Modeling Extrastriate Areas

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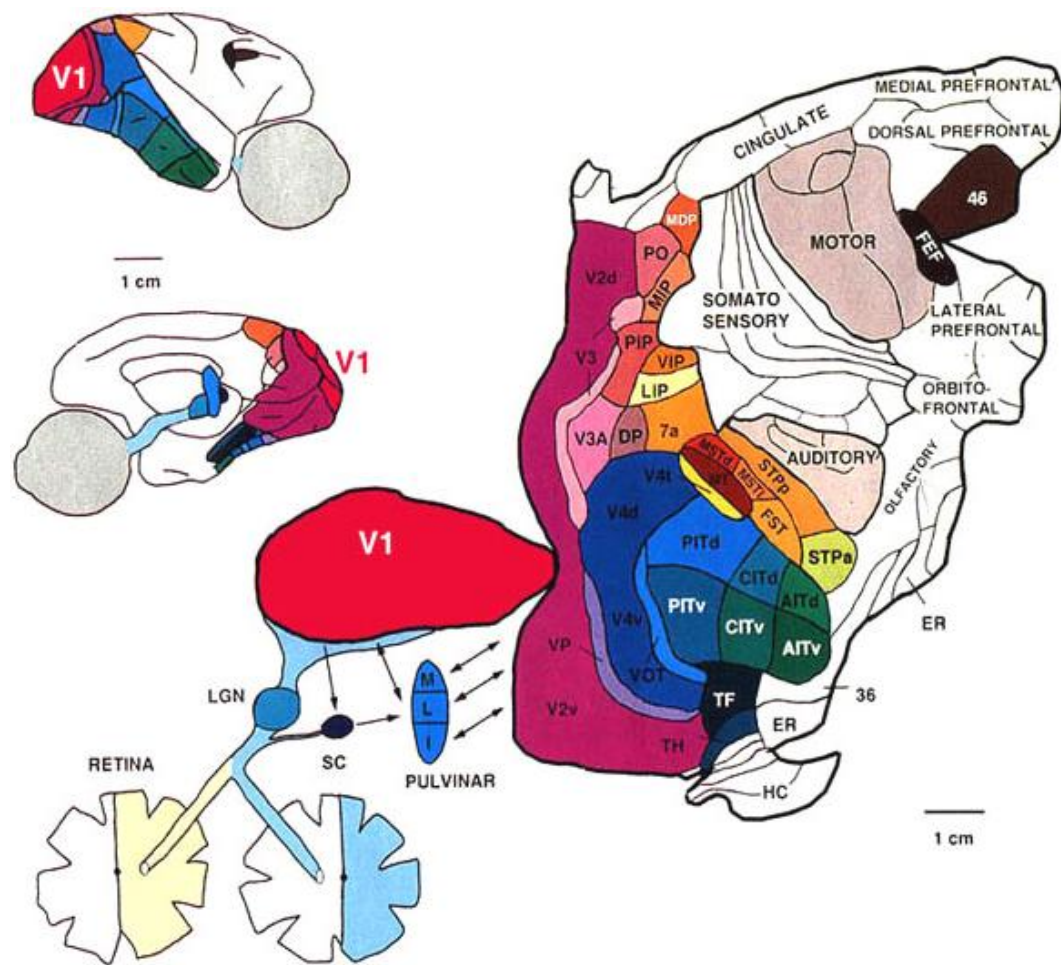
Higher areas

Macaque visual areas
(Van Essen et al. 1992)

- Many higher areas beyond V1

- Selective for faces, buildings, self-motion, etc.

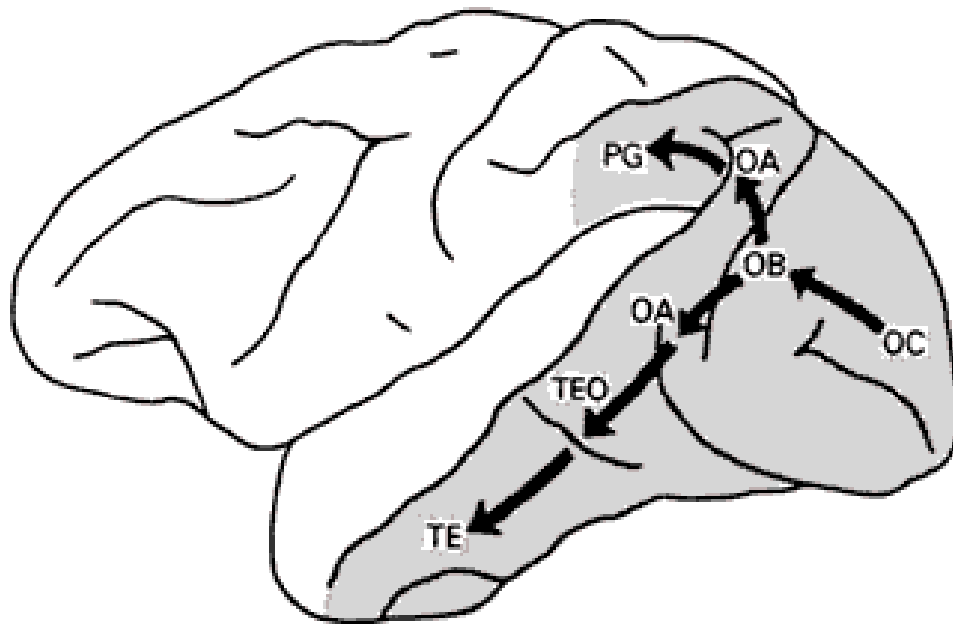- Not as well understood

What/Where streams

Typical division:

Ventral stream:
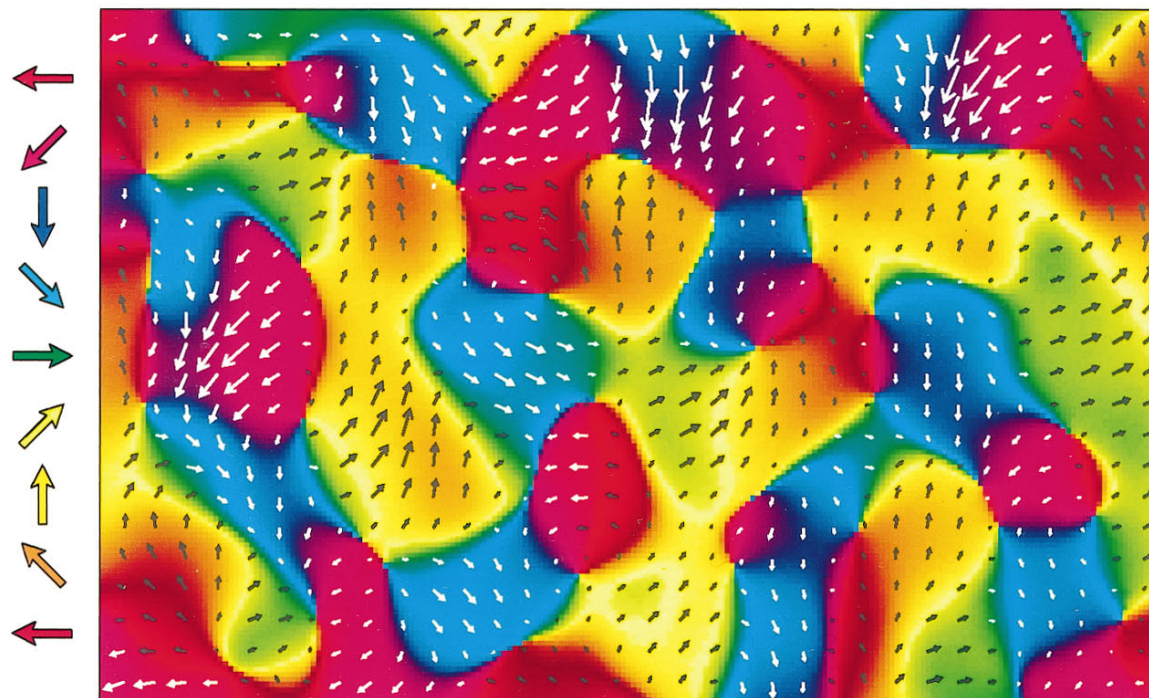
"What" pathway

from V1 to temporal

cortex (IT)

Dorsal stream:

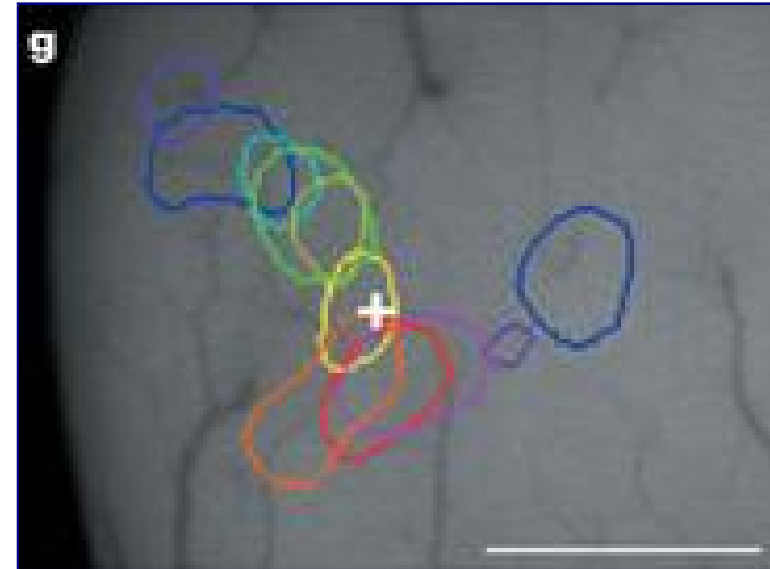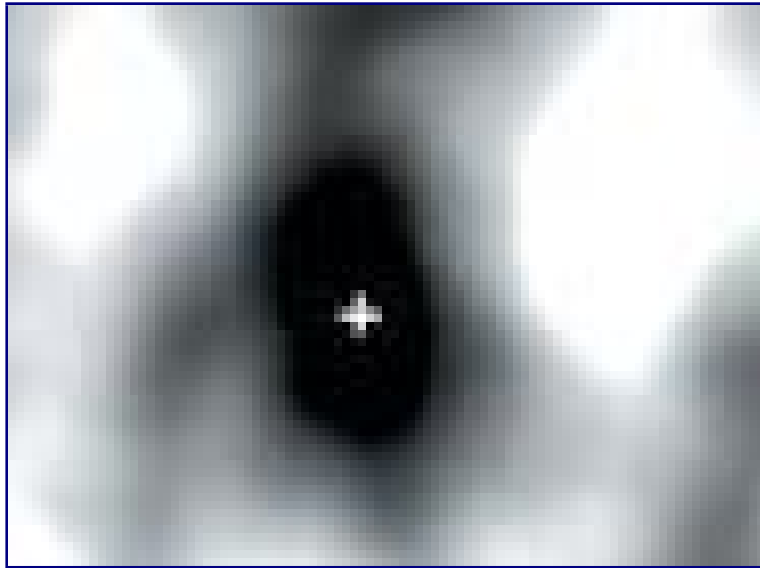"Where" pathway

from V1 to parietal

cortex (e.g. MT)

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 $\times$ 1.0mm

- 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

(Xu et al. 2006)

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)
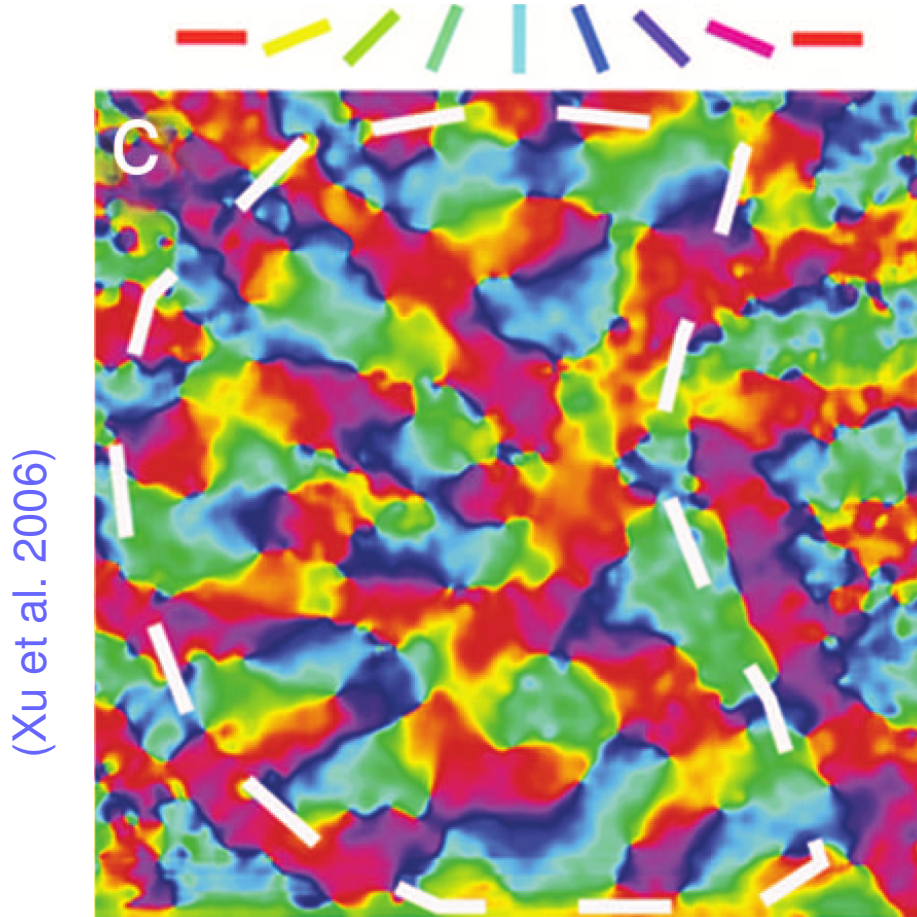
Object selectivity in IT
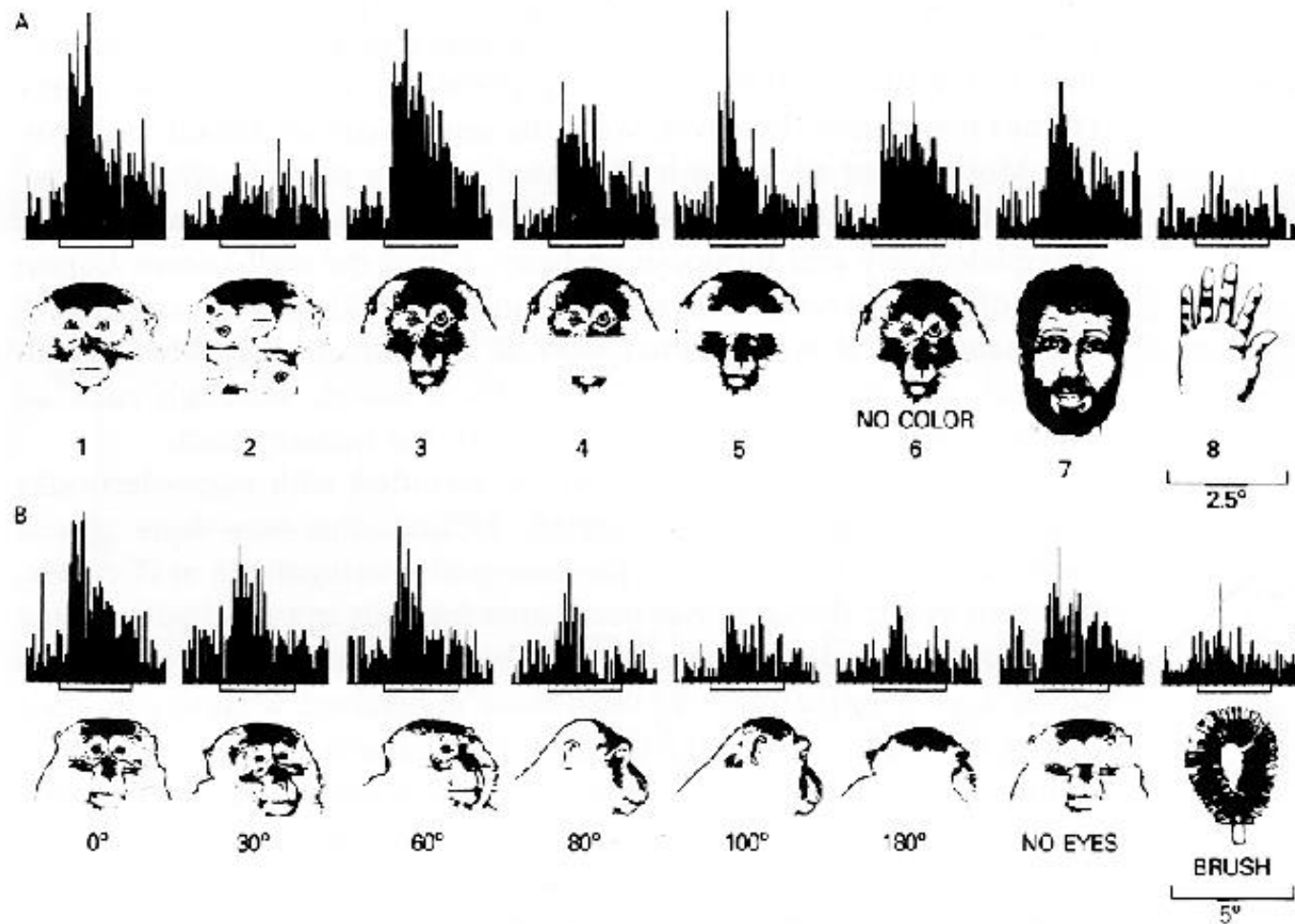
(Bruce et al. 1981)

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

Rapid Serial Visual Presentation
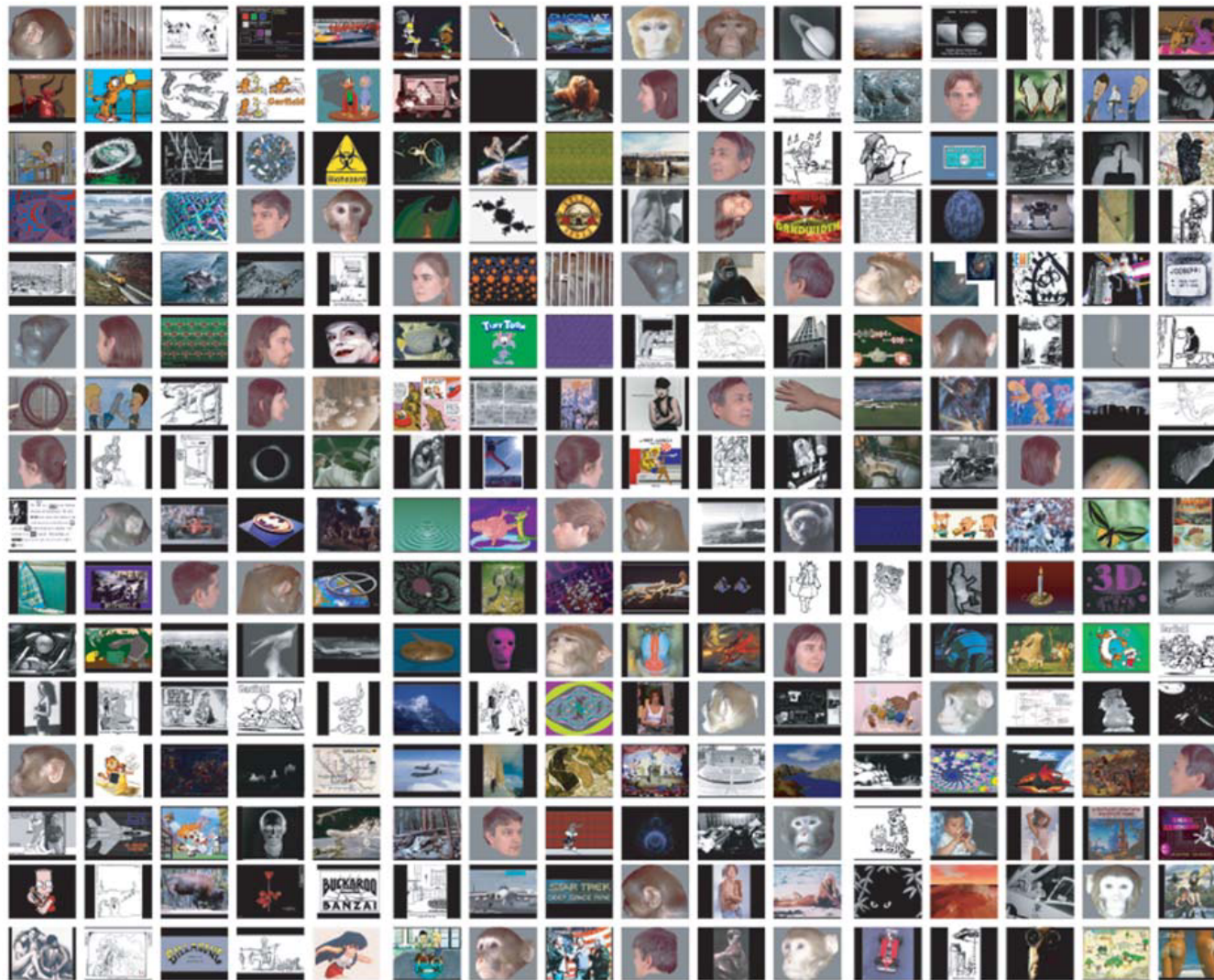
(Földiák et al. 2004)

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
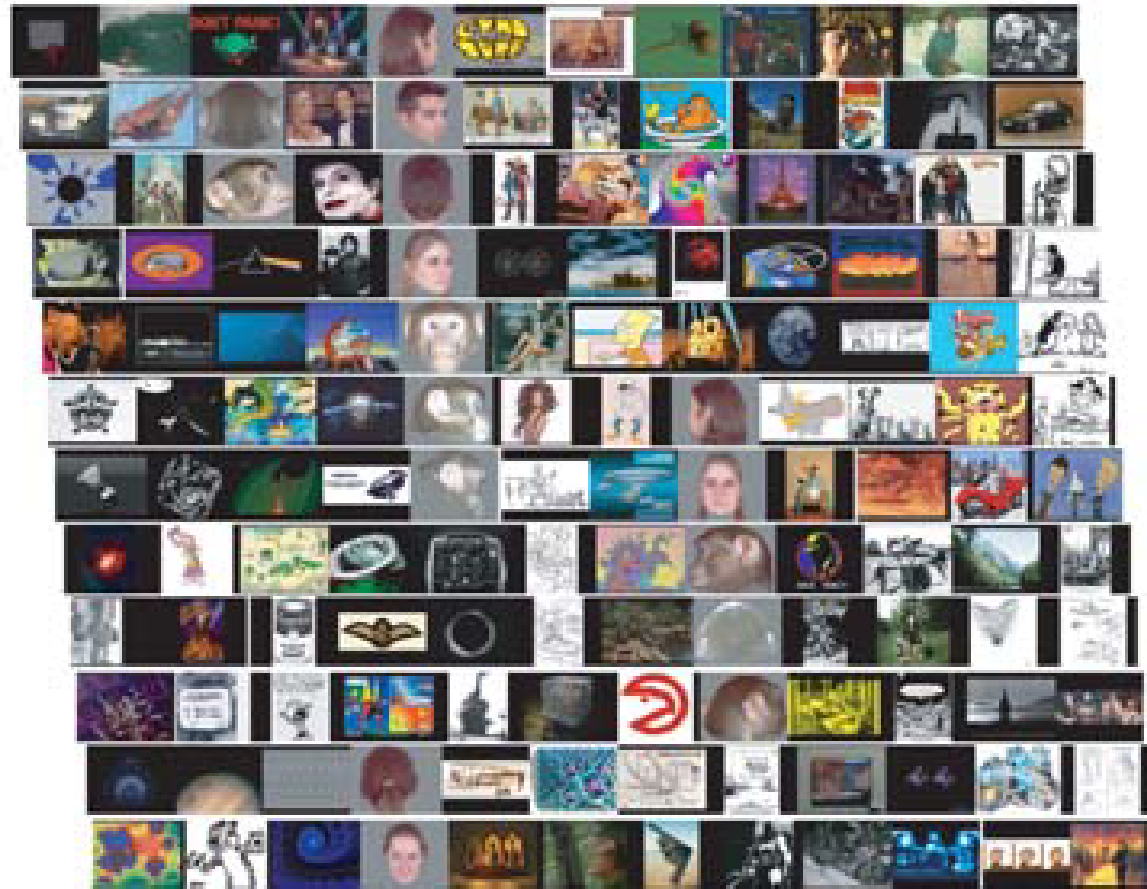
(Földiák et al. 2004)

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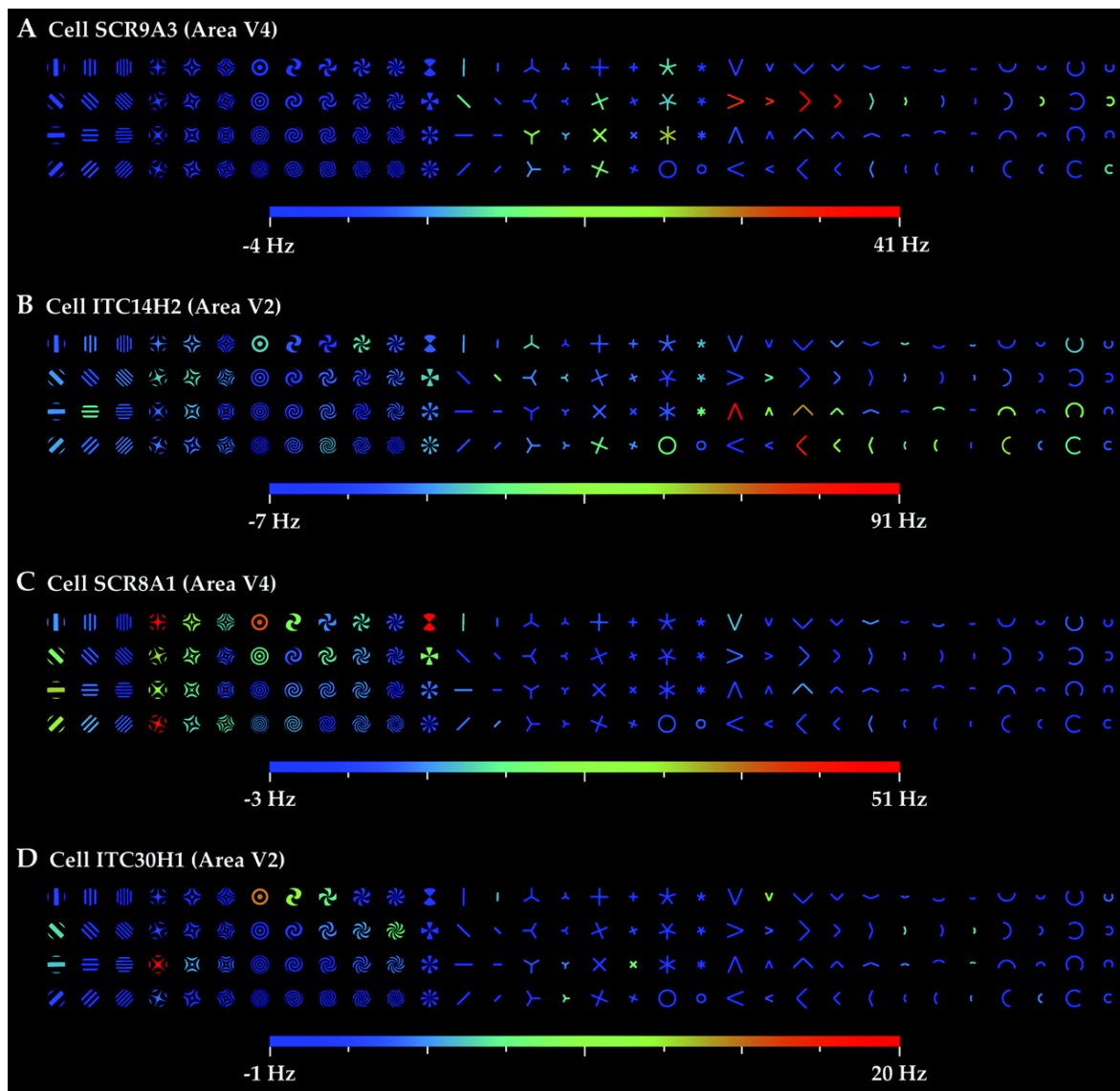
Difficult to see differences in kind in responses to geometric stimuli across the hierarchy

Macaque; (Hegdé & Van Essen 2007)

Form expertise

GREEBLES

FAMILY

samar   osmit   galli   radok   tasio

GENDER

plok

glip

two greebles of the same gender and same family →
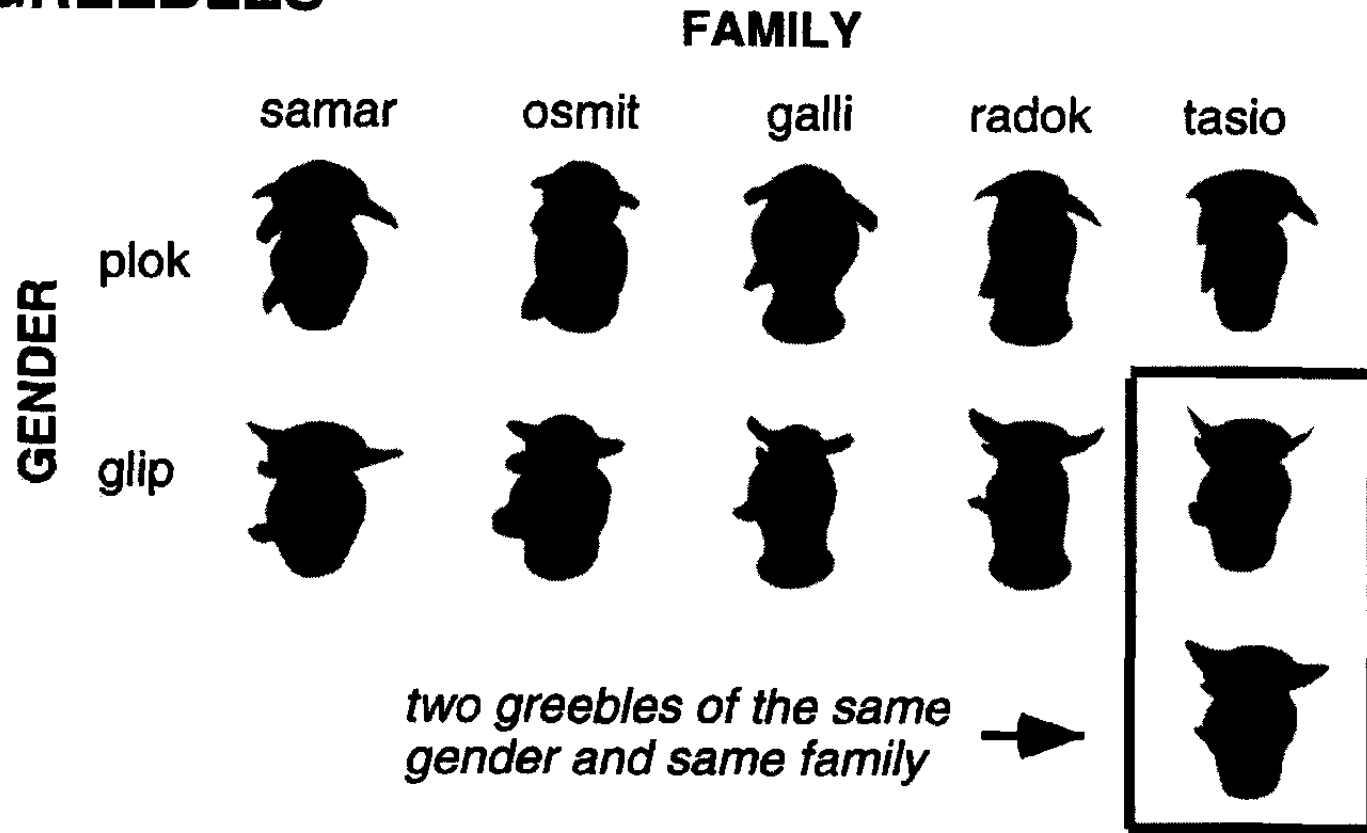
(Gauthier & Tarr 1997)

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

Face aftereffects

"The usual suspects"

Adam (button 1)

Jim (button 2)

John (button 3)

Henry (button 4)

Original face   Anti-face

0.25 0.50 0.75 1.00
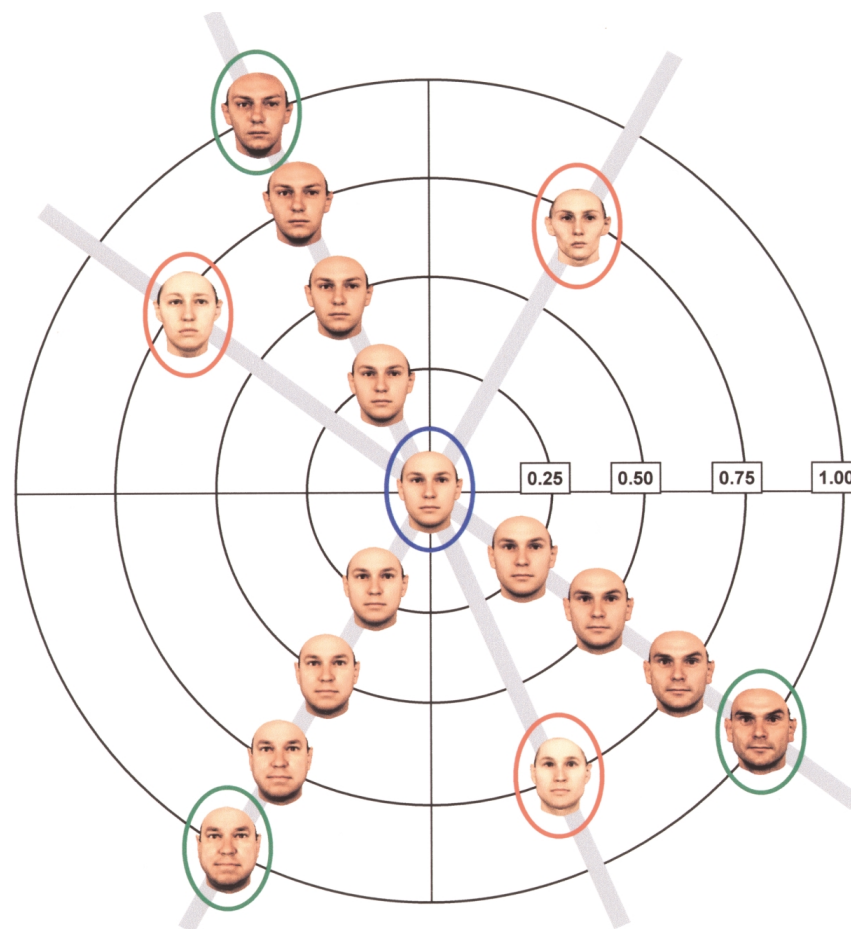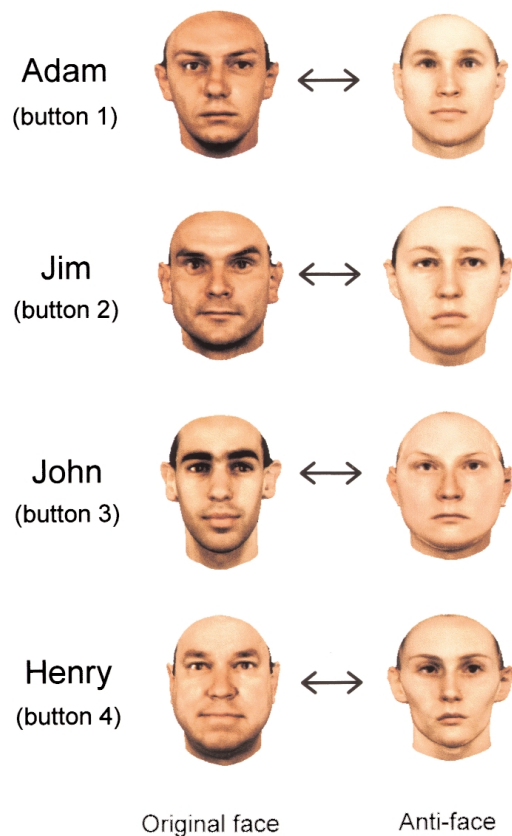
(Leopold et al. 2001)

Aftereffects are seemingly universal. E.g.

face aftereffects: changes in identity judgments;

blur/sharpness aftereffects, contrast aftereffects…

Face aftereffects same as TAE?

TAE

FAE
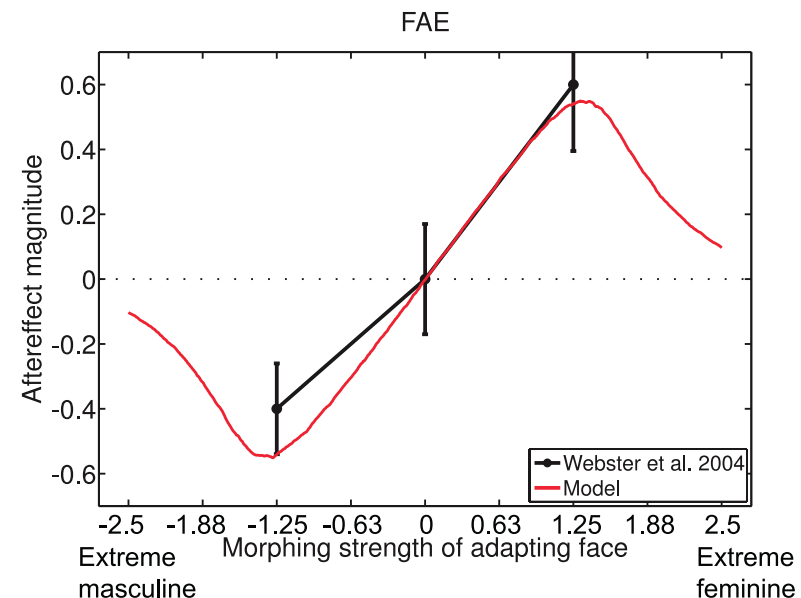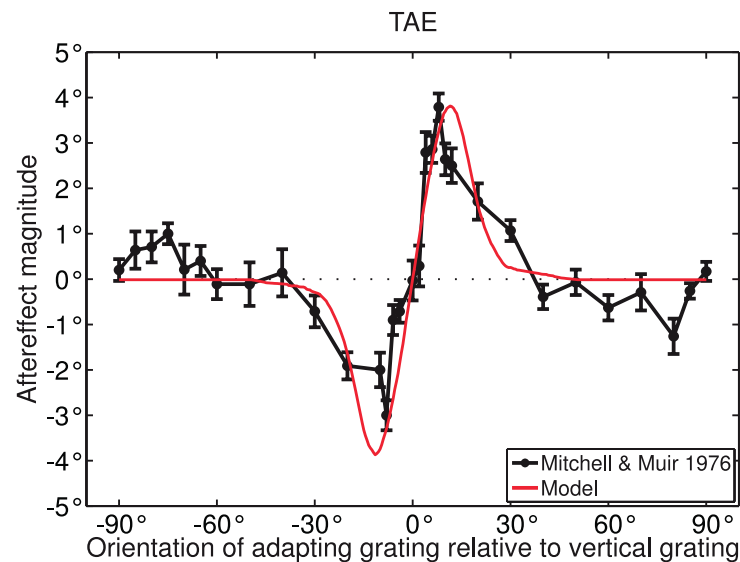
(Zhao et al. 2011)

People have elaborate theories about high-level aftereffects, but we successfully tested a clear prediction of the assumption that they are just like the TAE

(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.

In the extreme: Jennifer Aniston neurons (Quian Quiroga et al. 2005).

Why is invariance hard?

Simple template-based models won't provide much invariance,

but could build out of many such cells, or constellations of features.

RF sizes

VisNet

Layer 4

Layer 3

Layer 2

Layer 1

(Wallis & Rolls 1997)

Develops neurons with invariant tuning

Assumes fixed V1 area

Ignores topographic organization
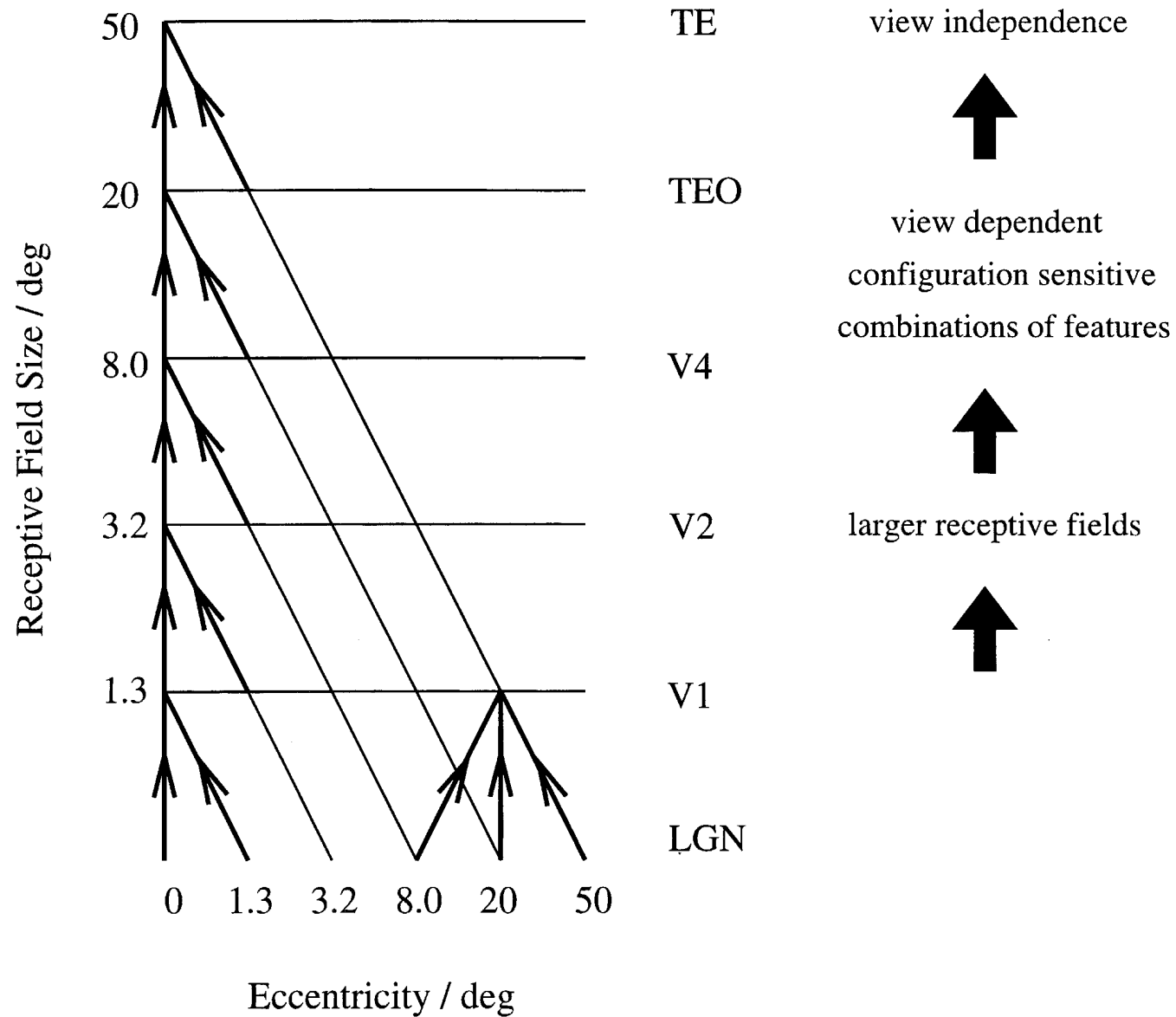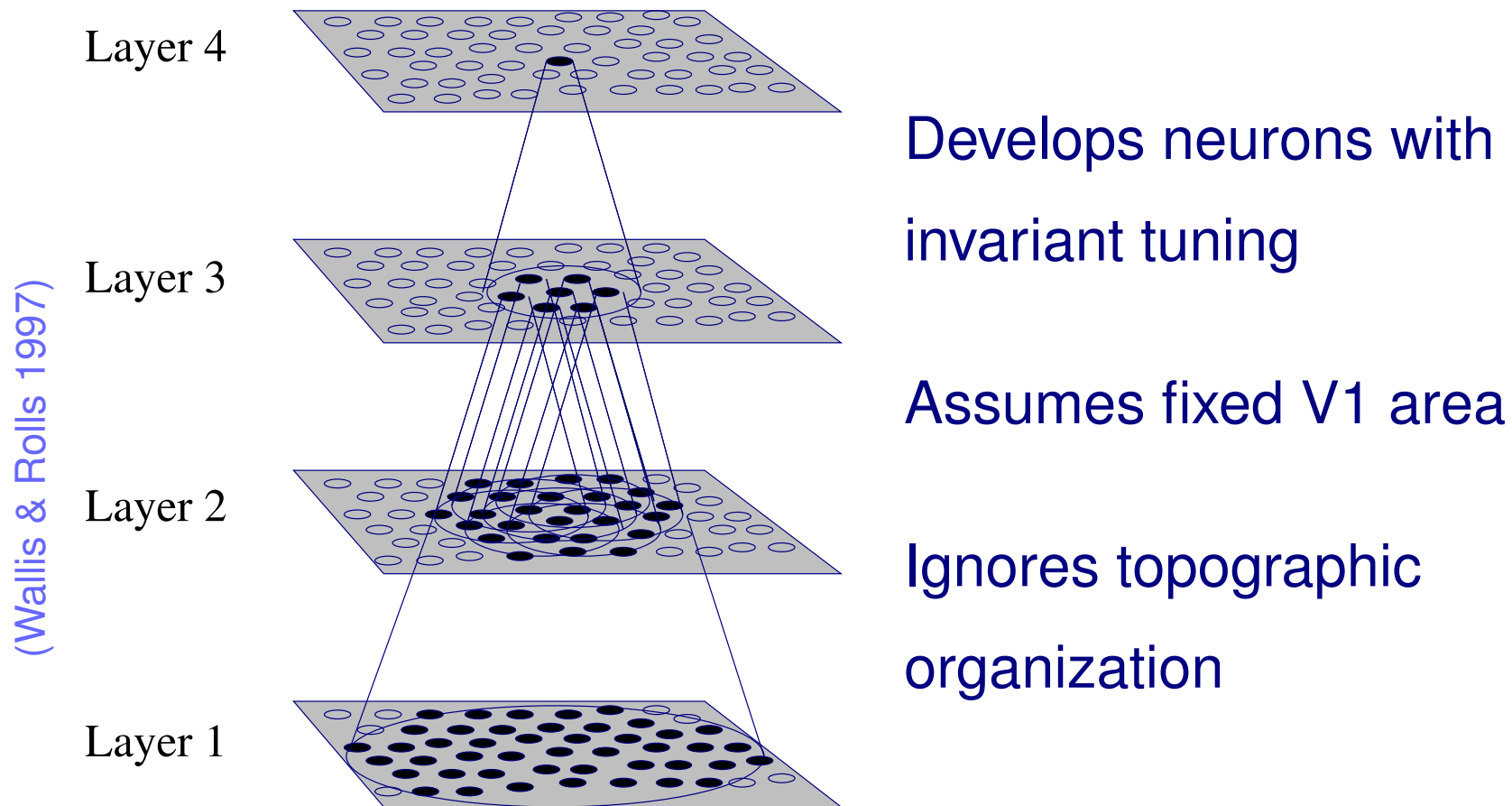
Trace learning rule

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

$$\Delta w_j = \alpha y^\tau x_j{}^\tau \qquad (1)$$

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

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

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

General technique for invariant responses? Need not be a special learning rule, if activity itself persists locally.

HMAX

(Riesenhuber & Poggio 1999)

view-tuned cells

"complex composite" cells (C2)

"composite feature" cells (S2)

complex cells (C1)

simple cells (S1)

— weighted sum
— MAX
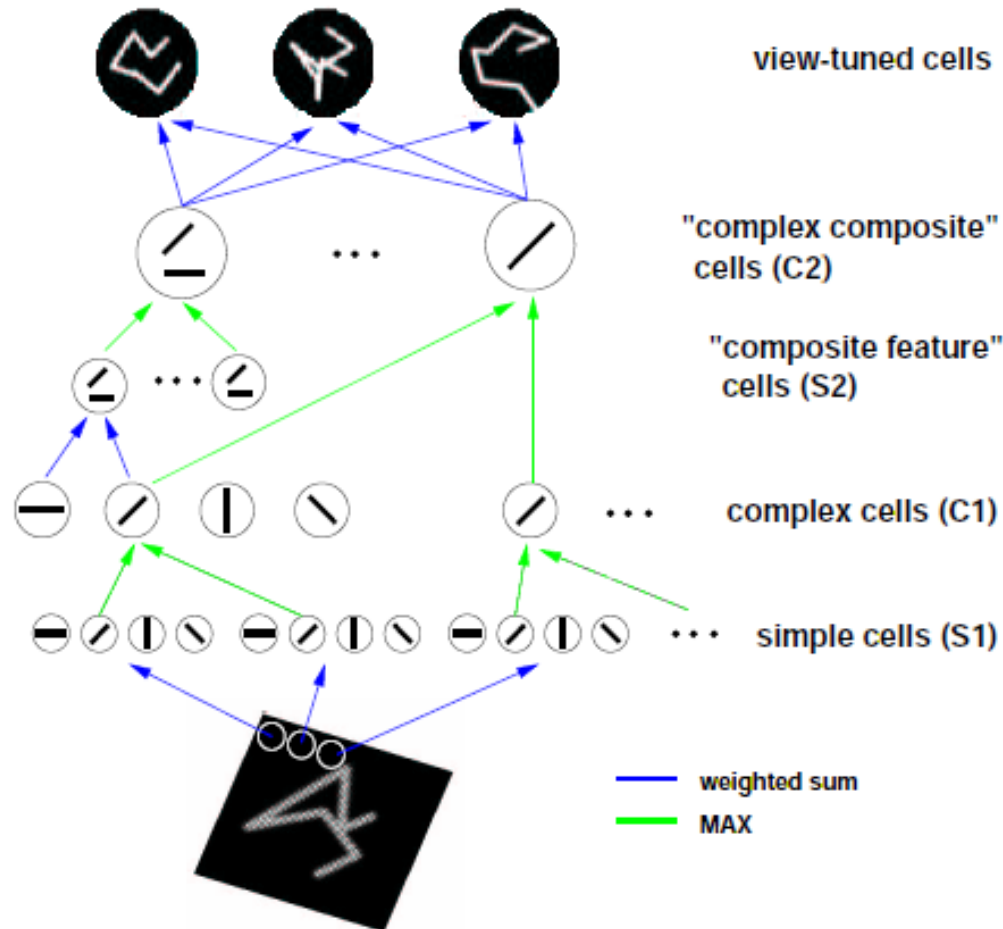
Top level (only) learns view, position, size invariant recognition

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

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

No clear topography

Koch and Itti saliency maps

Input image

Linear filtering

colors   intensity   orientations

Center-surround differences and normalization

Feature   maps

(12 maps)   (6 maps)   (24 maps)

Across-scale combinations and normalization

Conspicuity   maps

Linear combinations

Saliency map

Winner-take-all   Inhibition of return
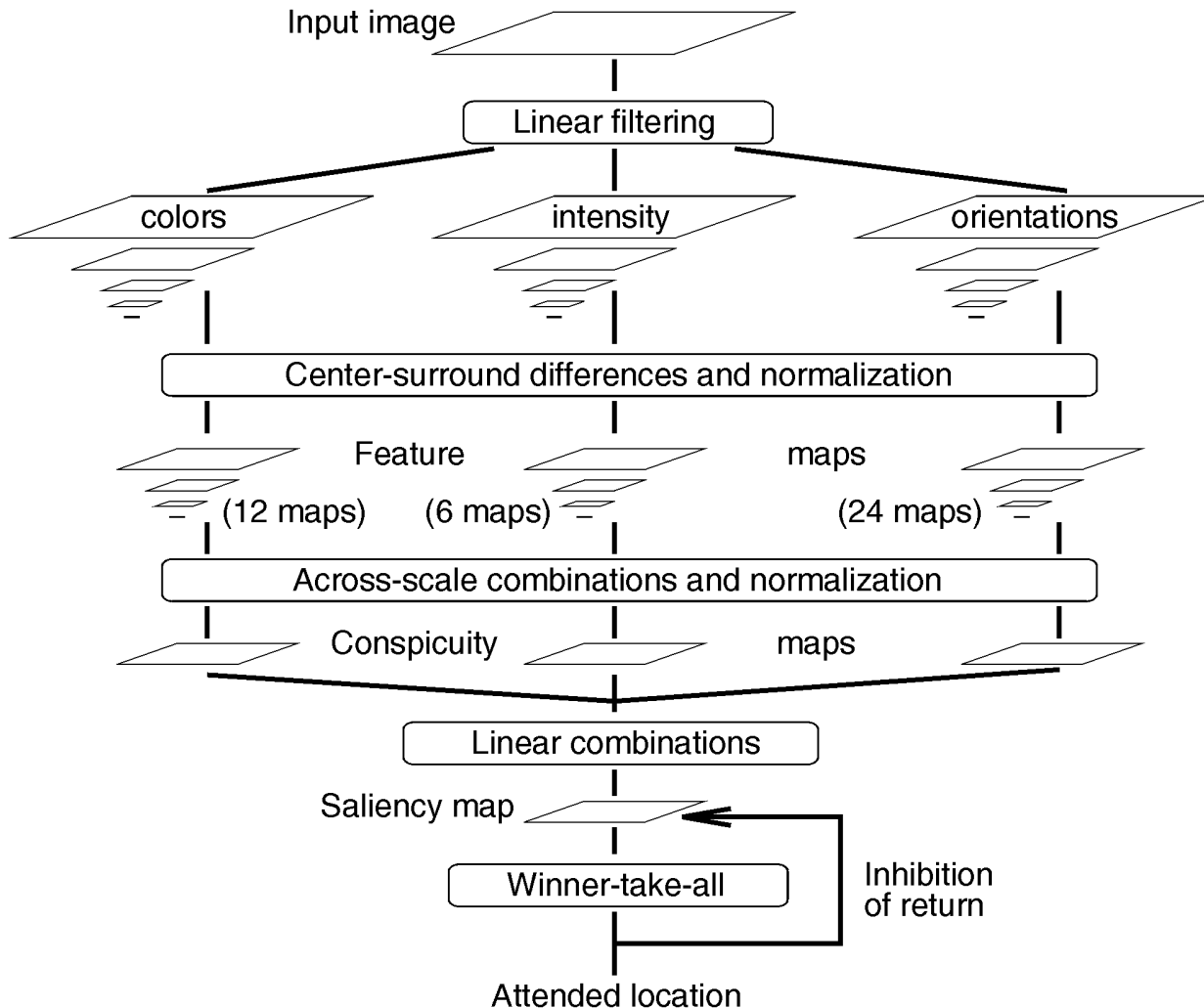
Attended location

(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

WHAT-Path Recognition
(Recurrent Pyramidal Receptive Field Structure)

WHERE-Path Spatial Attention

Local Lateral Inhibition

IT

PF46v
PF46d

Local Lateral Inhibition

PP

Local Lateral Inhibition

V4

MT

Local Lateral Inhibition

Local Lateral Inhibition

V2

Local Lateral Inhibition

Local Lateral Inhibition

V1

Local Lateral Inhibition

LGN - Retinal Input

(Deco & Rolls 2004)

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

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.

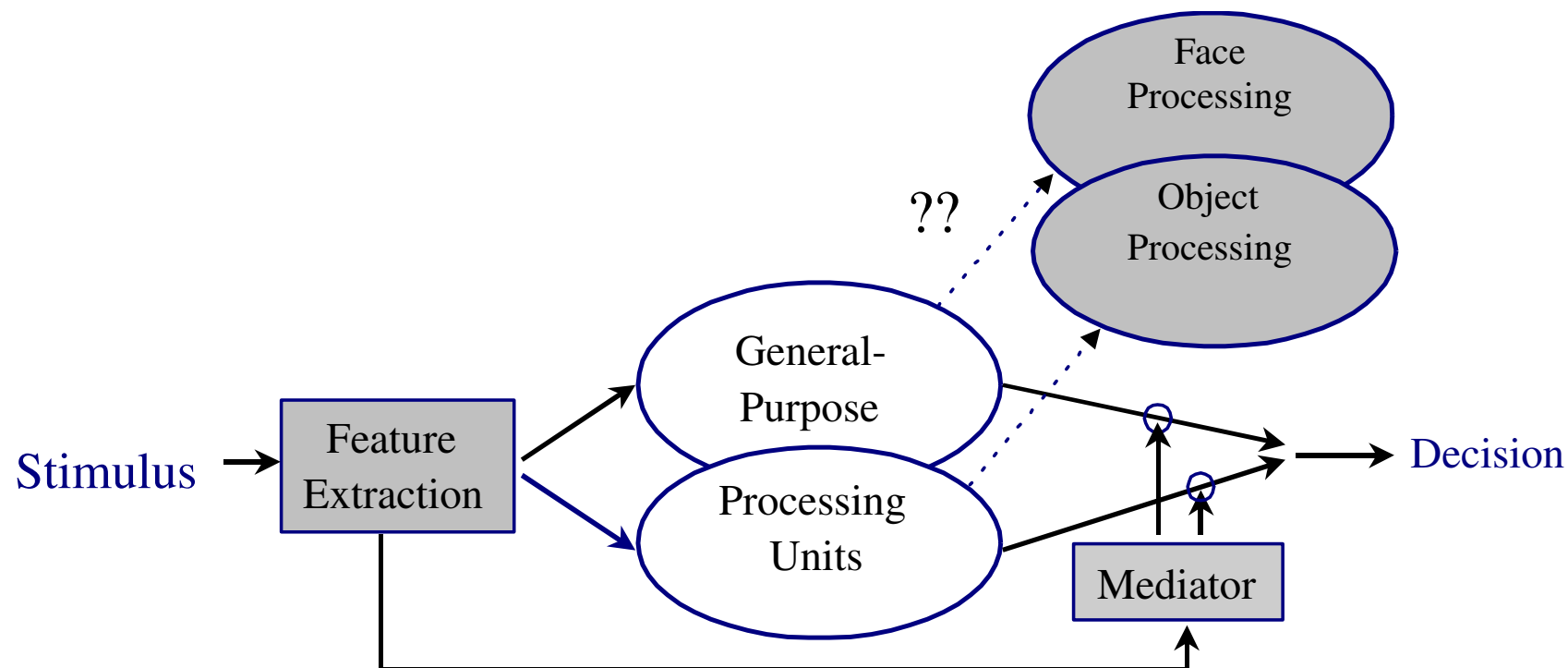At higher levels, neurons become multisensory and sensorimotor.

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

Output to and 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 or virtual environment – will need embodied models.

Summary

- Need to include many areas besides V1

- Complexity and lack of data are serious problems

- Eventually: situated, embodied, possibly virtual, 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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