

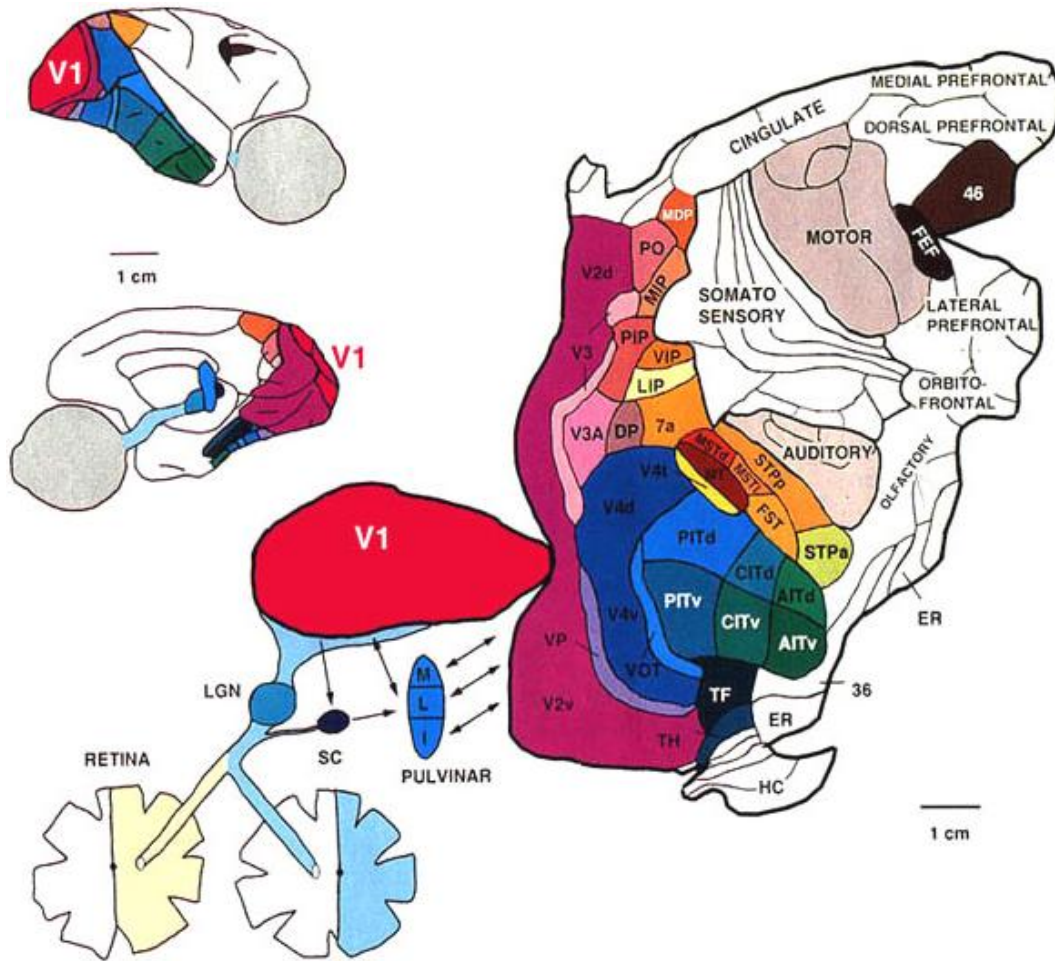
# Modeling Extrastriate Areas

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# Higher areas



- Many higher areas beyond V1
- Selective for faces, buildings, self-motion, etc.
- Not as well understood

## Macaque visual areas (Van Essen et al. 1992)

# What/Where streams

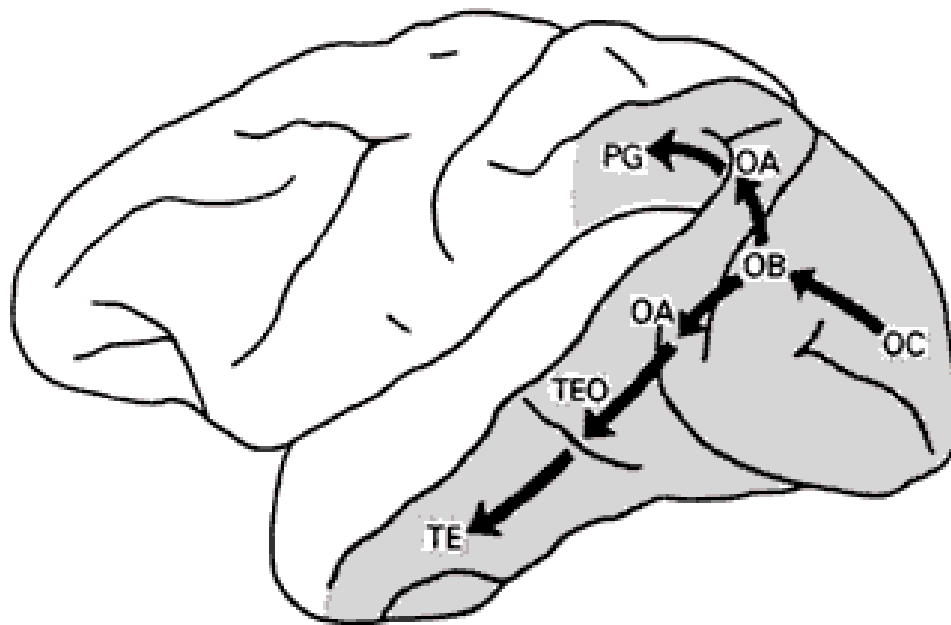
Typical division:

## Ventral stream:

“What” pathway  
from V1 to temporal  
cortex (IT)

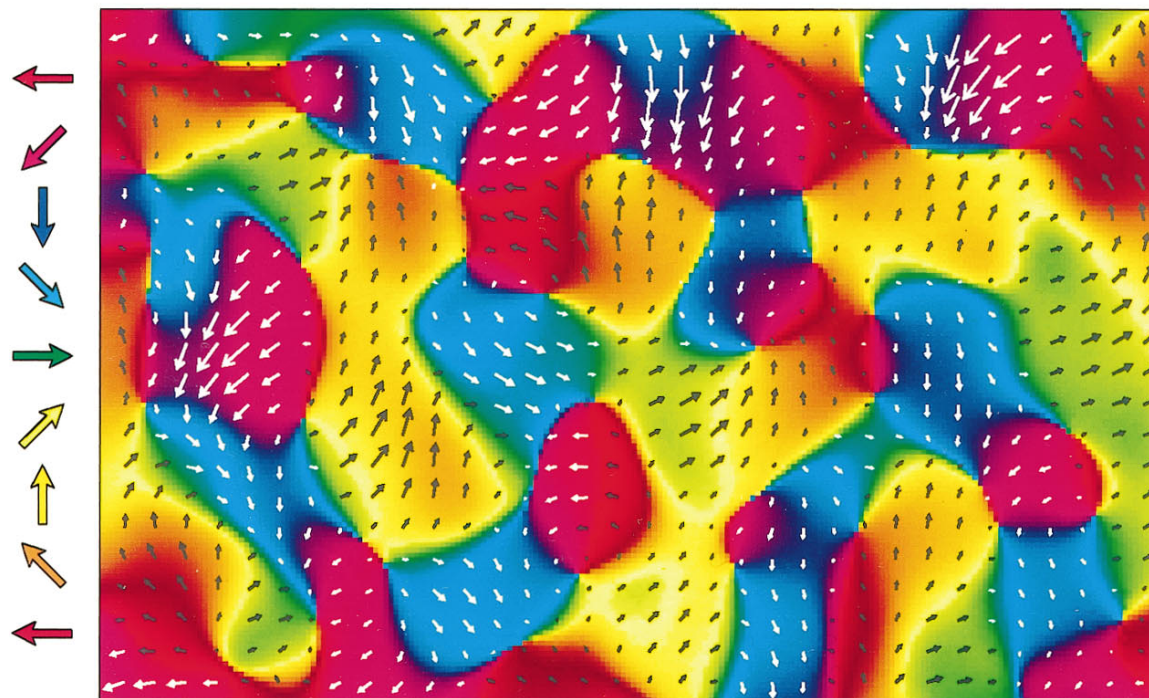
## Dorsal stream:

“Where” pathway  
from V1 to parietal  
cortex (e.g. MT)



(Ungerleider & Mishkin 1982)

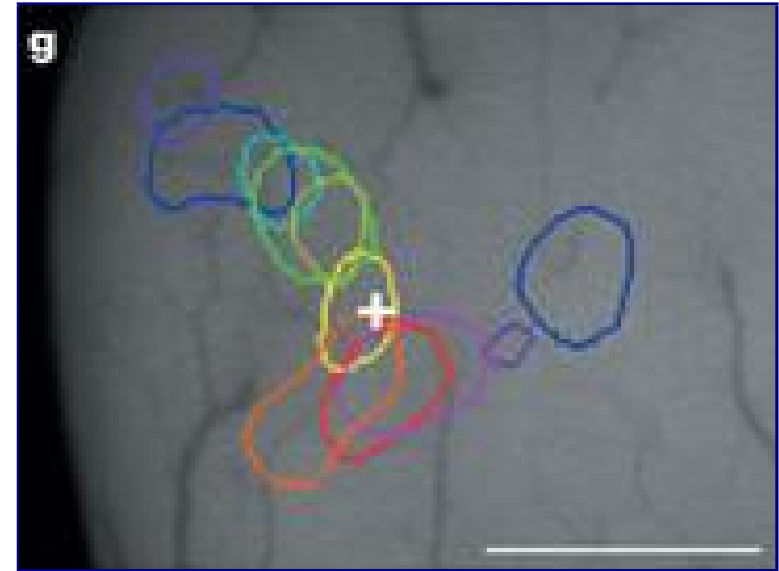
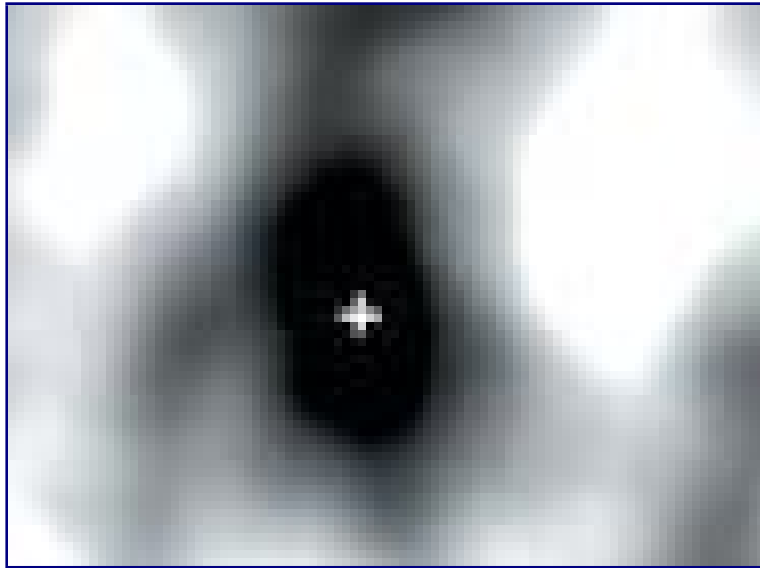
# V2 OR/DR map



V2 cat direction map (Shmuel & Grinvald 1996)

- Except OD, maps found in V1 are usually also found in V2
- RFs are larger, maybe more complex (not really clear)
- Macaque V2 has complicated organization of thick/thin/pale stripes selective for color, luminance, etc.

# V2 Color map



Xiao et al. 2003 – Macaque;  $1.4 \times 1.0$ mm

- Like V1, color preferences organized into blobs
- Rainbow of colors per blob (Xiao et al. 2007: in V1 too?)
- Arranged in order of human perceptual color charts (CIE/DIN)
- Feeds to V4, which is also color selective

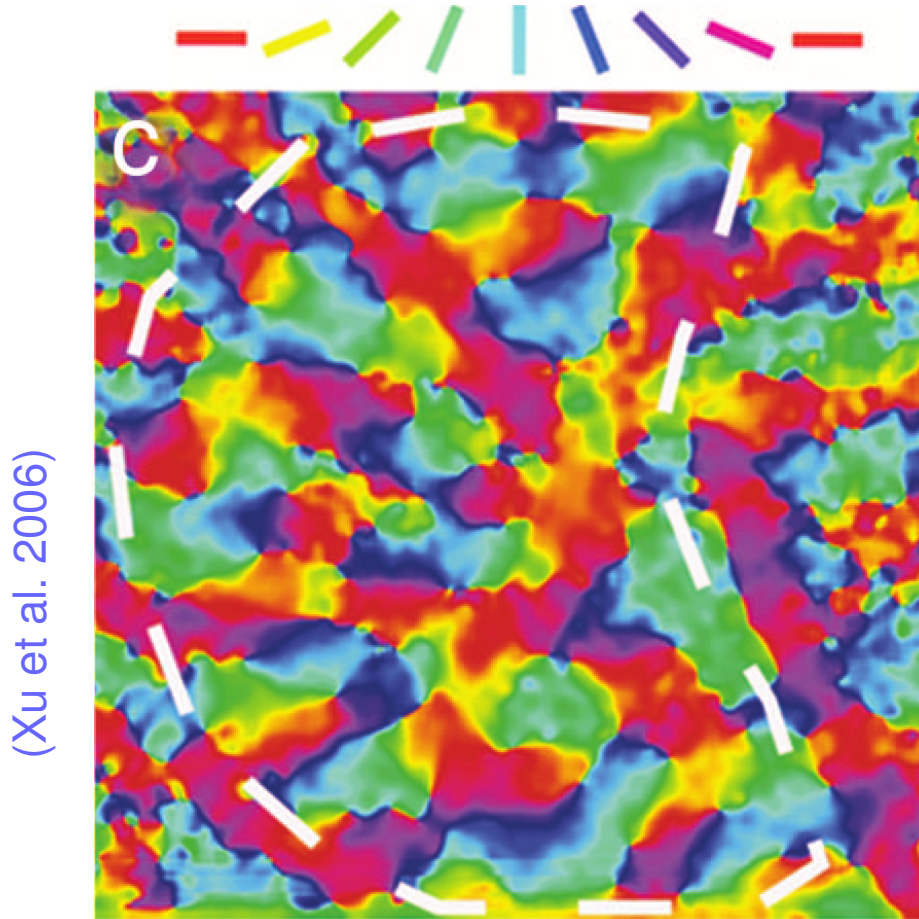
# MT/V5

MT has orientation maps,  
but the neurons are more  
motion and direction selective

Involved in estimating  
optic flow

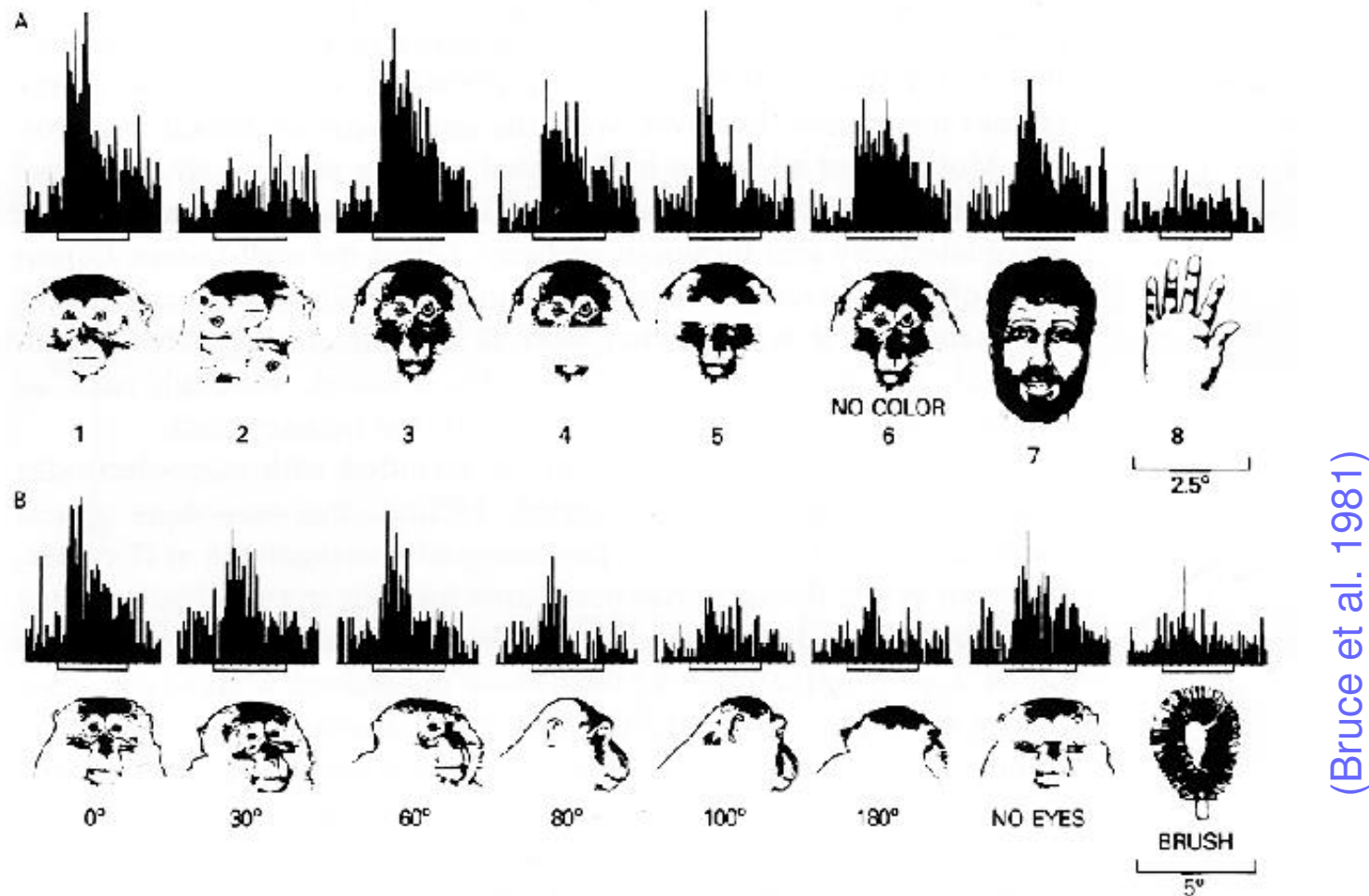
Neural responses in MT  
have been shown to  
directly reflect and  
determine perception of  
motion direction

(Britten et al. 1992; Salzman et al. 1990)



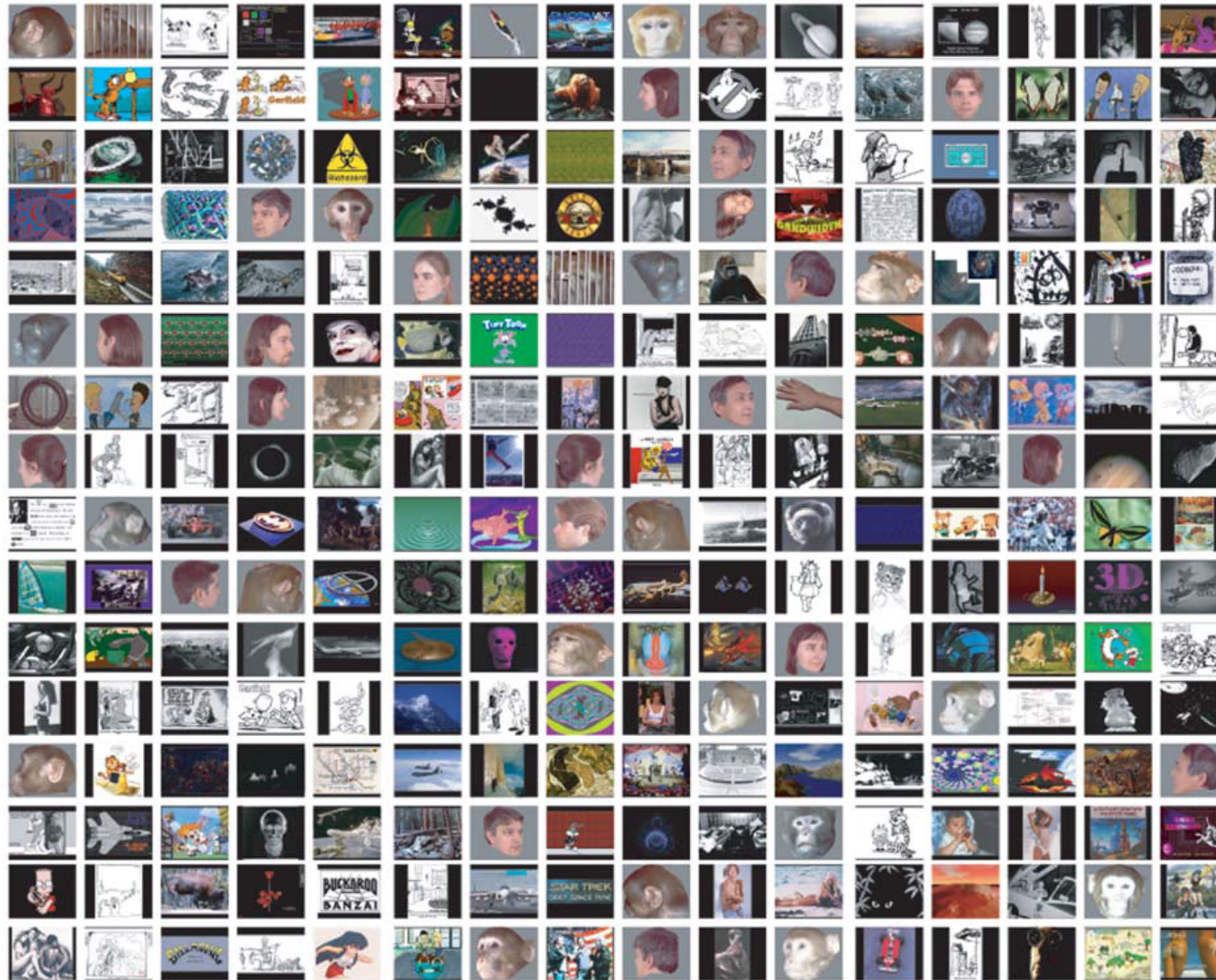


# Object selectivity in IT



Some cells show greater responses to faces than to other classes; others to hands, buildings, etc. Hard to interpret, though.

# Rapid Serial Visual Presentation



(Földiák et al. 2004)

1000s of images ( $> 15\%$  faces) presented to neuron for 55 or 110ms



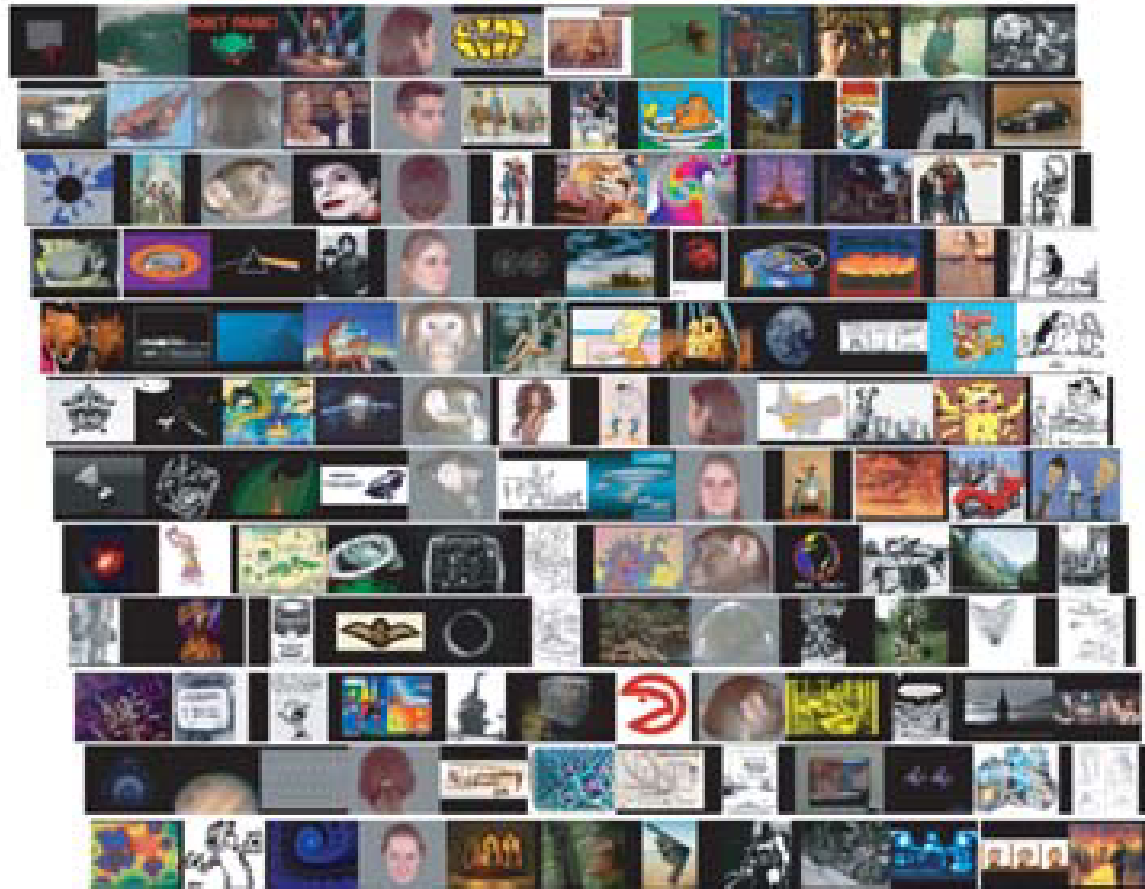
# RSVP: Face-selective neurons



(Földiák et al. 2004)

- Some monkey STSa neurons show clear preferences
  - top 50 faces are images
- Response low to remaining patterns
- Concern: faces are the only special category (overrepresented, aligned, blank background)

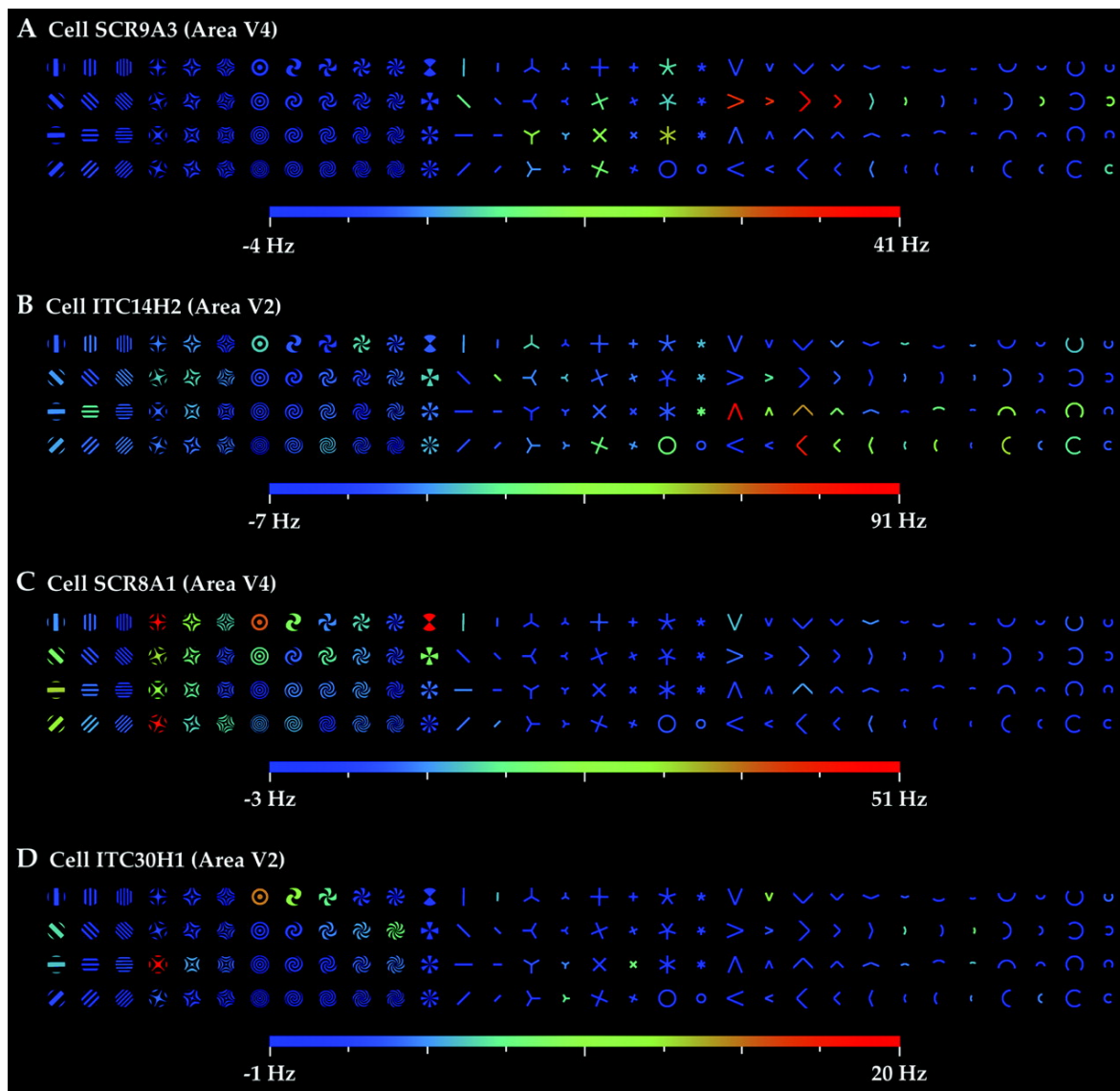
# RSVP: Non-face-selective neurons



(Földiák et al. 2004)

- Other neurons don't make much sense at all
- See also Naselaris et al. (2009); mapping based on semantic category for tagged images

# Parametric testing

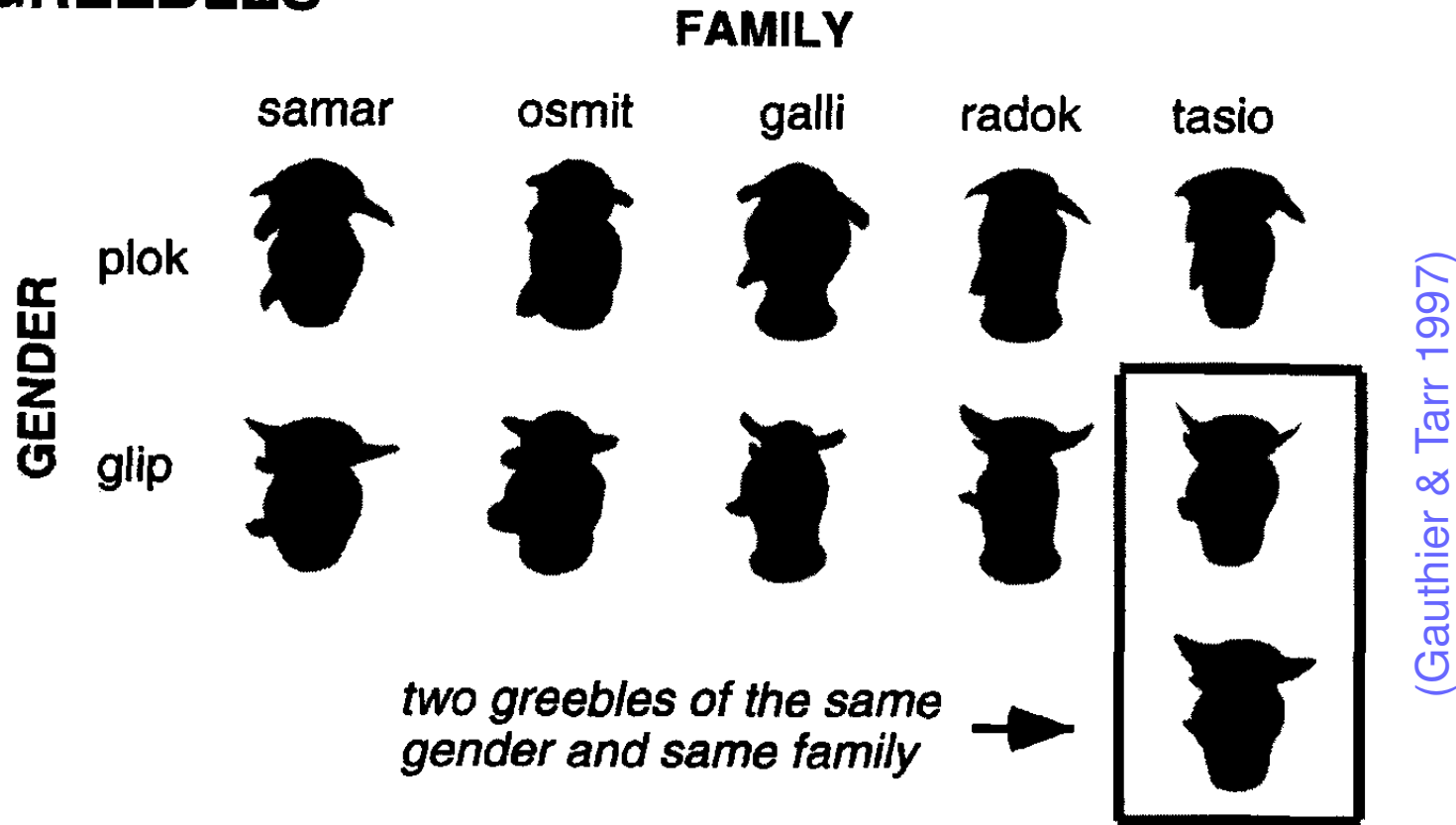


Difficult to see  
differences in  
kind in  
responses to  
geometric  
stimuli across  
the hierarchy

Macaque; (Hegd  & Van Essen 2007)

# Form expertise

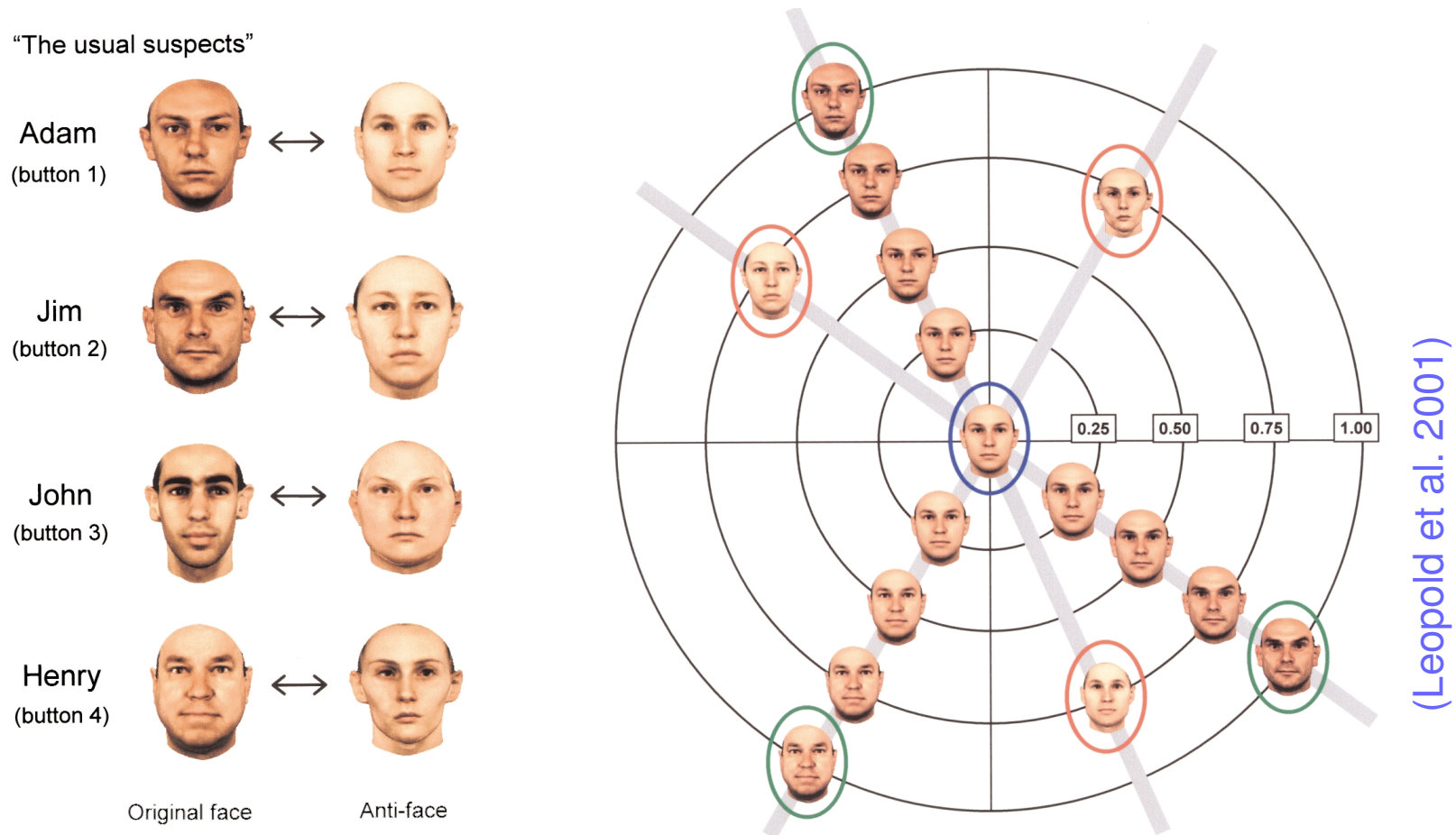
## GREEBLES



Most of the “specialness” of faces appears to be shared by other object categories requiring configural distinctions between similar examples.

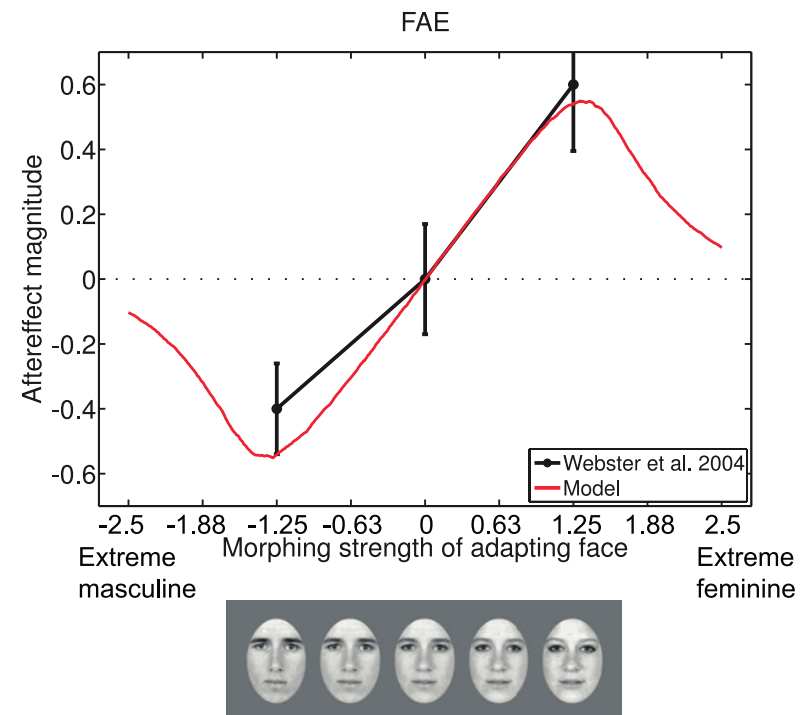
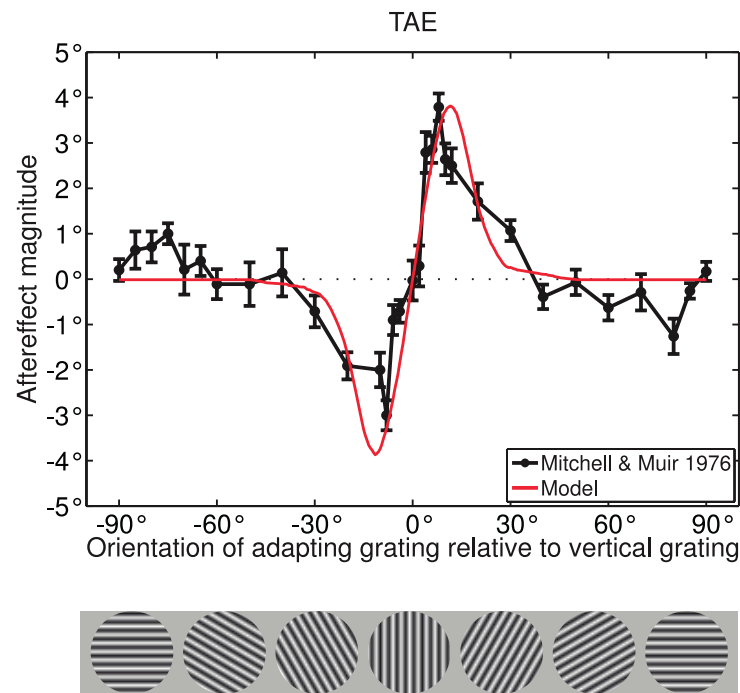


# Face aftereffects



Aftereffects are seemingly universal. E.g.  
face aftereffects: changes in identity judgments;  
blur/sharpness aftereffects, contrast aftereffects...

# Face aftereffects same as TAE?



(Zhao et al. 2011)

People have elaborate theories about high-level aftereffects, but we tested a clear prediction of the assumption that they are just like the TAE, and were proven correct (Zhao et al. 2011)

# Invariant tuning

Higher level ventral stream cells have response properties invariant to size, viewpoint, orientation, etc.

Similar to complex cells, but higher-order. E.g. can respond to face regardless of its location and across a wide range of sizes and viewpoints.

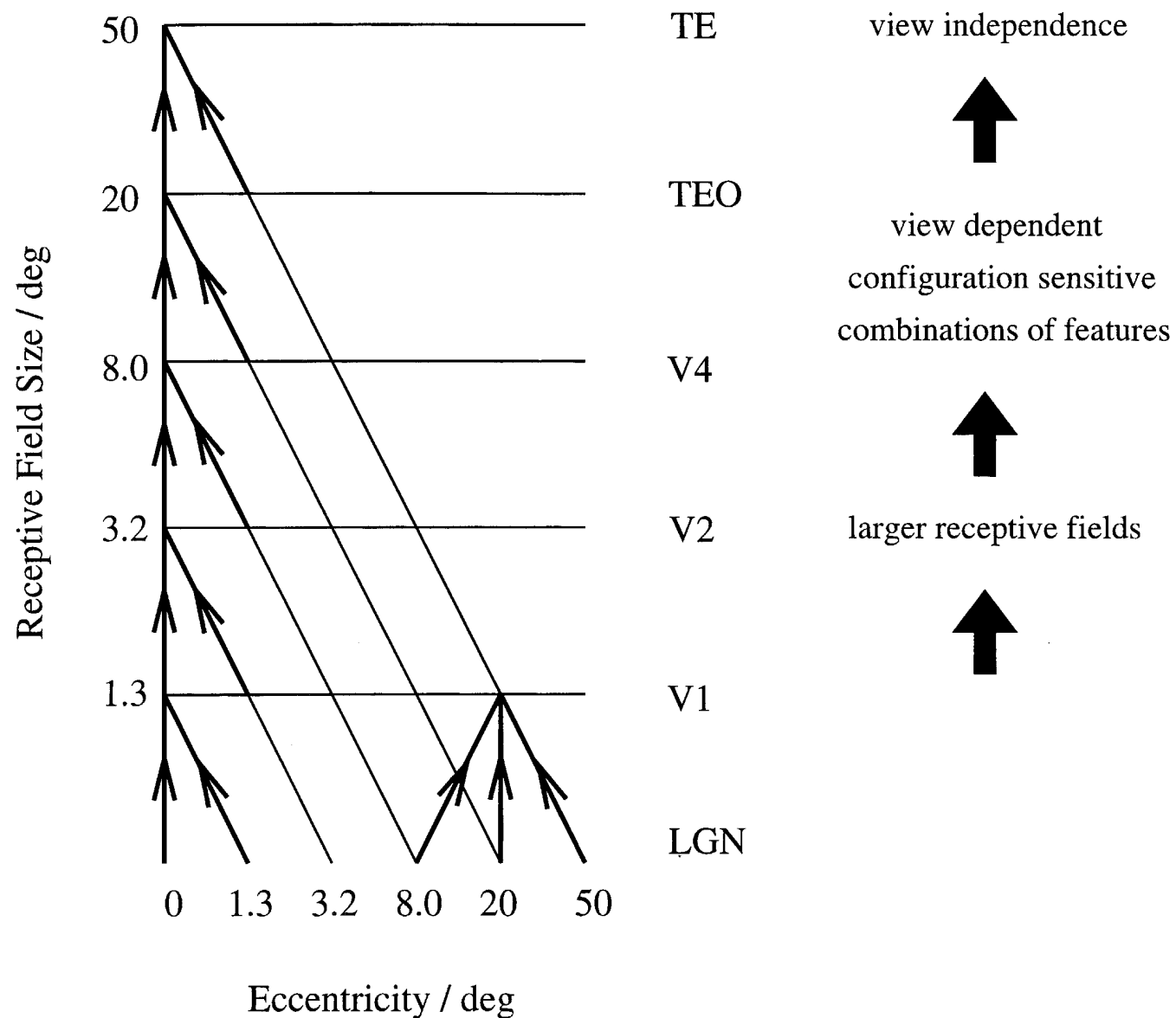
# Why is invariance hard?



Simple template-based models won't provide much invariance, but could build out of many such cells.

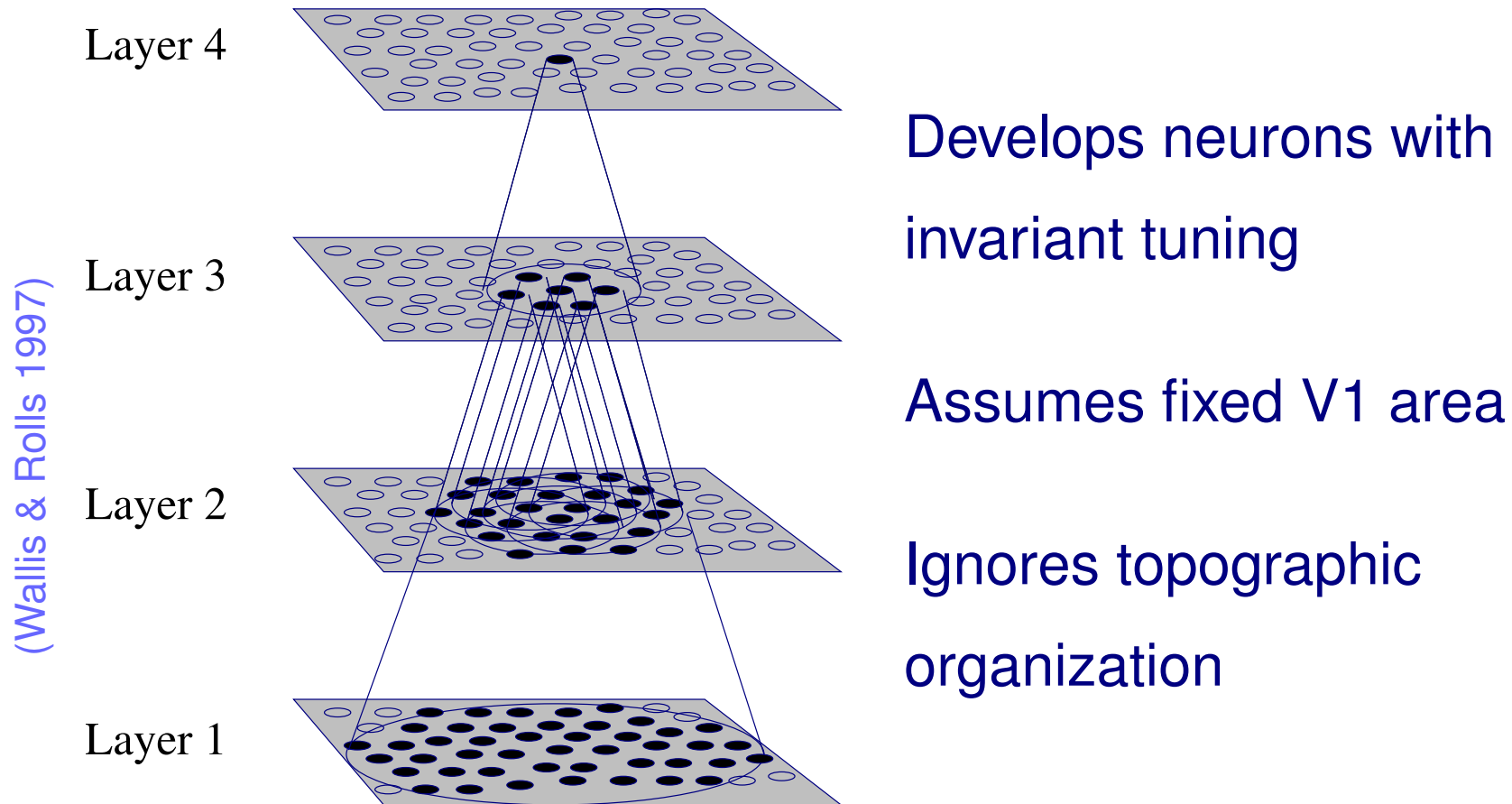


# RF sizes



(Rolls 1992)

# VisNet



# Trace learning rule

VisNet uses the trace learning rule proposed by Földiák (1991). Based on Hebbian rule for activity  $y^\tau$  and input  $x_j^\tau$ :

$$\Delta w_j = \alpha y^\tau x_j^\tau \quad (1)$$

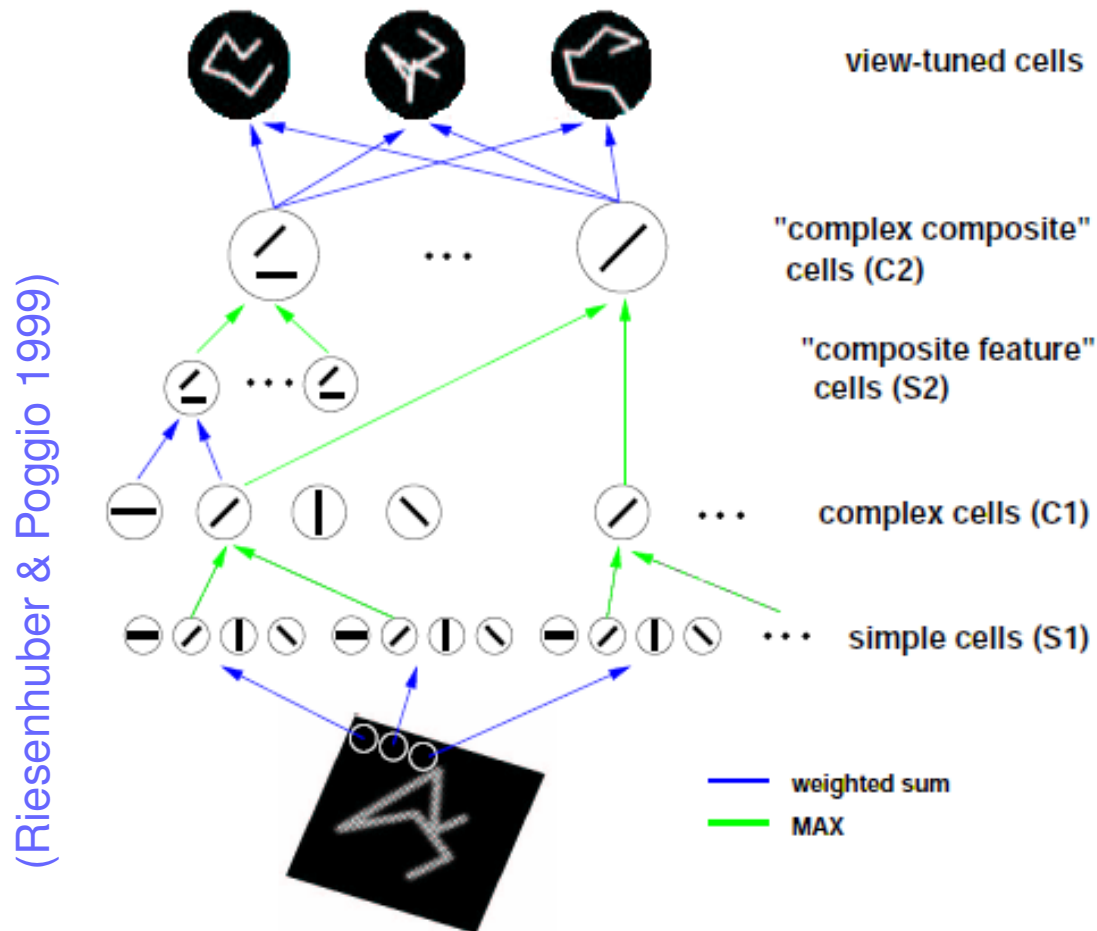
but modified to use recent history (“trace”) of activity:

$$\Delta w_j = \alpha \bar{y}^\tau x_j^\tau \quad (2)$$

$$\bar{y} = (1 - \eta) y^\tau + \eta \bar{y}^{\tau-1} \quad (3)$$

General technique for invariant responses?

# HMAX



Top level (only) learns  
view, position, size  
invariant recognition

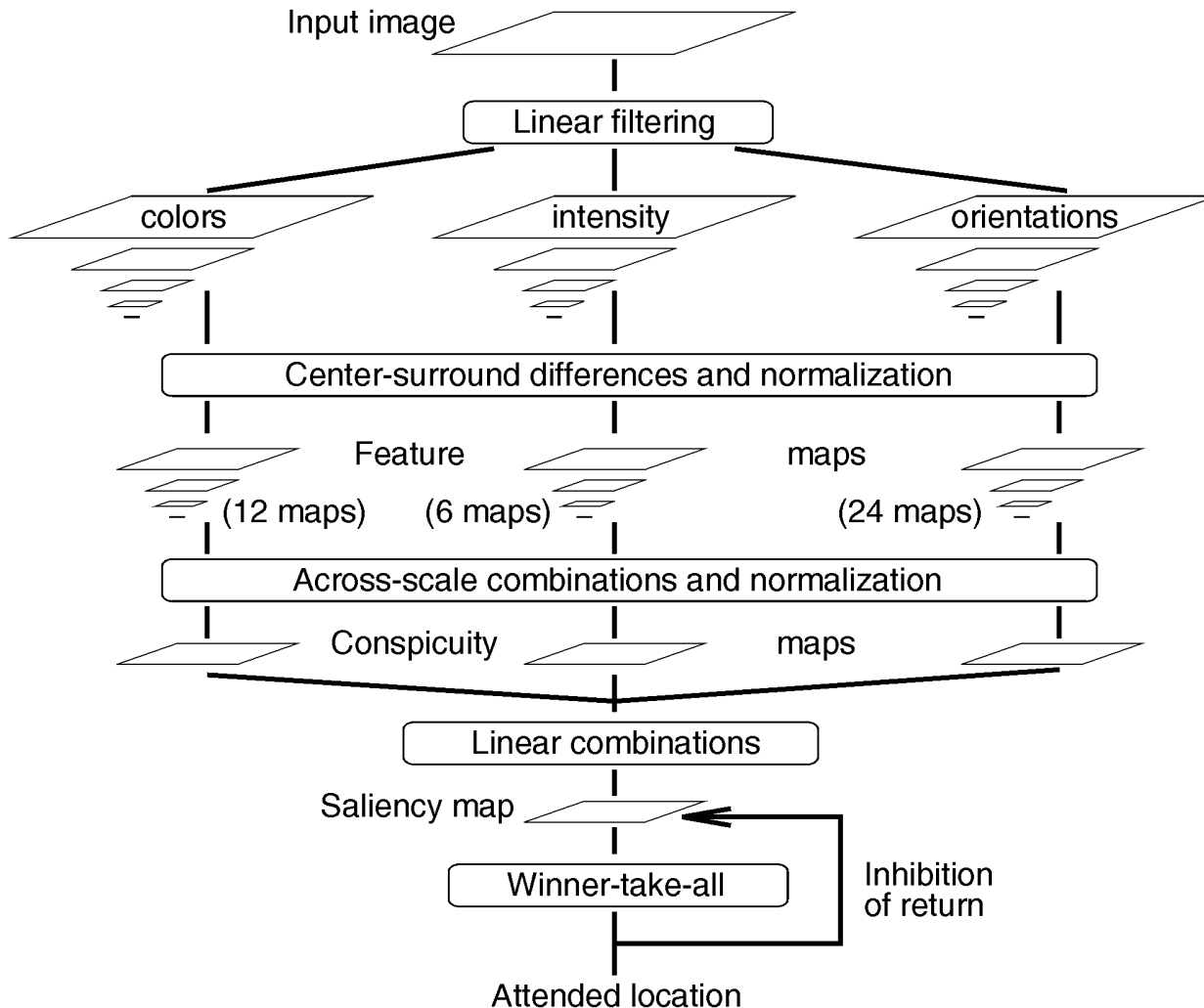
Max (C) units:  
nonlinear pooling,  
like complex cells

Linear (S) units:  
feature templates,  
like simple cells

No clear topography



# Koch and Itti saliency maps



(Itti, Koch, & Niebur 1998)

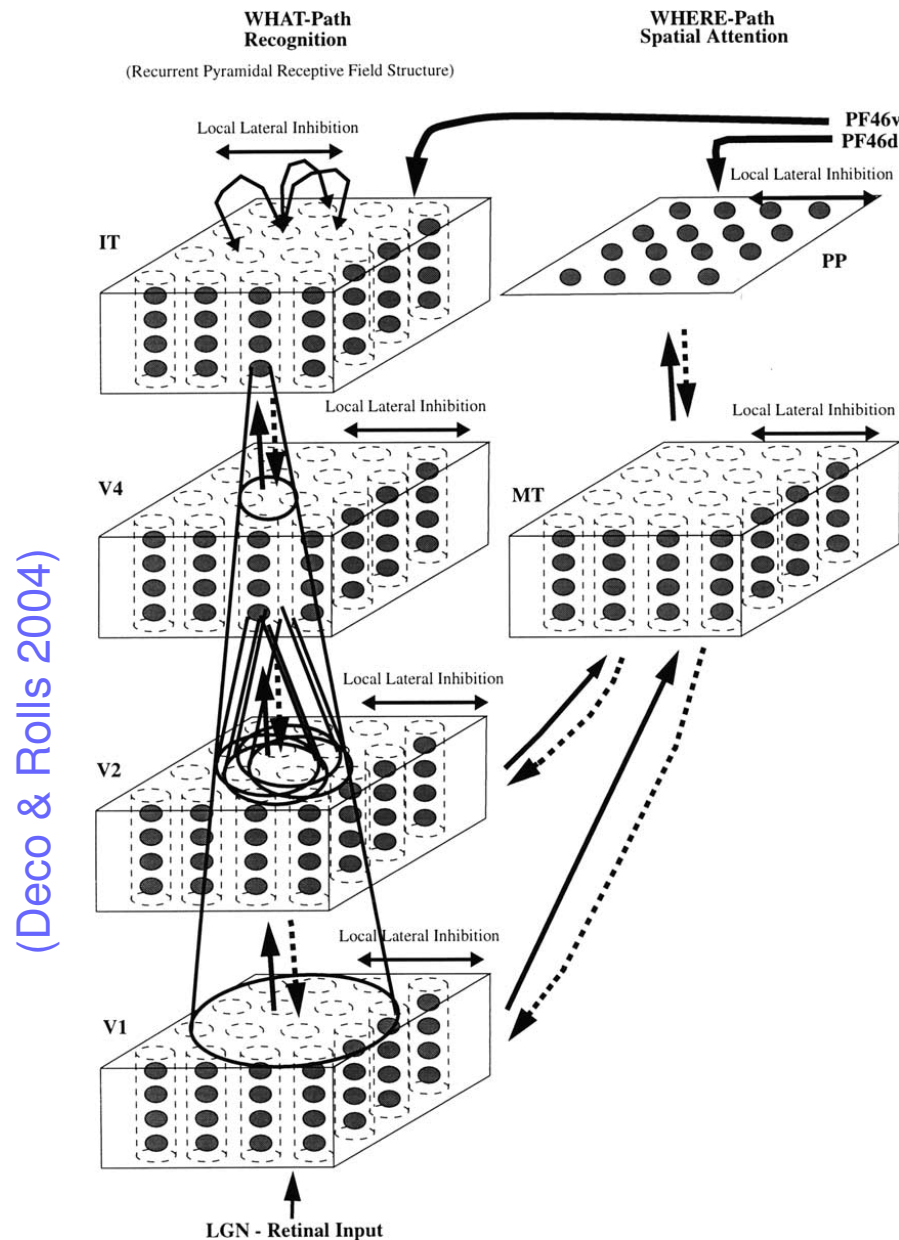
Attention model:  
most salient  
feature attended

Various feature  
maps pooled at  
different scales

Single winner:  
attended location

Inhibition of return:  
enables scanning

# Other attention models

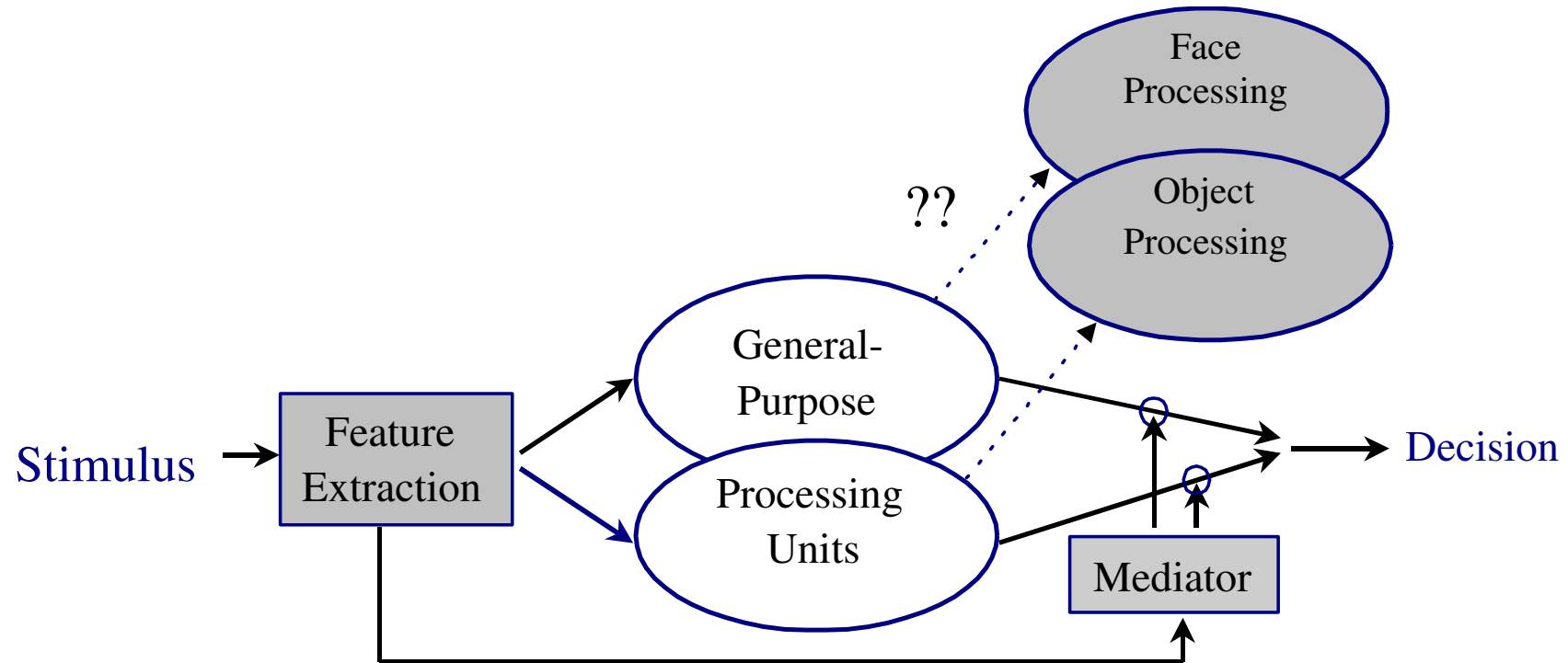


There are a number of other models of behavior like attention, most quite complex

Hard to tie individual model areas to specific experimental results from those areas

Also need to include superior colliculus

# Modeling separate streams



(Dailey & Cottrell 1999)

Slight biases are sufficient to make one stream end up selective for faces, the other for objects

# More complexities

Need to include eye movements, fovea/periphery.

At higher levels, neurons become multisensory.

Eventually, realistic models will need to include auditory areas, touch areas, etc.

Feedback from motor areas is also more important at higher levels.

Training data for such models will likely be harder to make than building a robot – will need embodied models.



# Summary

- Need to include many areas besides V1
- Complexity and lack of data are serious problems
- Eventually: situated, embodied models
- May be useful to focus on species with just V1 or a few areas before trying to tackle whole visual hierarchy
- Lots of work to do

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