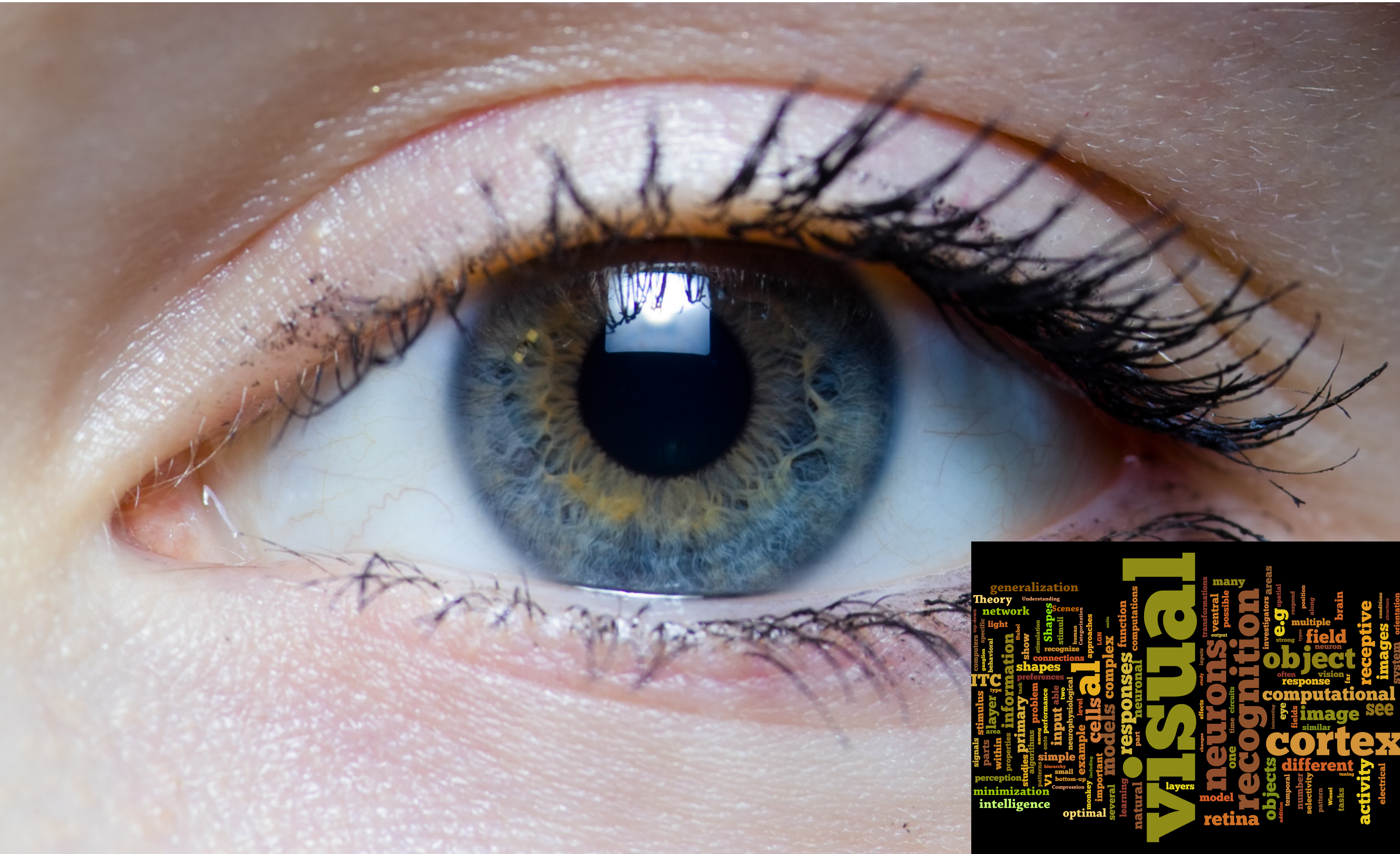
Visual Object Recognition
Computational Models and Neurophysiological Mechanisms
Neuro 130/230. Harvard College/GSAS 78454

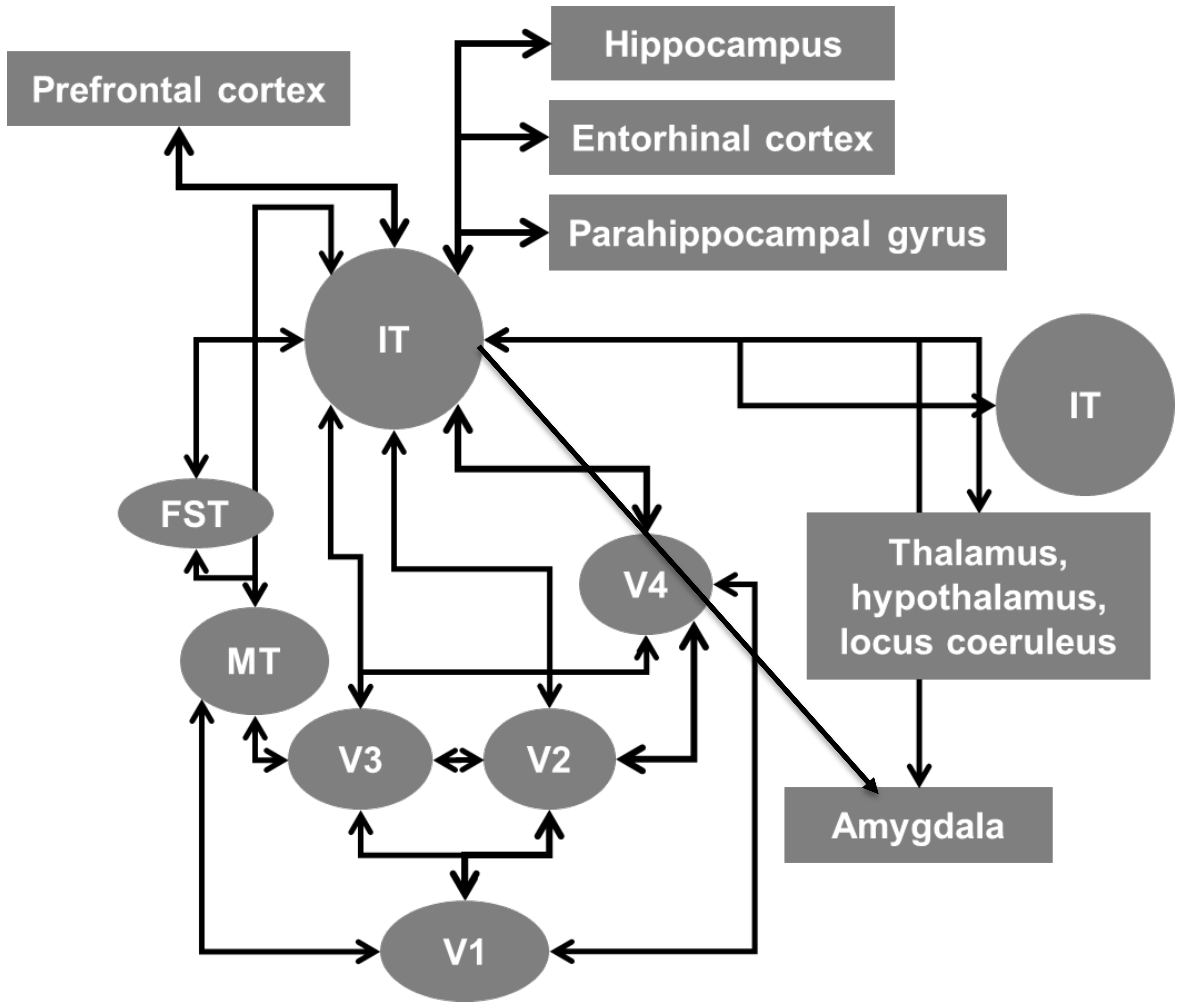


Visual Object Recognition
Computational Models and Neurophysiological Mechanisms
Neurobiology 230. Harvard College/GSAS 78454

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
Class 12 [11/29/2021]. Visual Consciousness

FINAL EXAM, PAPER DUE 12/14/2021. No extensions.

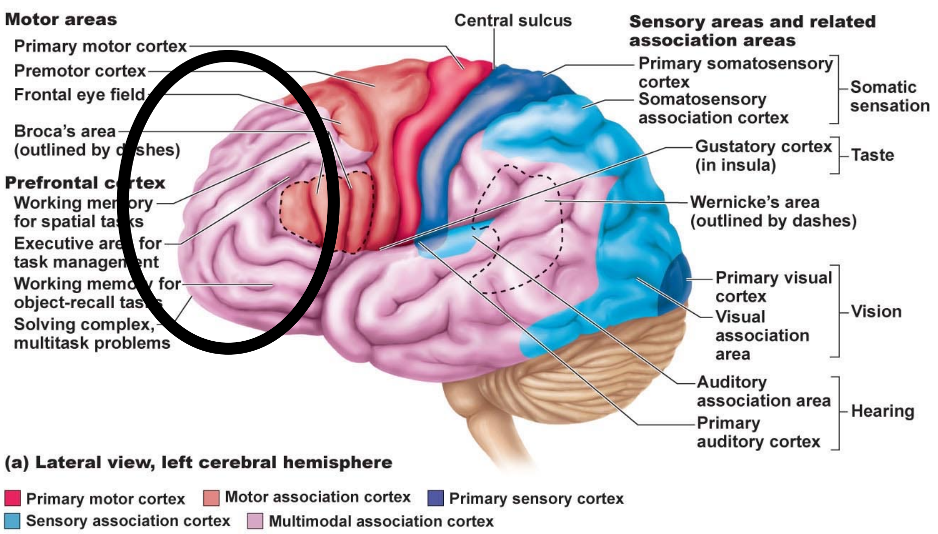
Anatomical projections of inferior temporal cortex



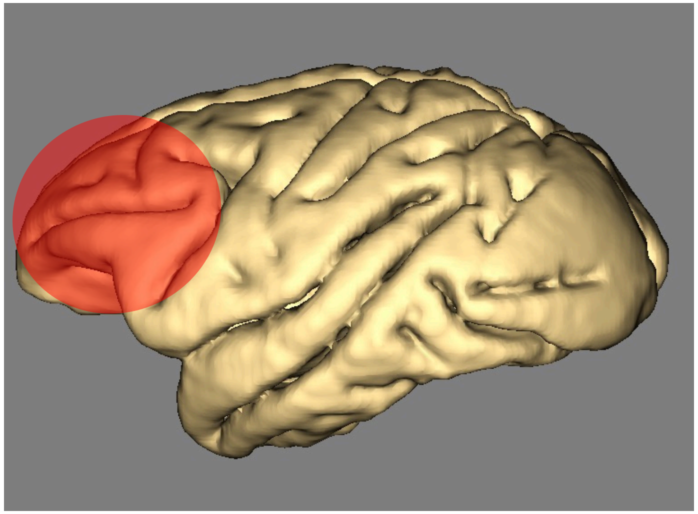
Markov et al 2014

Prefrontal cortex: the central executive

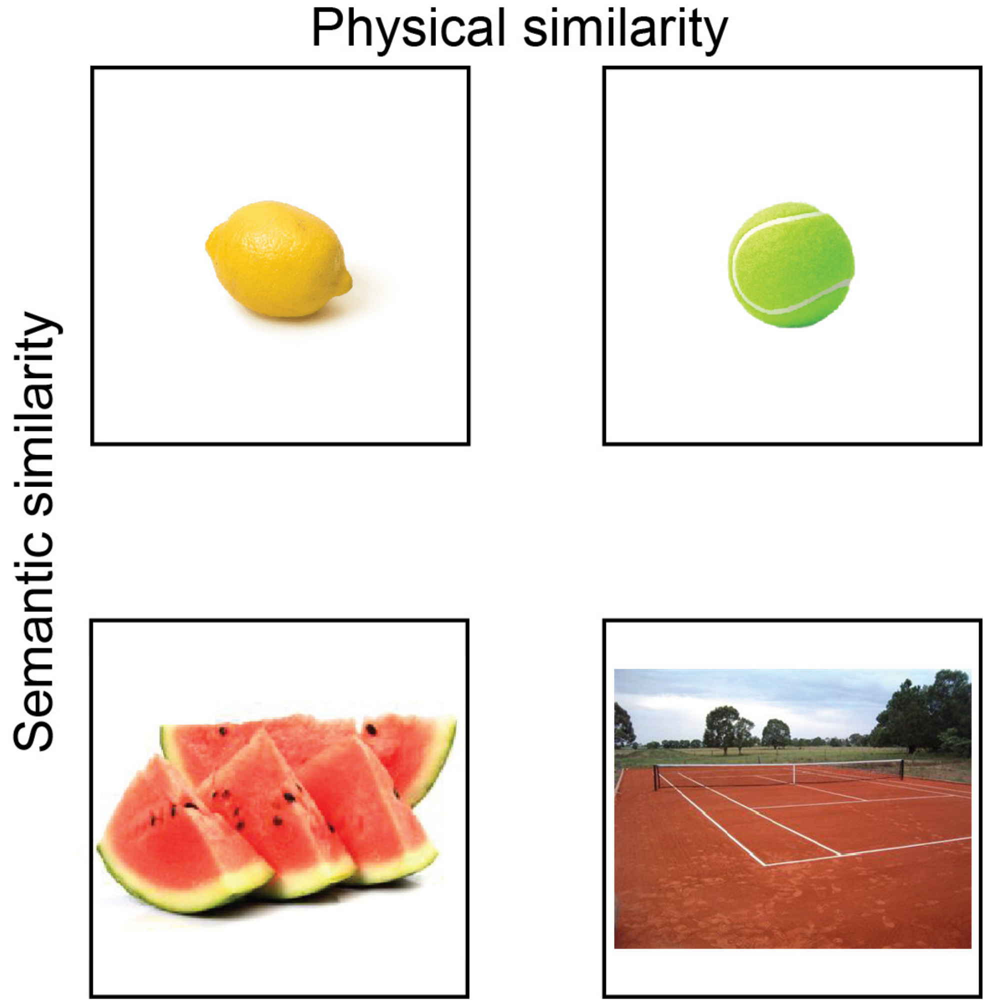
Human brain



Macaque brain



ITC represents visual shapes, not semantics



Categorical responses in PFC but not IT

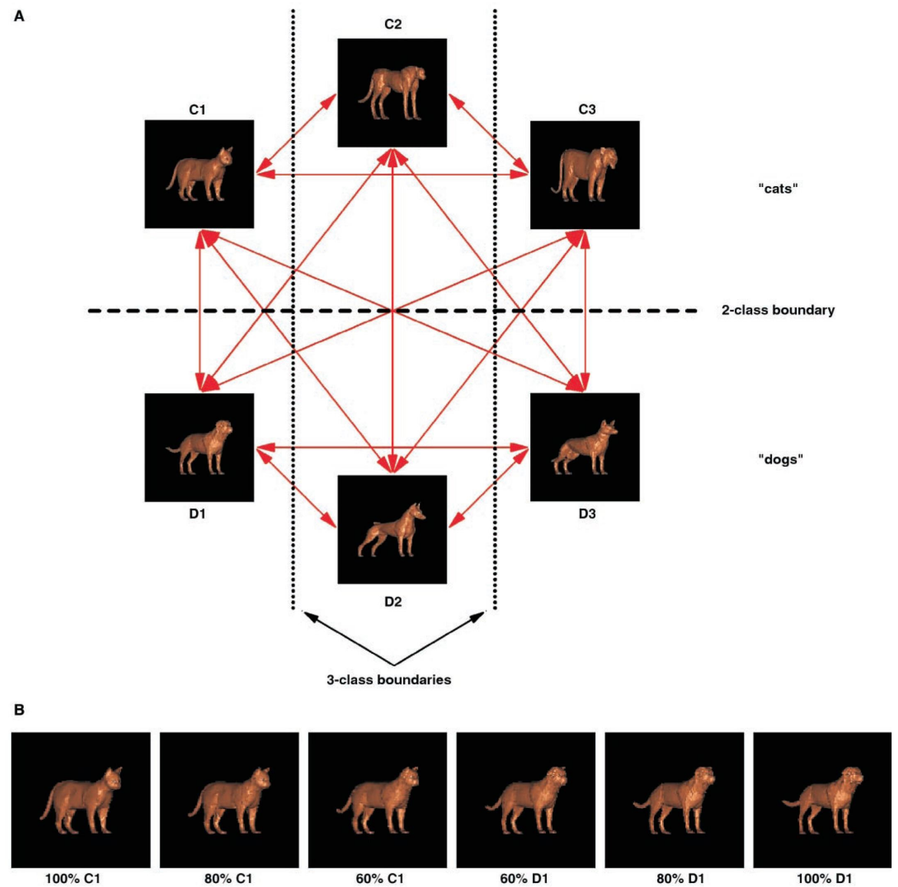
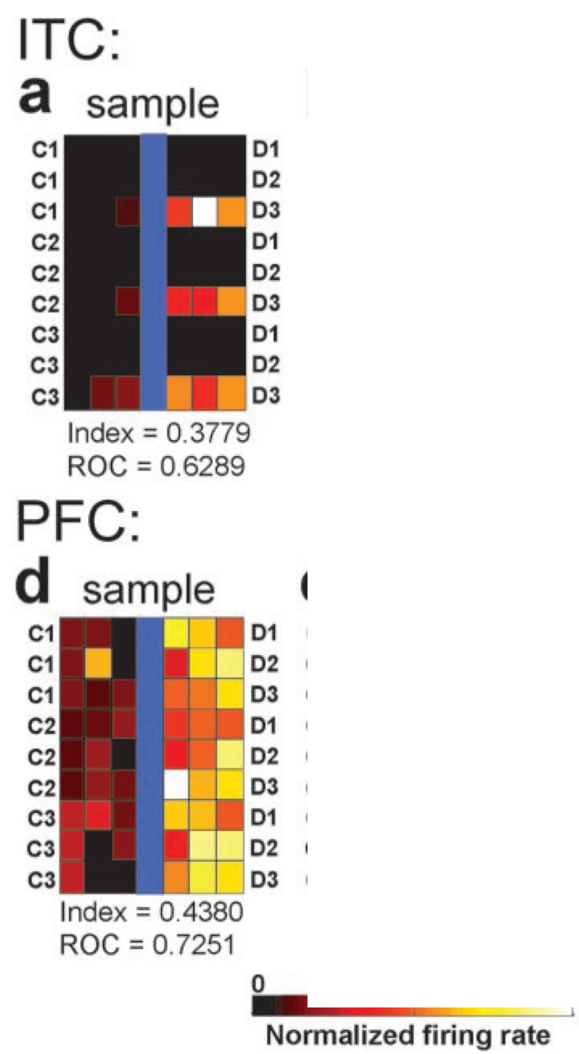


Fig. 1. The stimuli. (**A**) Monkeys learned to categorize randomly generated "morphs" from the vast number of possible blends of six prototypes. For neurophysiological recording, 54 sample stimuli were constructed along the 15 morph lines illustrated here. The placement of the prototypes in this diagram does not reflect their similarity. (**B**) Morphs along the C1-D1 line.

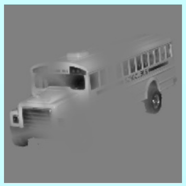


Freedman et al., 2001; Freedman et al., 2003.

Pattern completion of partially occluded objects

Evaluating pattern completion

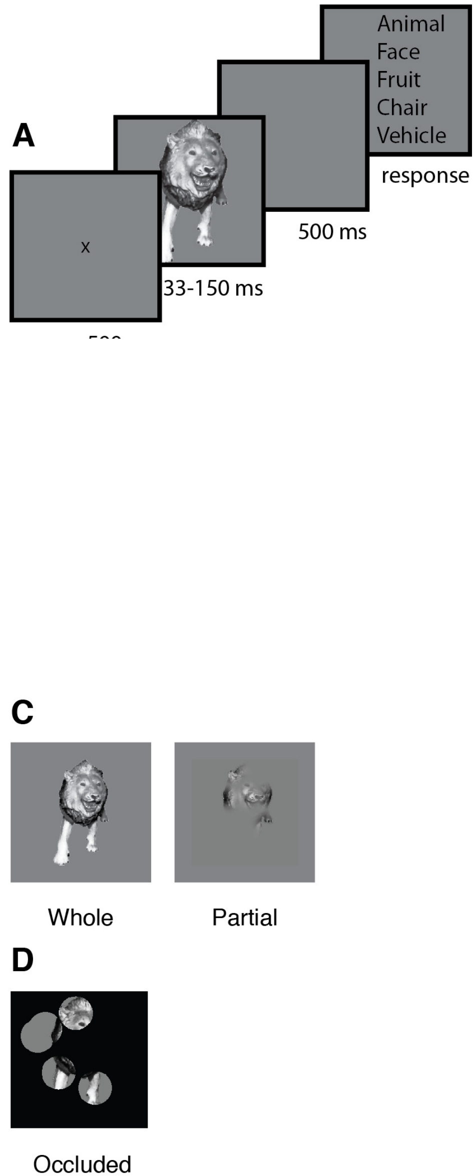
20 bubbles



10 bubbles

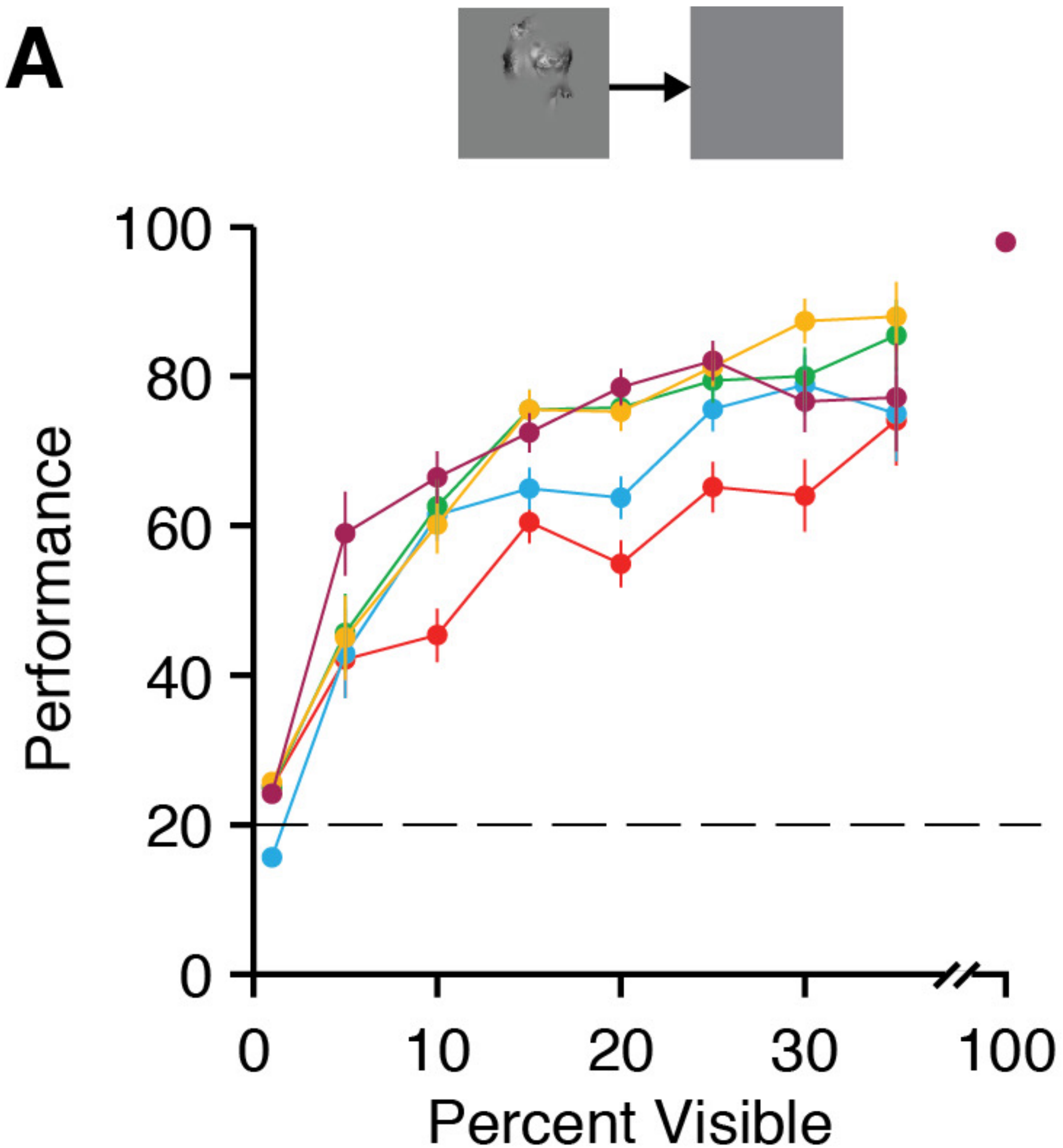
6 bubbles

4 bubbles

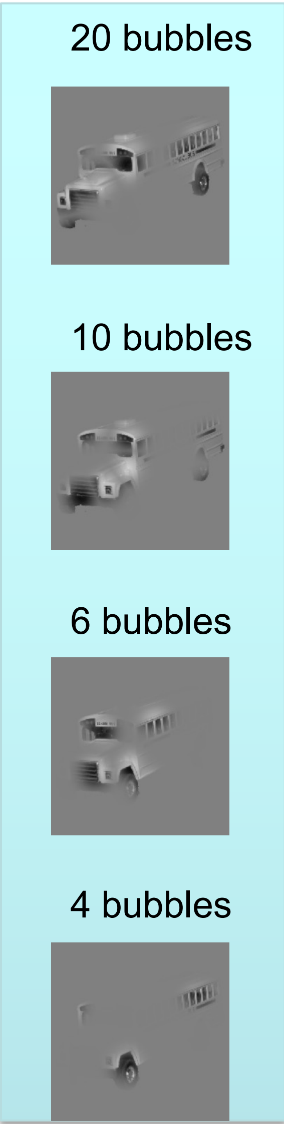


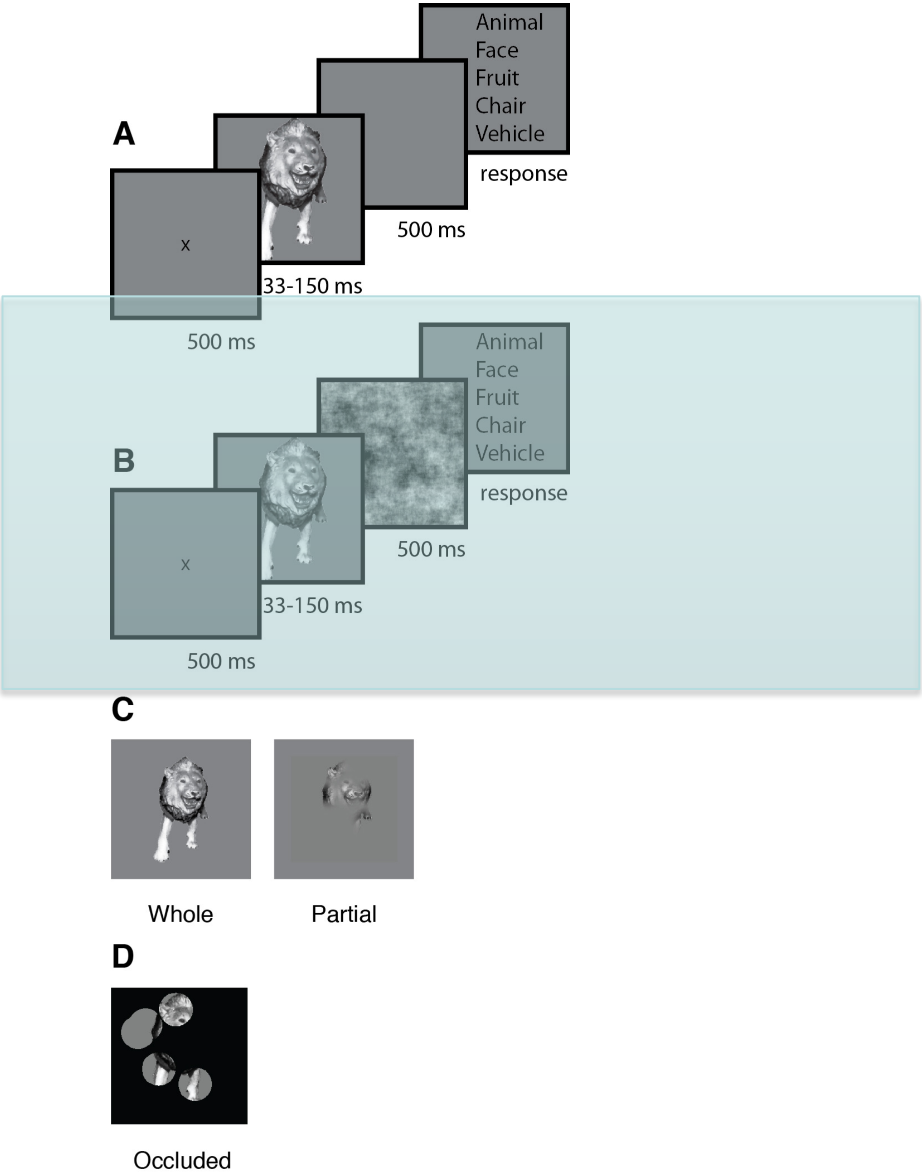
Tang et al 2014, 2018

Strong robustness to limited visibility

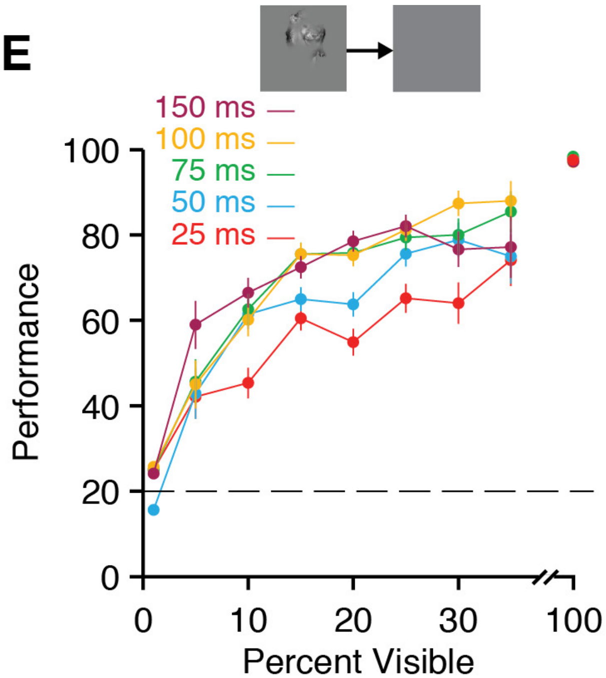


Interrupting processing by backward masking

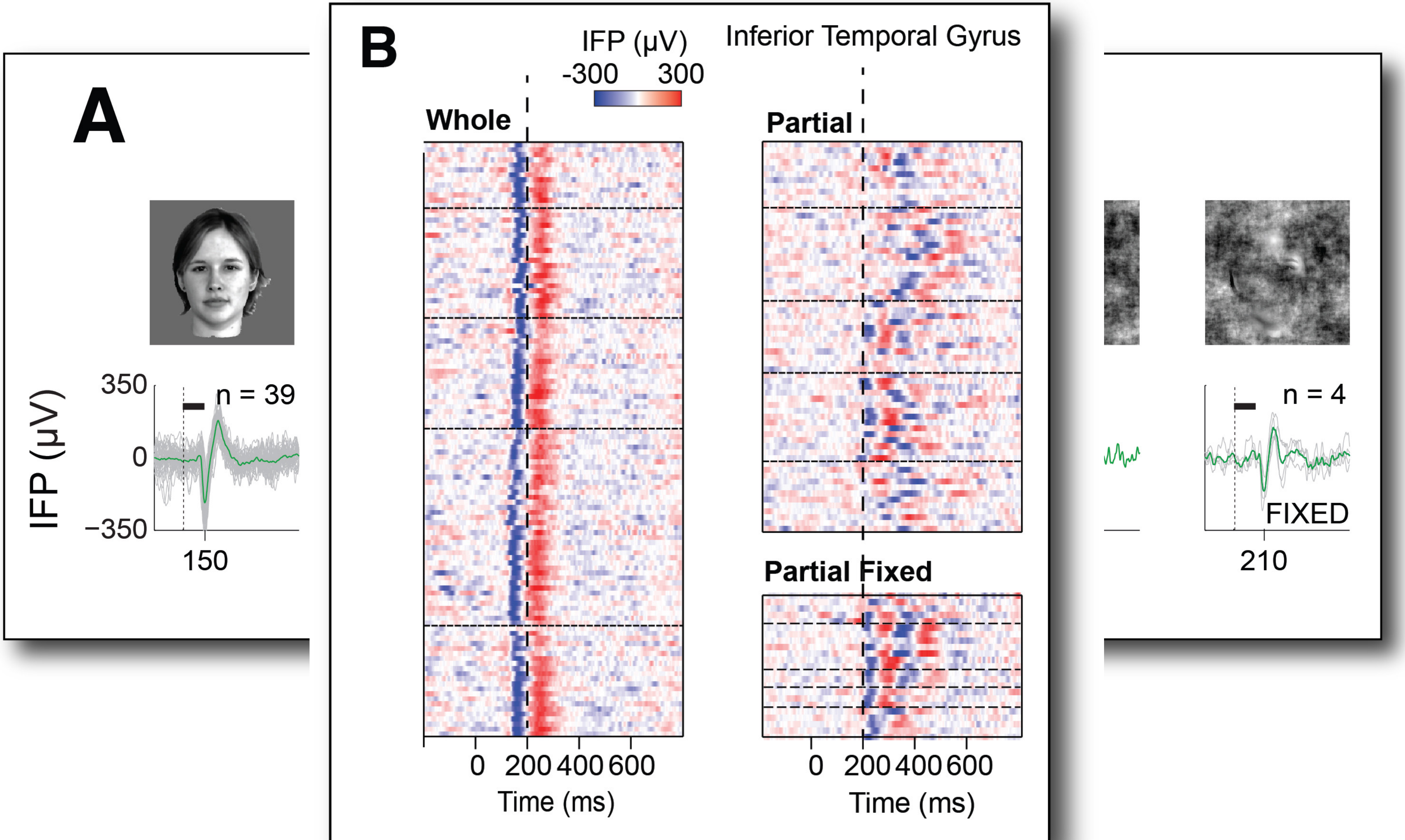




Backward masking disrupts pattern completion

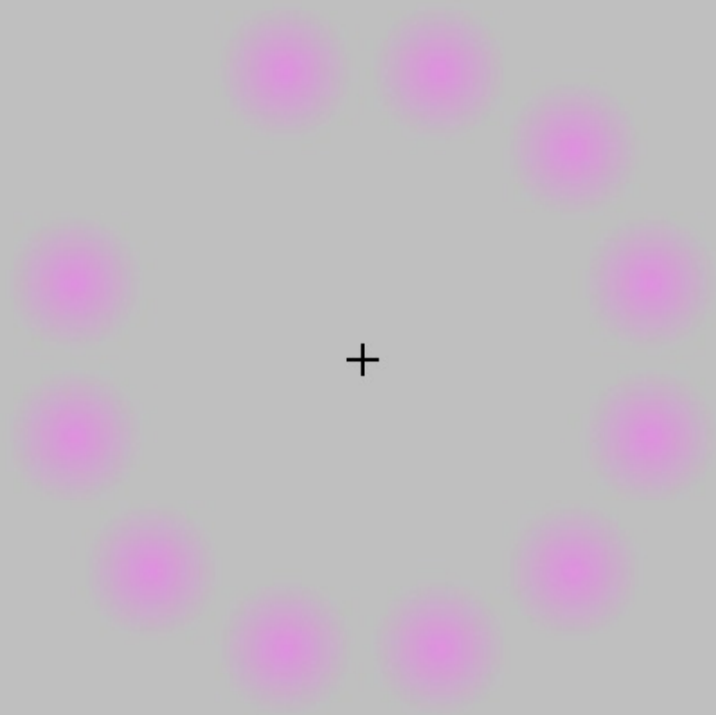


Delayed neural responses to occluded obejcts



Inferior Temporal Gyrus

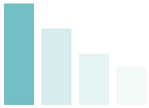
Perception is not a constant function of input

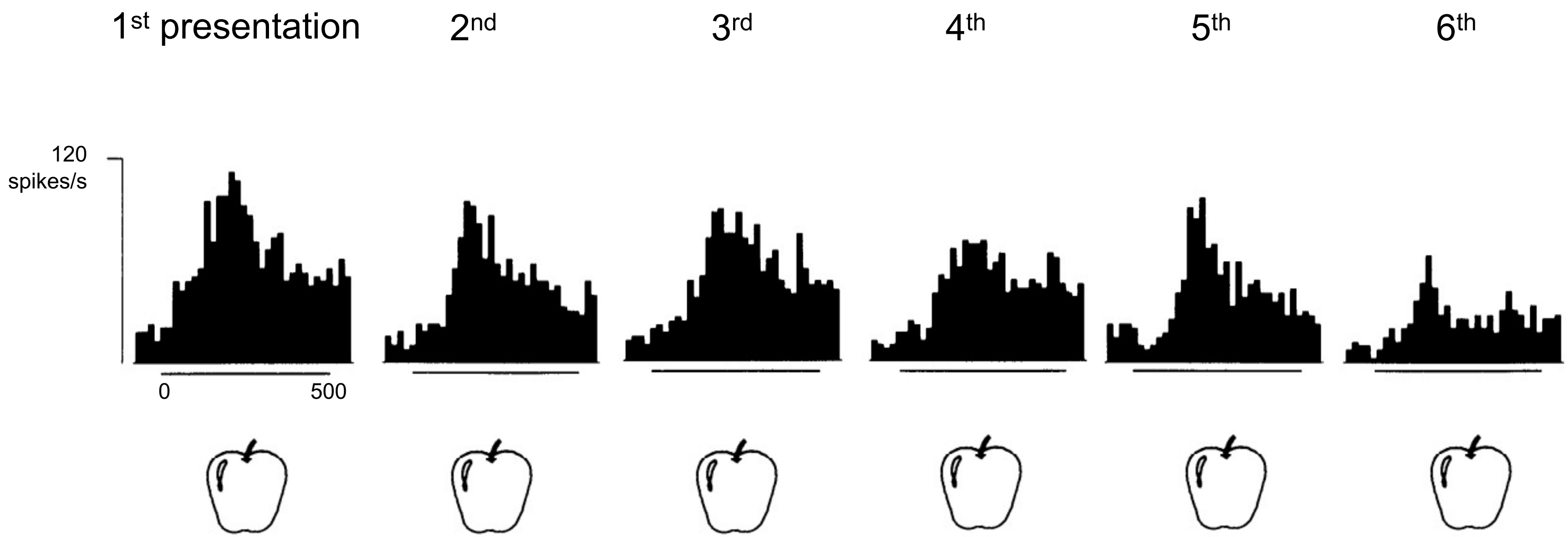


Perception is not a constant function of input

Neural responses are not a constant function of input

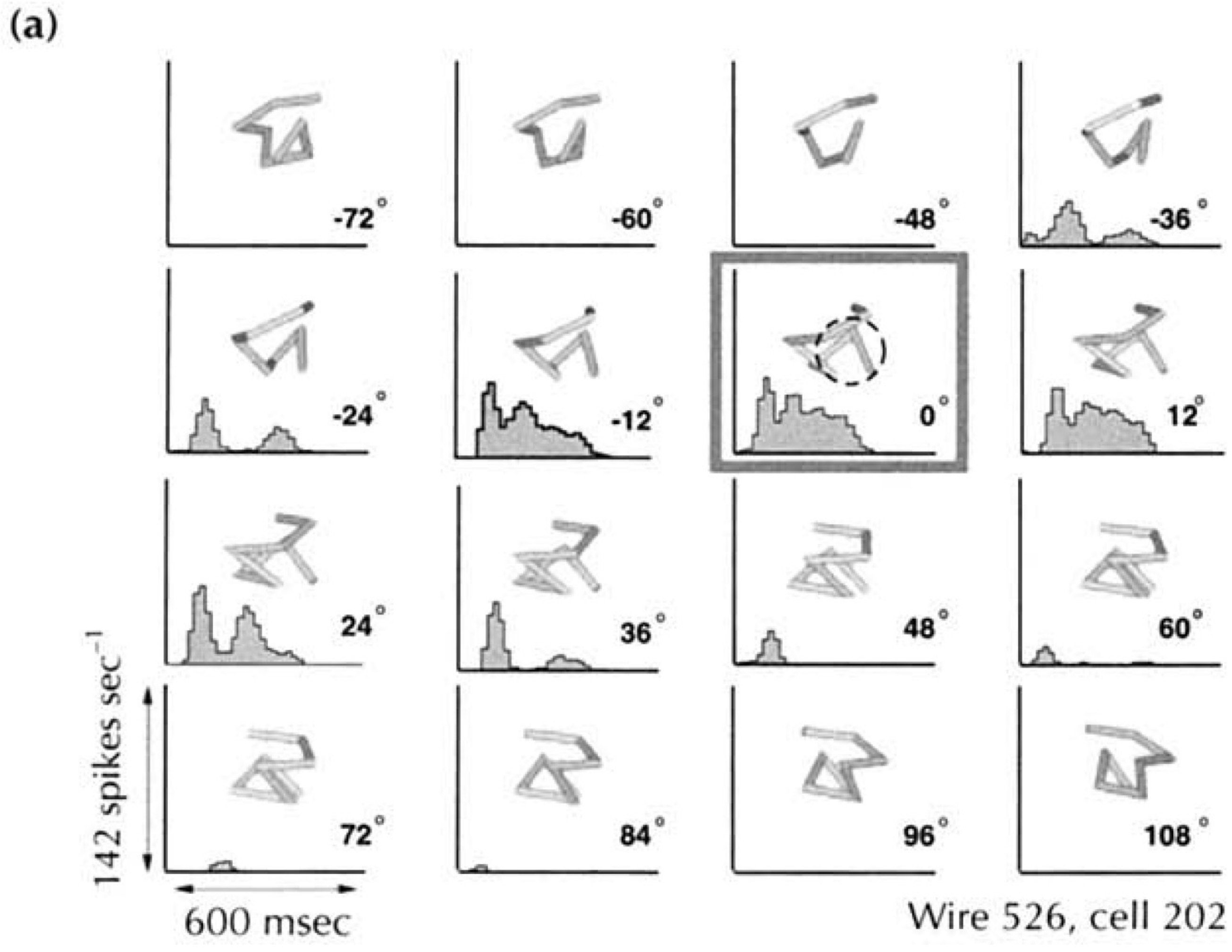
"Repetition suppression"





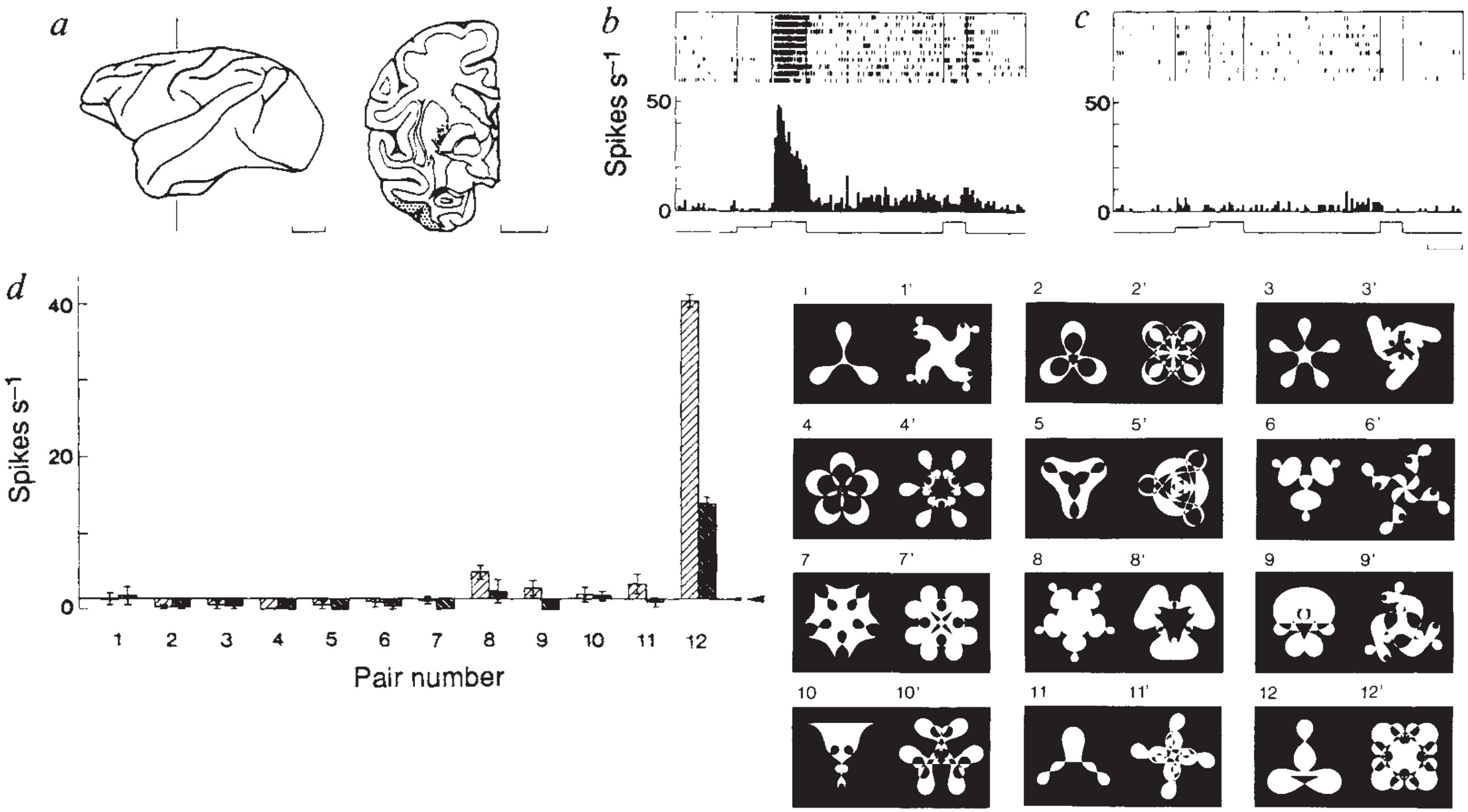
Li, Miller, and Desimone, *J Neurophysiol* (1993)

Neuronal tuning in ITC arises a consequence of learning



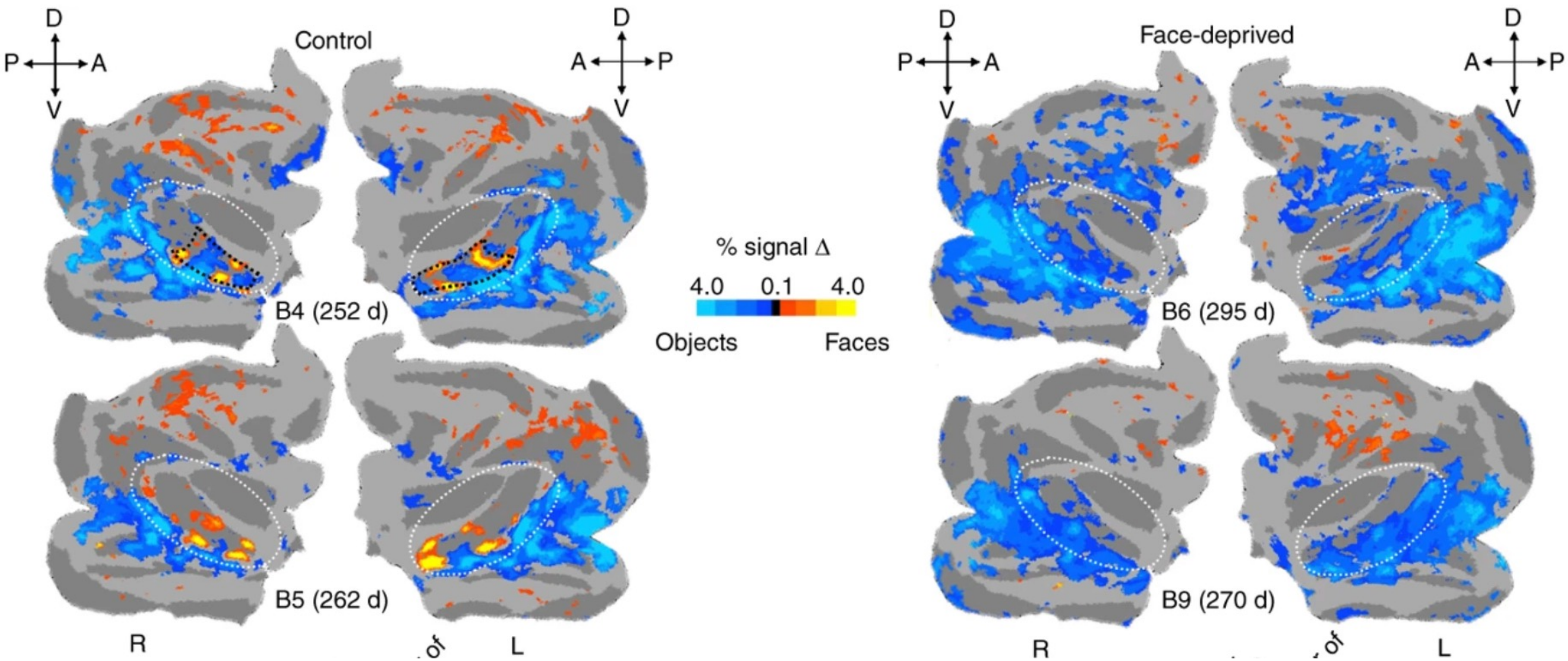
Logothetis et al 1995

Learning alters neuronal responses in ITC



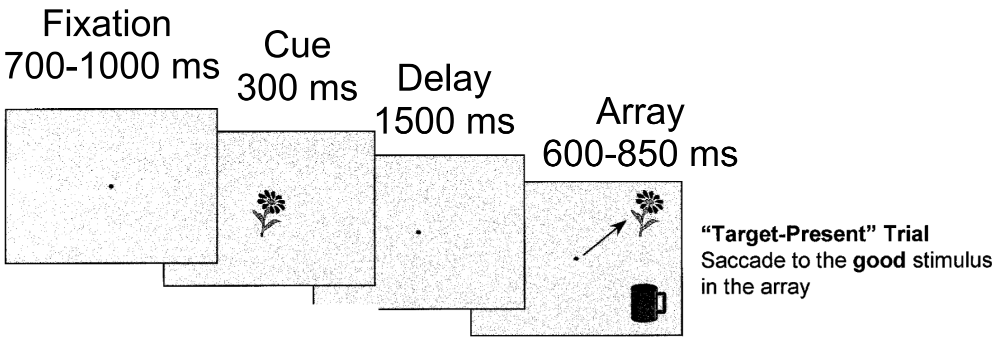
Sakai and Miyashita 1991

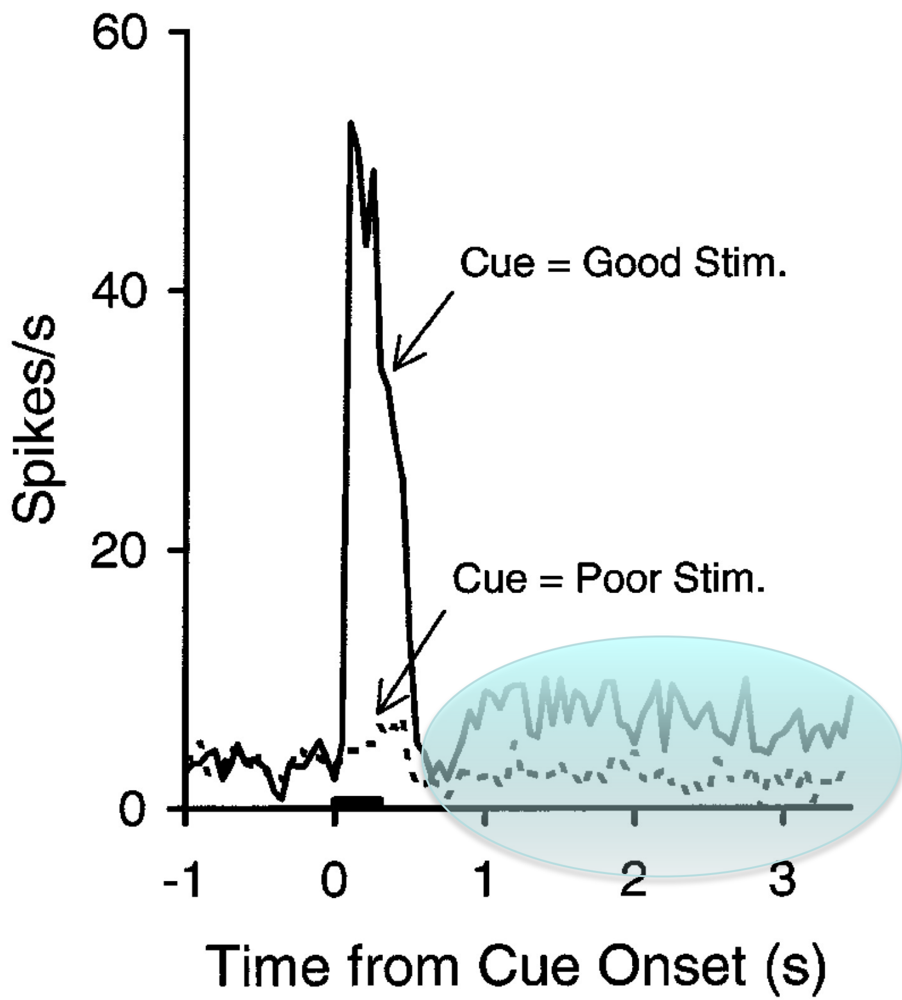
Seeing faces is necessary to have neural signals that respond to faces



Arcaro et al, Nature Neuroscience 2017

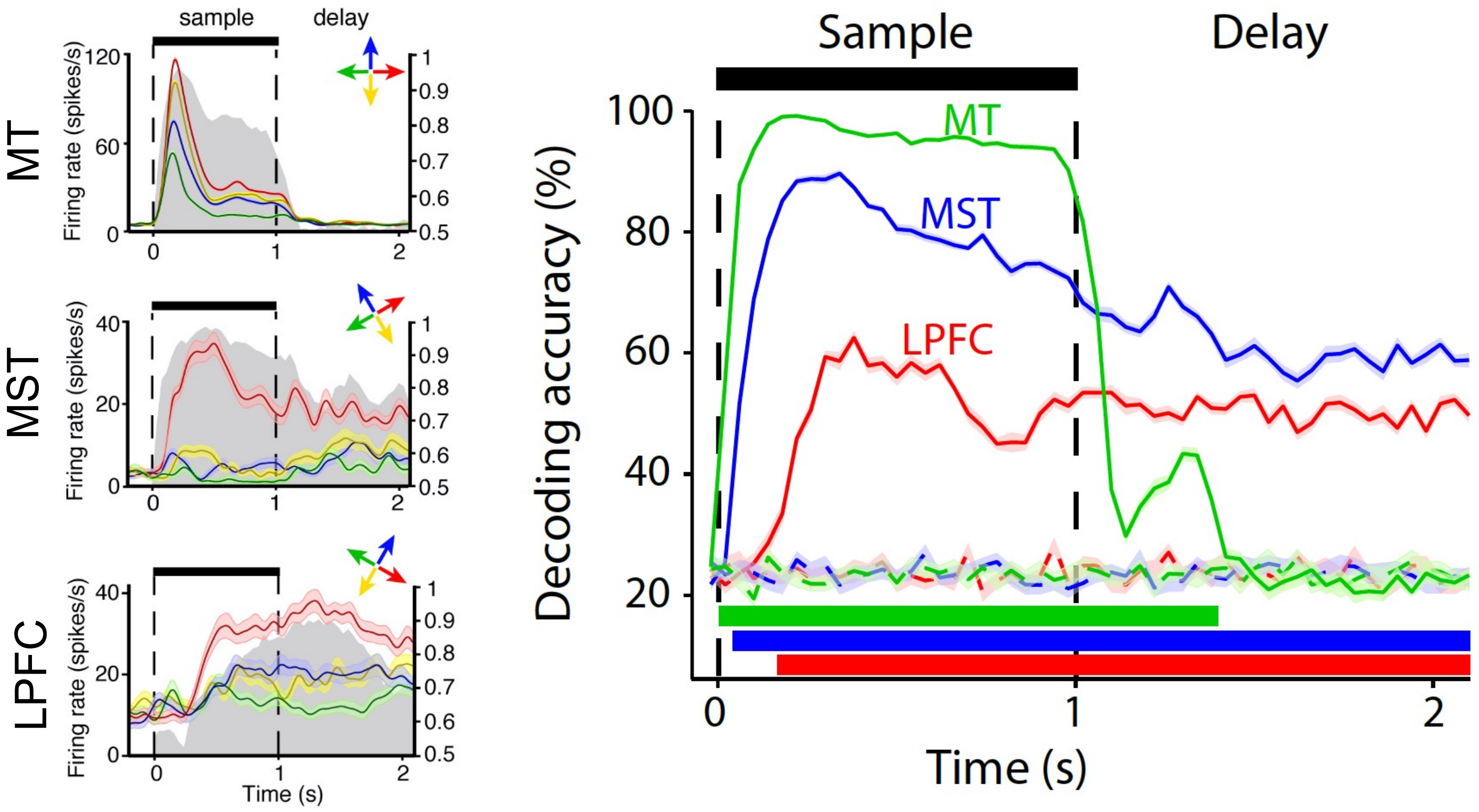
ITC can represent information even in the absence of a visual stimulus!





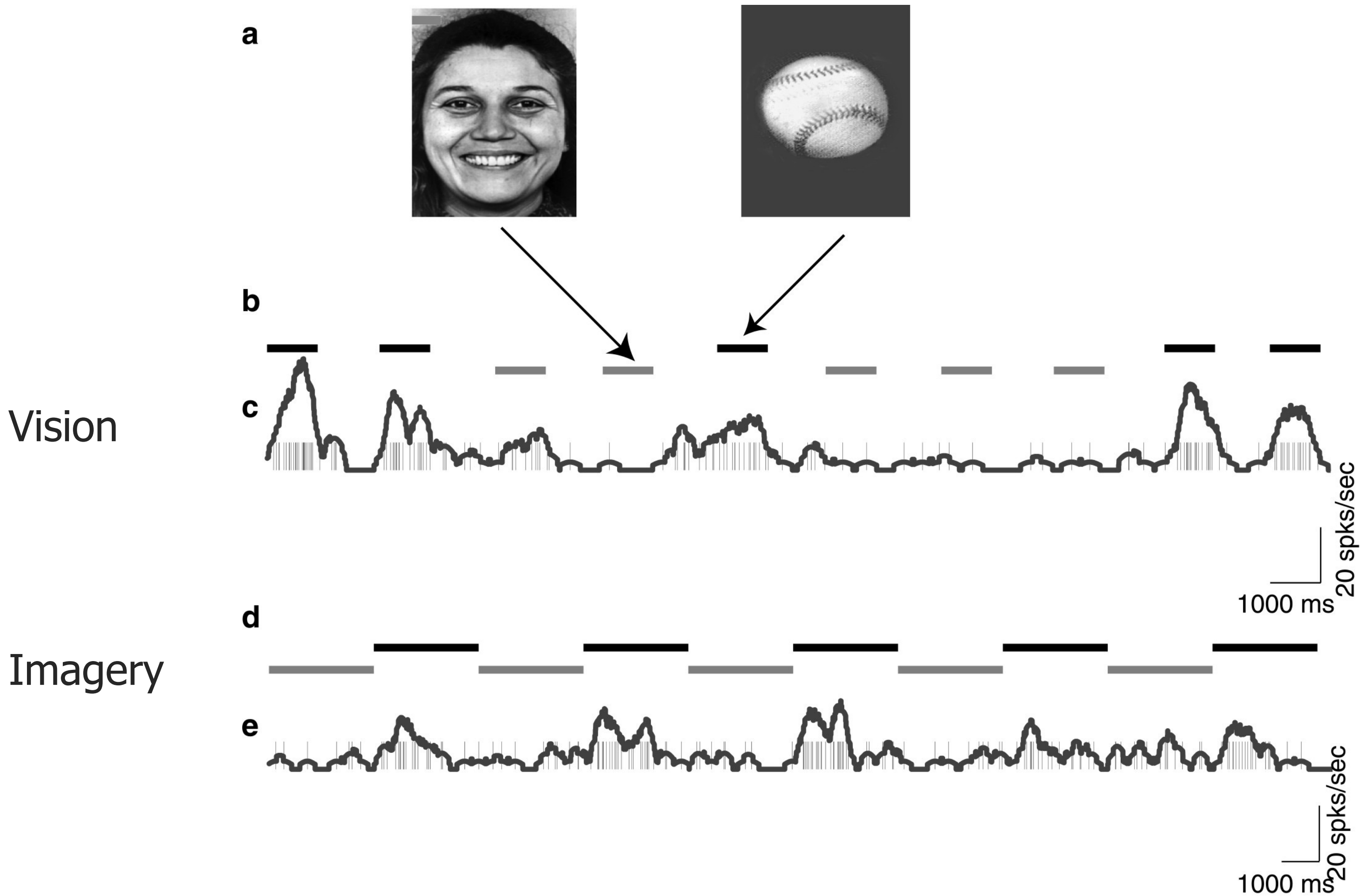
Chelazzi et al 1998

Working memory representations are absent in early visual cortex and emerge in visual association cortex



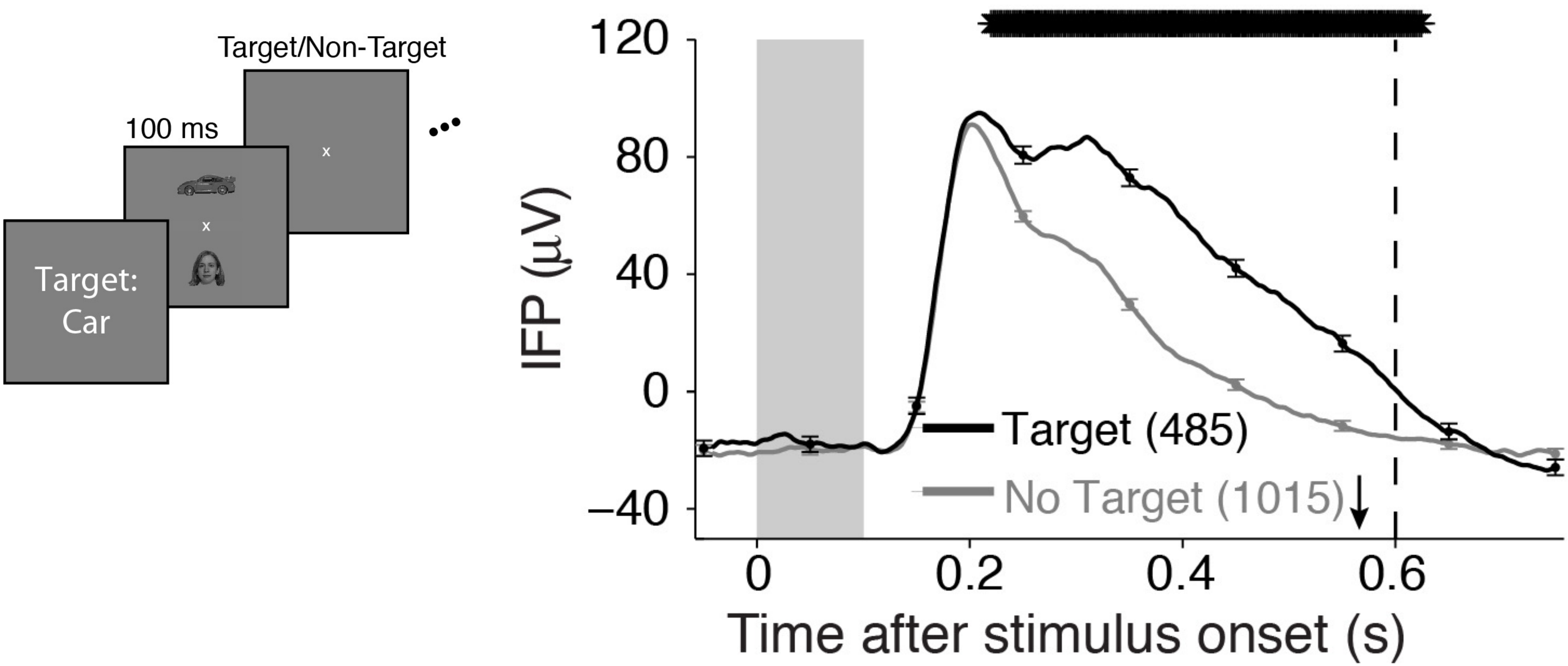
Mendoza-Halliday et al., *Nat. Neurosci.* 2014

Selective responses during visual imagery in the human brain



Kreiman et al 2000

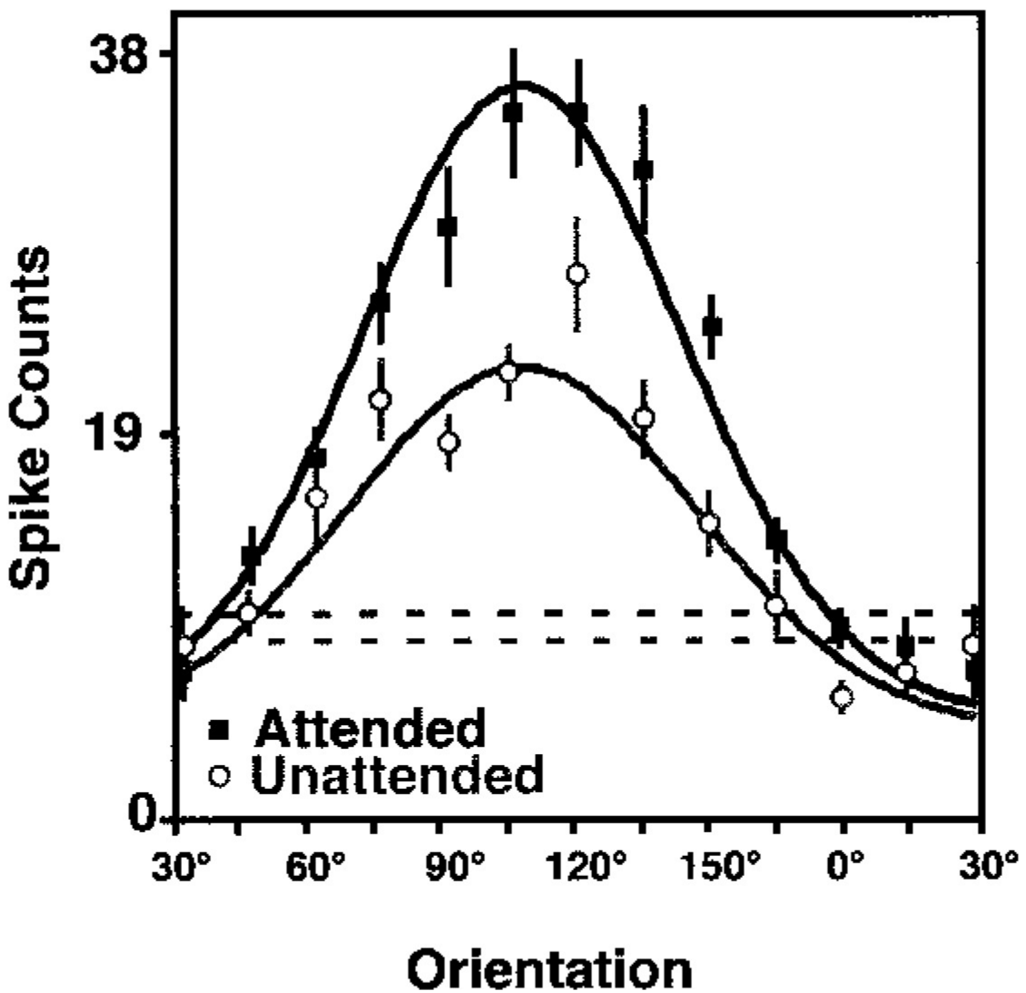
Task demands modulate activity in ventral visual cortex



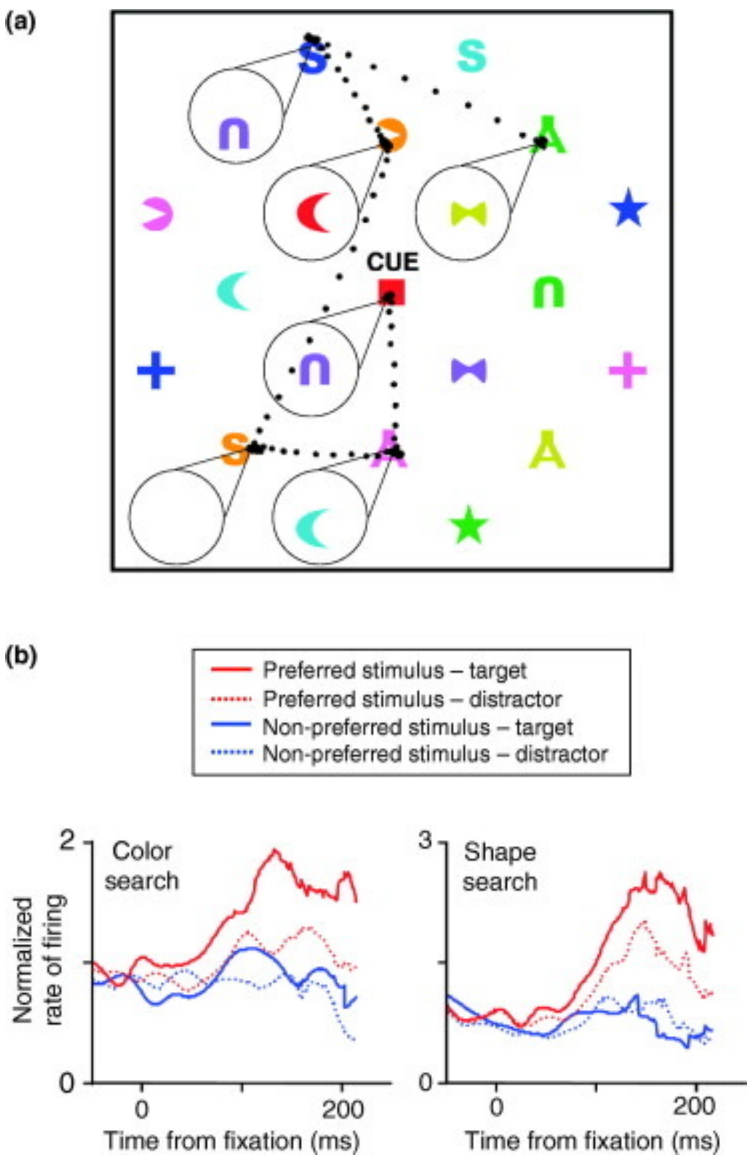
Bansal et al 2014

Attention is essential for vision

Pay attention!



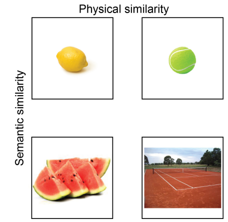
Feature-based attention



Bichot et al. Science 2005

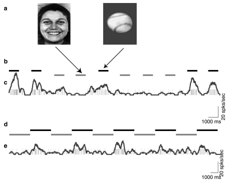
Summary

- ITC neurons represent shape, not semantic information



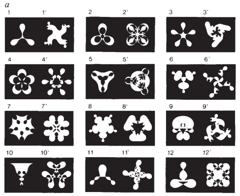
- ITC neurons can complete patterns from partially visible stimuli.

- Neural responses continue representing selective visual information even in the absence of a visual stimulus.



- Neuronal responses in ITC are modulated by task demands, including attention

- Neuronal tuning properties are the result of experience with visual world statistics.



Further reading

- Connor, C. E., Brincat, S. L., & Pasupathy, A. (2007). Transformation of shape information in the ventral pathway. Curr Opin Neurobiol, 17(2), 140-147.

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

- Hubel, D. and T. Wiesel (1959). "Receptive fields of single neurons in the cat's striate cortex." Journal of Physiology (London) 148: 574-591.
- Desimone, R., et al. (1984). "Stimulus-selective properties of inferior temporal neurons in the macaque." Journal of Neuroscience 4(8): 2051-2062.
- Felleman, D. J. and D. C. Van Essen (1991). "Distributed hierarchical processing in the primate cerebral cortex." Cereb Cortex 1: 1-47.
- Schmolesky, M., et al. (1998). "Signal timing across the macaque visual system." Journal of Neurophysiology 79(6): 3272-3278.
- Wallis, G. and E. T. Rolls (1997). "Invariant face and object recognition in the visual system." PROGRESS IN NEUROBIOLOGY 51(2): 167-194.
- Hegde, J., & Van Essen, D. C. (2007). A comparative study of shape representation in macaque visual areas v2 and v4. Cereb Cortex, 17(5), 1100-1116.
- von der Heydt, R., Peterhans, E., & Baumgartner, G. (1984). Illusory contours and cortical neuron responses. Science, 224, 1260-1262.
- Luck, S. J., Chelazzi, L., Hillyard, S. A., & Desimone, R. (1997). Neural mechanisms of spatial selective attention in areas V1, V2, and V4 of macaque visual cortex. J Neurophysiol, 77(1), 24-42.
- David, S. V., Hayden, B. Y., & Gallant, J. L. (2006). Spectral receptive field properties explain shape selectivity in area V4. J Neurophysiol, 96(6), 3492-3505.
- Kusunoki M, Moutoussis K, Zeki S (2006) Effect of background colors on the tuning of color-selective cells in monkey area V4. J Neurophysiol 95:3047-3059
- Liu H, Agam Y, Madsen J, Kreiman G. (2009) Timing, timing, timing: Fast decoding of object inforrmation from intracranial field potentials in human visual cortex. Neuron 62:281-290
- Freeman, J. and E. P. Simoncelli (2011). "Metamers of the ventral stream." Nat Neurosci 14(9): 1195-1201.
- Kobatake, E. and K. Tanaka (1994). "Neuronal selectivities to complex object features in the ventral visual pathway of the macaque cerebral cortex." J Neurophysiol 71(3): 856-867