Visual Object Recognition

Neurobiology 230 – Harvard / GSAS 78454

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

Web site: http://tinyurl.com/vision-class

Dates: Mondays

Time: 3:30 – 5:30 PM

Location: Biolabs 1075

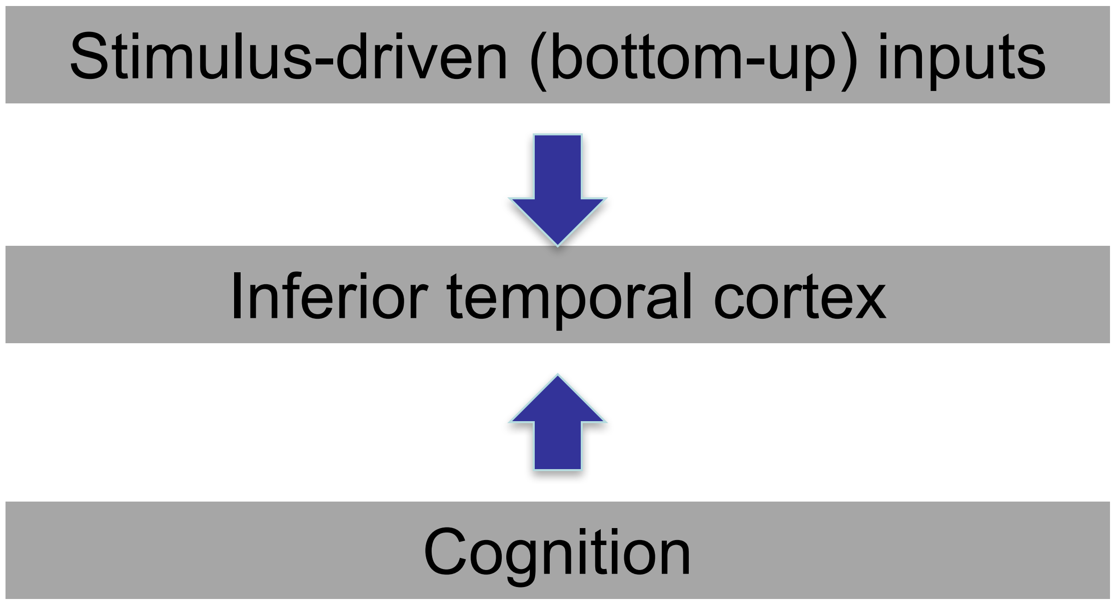
Contact information:

Gabriel Kreiman

gabriel.kreiman@tch.harvard.edu

617-919-2530

Outline


Stimulus-driven (bottom-up) inputs
Inferior temporal cortex
Cognition

Outline

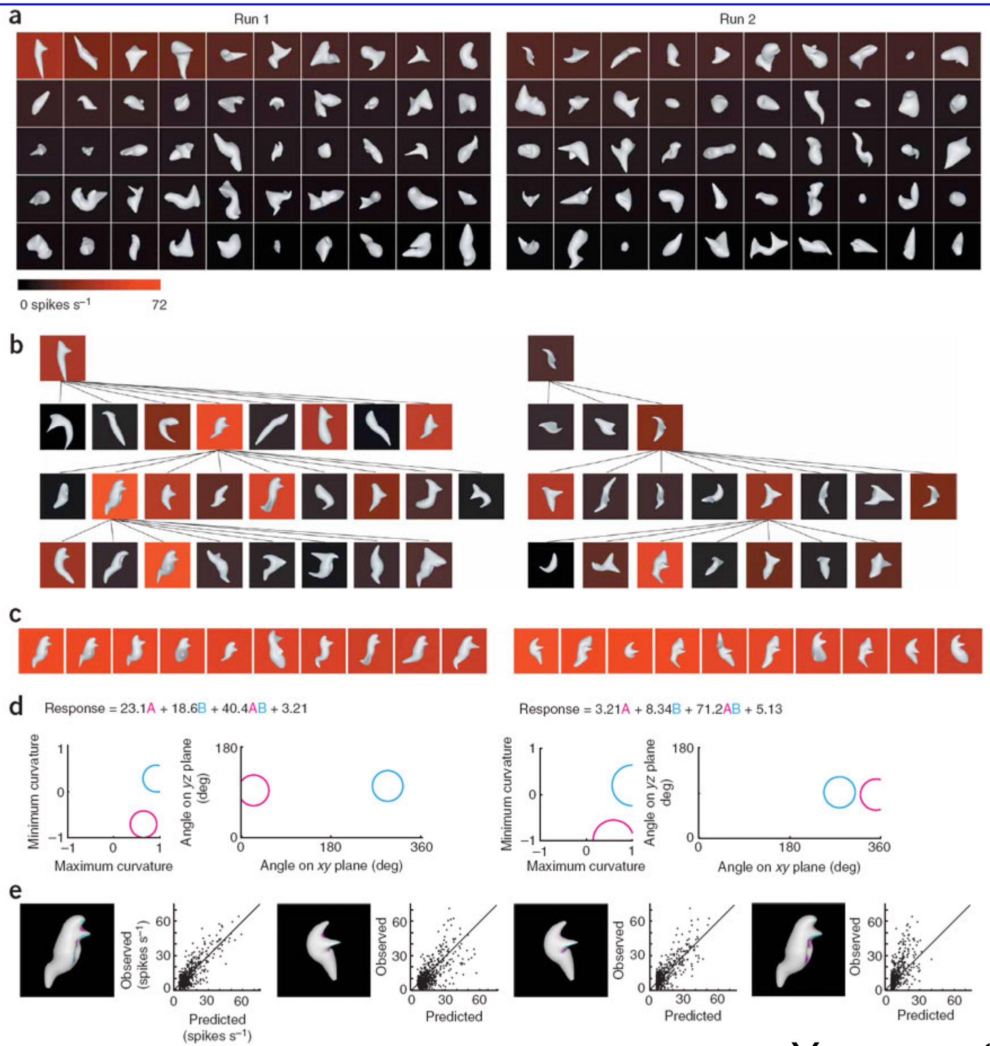
- **Probing high level neural responses**
- Manipulating invariant Inferior Temporal Cortex (ITC) responses
- ITC responses match behavior
- ITC responses are modulated by cognition
- ITC neurons continue to respond in the absence of a stimulus
- Categorization and responses to non-metric stimulus properties

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



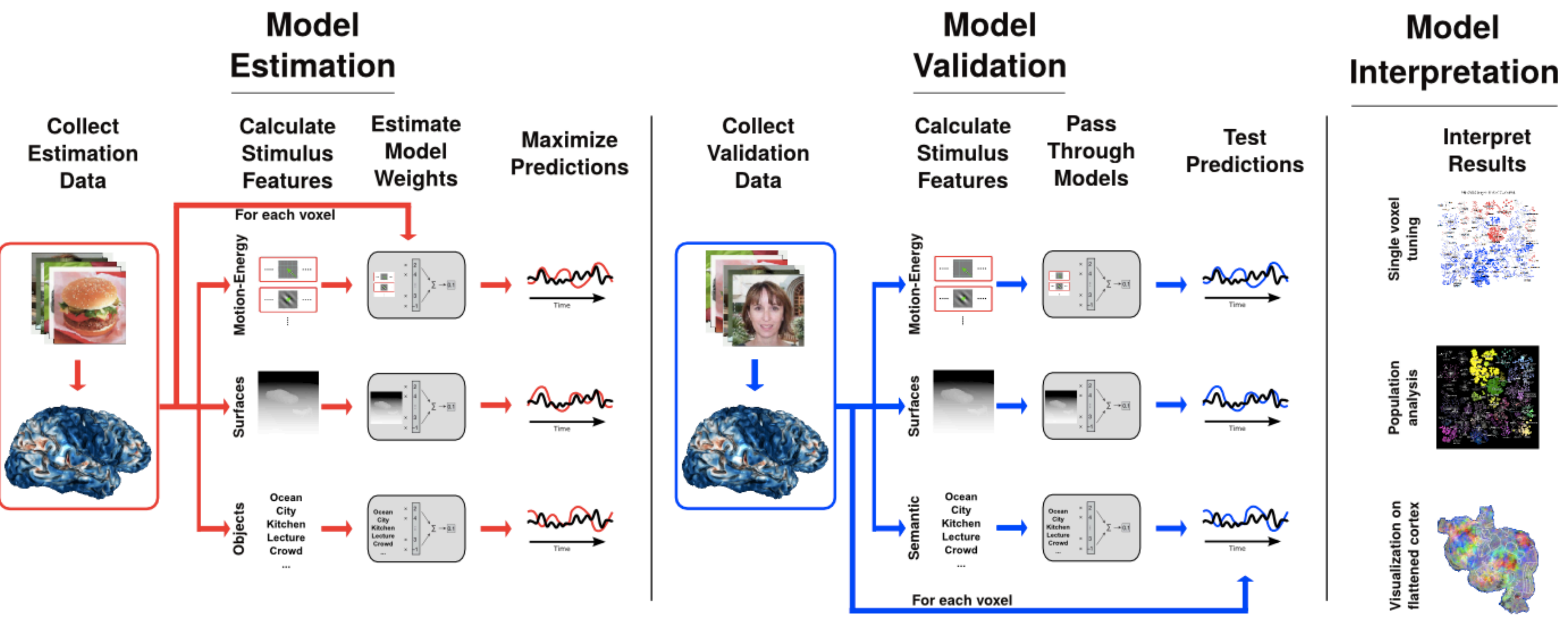
Initial generation (random)

Partial examples across 4 generations

Top 10 stimuli (out of 500

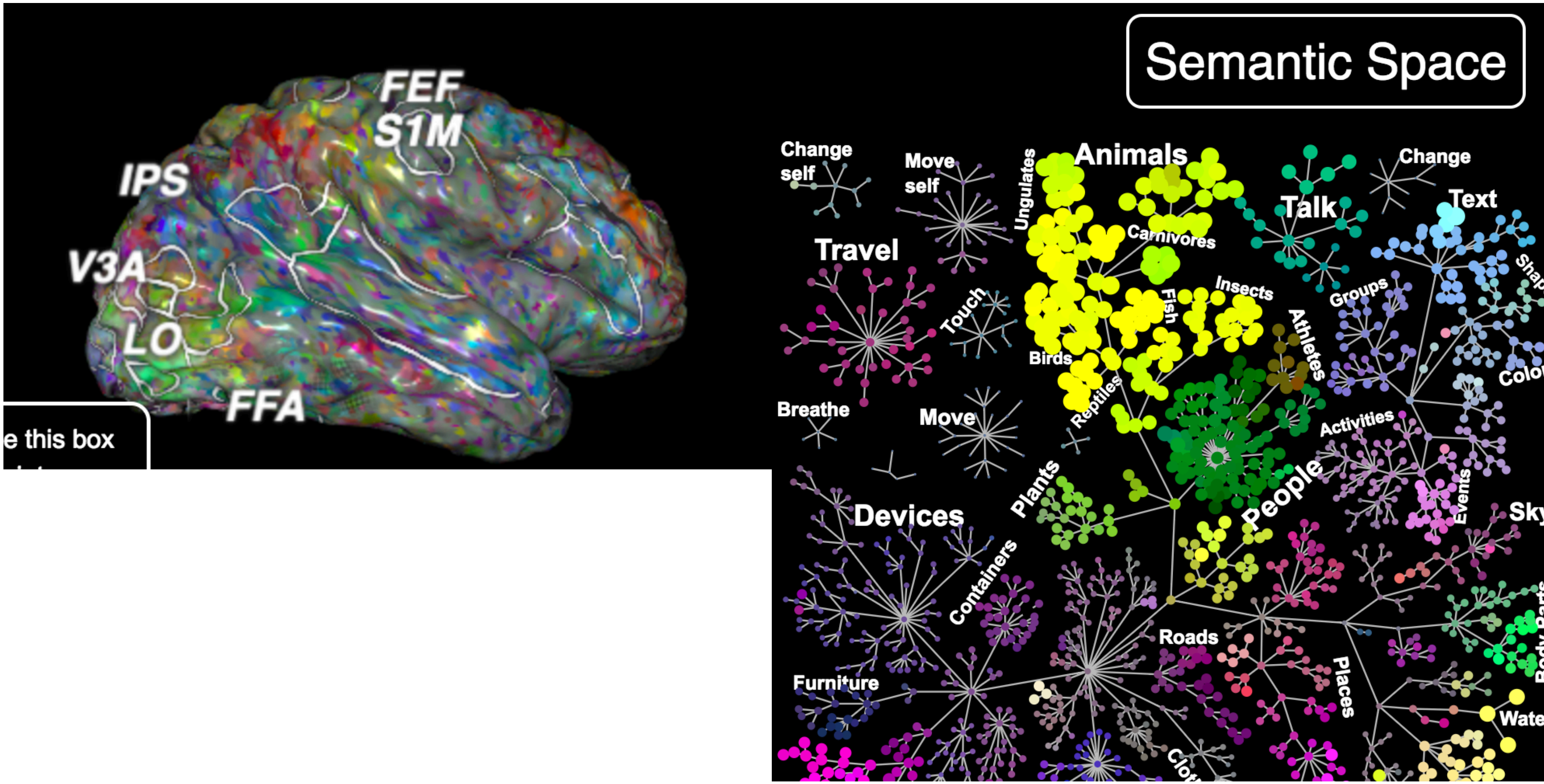
Yamane et al Nature Neuroscience 2008

Using natural movies to probe neural visual responses

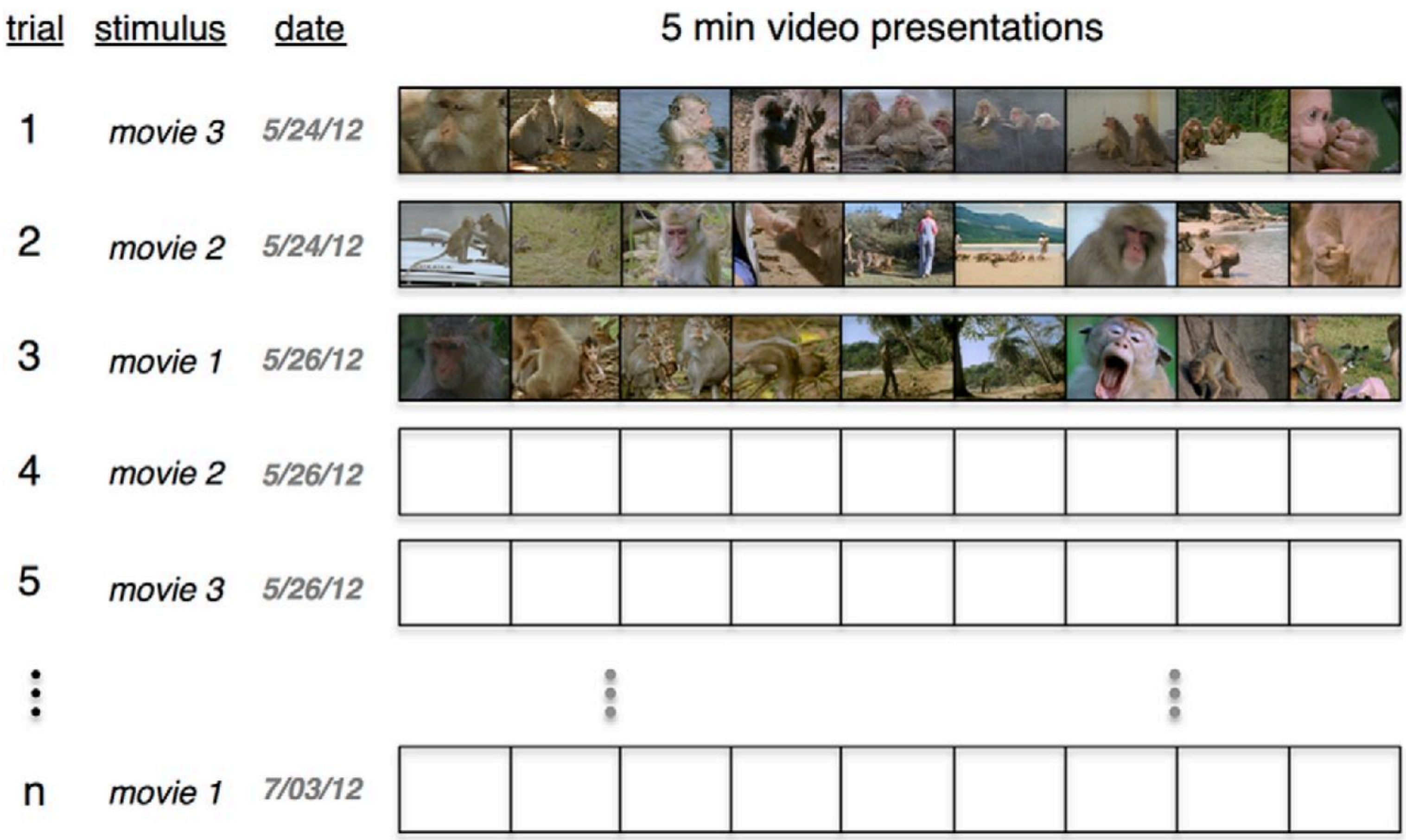


Huth et al., Neuron 2012

Using natural movies to probe neural visual responses

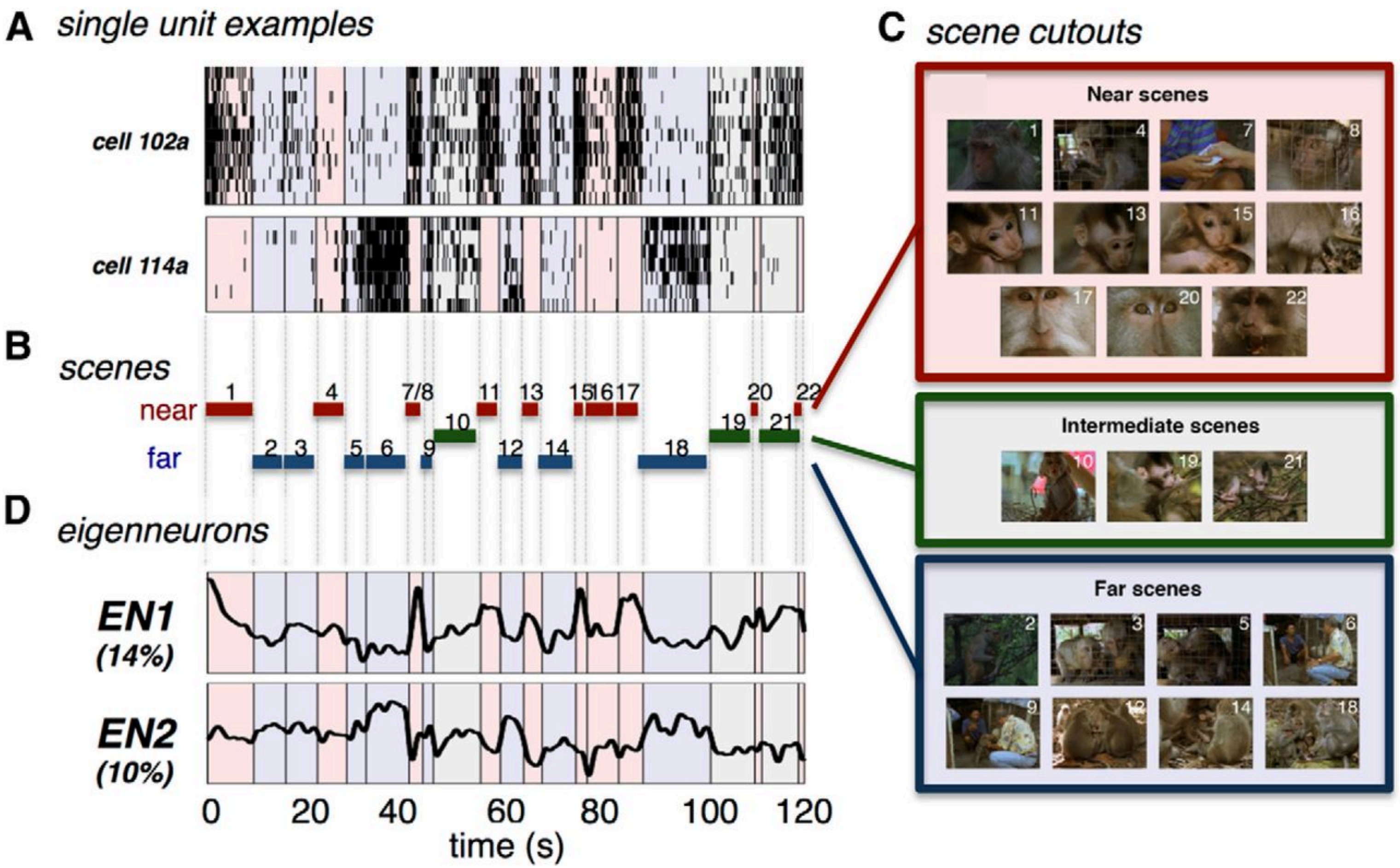


Using natural movies to probe neural visual responses



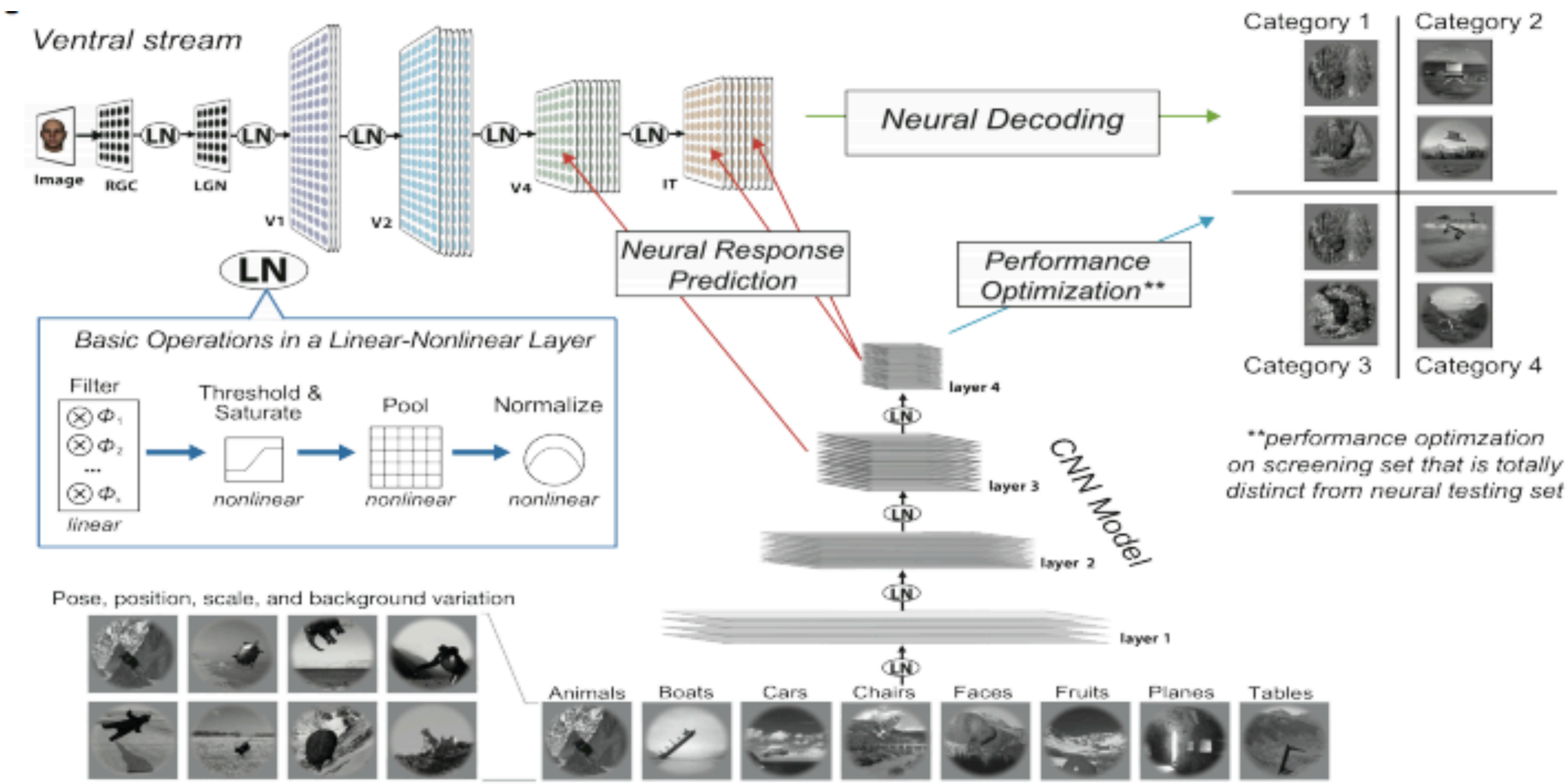
McMahon et al., J. Neurosci 2015

Using natural movies to probe neural visual responses



McMahon et al., J. Neurosci 2015

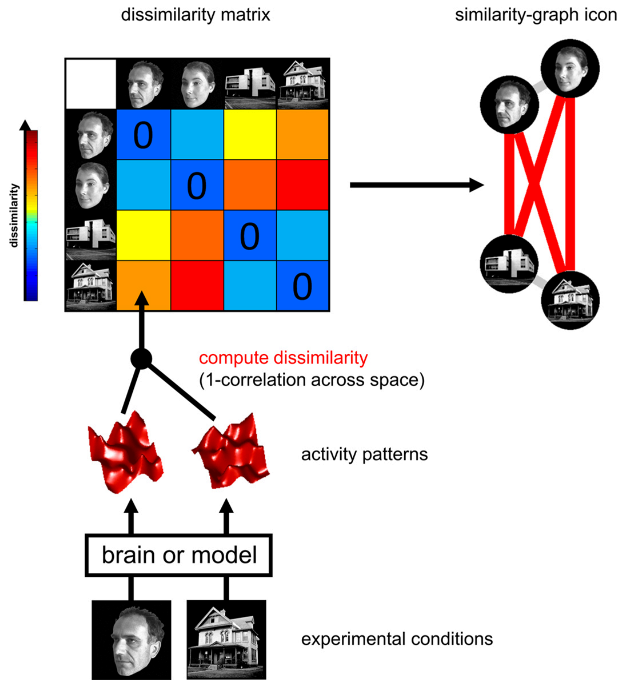
Analyzing neural responses with computational models

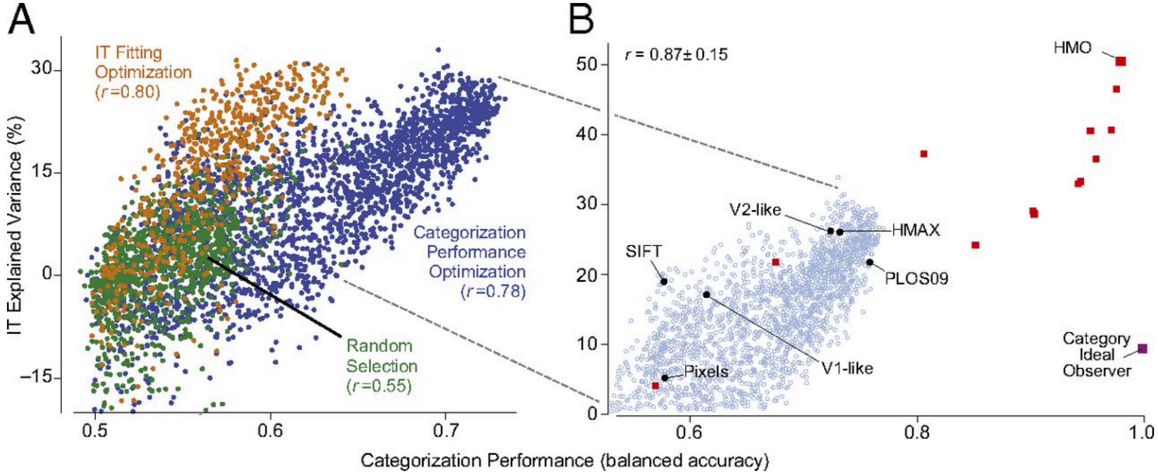


Yamins et al., 2014

Analyzing neural responses with computational models

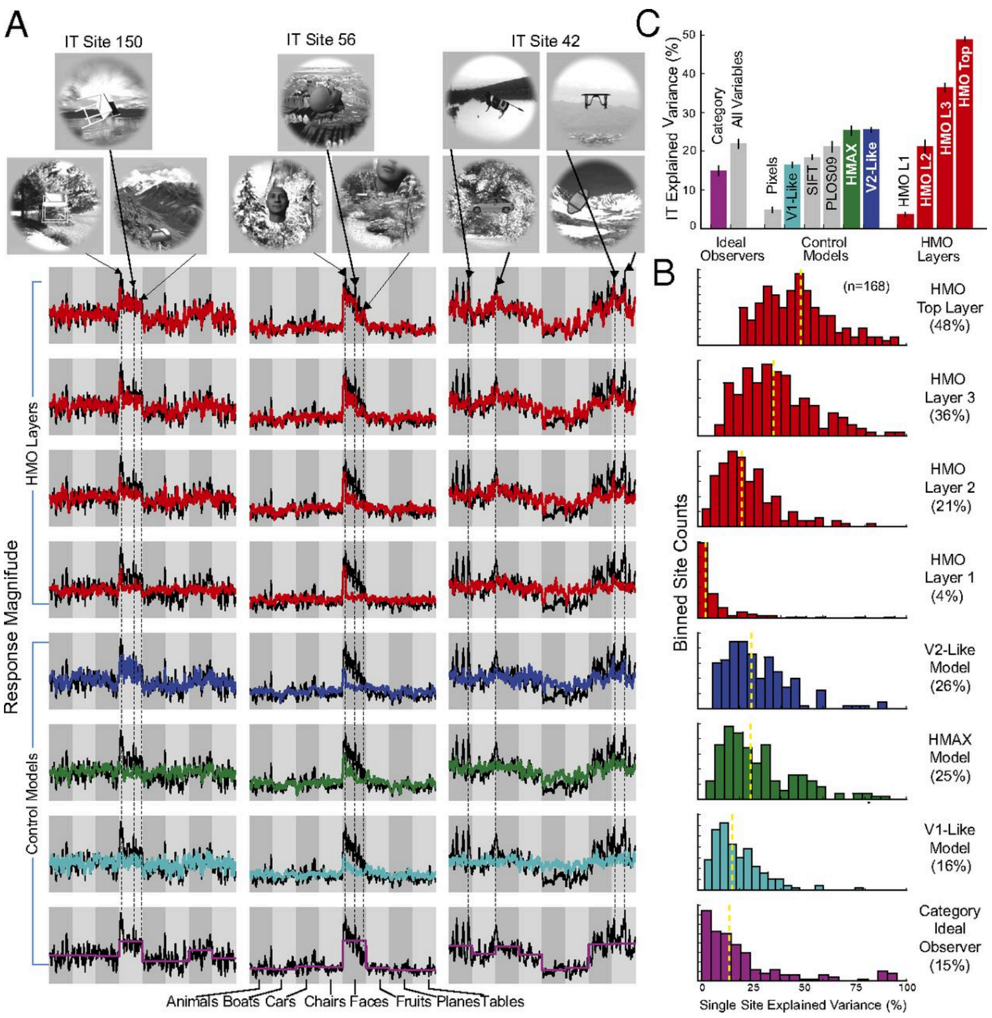
- Model matching as a tool to interpret neural responses.





Kreigeskorte et al., 2008
Yamins et al., 2014

Analyzing neural responses with computational models



Yamins et al., 2014

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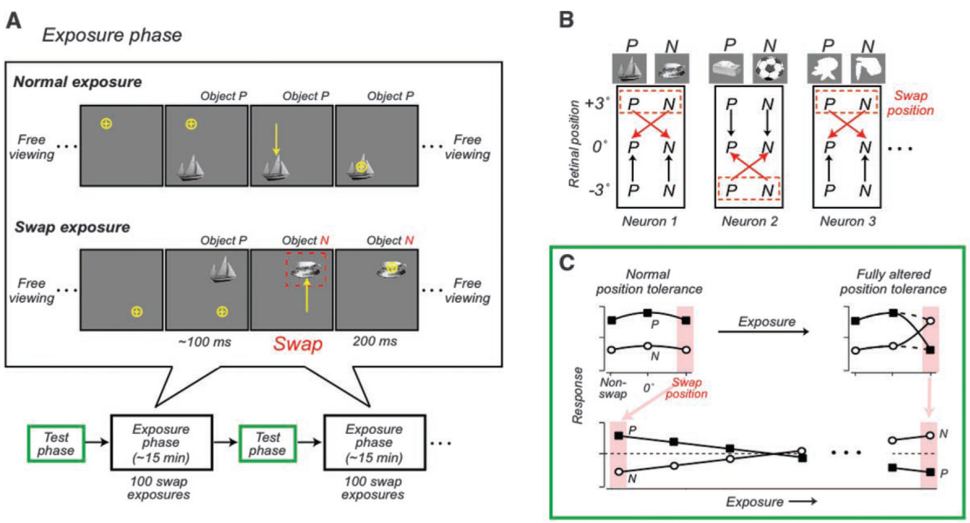
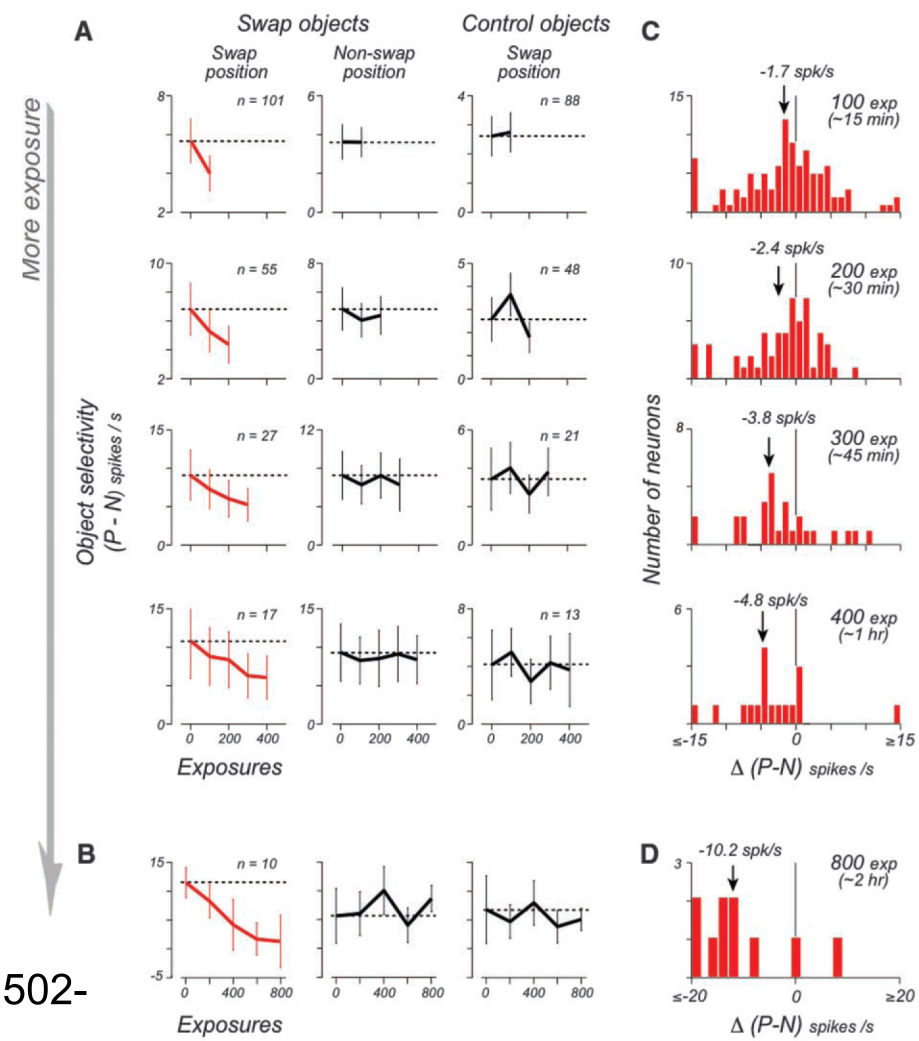
Training can rapidly alter neuronal responses





Li, N., & Dicarlo, J. J. (2008). Science, 321(5895), 1502-1507.

Neural responses can be stable over days

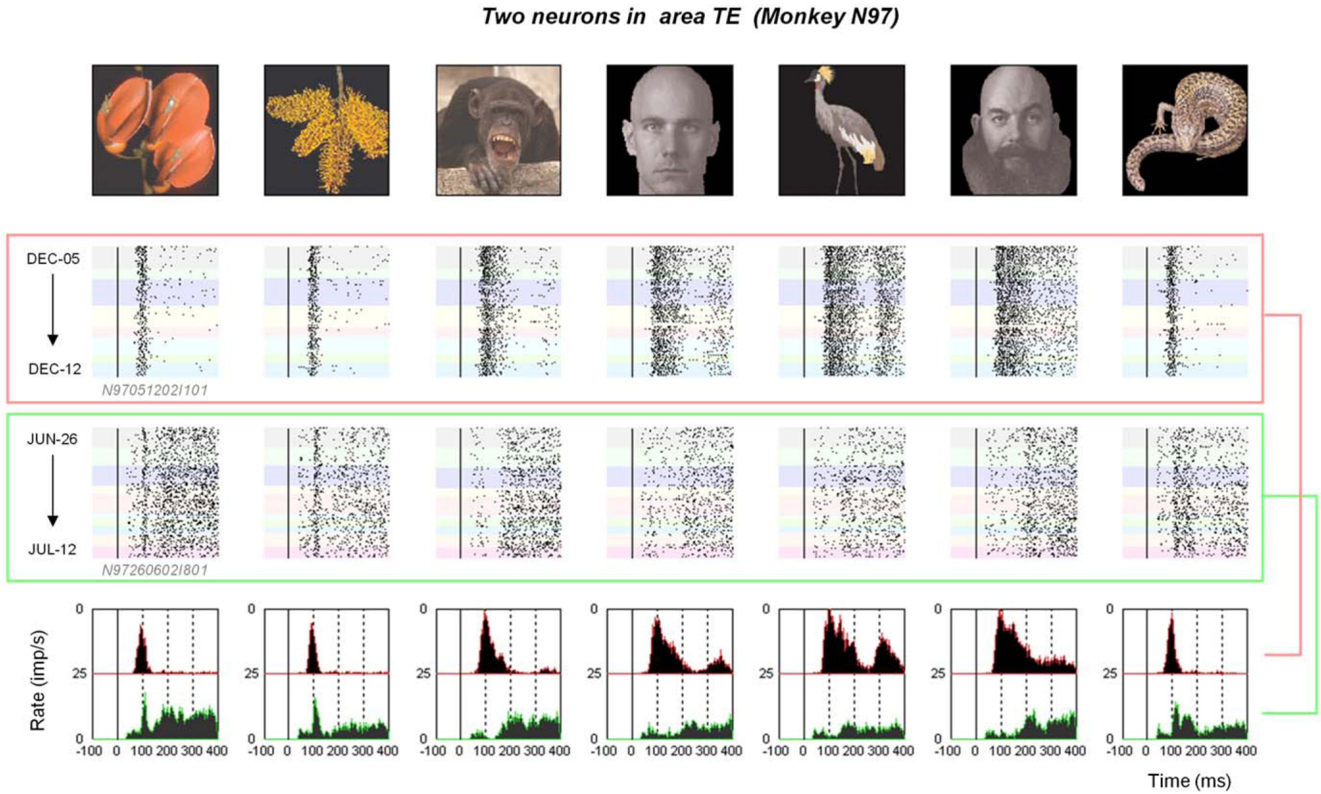


Figure 1. Single unit responses in area TE. Data are shown from two neurons from monkey N97. The two neurons were recorded on two different microwires (channels of electrodes bundle marked as I1 and I8) and during two different time periods. Directly below each image, the action potential responses are 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.

Bondar, I., et al. (2009). "Long-term stability of visual pattern selective responses of monkey temporal lobe neurons " PLoS One **9**(12).

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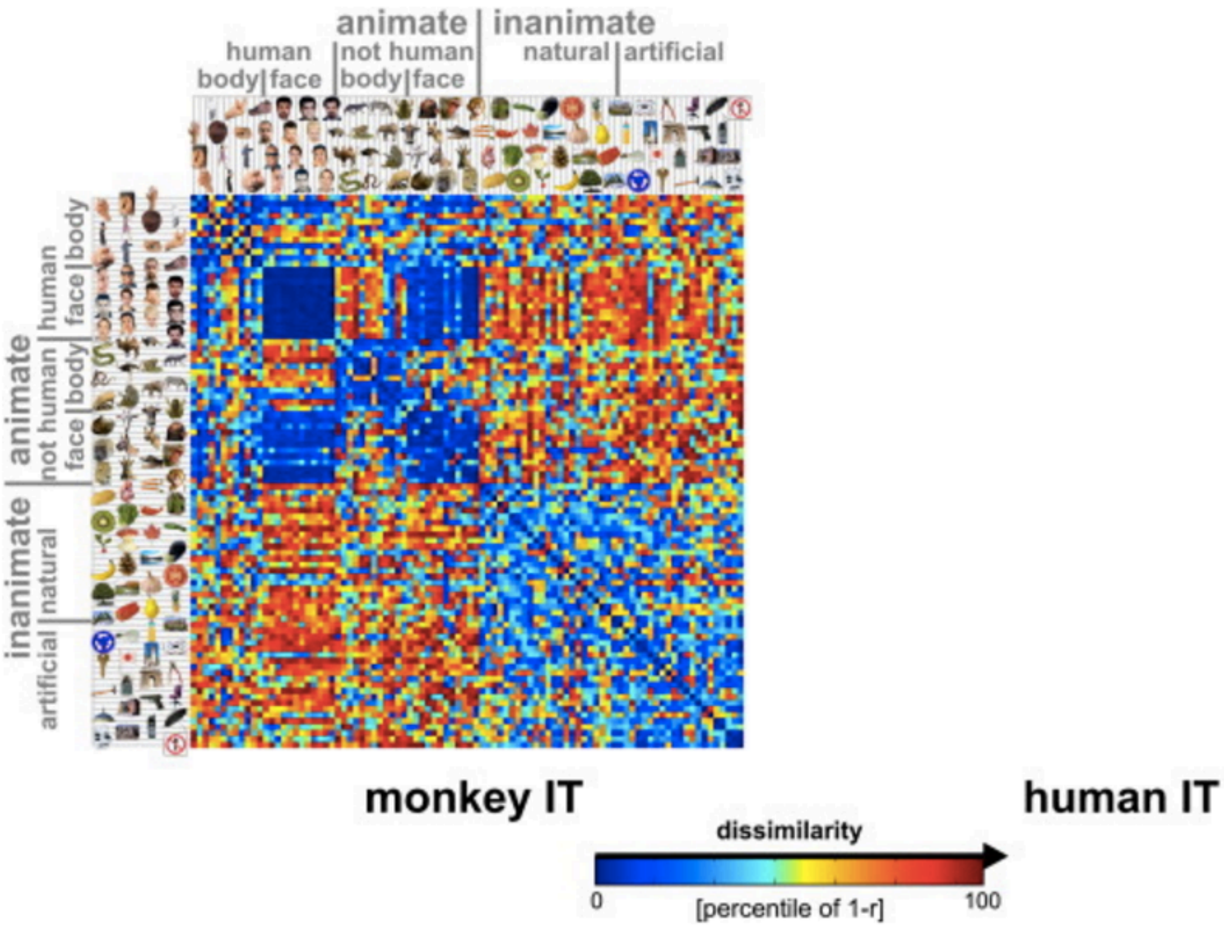
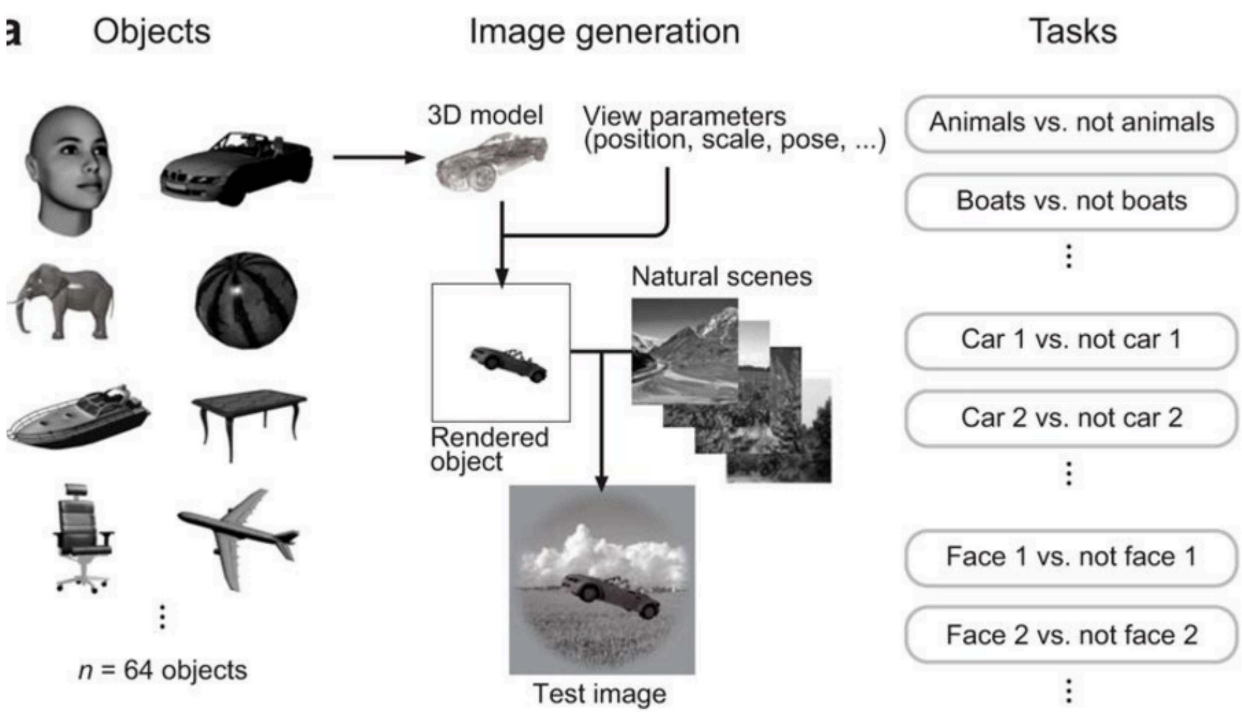
Matching category responses of man and monkey



Kriegeskorte et al., Neuron, 2008

IT population activity accurately predicts human object recognition performance



Majaj et al., J. Neurosci., 2015

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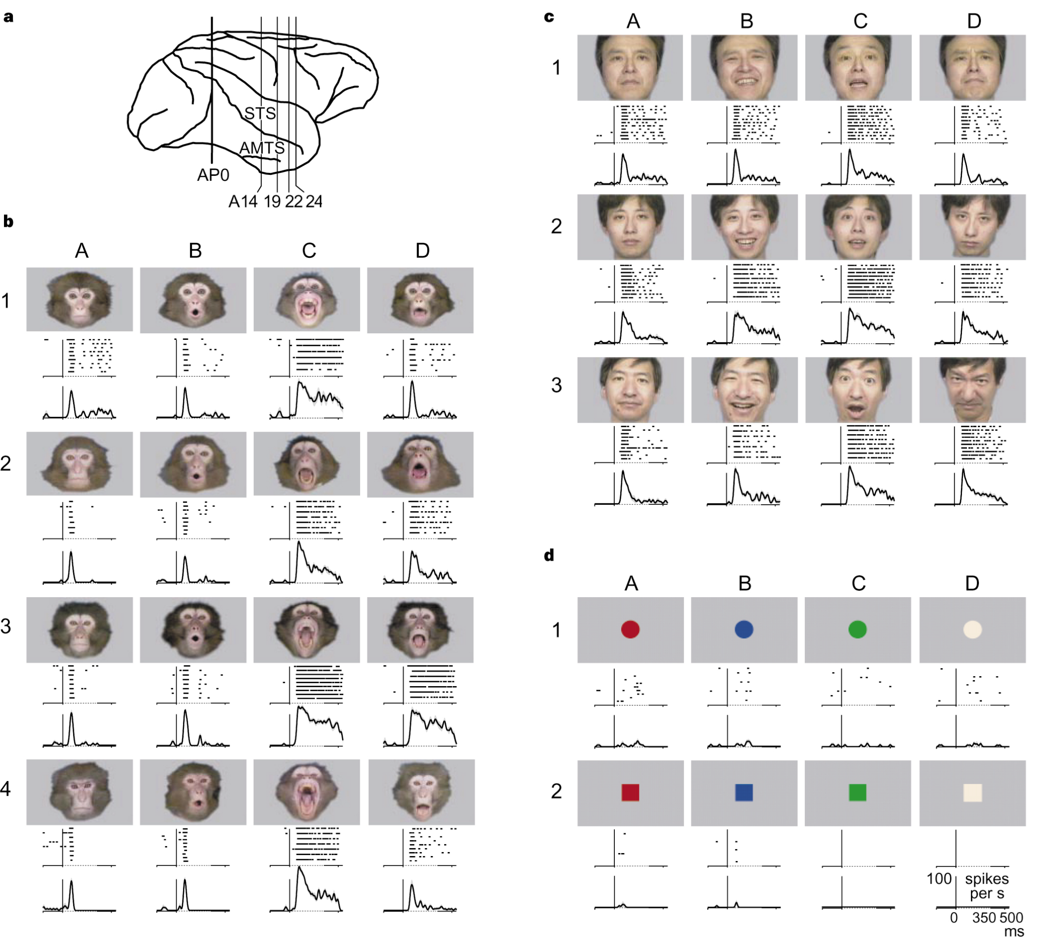
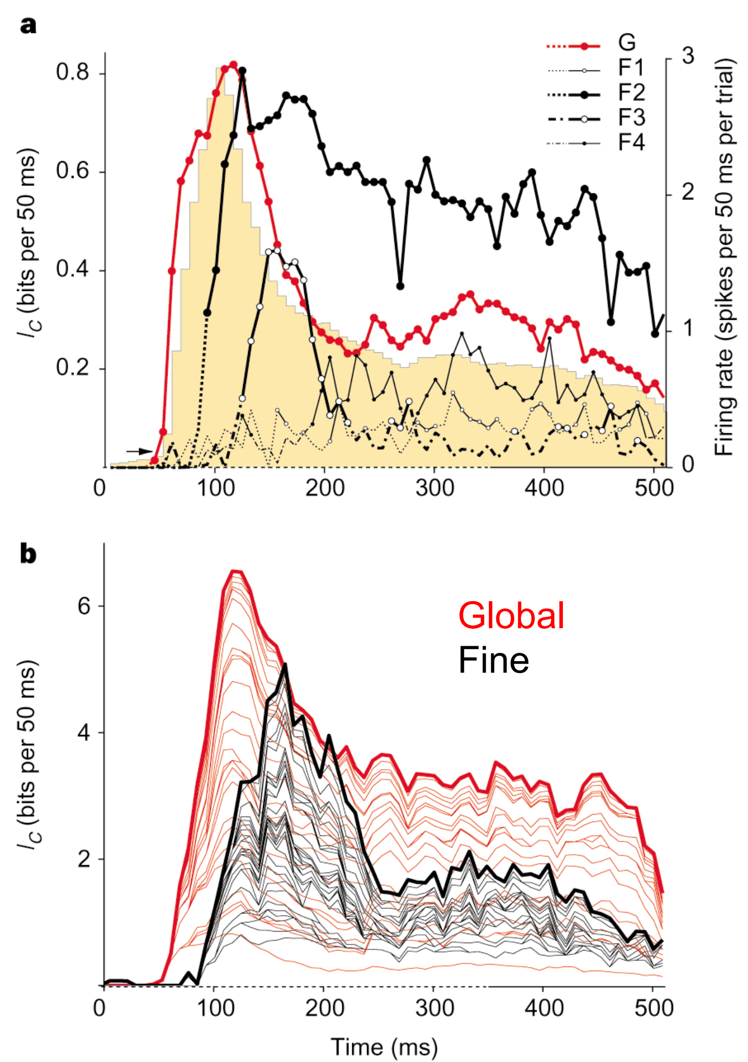
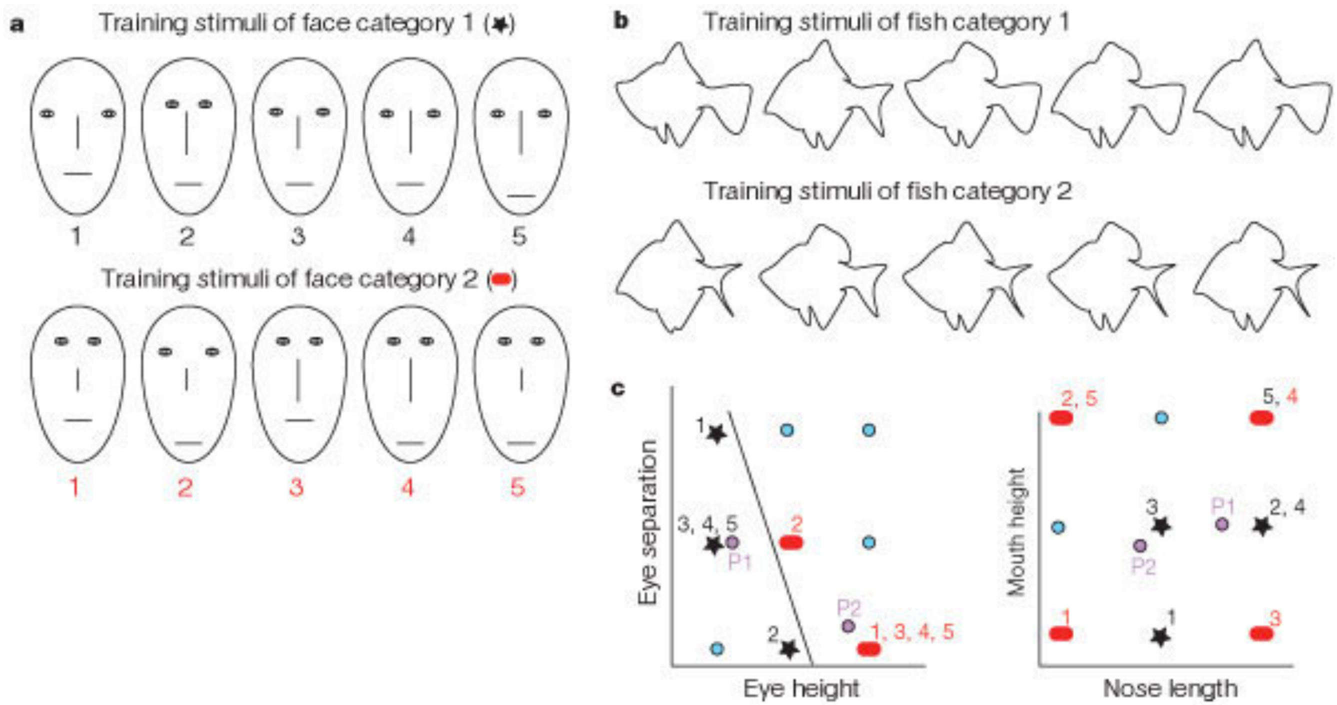
Response latencies depend on stimuli/questions

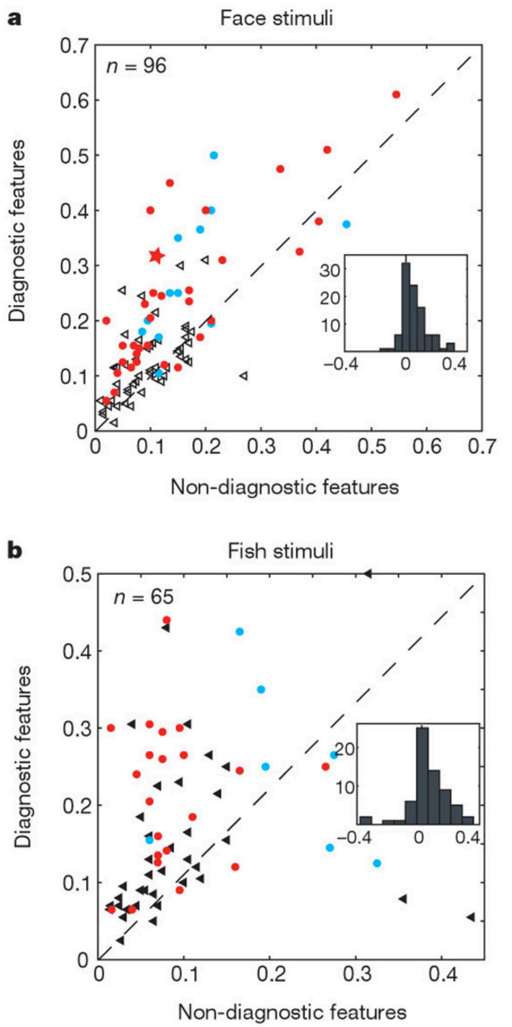




Sugase et al Nature 1999

Neuronal activity in ITC can be modulated by tasks





Sigala et al 2002

Neuronal activity in ITC can be modulated by tasks

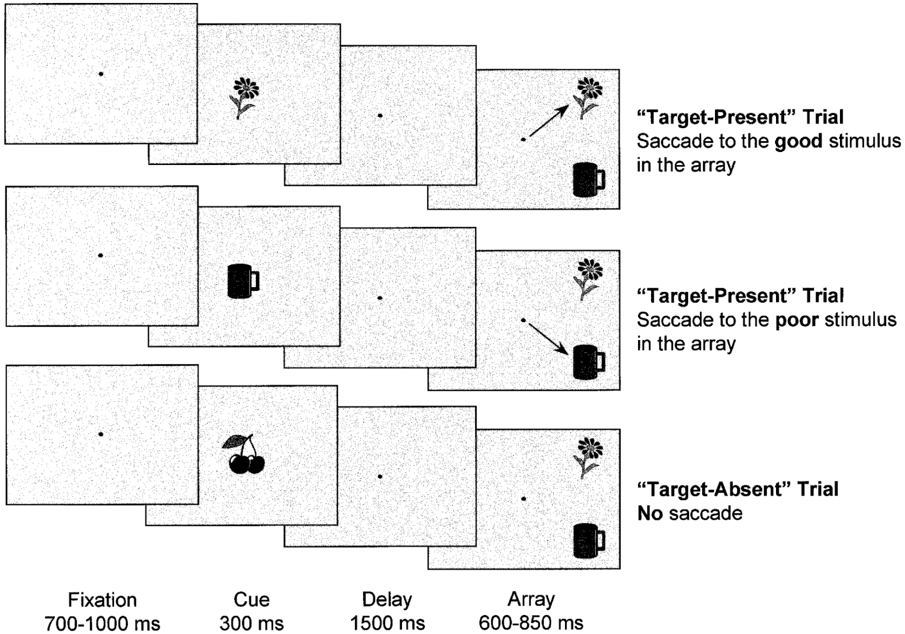
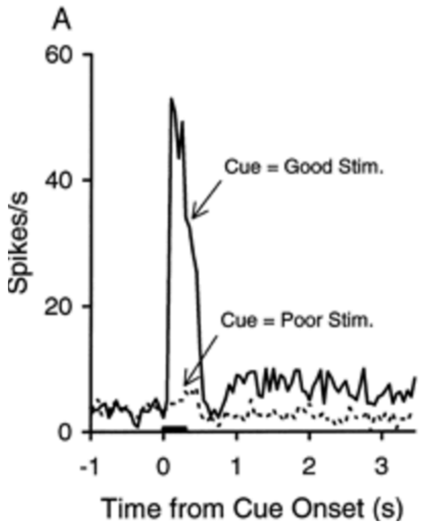
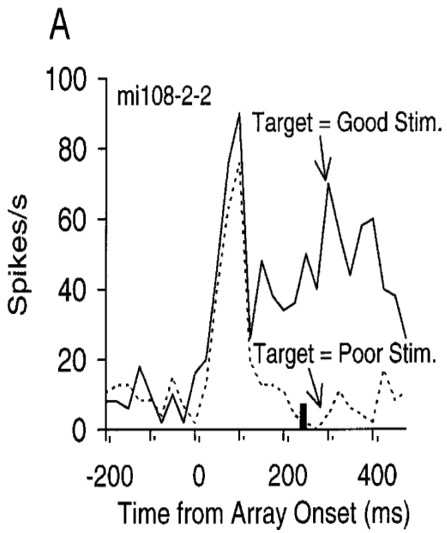


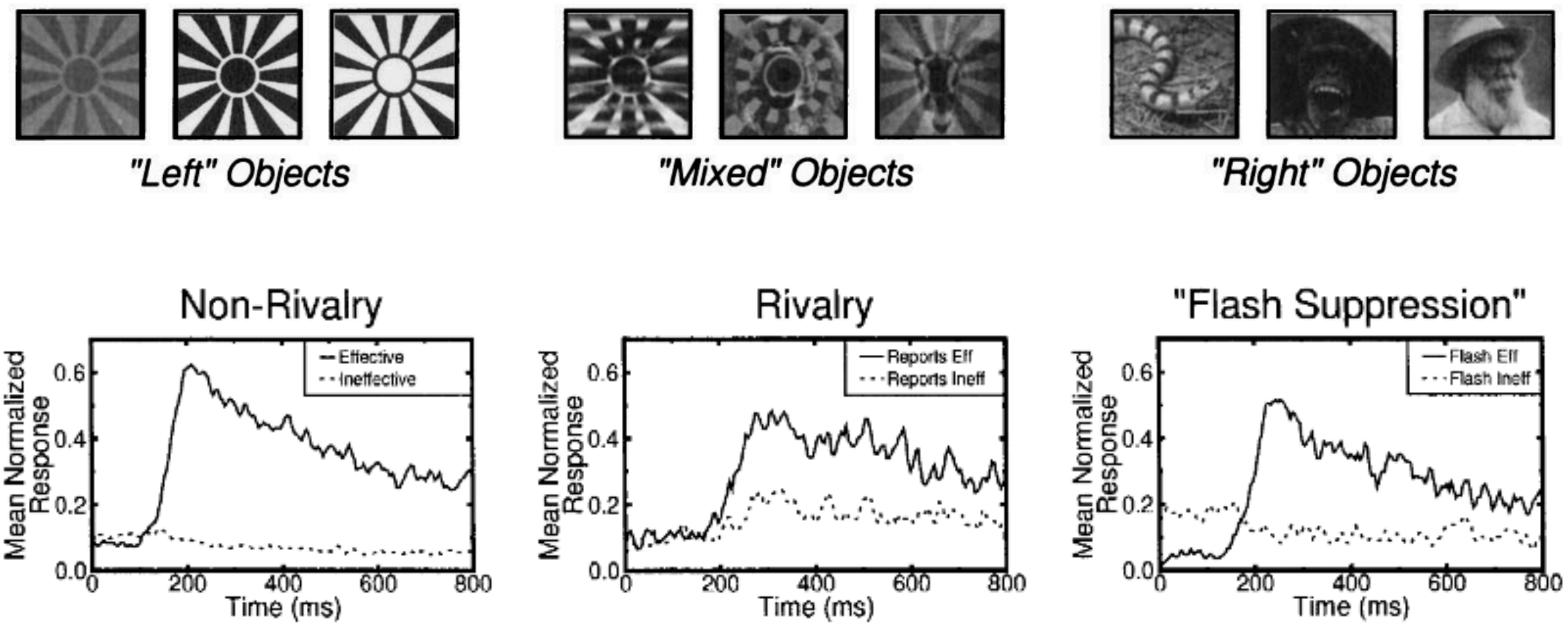
FIG. 1. Stimulus sequences for representative trials in the task with 2-stimulus arrays, with the array confined to the hemifield contralateral to the recording site.





Chelazzi et al 1998

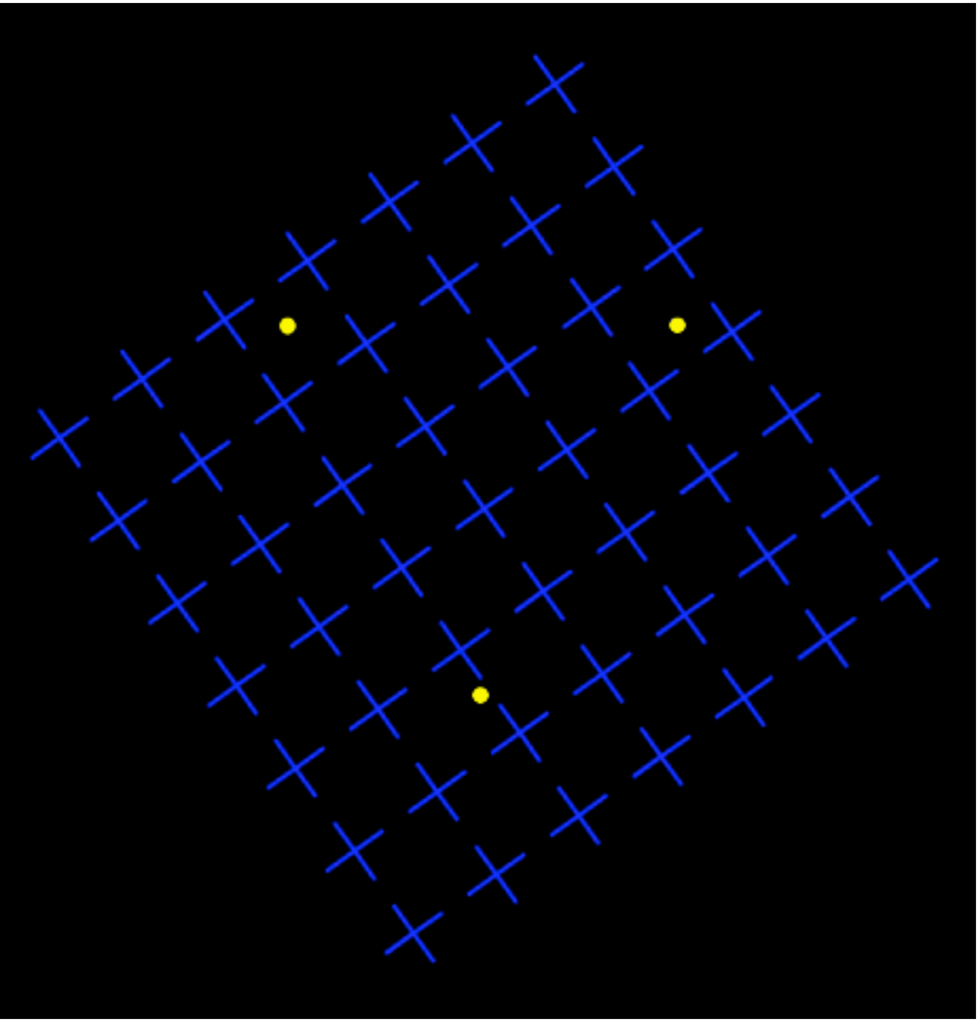
Neural responses can reflect perception

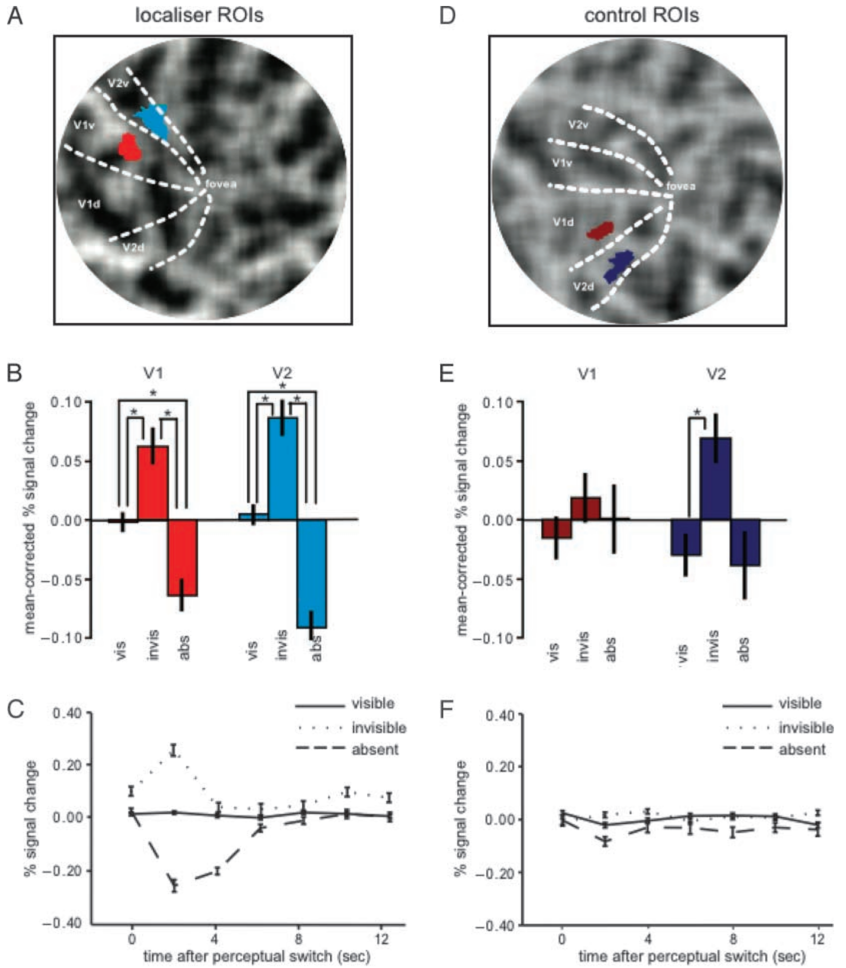


Here, shown with binocular rivalry and flash suppression

Sheinberg DL and Logothetis NK, PNAS 94:3409-3413, 1997

Neural responses can reflect perception

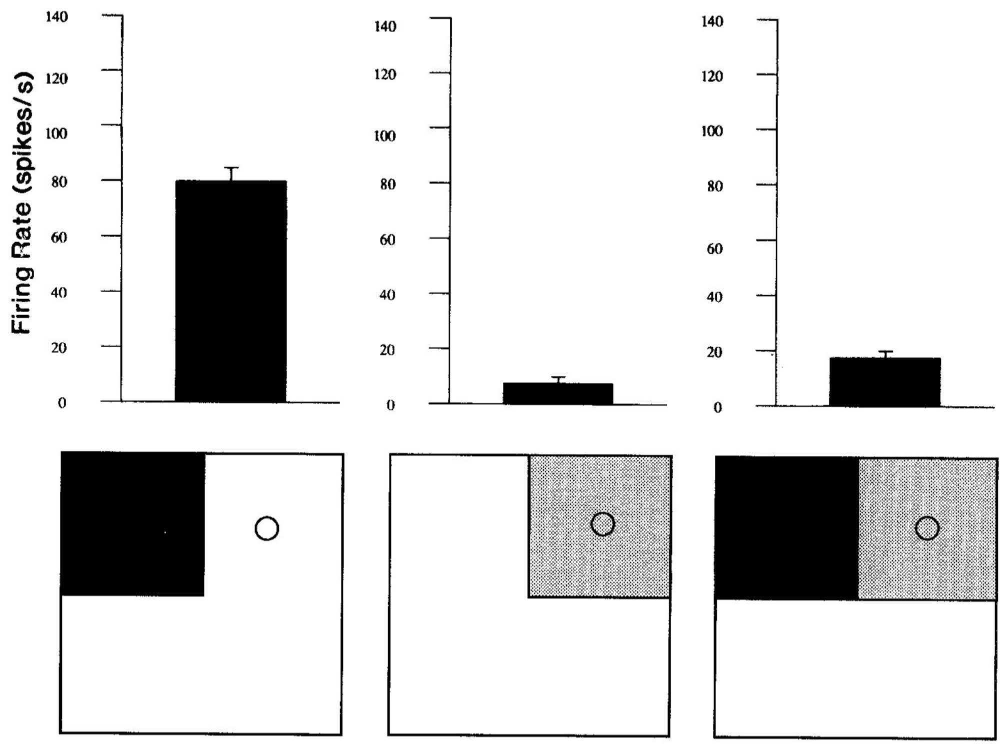




Schölvinck and Rees, J Cog Neuro 22: 1235-1243 (2009)

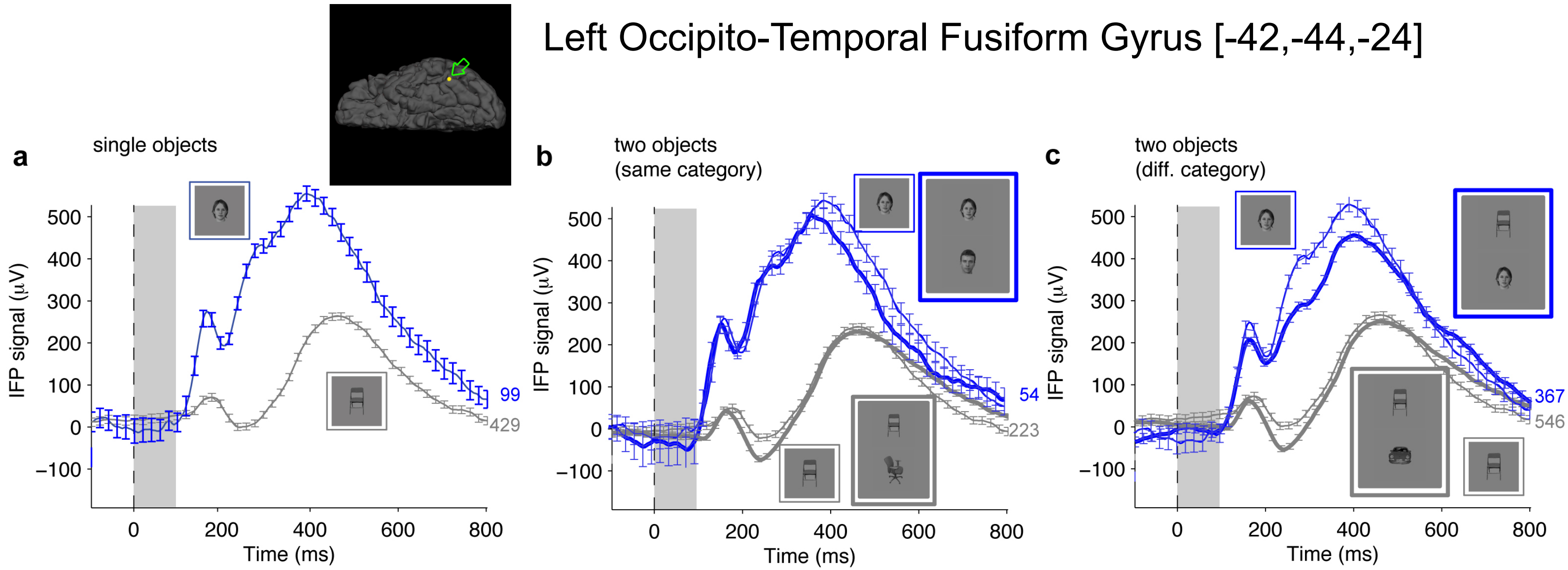
Clutter reduces neural responses

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 centre 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



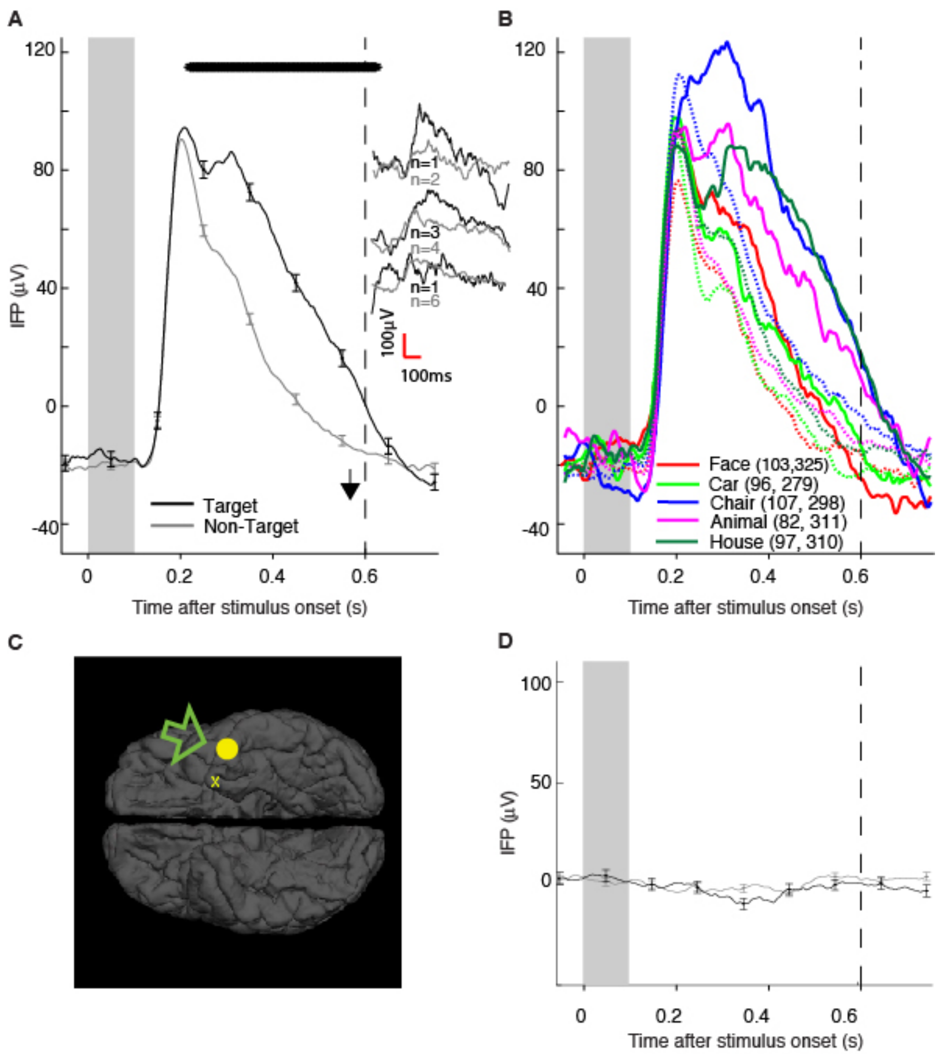
Rolls, E.T., and Tovee, M.J. (1995). Exp Brain Res 103, 409-420.

And yet the problem of clutter can be resolved at the population level



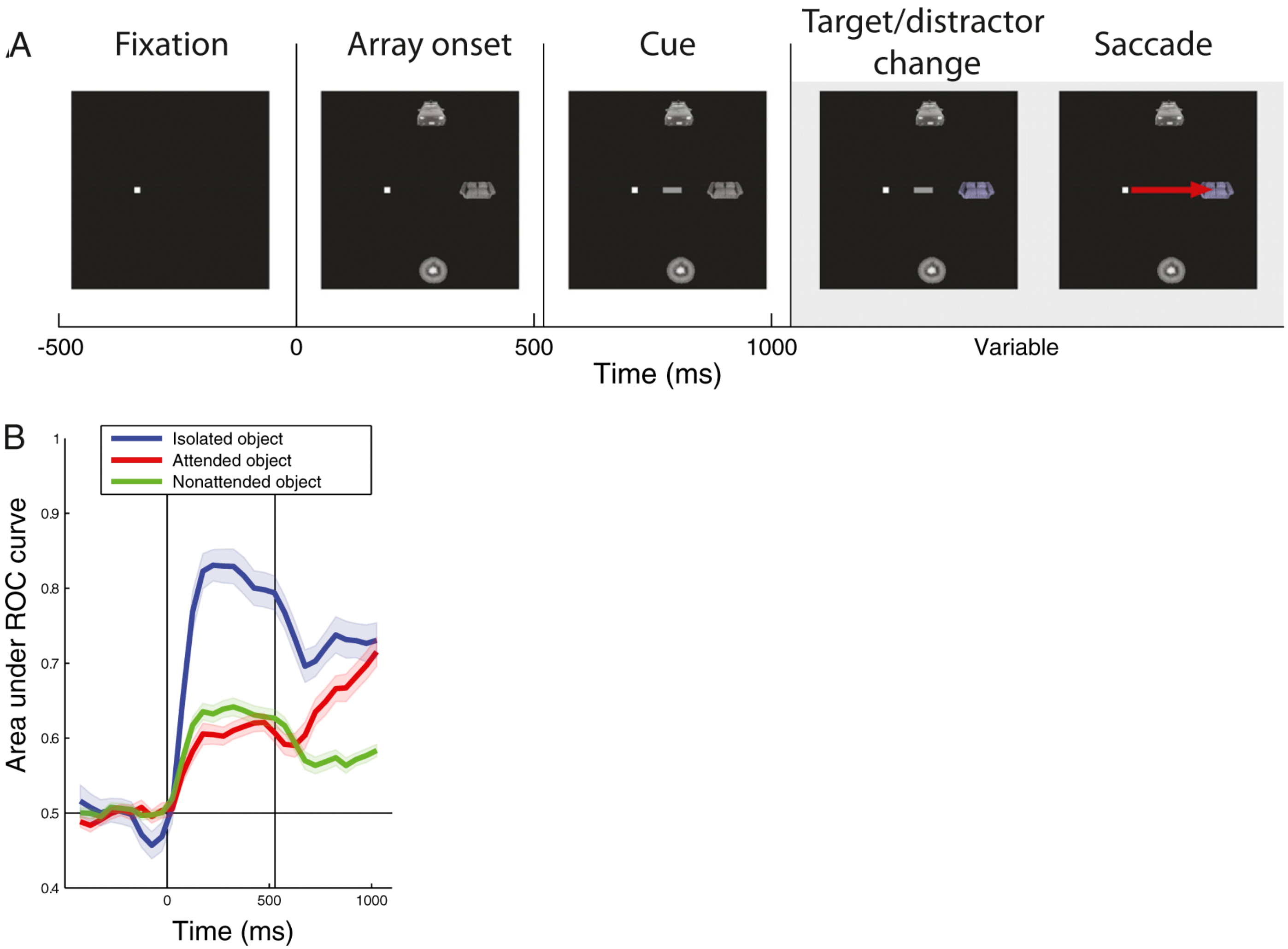
Agam et al. Current Biology 2010

Target detection modulates responses in human ventral visual system



Bansal *et al*

Attentional modulation in ITC



Zhang et al 2011

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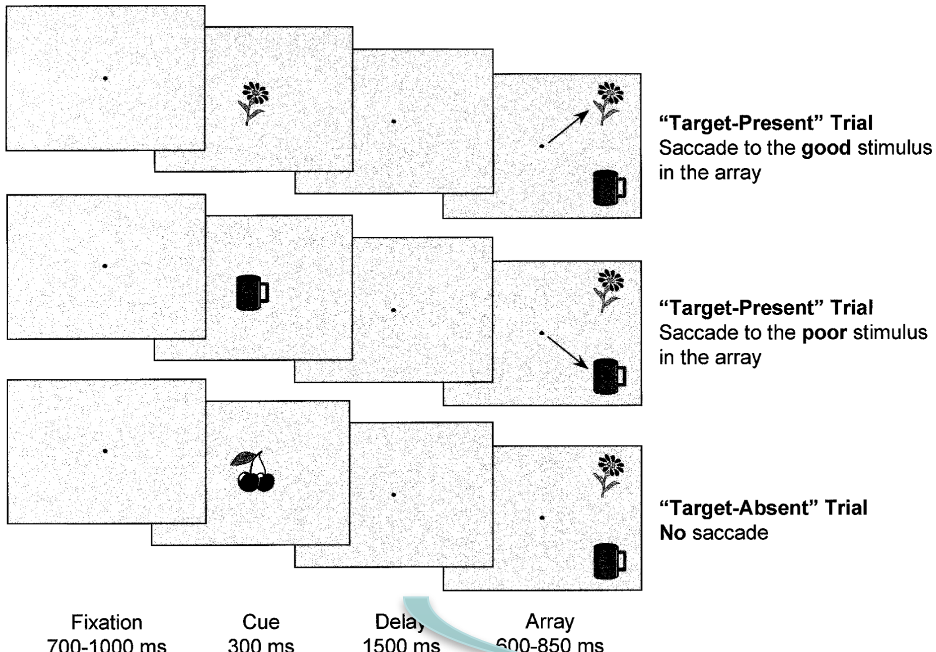
Neuronal responses in ITC persist during DMTS task



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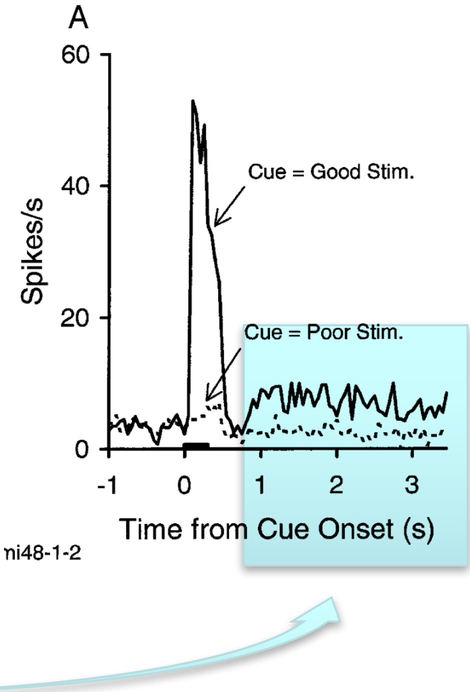
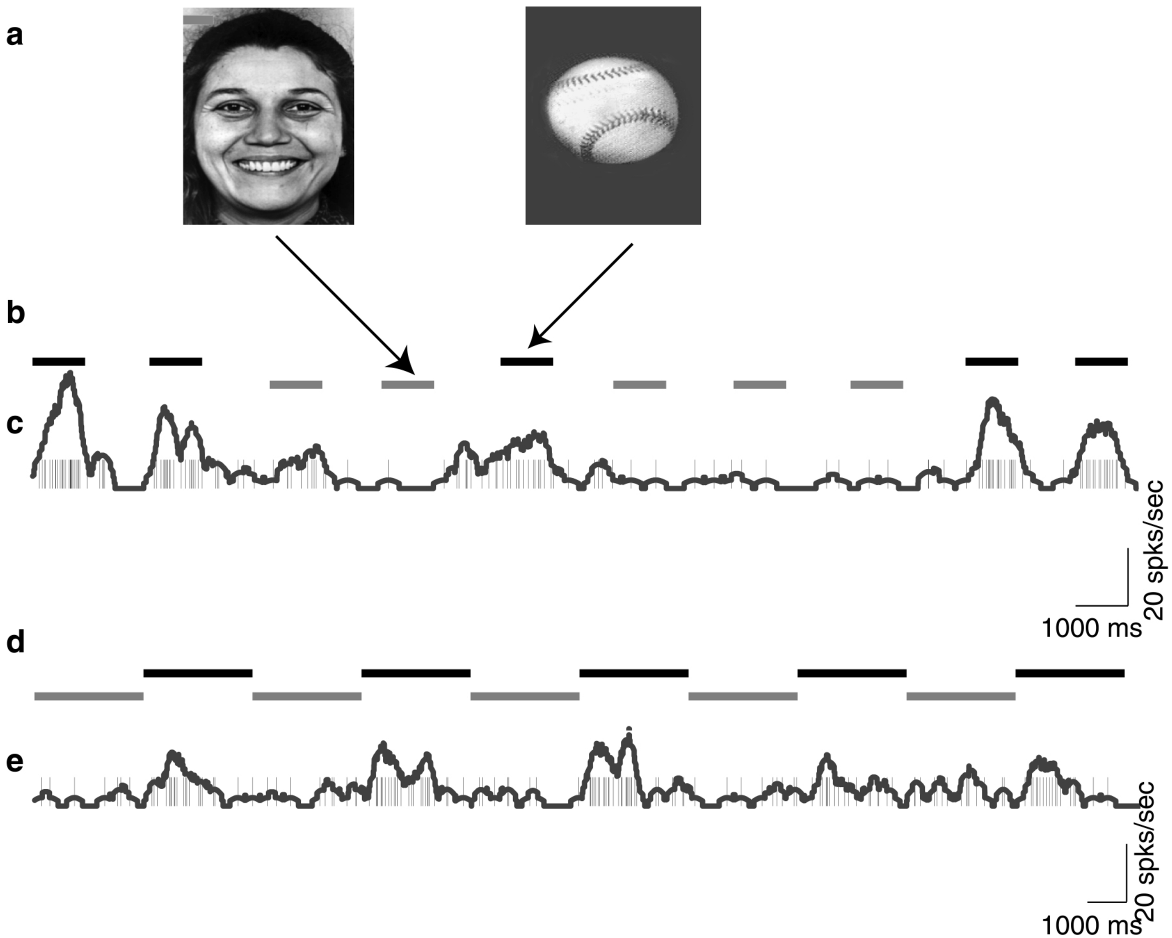


Chelazzi, L., Duncan, J., Miller, E.K., and Desimone, R. (1998). J. Neurophysiology 80, 2918-2940.

Selective responses during visual imagery in the human brain

Vision

Imagery



Kreiman et al. Nature 2000

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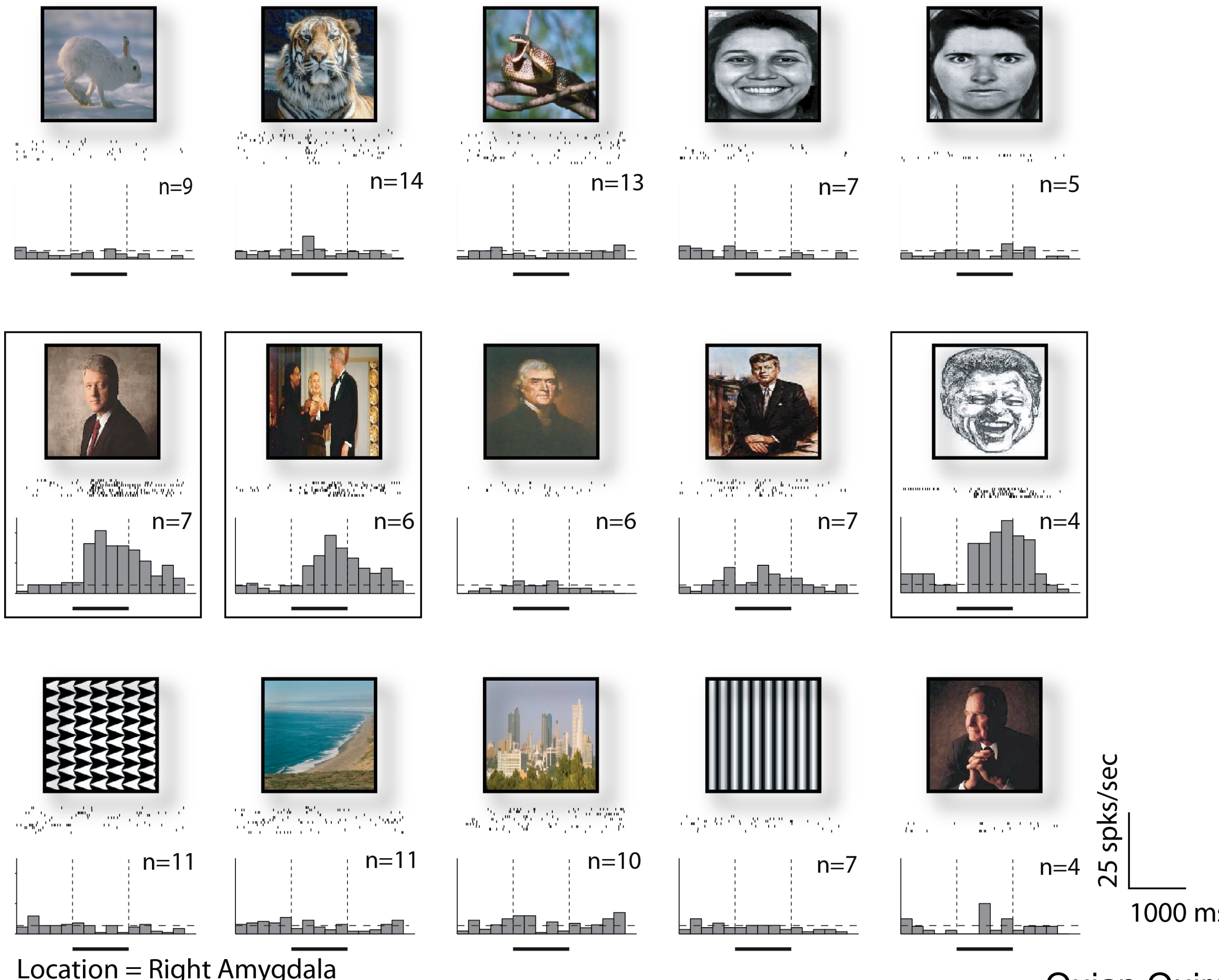
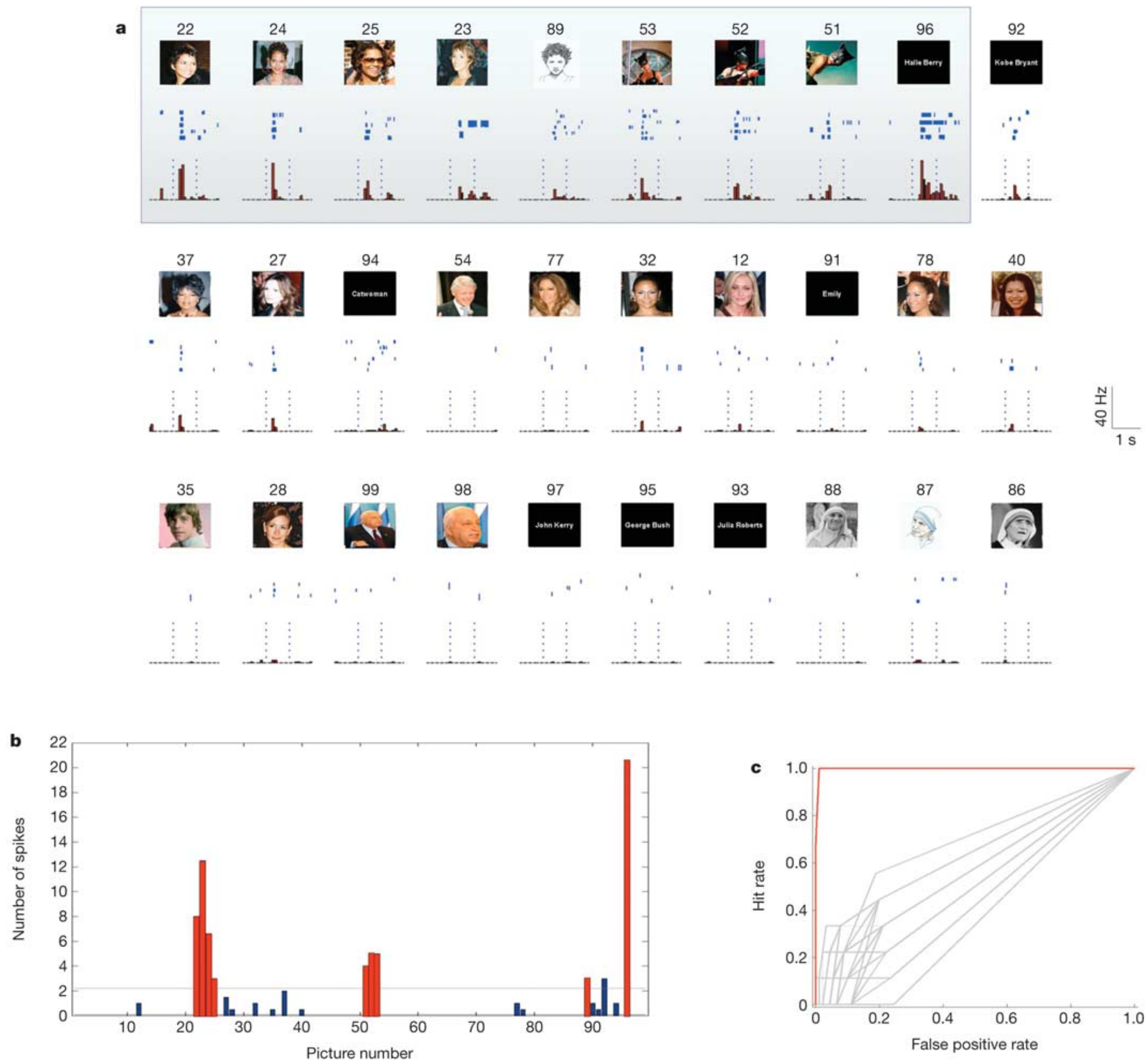
Selectivity and tolerance beyond ITC in humans



Quian Quiroga et al 2005

Selectivity and tolerance beyond ITC in humans

Microwire location:
right amygdala



Quian Quiroga et al 2005

Categorical responses in the macaque pre-frontal cortex

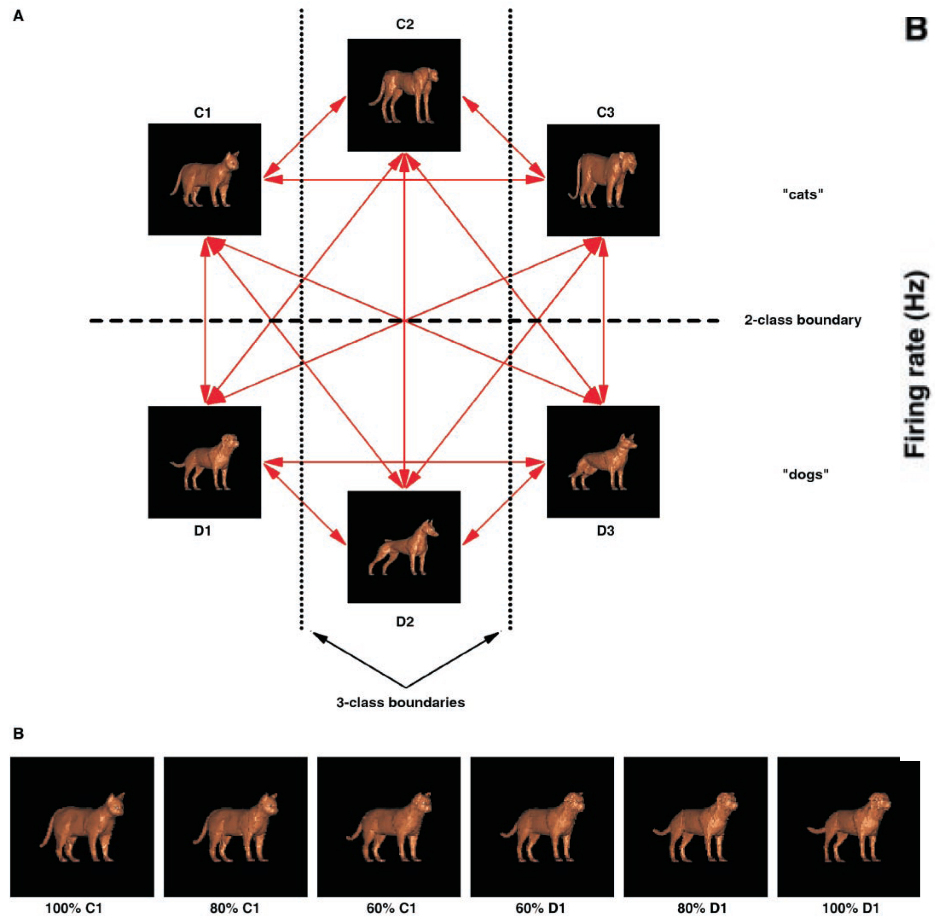
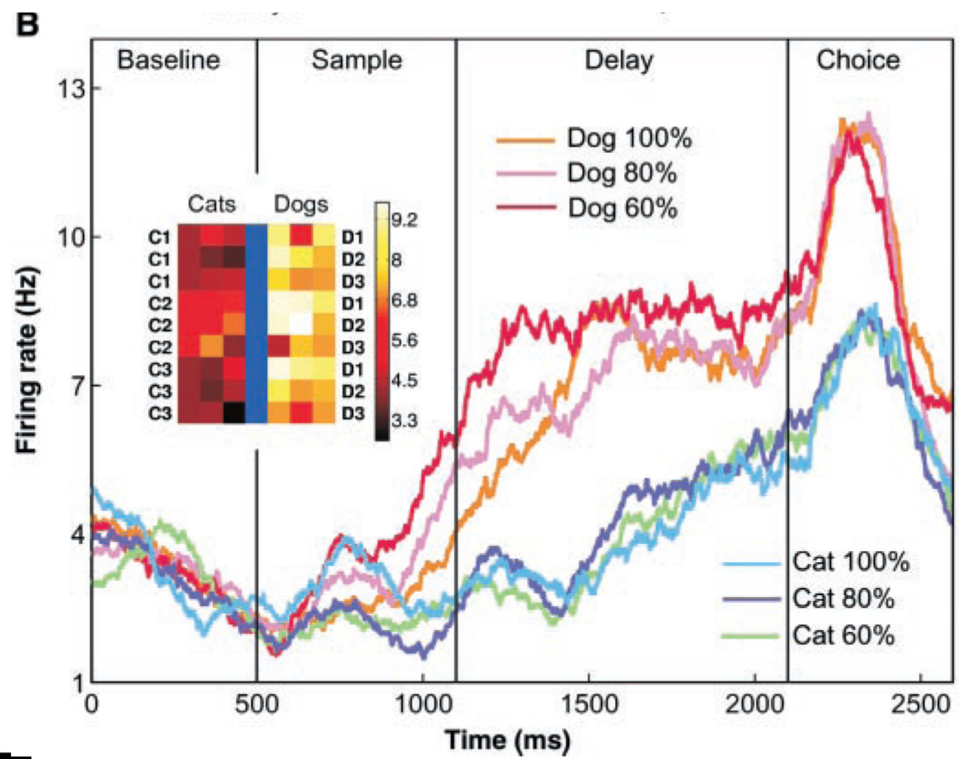
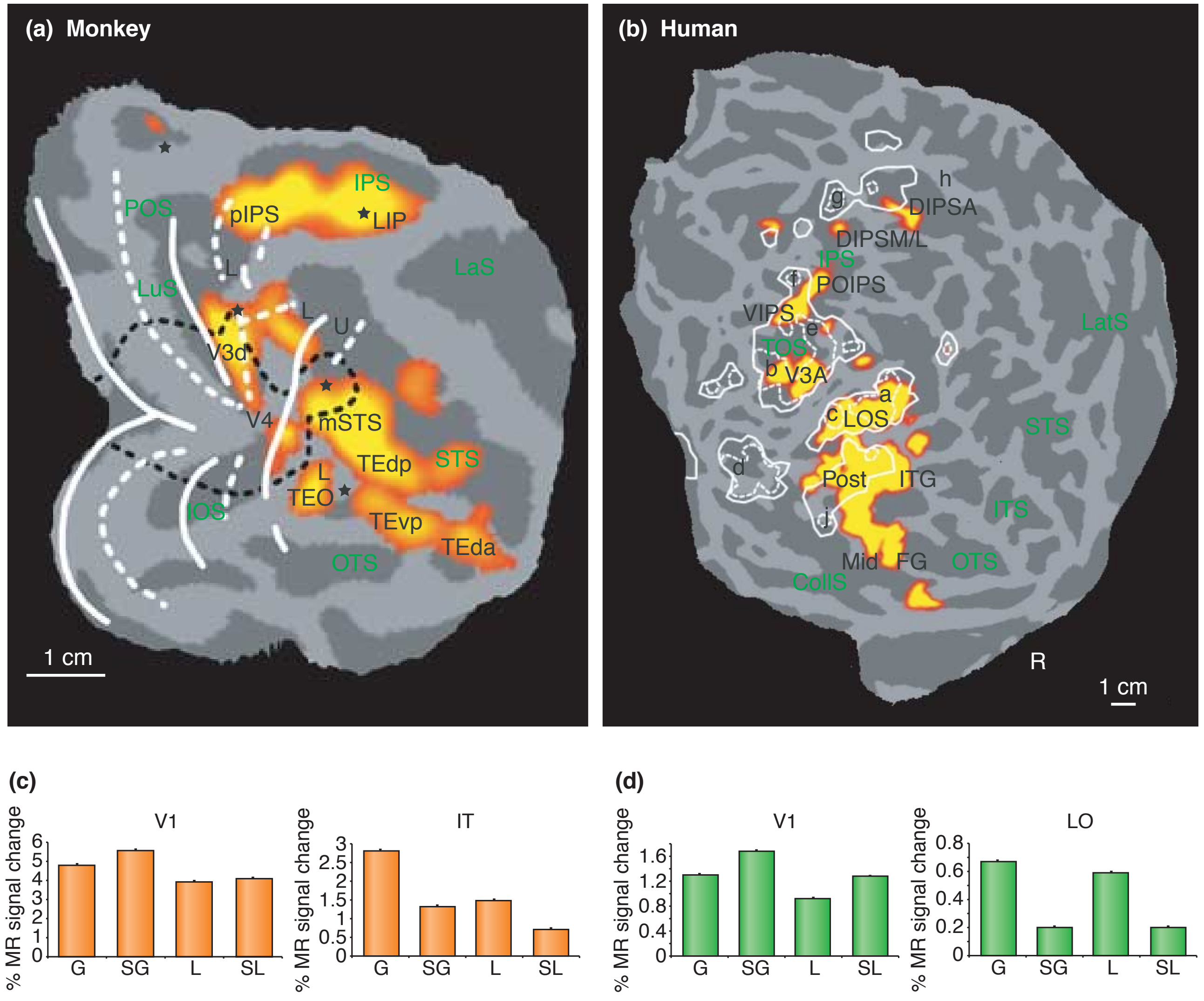


Fig. 1. The stimuli. (**A**) Monkeys learned to categorize randomly generated "morphs" from the vast number of possible blends of six prototypes. For neurophysiological recording, 54 sample stimuli were constructed along the 15 morph lines illustrated here. The placement of the prototypes in this diagram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



Freedman, D., et al. (2001). "Categorical representation of visual stimuli in the primate prefrontal cortex." Science **291**: 312-316.

Caveat: human and monkey brains differ



Orban, Van Essen, and Vanduffel, TICS 8 2004

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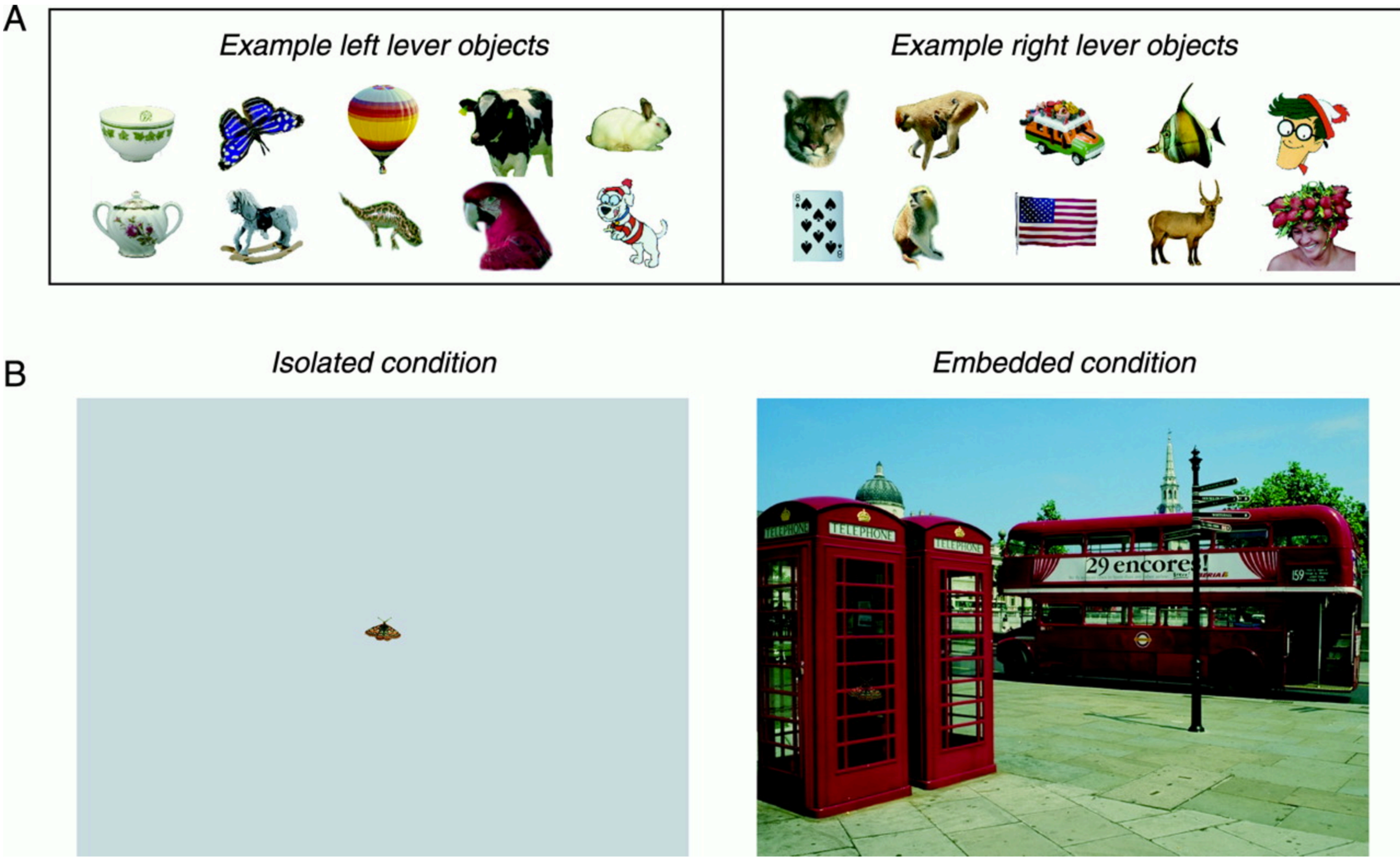
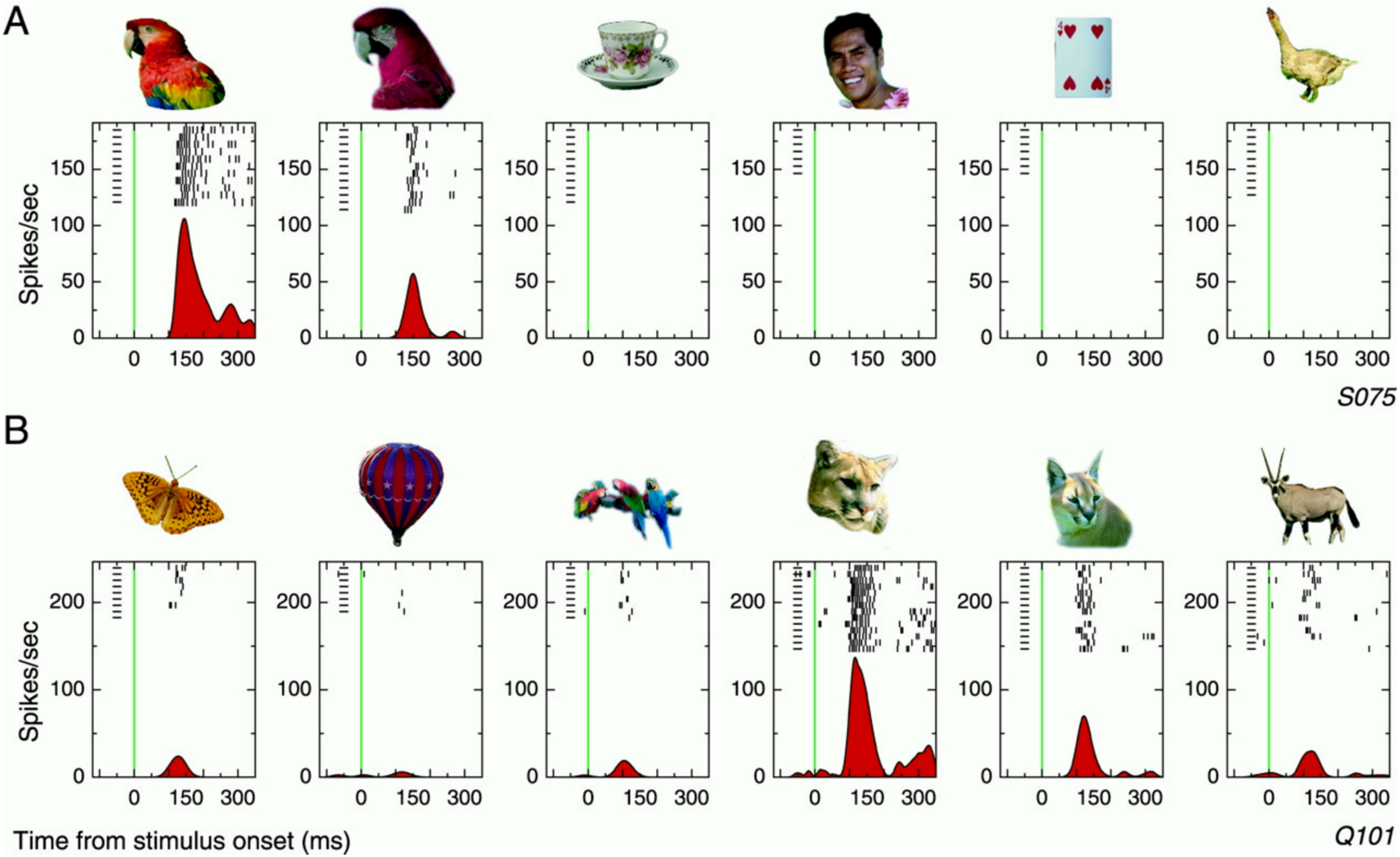
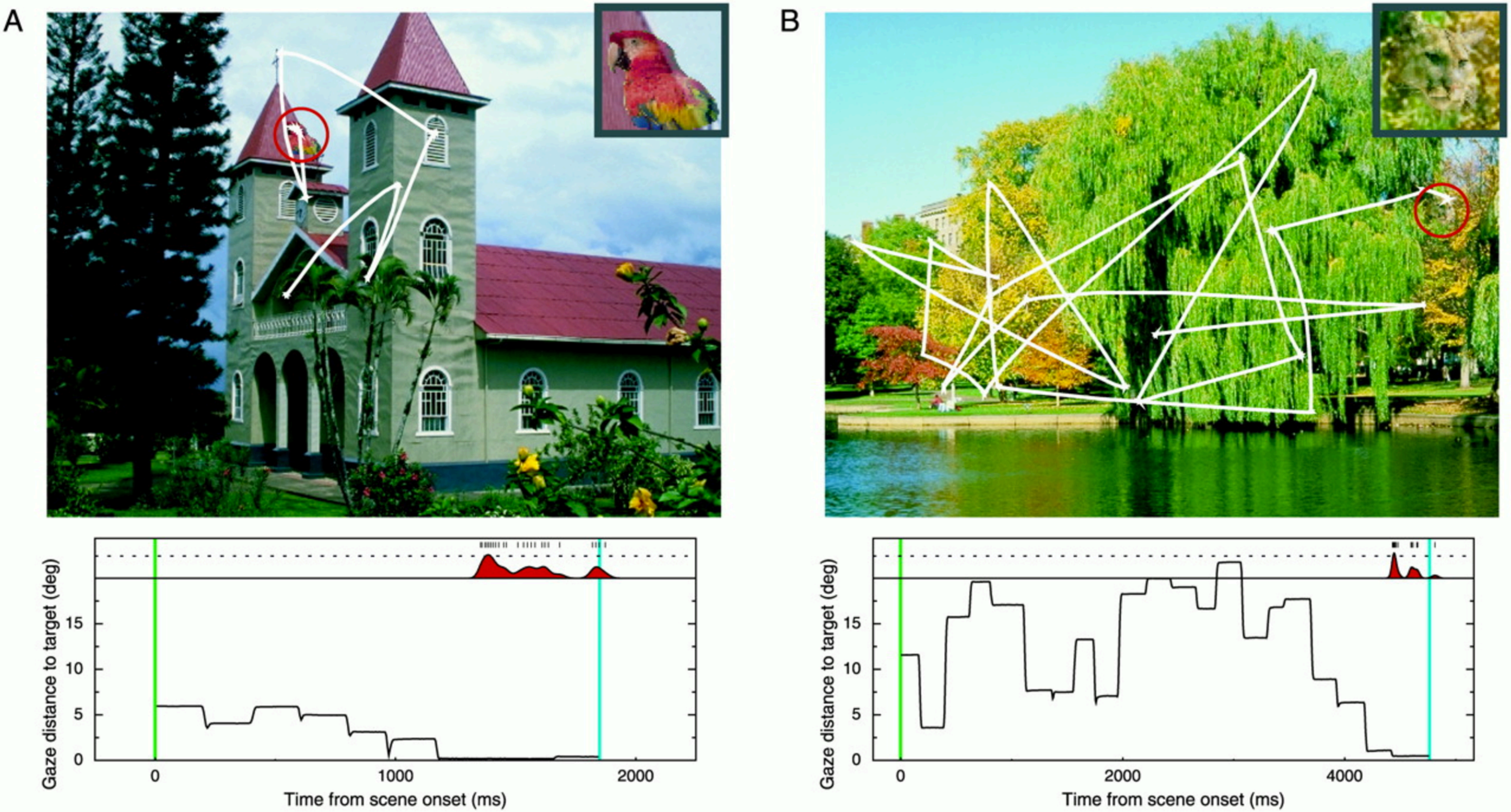
Noticing Familiar Objects in Real World Scenes: The Role of Temporal Cortical Neurons in Natural Vision

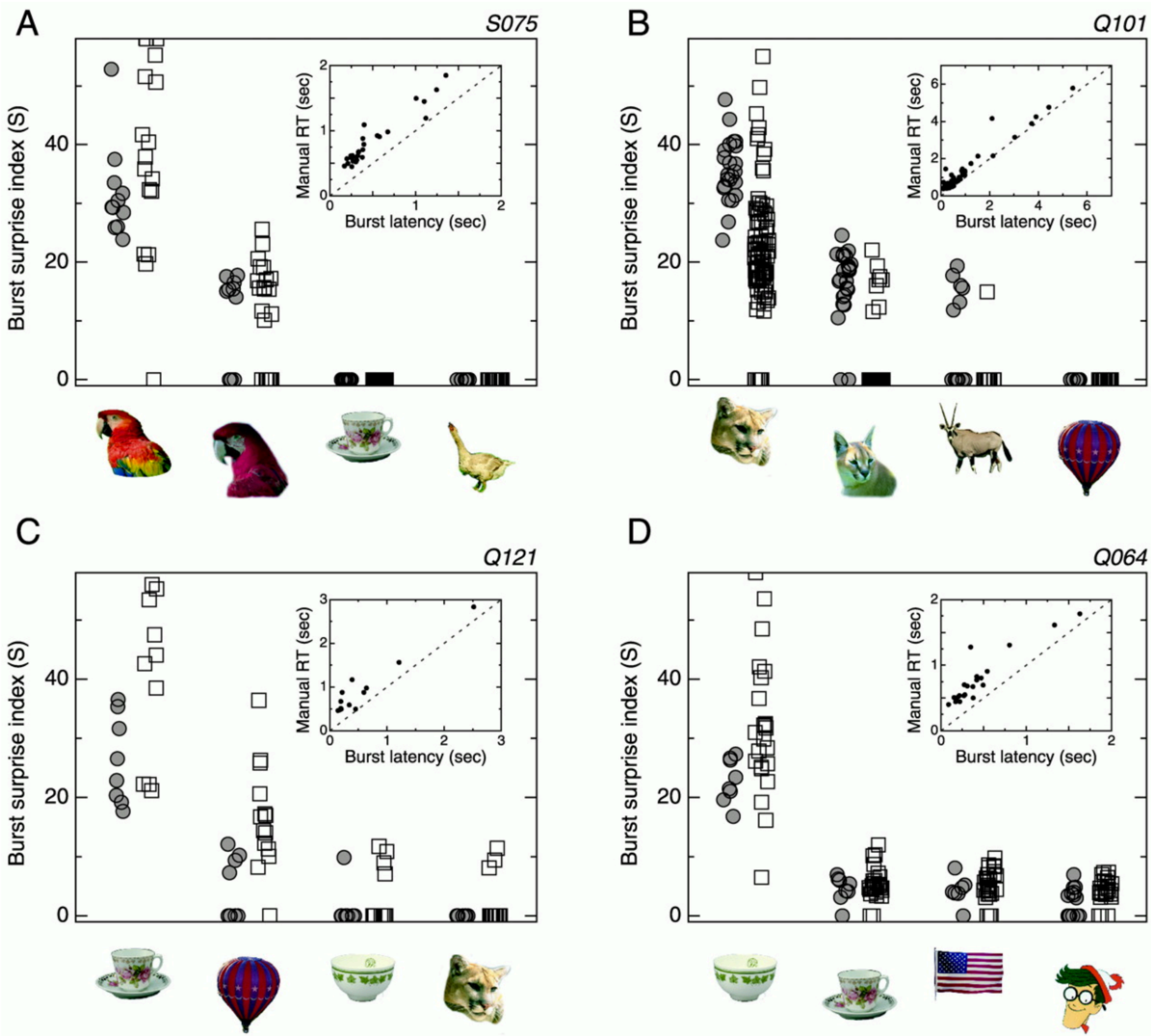
David L. Sheinberg and Nikos K. Logothetis

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

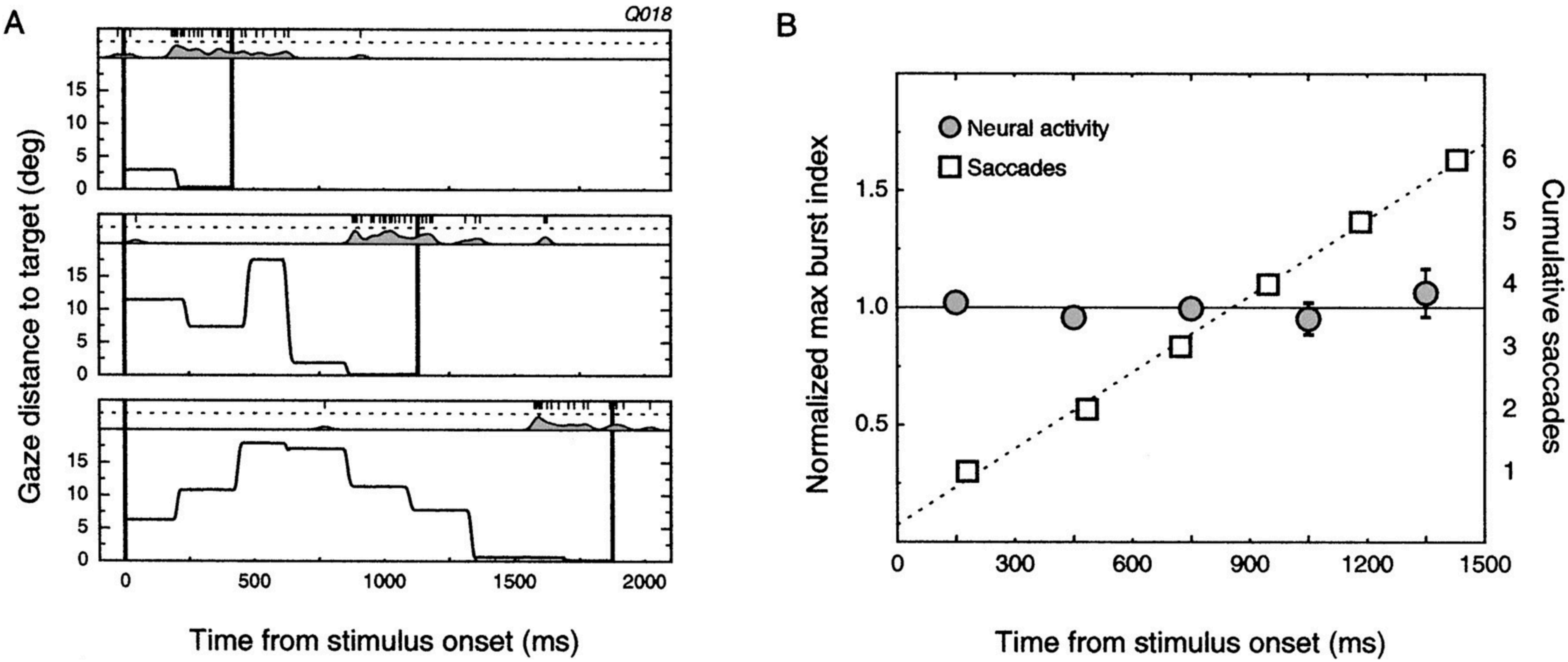

A
Example left lever objects
Example right lever objects
B
Isolated condition
Embedded condition
TELEPHONE
TELEPHONE
TELEPHONE
29 encores!
159

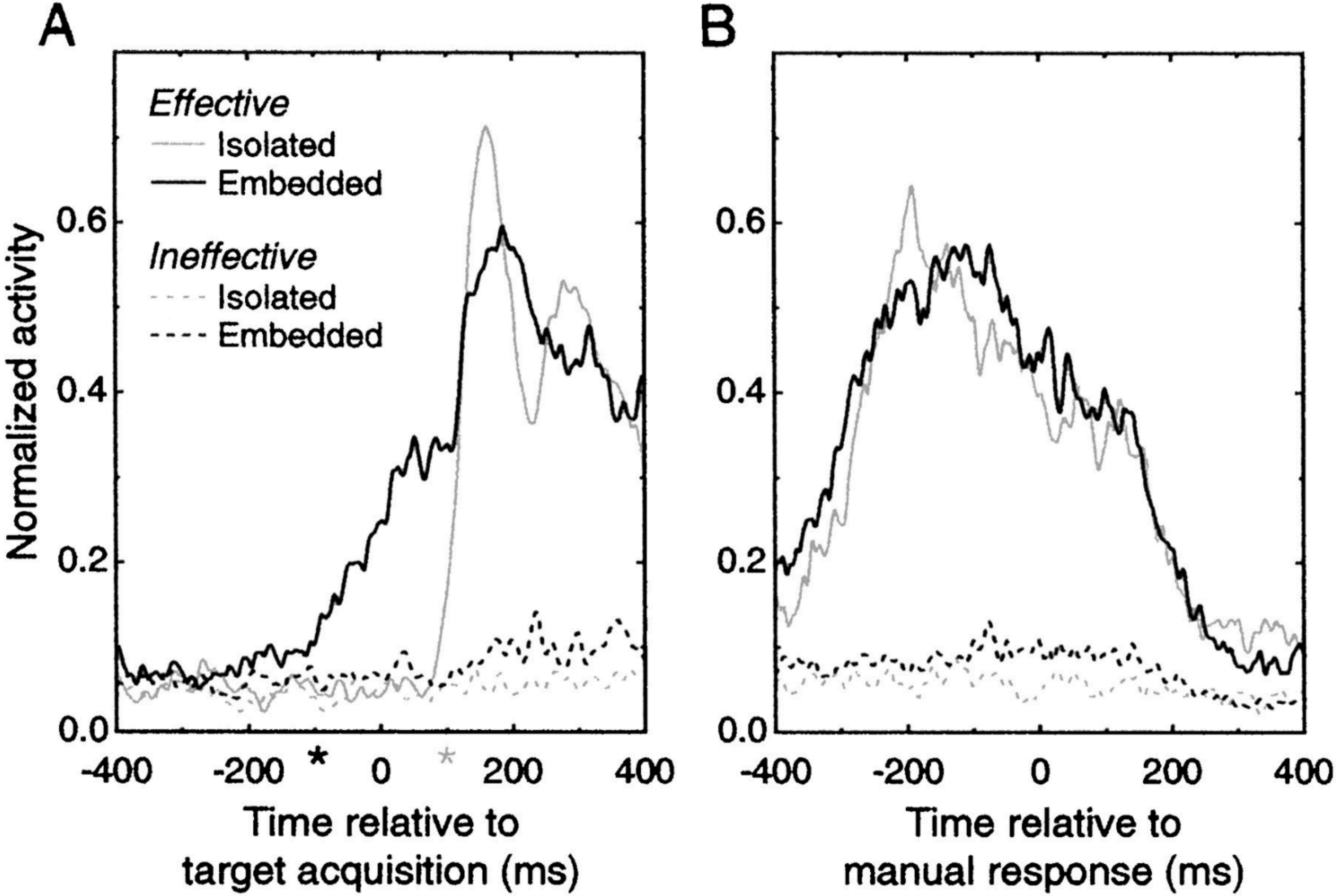

A
Spikes/sec
0
50
100
150
0
150
300
S075
B
Spikes/sec
0
100
200
0
150
300
Time from stimulus onset (ms)
Q101

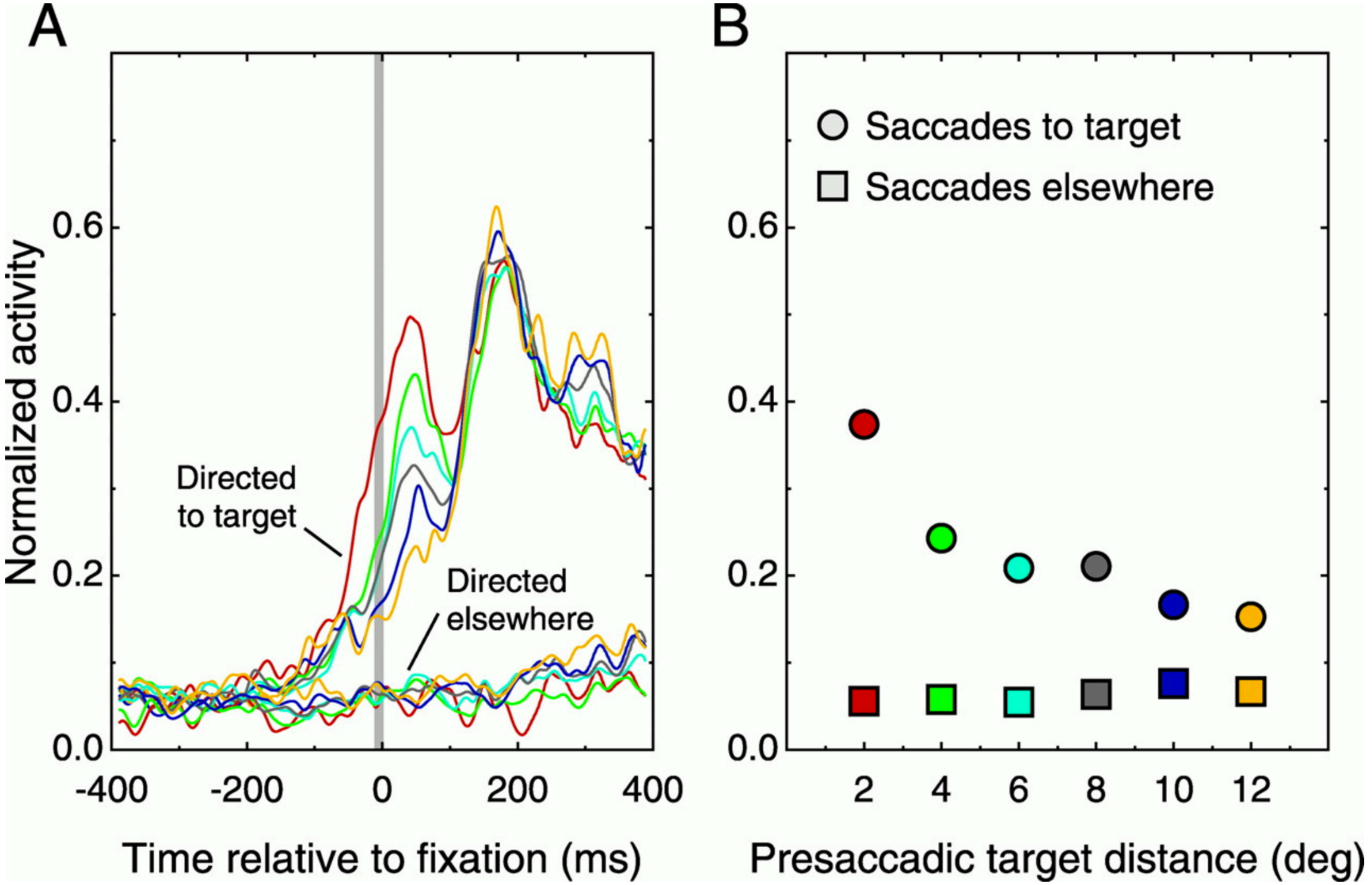

A
B
Gaze distance to target (deg)
Time from scene onset (ms)
0
5
10
15
1000
2000
4000

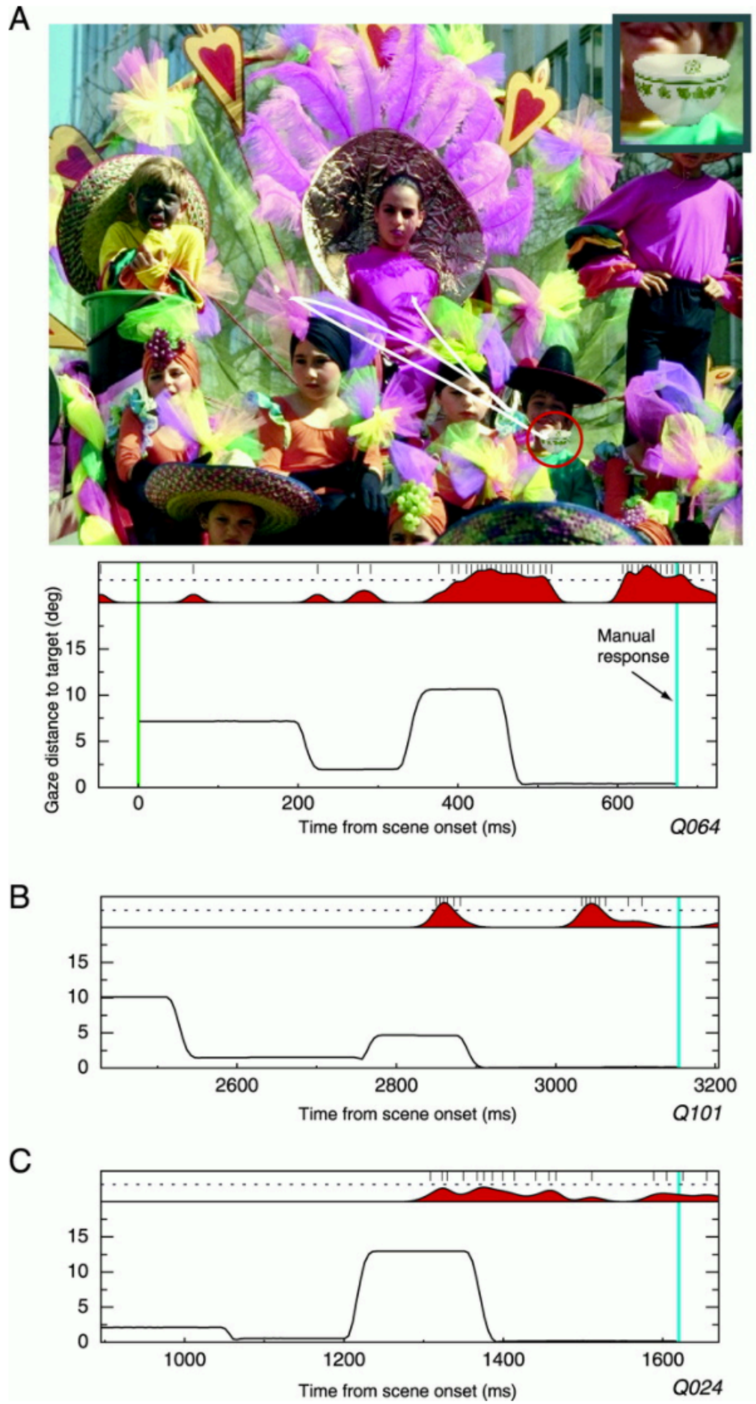


A
S075
B
Q101
C
Q121
D
Q064
Burst surprise index (S)
Manual RT (sec)
Burst latency (sec)


A
Q018
Gaze distance to target (deg)
0
5
10
15
0
500
1000
1500
2000
Time from stimulus onset (ms)
B
Neural activity
Saccades
Normalized max burst index
Cumulative saccades
0.5
1.0
1.5
1
2
3
4
5
6
0
300
600
900
1200
1500
Time from stimulus onset (ms)


A
B
Effective
Isolated
Embedded
Ineffective
Isolated
Embedded
Normalized activity
0.0
0.2
0.4
0.6
-400
-200
0
200
400
*
*
Time relative to
target acquisition (ms)
Time relative to
manual response (ms)


A
B
Normalized activity
0.0
0.2
0.4
0.6
Directed to target
Directed elsewhere
-400
-200
0
200
400
Time relative to fixation (ms)
Saccades to target
Saccades elsewhere
2
4
6
8
10
12
Presaccadic target distance (deg)


A
Gaze distance to target (deg)
Manual response
Time from scene onset (ms)
Q064
B
Time from scene onset (ms)
Q101
C
Time from scene onset (ms)
Q024