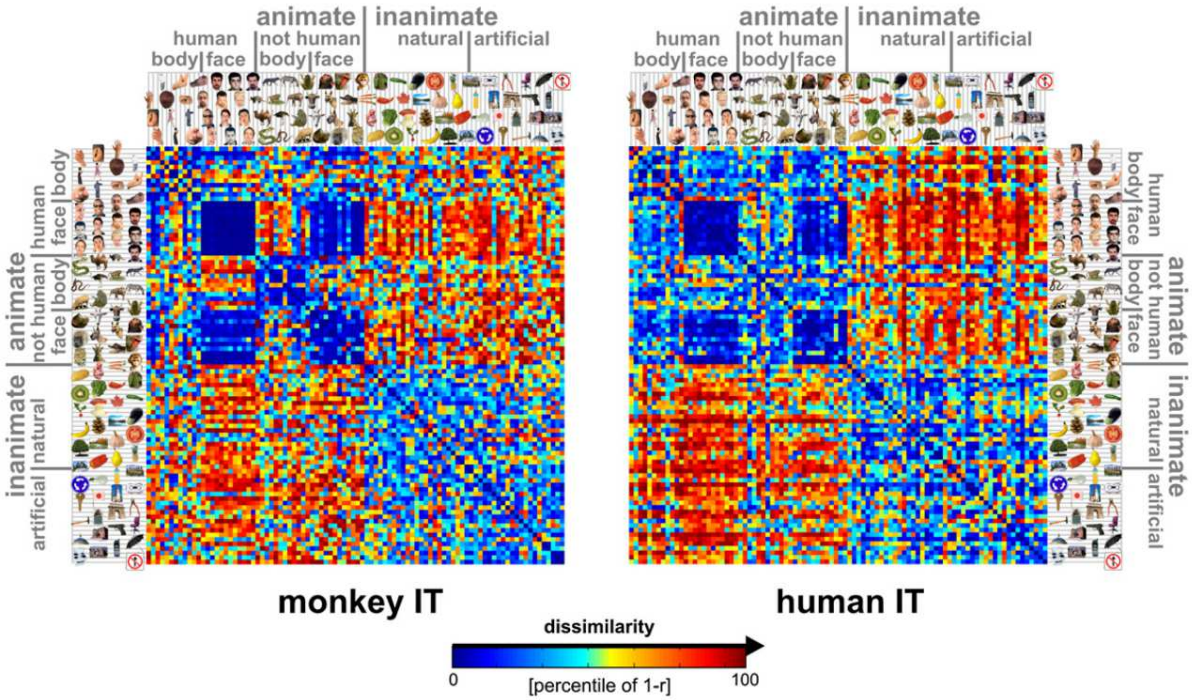
Feature Interactions



Matching IT response between human and monkey

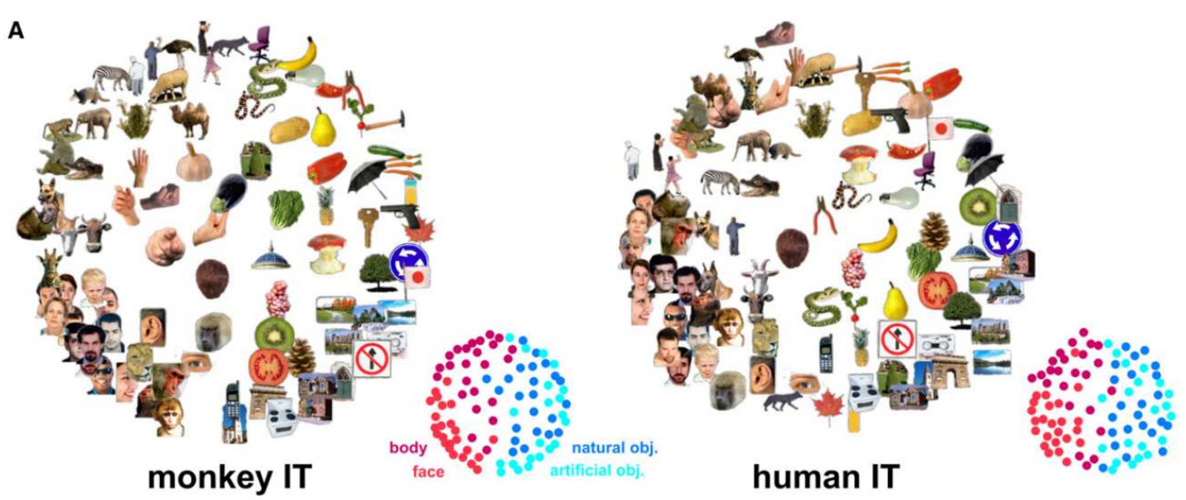
- Kriegeskorte, Mur, Ruff, Kiani, Bodurka, Esetky, Tanaka, & Bandettini. Neuron (2008)
  - 92 colorful stumulus images
  - Extracellular recording of 674 IT neurons in 2 macaque monkeys
  - High resolution fMRI within a 5cm thick slab of IT for 4 humans voxels 2 x 2 x2 mm → Includes IT and early visual cortex
  - One of the few studies to systematically compare between human and monkey
  - Qualitative very different type of data
  - Interesting analogies were found

Similarity of monkey IT response and human IT fMRI

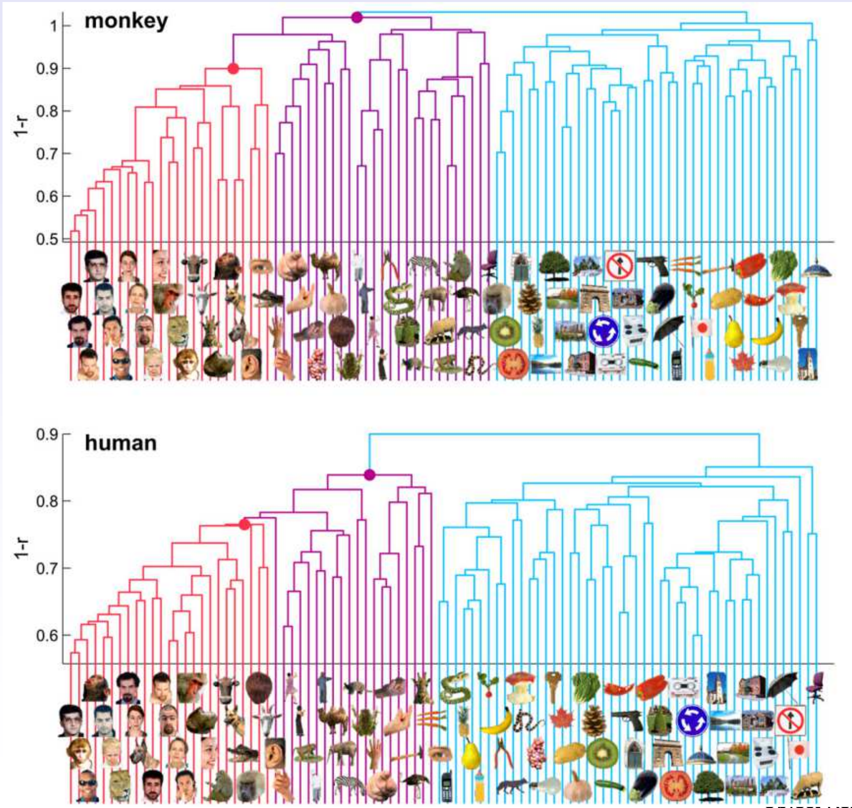


(Kriegeskorte et al. 2008)

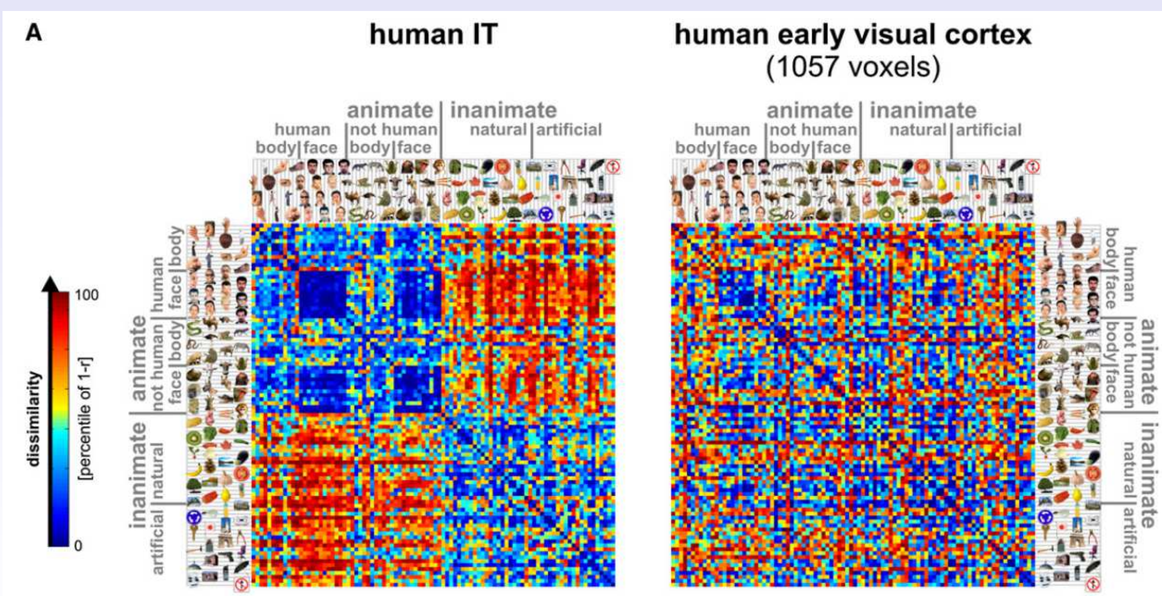
Multidimensional Scaling



Hierarchical Cluster Analysis

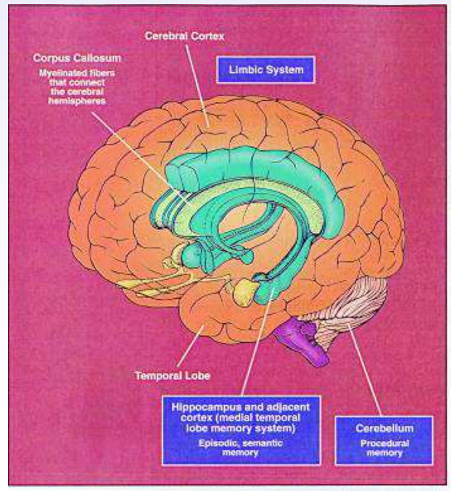


Comparison of IT and early visual cortex

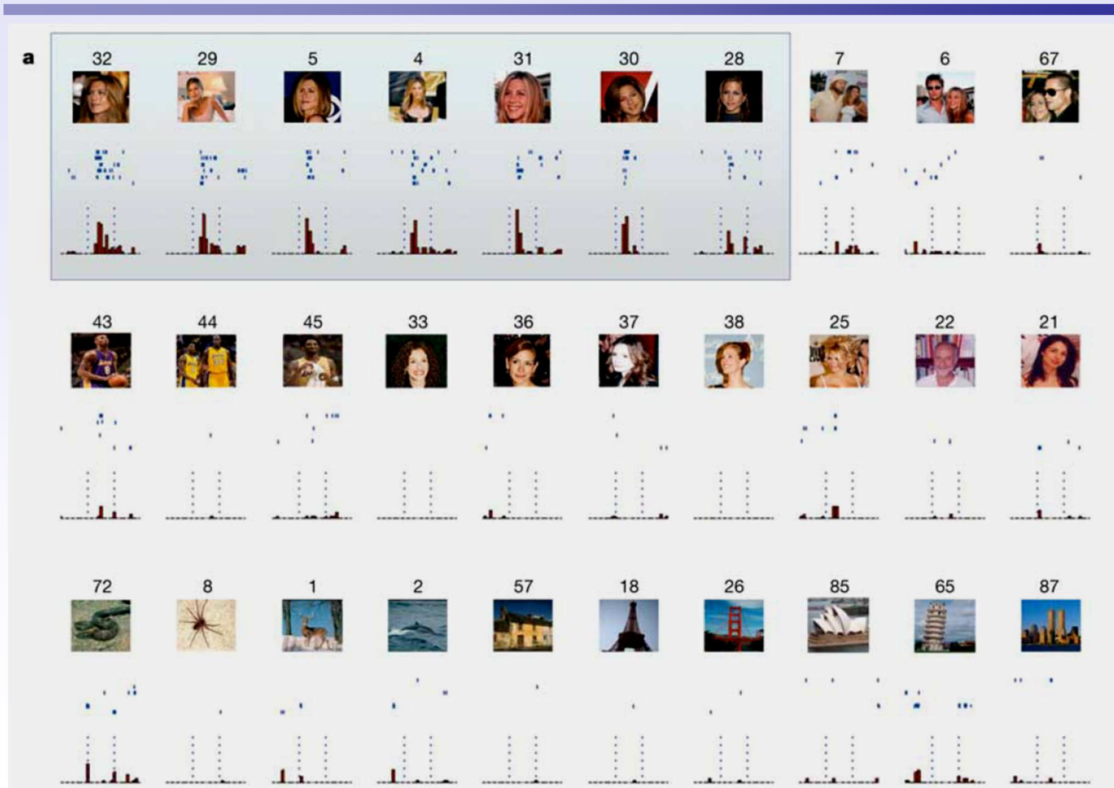


Grandmother cells revisited

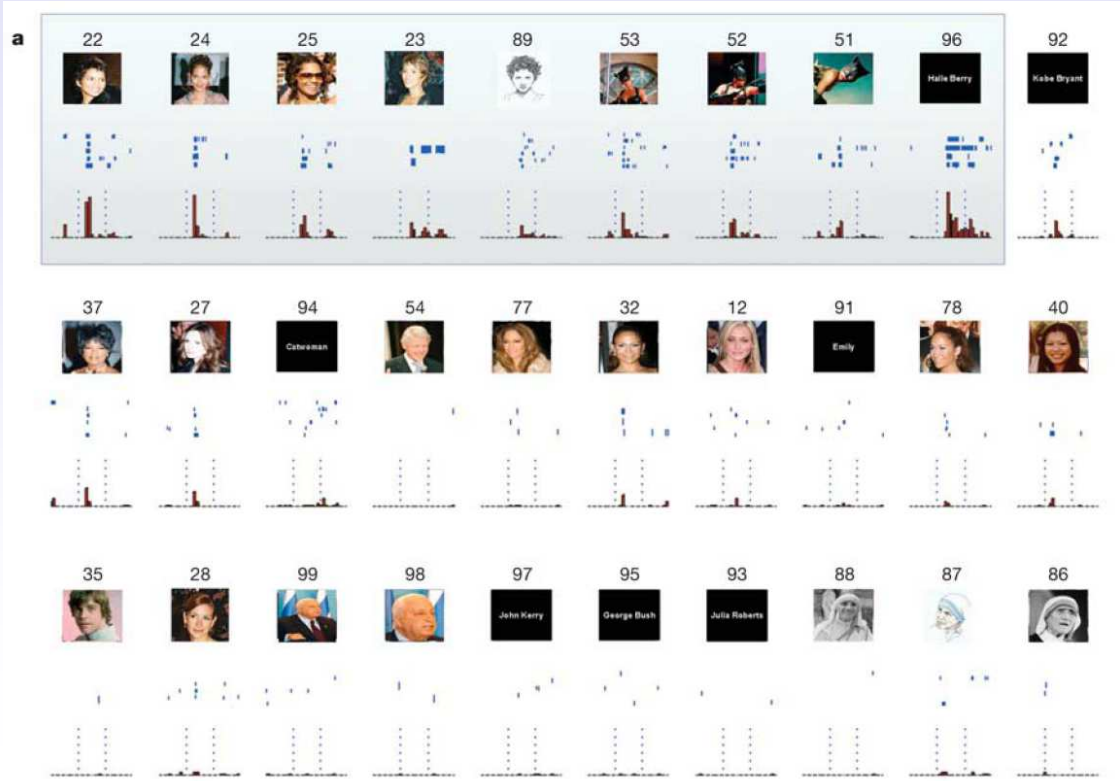
- Quiroga, Reddy, Kreiman, Koch, & Fried
  "Invariant visual representations by single neurons in the human brain". Nature (2005).
  - Recording in the mediotemporal lobe of human epilepsy patients
  - Systematic bootstrapping search procedure to identify invariant responses



Jennifer Aniston (Grandmother) Neuron



Halle Berry neuron



Sidney opera house neuron