# Visual Attention

- We use our visual system to provide us with information to accomplish some behavioral goal.
- How does the brain represent information about the visual scene AND its behavioral context?

*"Every one knows what attention is. It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration, of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others, and is a condition which has a real opposite in the confused, dazed, scatterbrained state …"*

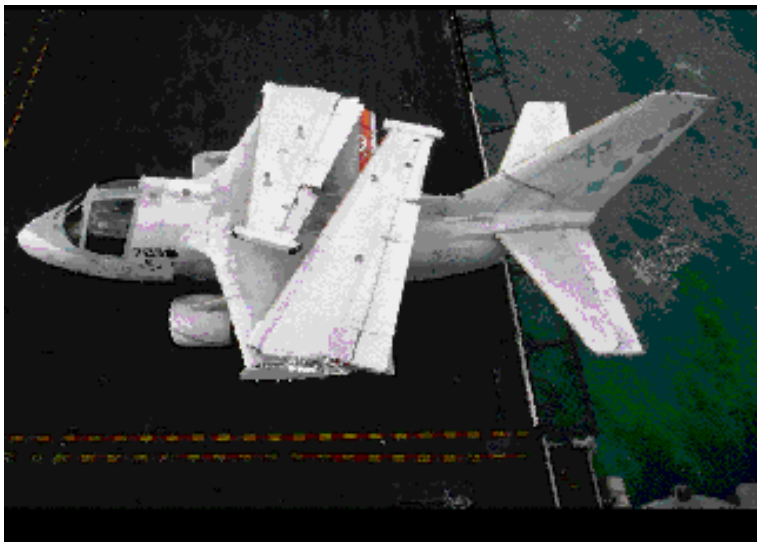
*Our attention is sensitive to, and captured by, "..strange things, moving things, wild animals, bright things, pretty things, metallic things, words, blows, blood, etc".*

William James (1890), *The Principles of Psychology*

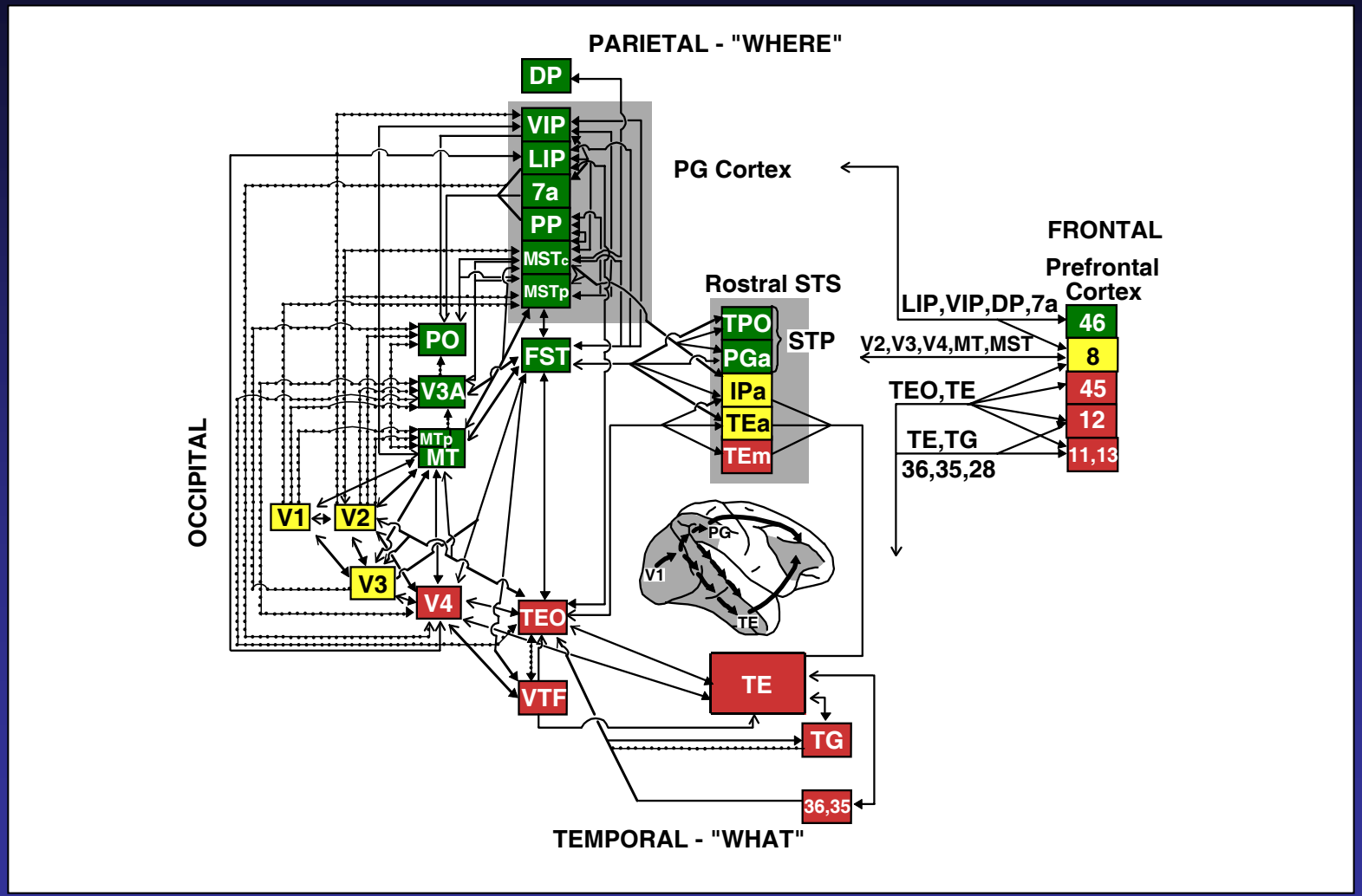
# Visual Attention

- Is guided through voluntary and involuntary mechanisms (aka endogenous, exogenous; top-down, bottom-up)
- Can be overt or covert. Integral to oculomotor control
- Sensory benefits: Increased sensitivity, more accurate, and respond more rapidly to attended items.
- Has limited capacity. Difficult to attend to multiple items simultaneously.
- Attention acts as a gatekeeper to memory and cognitive control.

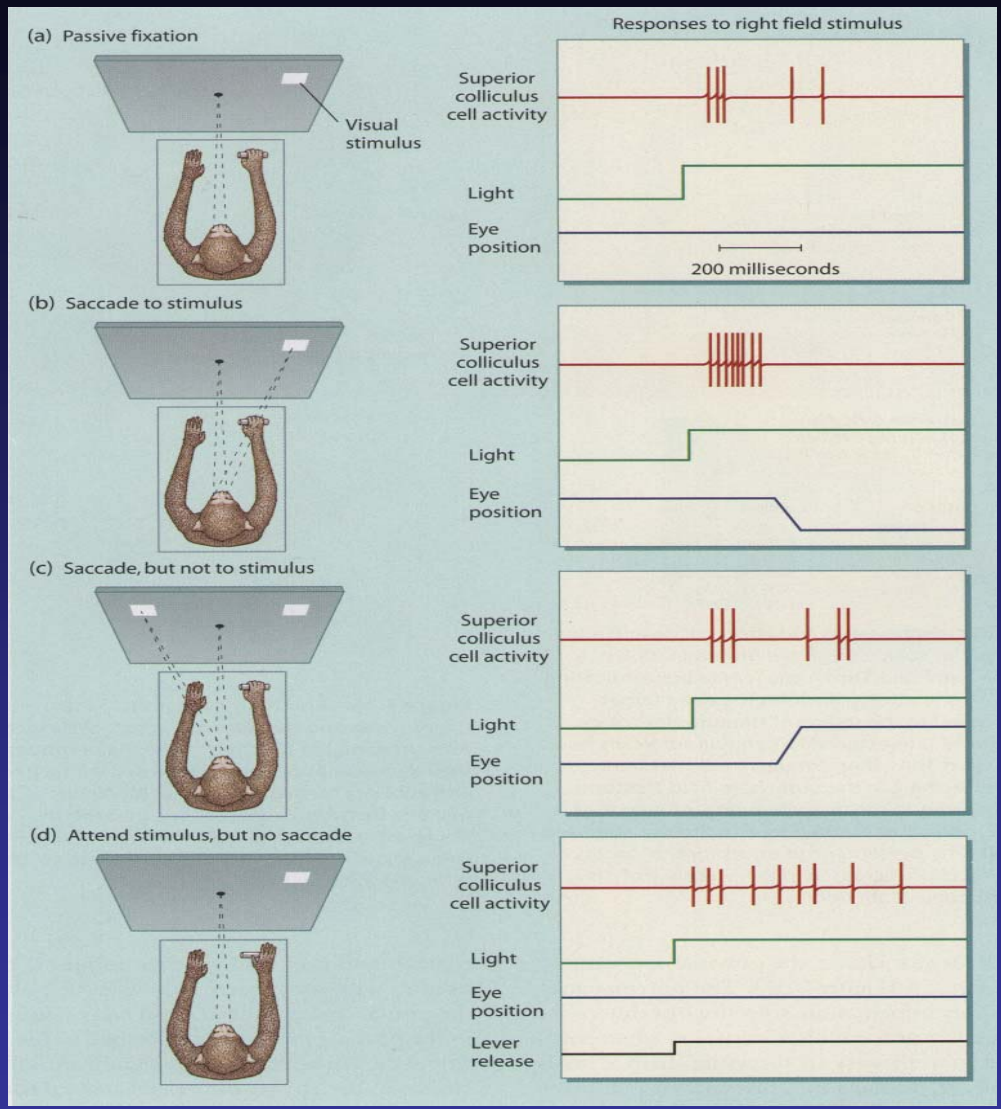
# Change Blindness (Rensink et al., 2000)



# Neurophysiological measures of attention



# Response enhancement in the superior colliculus (Wurtz et al., 1982)




Enhanced response to stimulus only when it was the target of an eye movement.
Does not indicate that neurons in superior colliculus represent a pure attentional signal.

# Response enhancement in parietal cortex (Wurtz et al., 1982)

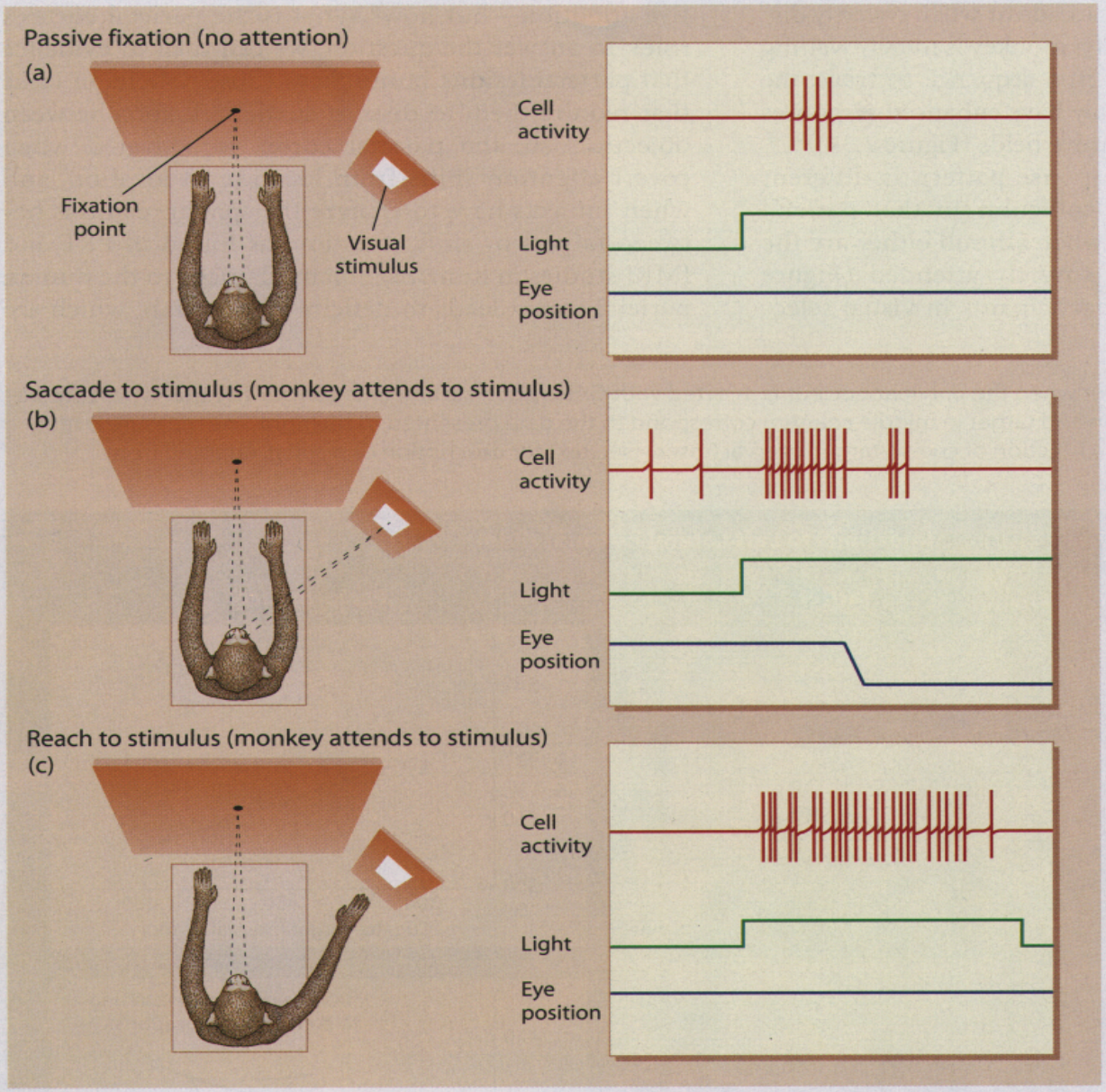
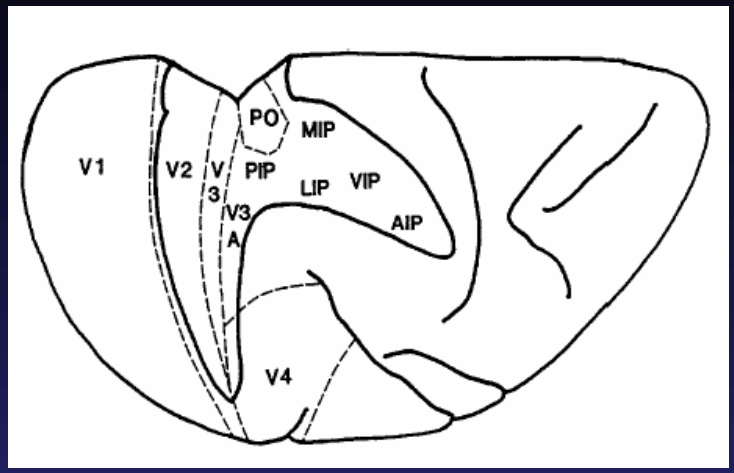
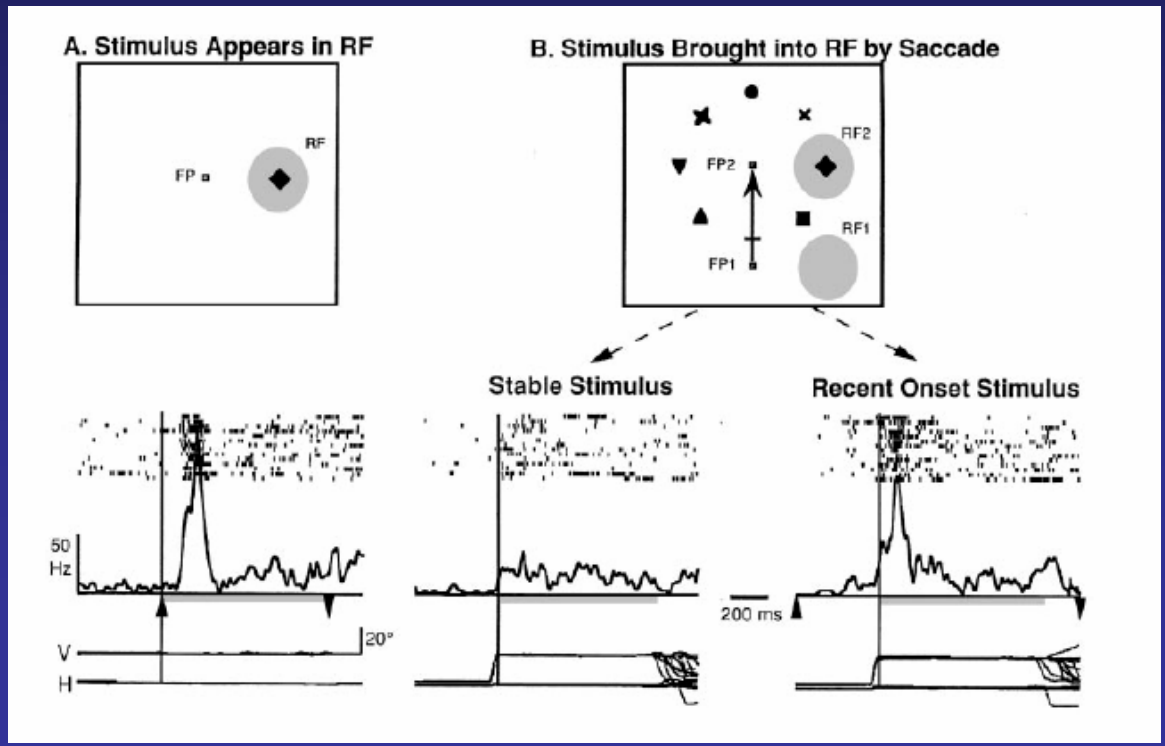



**Figure 7.38** Properties of parietal neurons in visual attention. Three conditions are shown. **(a)** The monkey passively fixates while a lateral field stimulus is presented, generating some action potentials from the neuron **(right)**. **(b)** The monkey has the task of making a saccadic eye movement to the target when it appears, and this increases the rate of neuron firing. **(c)** The neuron increases its firing rate to targets that are presented and covertly attended, when the animal must keep its eyes fixated straight ahead but is required to reach to the target. This demonstrates that the neuron is spatially selective, a sign of covert attention. Adapted from Wurtz et al. (1982).

# Effect of stimulus salience in area LIP (Gottlieb et al, 1998)



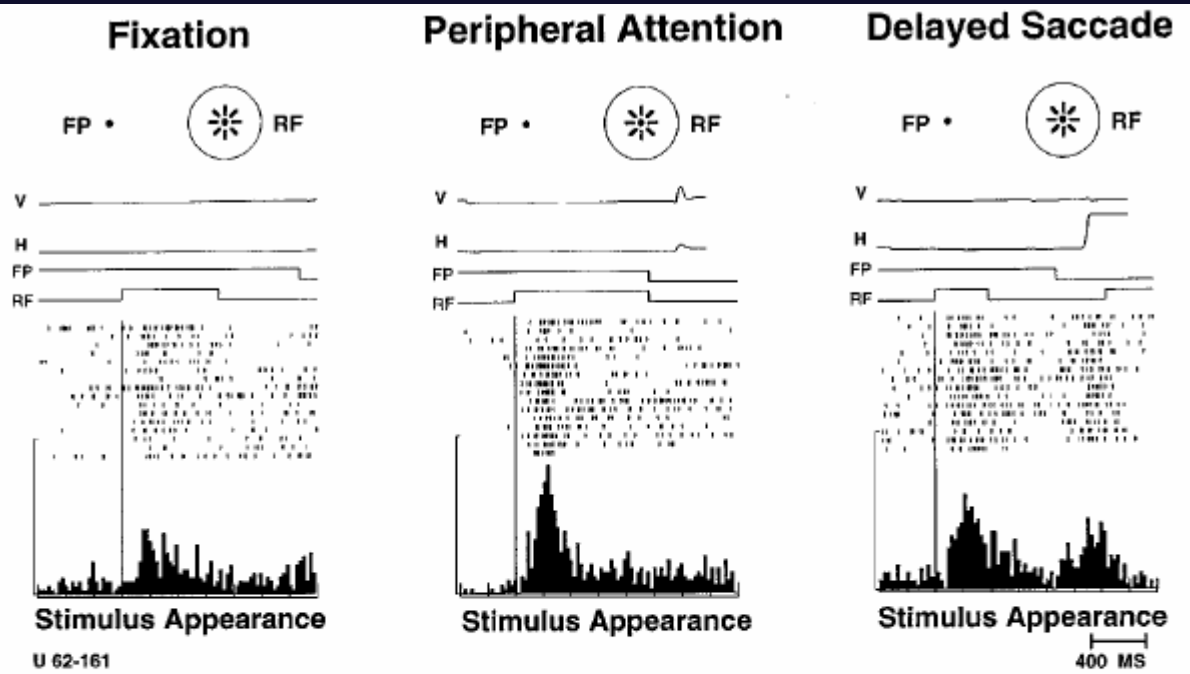



*Figure 5* Behavioral enhancement of visual responses in LIP. Each panel shows a cartoon with the locations of the receptive field (RF) and fixation point (FP). Horizontal (H) and vertical (V) eye position traces are shown for a single trial, with the time course of the lights at the fixation point (FP) and the stimulus (RF) shown beneath. The neuron responds when the stimulus appears in its receptive field (*left*, Fixation). The visual response is enhanced when the monkey will respond to the stimulus by making a hand movement when it dims (*center*, Peripheral Attention) or when the monkey will make a saccade to the stimulus (*right*, Delayed Saccade). Note the second burst in the Delayed Saccade Task. This burst was synchronized with saccade onset. This cell also discharged in association with learned saccades in total darkness, when there was no recent stimulus (not shown). Adapted from Goldberg et al (1990).

# Summary of studies in parietal cortex

- Enhanced response prior to saccade to RF stimulus
- No enhancement to stimulus outside RF
- Enhanced response to RF stimulus when task is lever press
- Enhanced response when stimulus has recent onset, prior to eye movement

*Spatial representation of stimulus salience*

# Observations from behavioral studies of neurological patients

**Neglect**

• A failure to acknowledge, explore, or respond to stimuli located towards the contralesional side of space.
• Typically the result of right parietal damage
• No sensory of motor damage
• Have anosognosia

**Extinction**

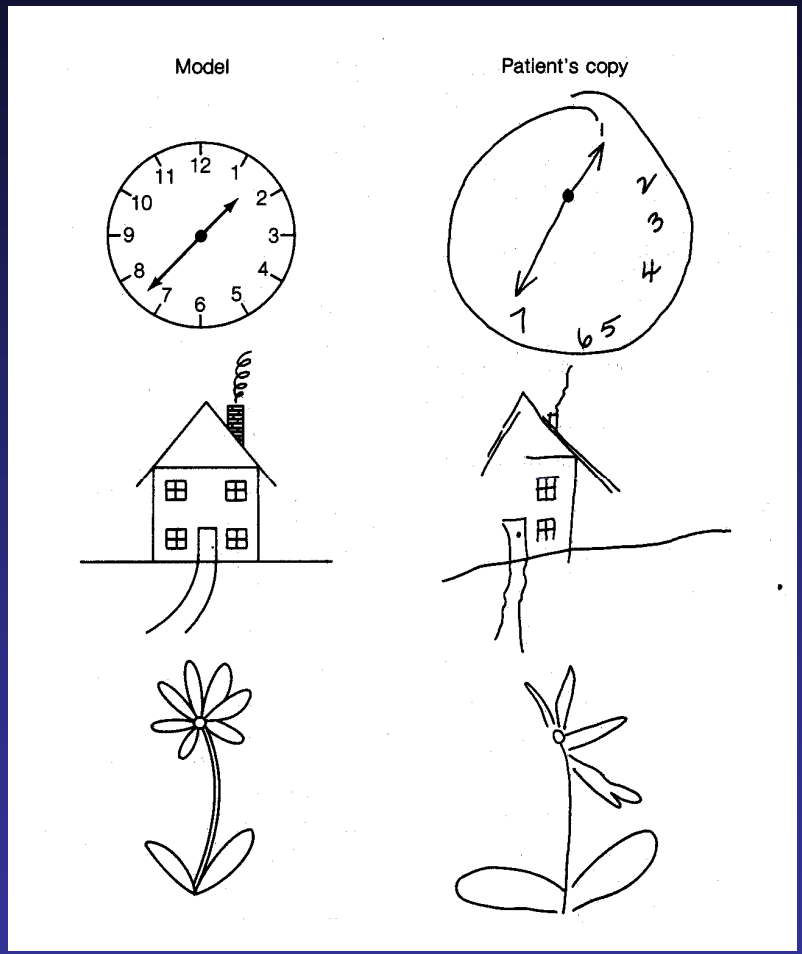
• Can attend to stimulus in contralateral visual field provided there are no stimuli in ipsilateral hemifield.
• The presence of another stimulus in ipsilateral hemifield draws attention and patient is no longer aware of stimulus in contralateral field.
• Thought to be a problem with disengaging attention

**Simultagnosia**

• Bilateral superior parietal damage, intact visual fields, unable to see multiple objects simultaneously

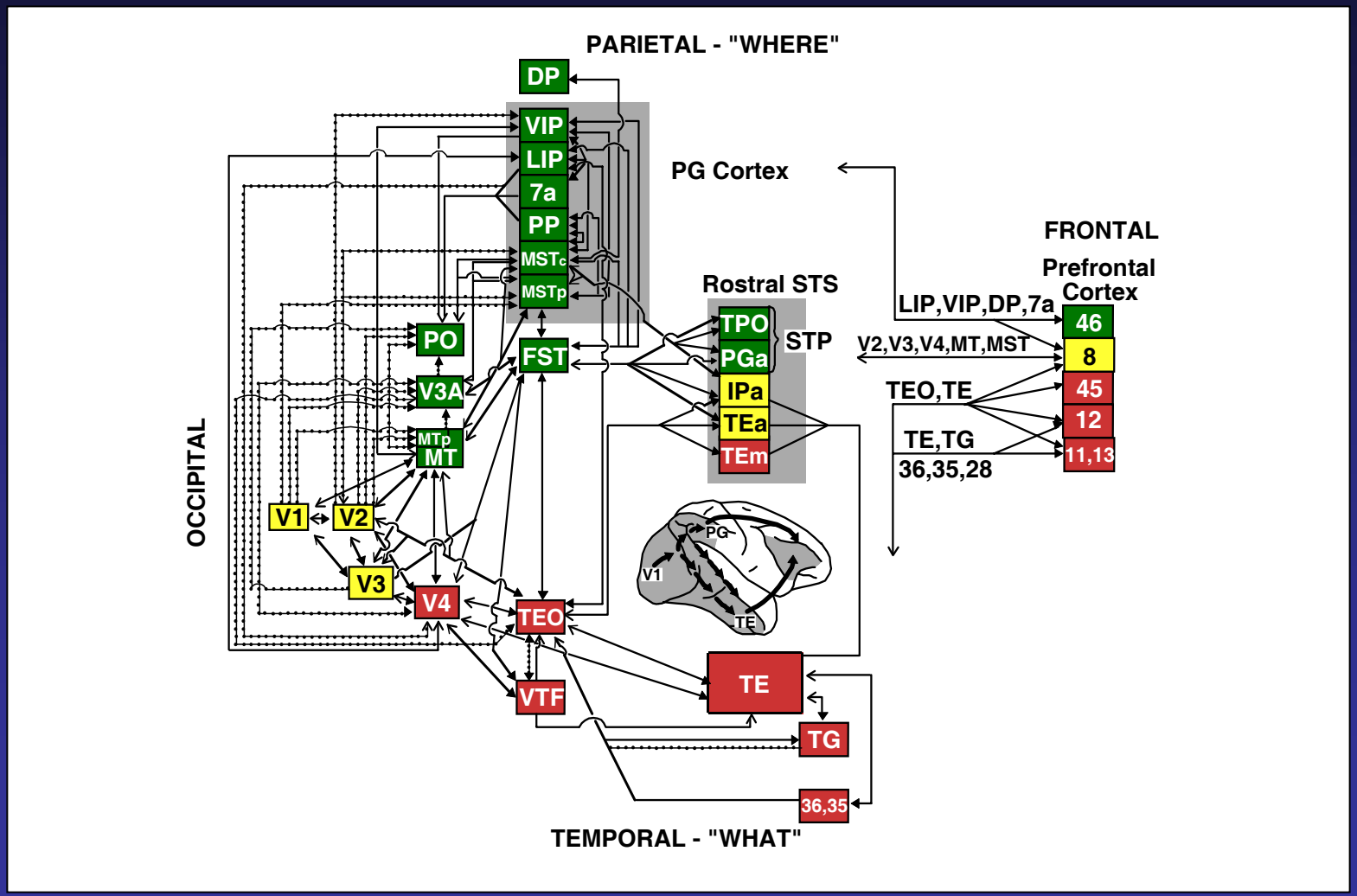
## Copying test for neglect

Three drawings on the right were made from models on the left by patients with unilateral visual neglect (from Kolb and Whishaw, 1990)

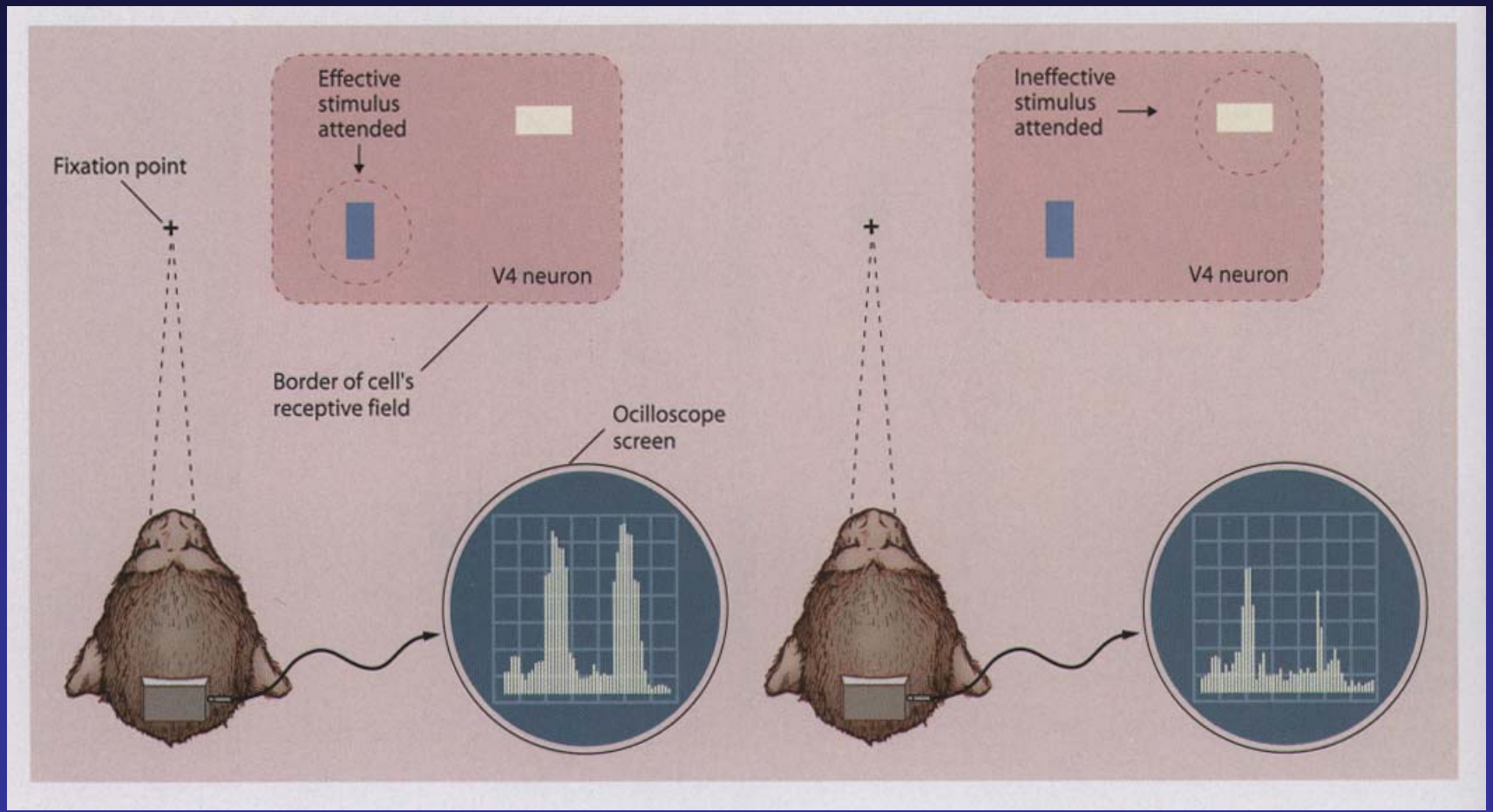


*Self-portraits of German artist Anton Raederscheidt at progressive time points after his stroke*

- Attention in the ventral stream (V1, V2, V4, IT)
- Limited Capacity
- Multiple stimuli in the receptive field

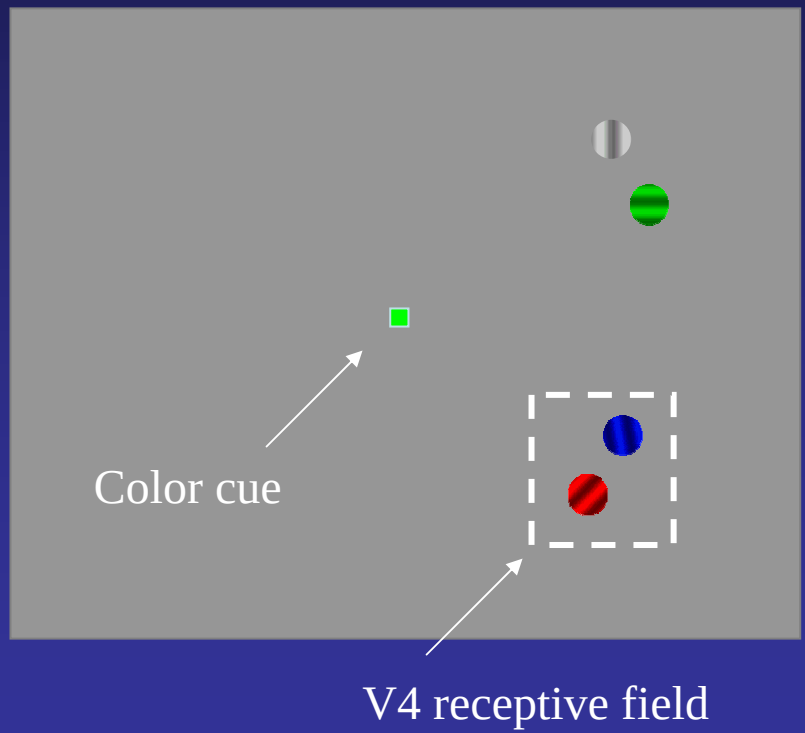


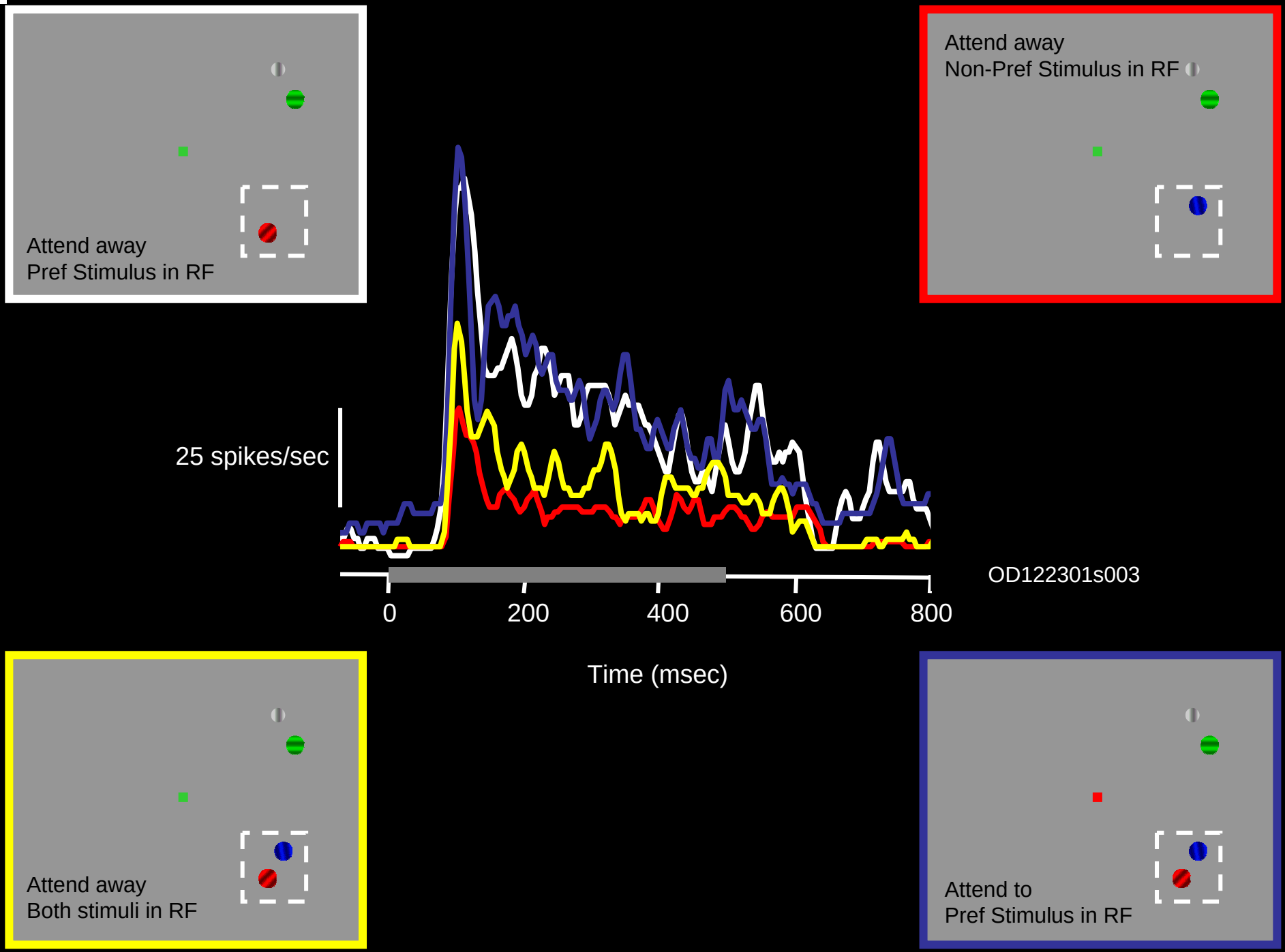
# Moran and Desimone (1985)



# Cued Attention Paradigm

Fixation spot cued the color of the valid grating




Attend away
Pref Stimulus in RF
Attend away
Non-Pref Stimulus in RF
25 spikes/sec
OD122301s003
0
200
400
600
800
Time (msec)
Attend away
Both stimuli in RF
Attend to
Pref Stimulus in RF

# Summary of V4 results

- Suppression of the response to the unattended stimulus
- Enhanced response to the attended stimulus if it was a preferred stimulus for that neuron
- Response of the V4 neuron is captured by the attended stimulus
- Similar findings in areas V2 and IT

# Biased competition theory of attention (Desimone and Duncan, 1995)

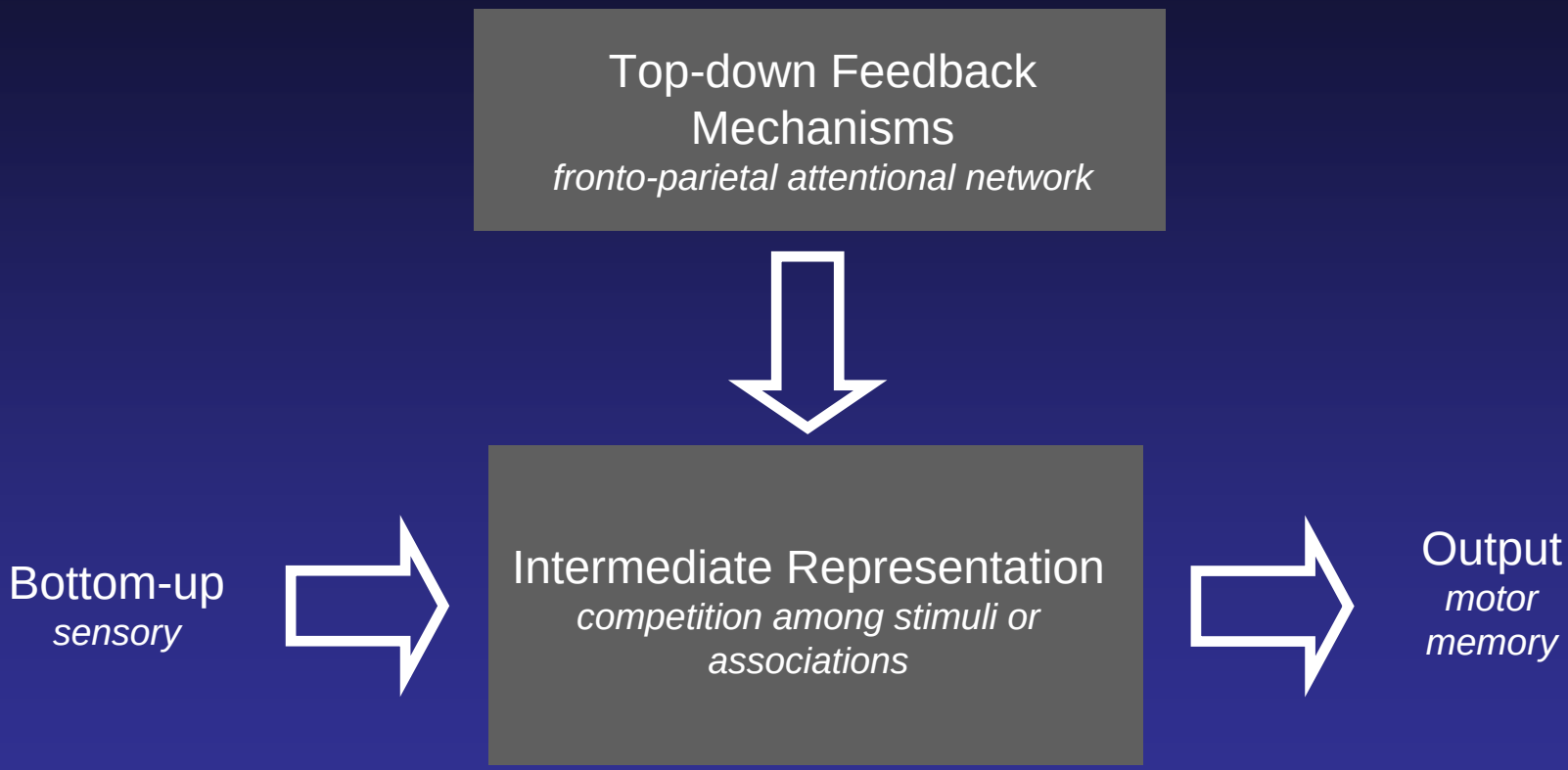
Assumptions:

• Given the limits on our ability to process several stimuli at once, visual objects compete for representational resources. Because the neural representations of objects are highly distributed, competitive processing occurs in many brain areas sensitive to visual input.

• Competition is integrated across several areas, such that neural populations that represent different aspects of a single object interact in a mutually facilitatory manner.

• The competition can be biased not only by bottom-up factors, but also by top-down influences that are based on current task demands.

# Biased Competition: Desimone and Duncan, 1995



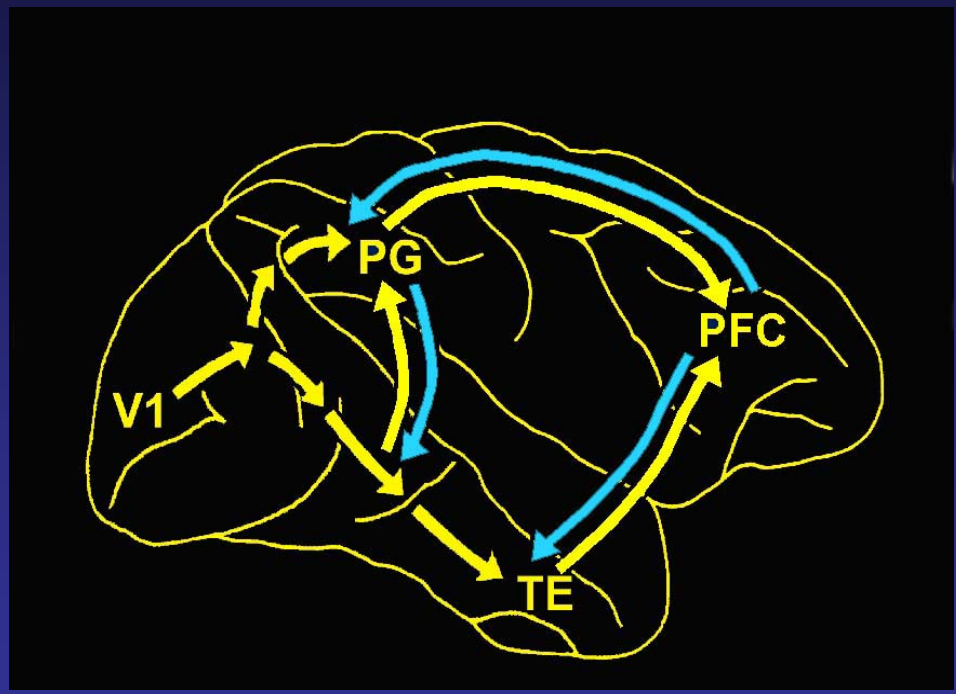
Questions:

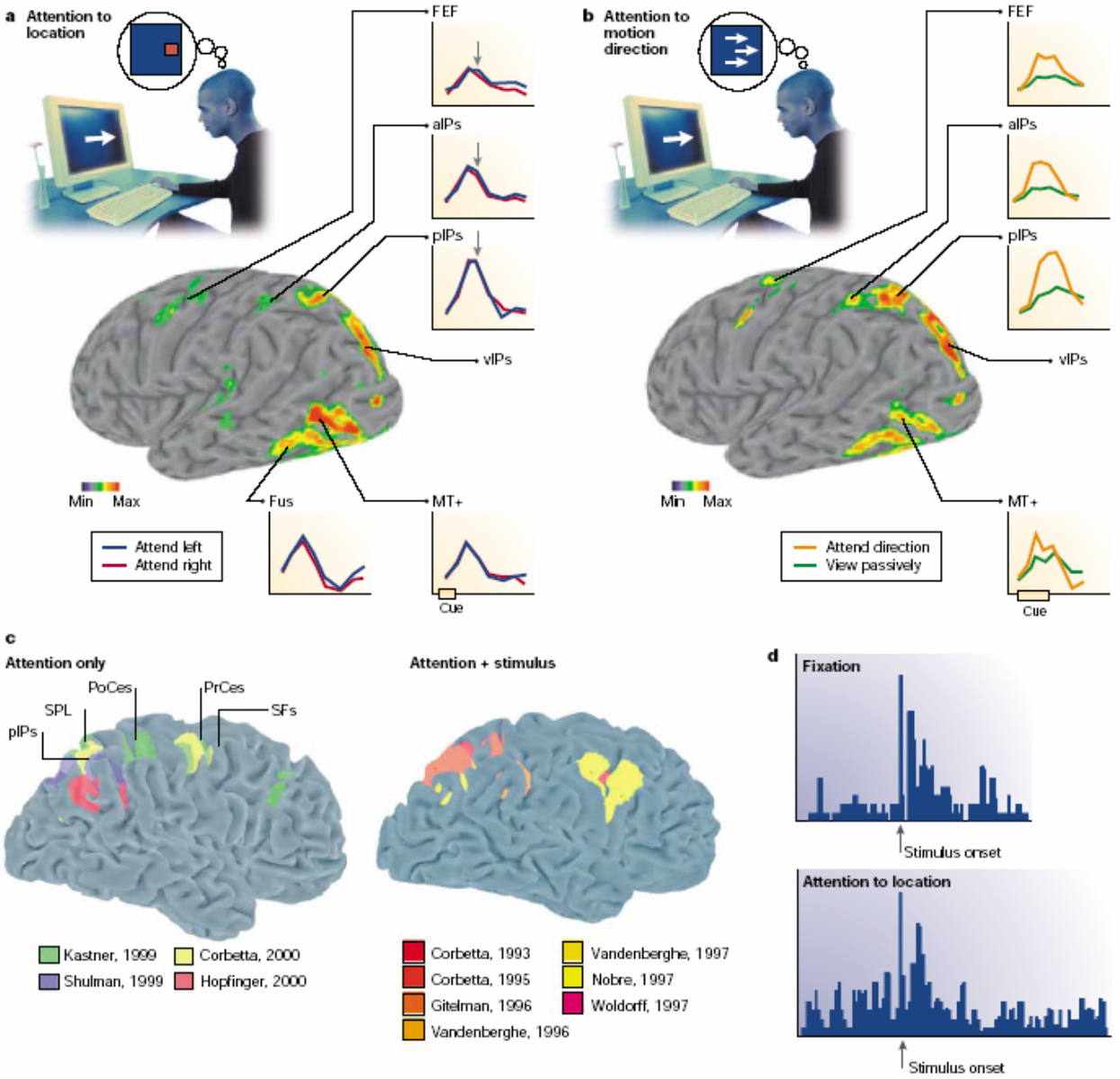
- How do the distributed neural populations ‘know’ that they are representing the attended object and, thus, enhance each other while suppressing the representation of unattended objects?

- What is the source of top-down signals?

- Are there dedicated neural systems for the direction of attention?

# Top-down control of visual attention




a Attention to location
FEF
aIPs
pIPs
vIPs
Min Max
Fus
MT+
Attend left
Attend right
Cue
b Attention to motion direction
FEF
aIPs
pIPs
vIPs
Min Max
MT+
Attend direction
View passively
Cue
c
Attention only
PoCes
PrCes
SPL
SFs
pIPs
Kastner, 1999
Corbetta, 2000
Shulman, 1999
Hopfinger, 2000
Attention + stimulus
Corbetta, 1993
Corbetta, 1995
Gitelman, 1996
Vandenberghe, 1996
Vandenberghe, 1997
Nobre, 1997
Woldorff, 1997
d
Fixation
Stimulus onset
Attention to location
Stimulus onset

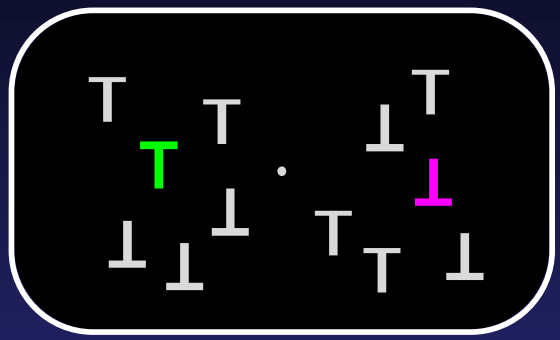
# Dorsal frontoparietal network for top-down control of visual attention

Stimulus-related activity is modulated by attention in occipital regions

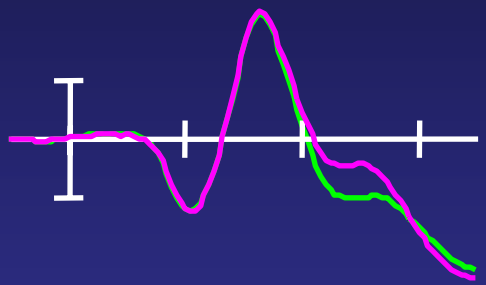
Frontal and parietal regions exhibit sustained activity during cue period in absence of stimulus array

# The N2pc component

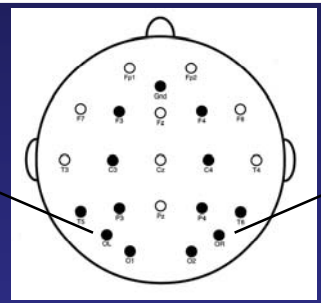
*Courtesy of Geoff Woodman*



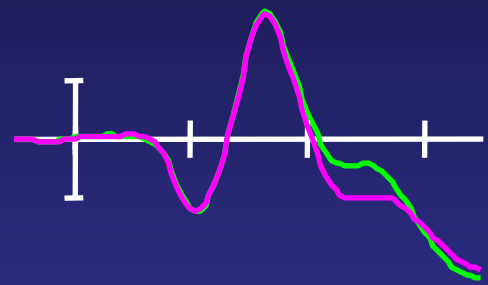
Left Hemisphere



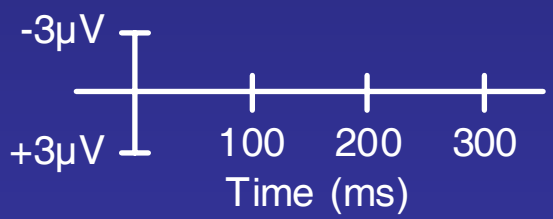
LVF Target
RVF Target



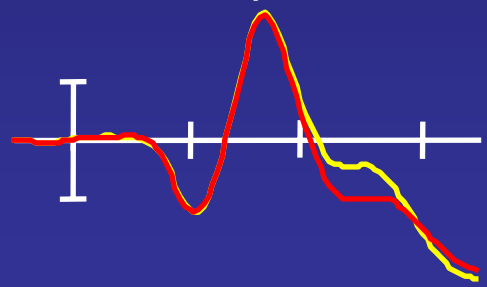
Right Hemisphere



LVF Target
RVF Target




Collapsed



Contralateral Target
Ipsilateral Target