9.01 Introduction to Neuroscience
Fall 2007

9.01 Chapter 21: Attention

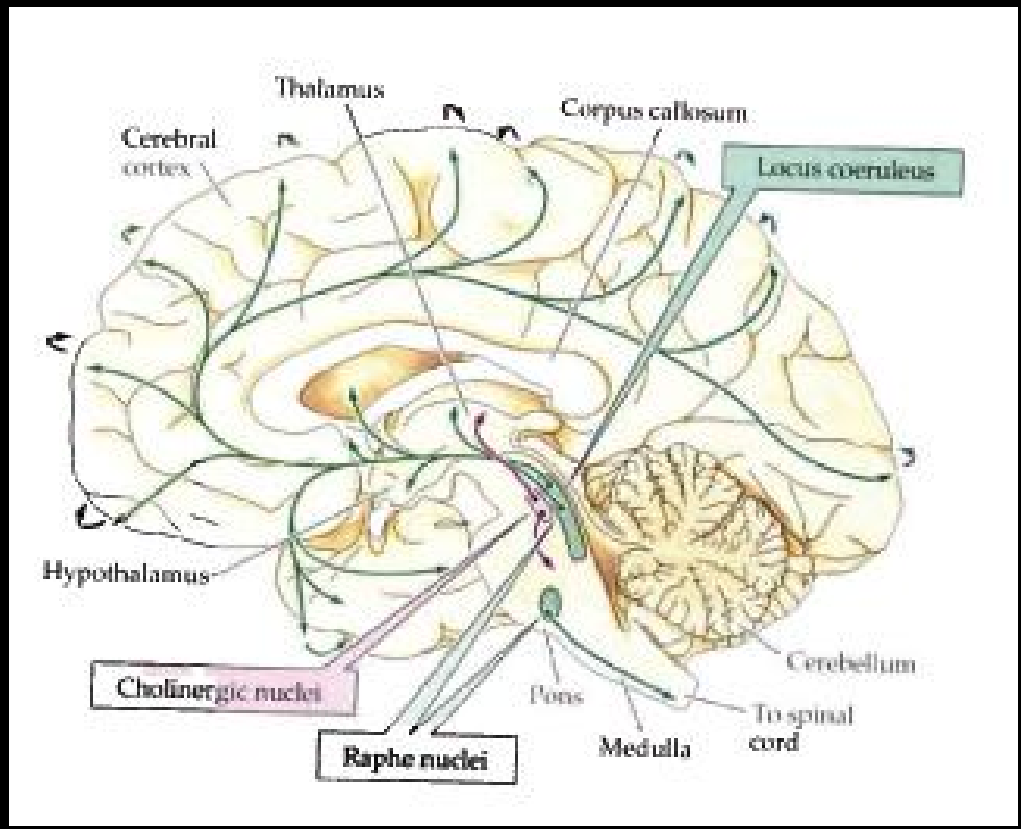
December 3, 2007
Robert Desimone

Outline

- Selective attention characterized by capacity limits and selectivity.
- Effects of attention on visual processing and awareness.
- The ventral object recognition stream, and its “top-down” control by attention.
- The fronto-parietal system for top-down attentional control, including the effects of fronto-parietal lesions (neglect).
- Interactions between prefrontal cortex and visual cortex.

Types of attention

- Arousal – not covered in this class session



- Selective attention – next slides

Selective attention and executive control


21 3 2001

Impairments of attention and executive control are common in mental disorders

- ADHD
- Schizophrenia
- Bipolar/Mania
- Major Unipolar Depression
- Parkinsons
- Alzheimers
- “Normal” Aging

Two major behavioral phenomena in attention: Limited processing capacity and selectivity

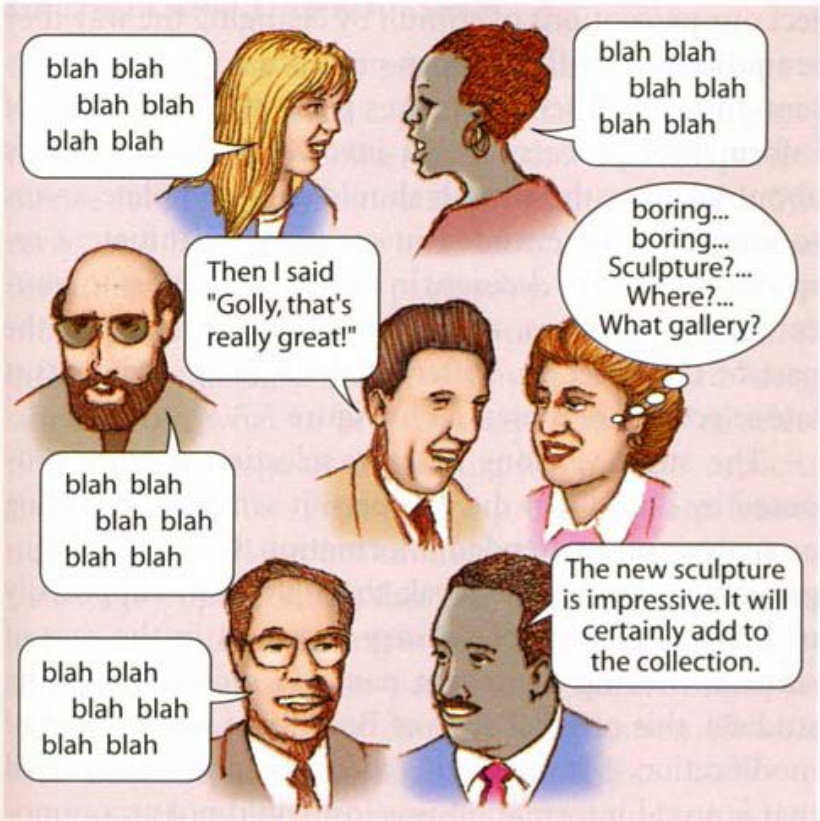


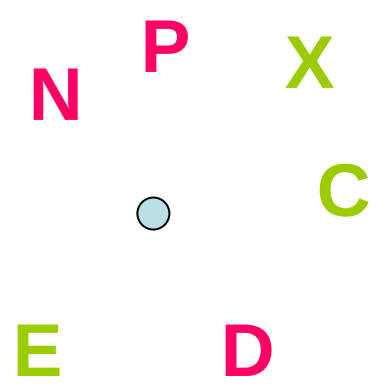
Figure 7.4 The cocktail party effect of Cherry (1953), illustrating how in the noisy confusing environment of the cocktail party, people are able to focus attention on a single conversation.

Cocktail Party Phenomenon

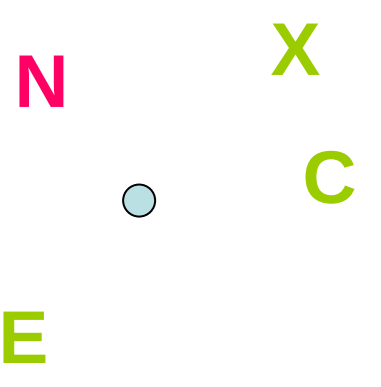
Two major behavioral phenomena in attention: Limited processing capacity (a vs b) and selectivity (a vs c)

Report red letters

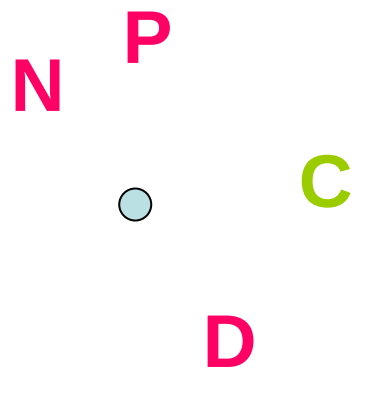
a



b



c



Alerting - Orienting

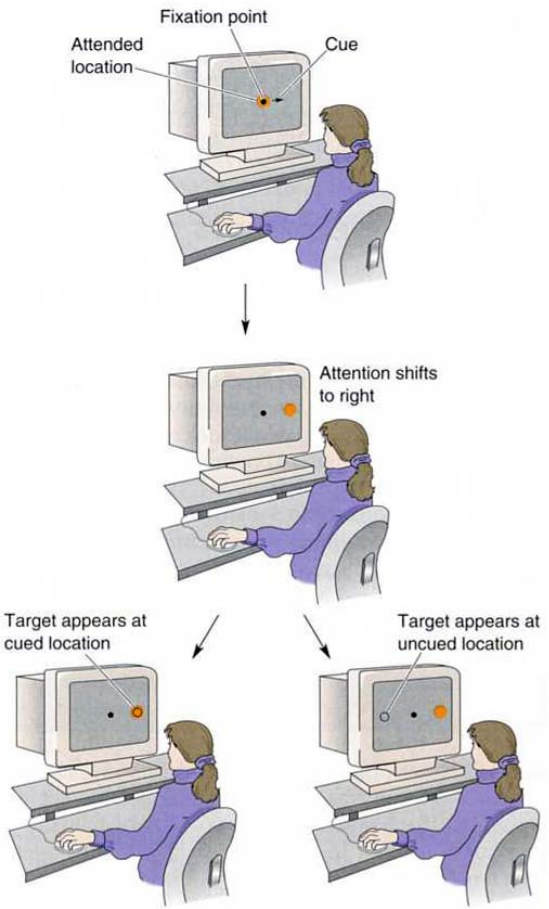


FIGURE 21.1
Measuring the effect of attention on visual detection. While an observer maintains steady fixation, a cue directs her to shift her attention to one side of the computer screen. In each trial, the observer indicates whether a circular target is seen on either side of the screen.

Alerting - Orienting

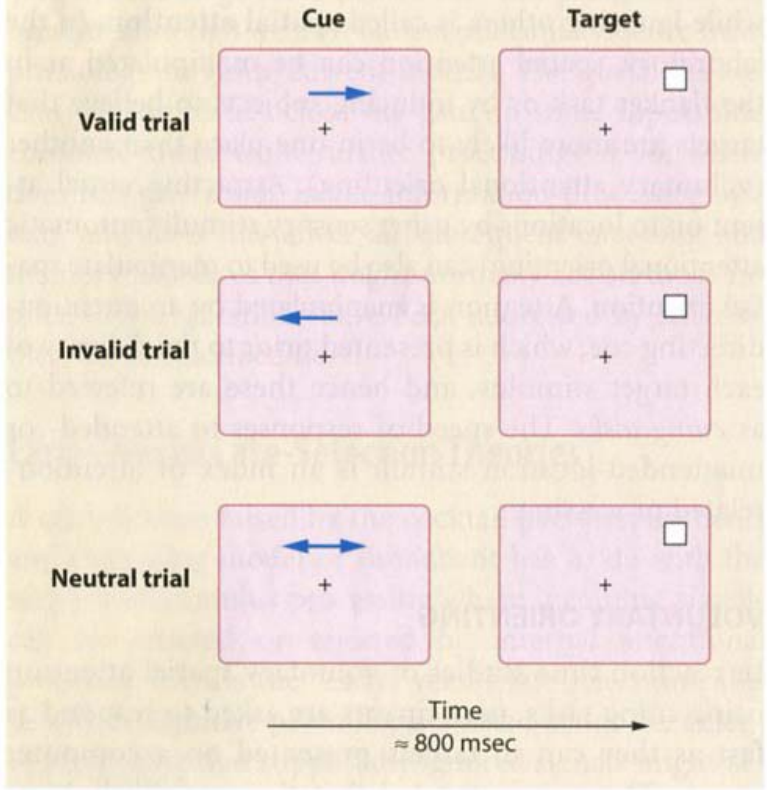


Figure 7.8 The spatial cuing paradigm of Posner and colleagues. A subject sits in front of a computer screen and fixates on the central cross. An arrow cue indicates to which visual hemifield the subject is to covertly attend. The cue is then followed by a target in either the correctly or the incorrectly cued location.

Alerting - Orienting

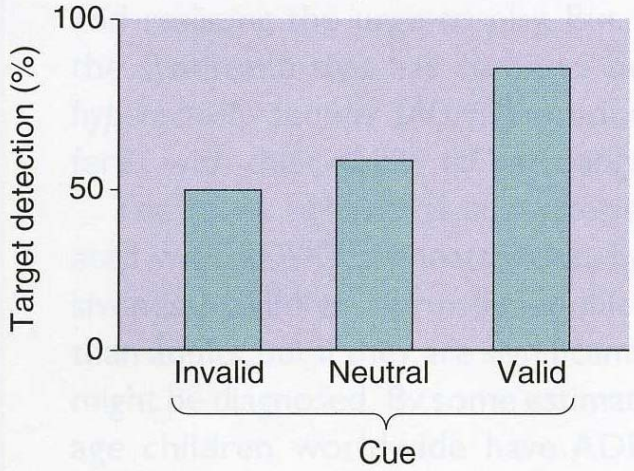


FIGURE 21.2
The effect of cueing on target detection. Subjects reported whether a small circle was detected to the left or right of the fixation point. On some trials, the cue was neutral, giving no indication to which side the circle would appear. Subjects detected the circle on a higher percentage of trials when a small arrow at the fixation point correctly indicated the side to which the target would appear (i.e., a valid cue). If the cue was invalid, pointing away from the side with the circle, the circle was less likely to be detected.

Alerting - Orienting

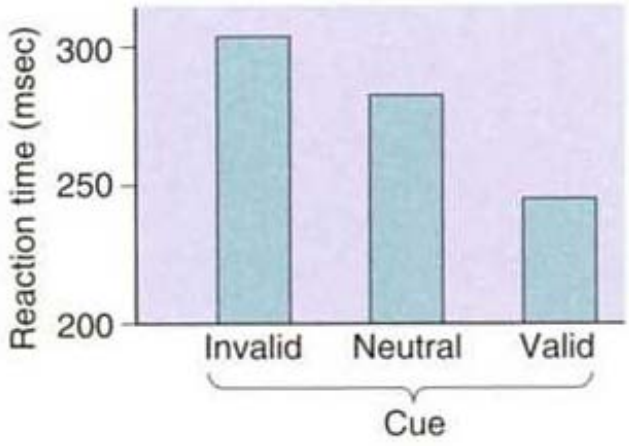
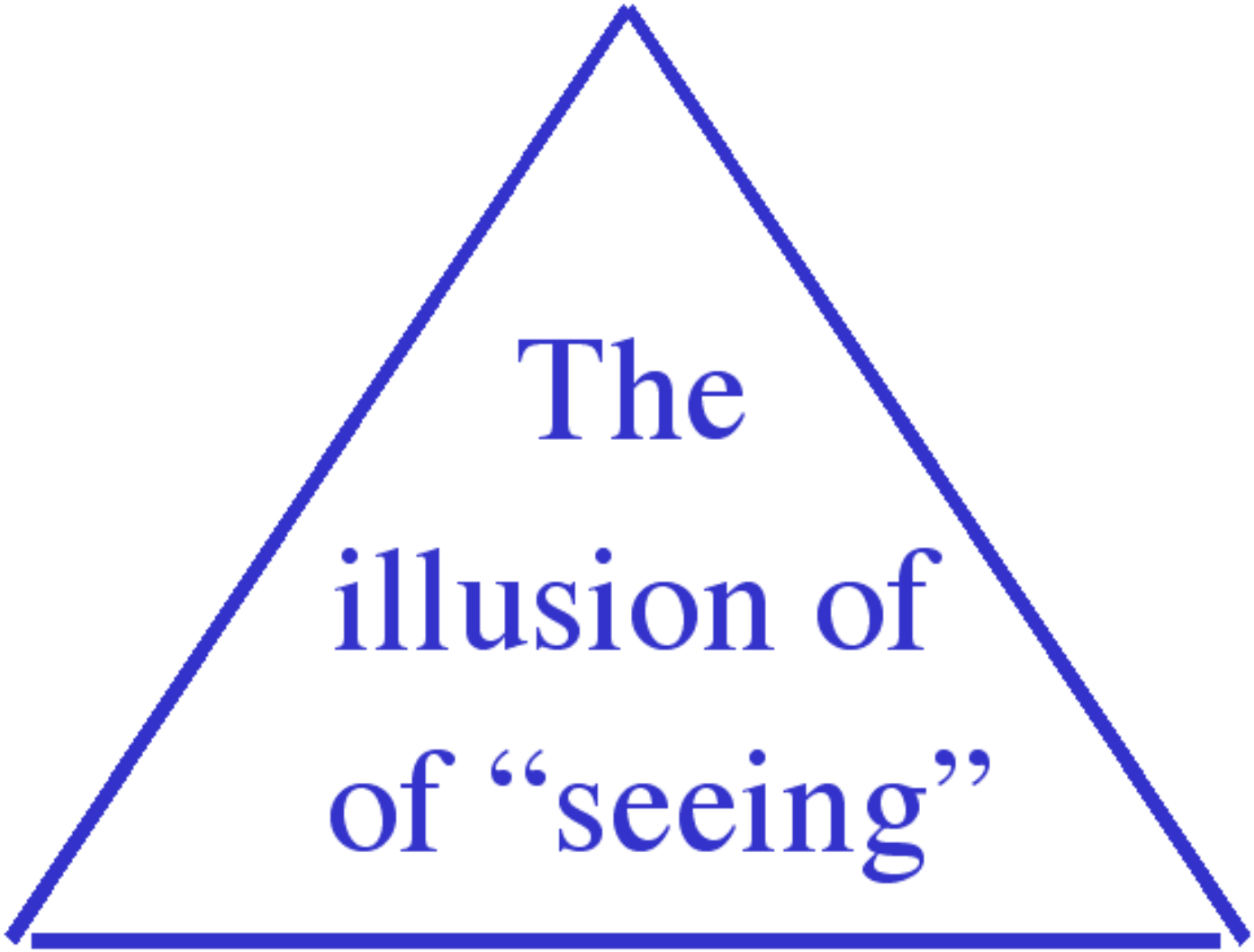


FIGURE 21.3
The effect of cueing on reaction time.
In neutral cue trials, the cue was a plus sign, which gave no indication of the likely location of the following target. In valid cue trials, the arrow-shaped cue pointed to the location where the target appeared, speeding reactions to the targets. When the cue was invalid, pointing in a direction opposite to where the target later appeared, reaction times were slower. (Source: Adapted from Posner, Snyder, and Davidson, 1980, Fig. 1.)

Impairments of attention and executive control are common in mental disorders

- ADHD
- Schizophrenia
- Bipolar/Mania
- Major Unipolar Depression
- Parkinsons
- Alzheimers
- “Normal” Aging

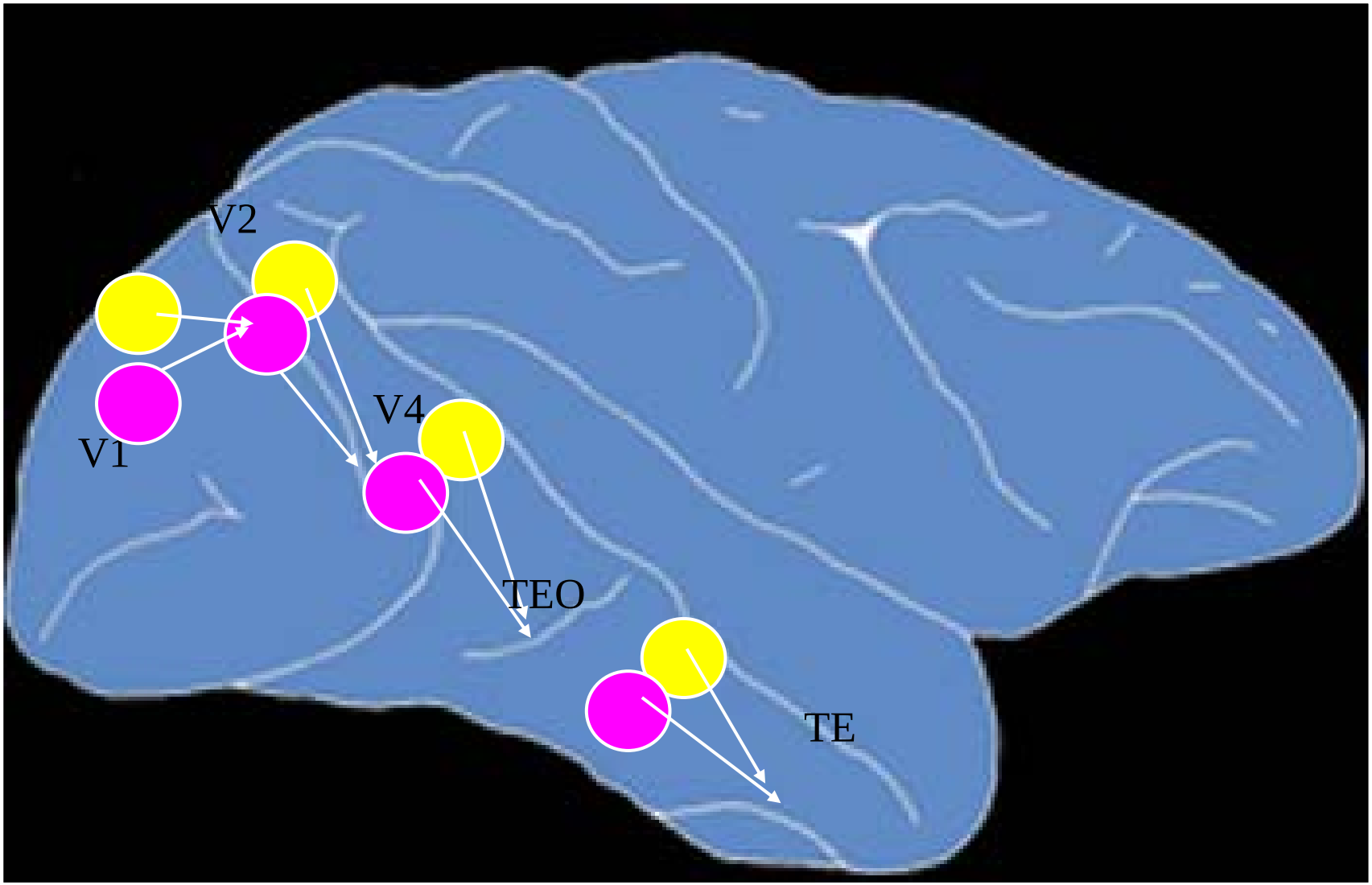
The effects of attention on visual processing and conscious awareness are profound


The
illusion of
of “seeing”

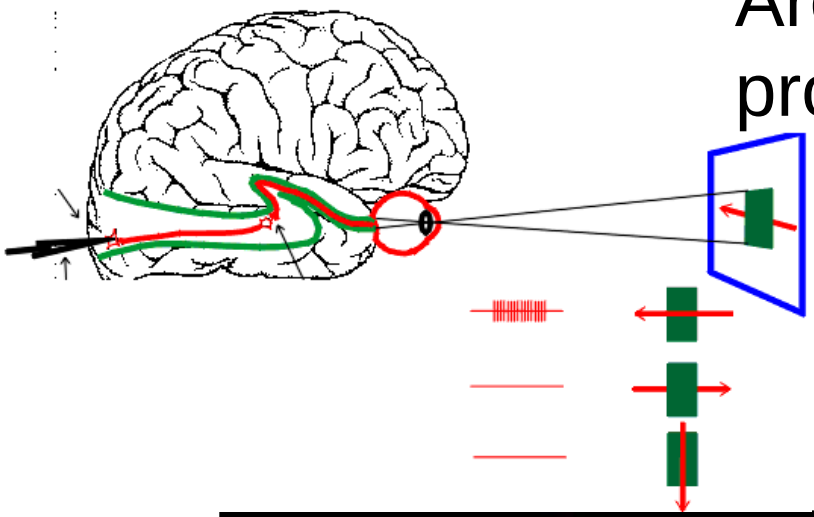
The neural basis of visual attention

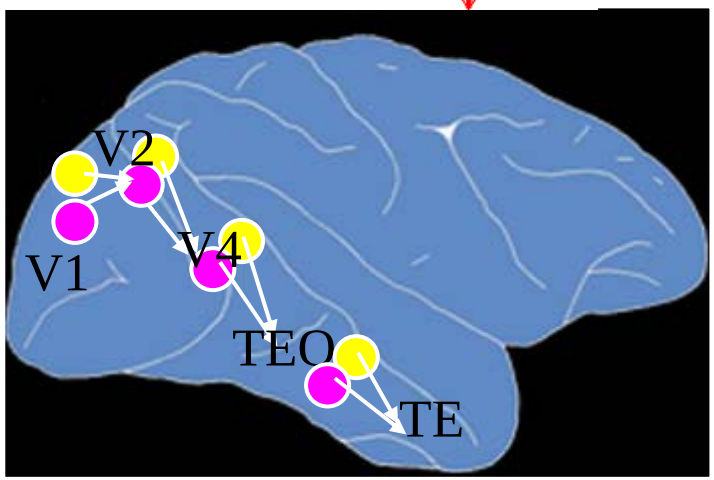
The role of attention in the object recognition stream

The ventral processing stream for object recognition

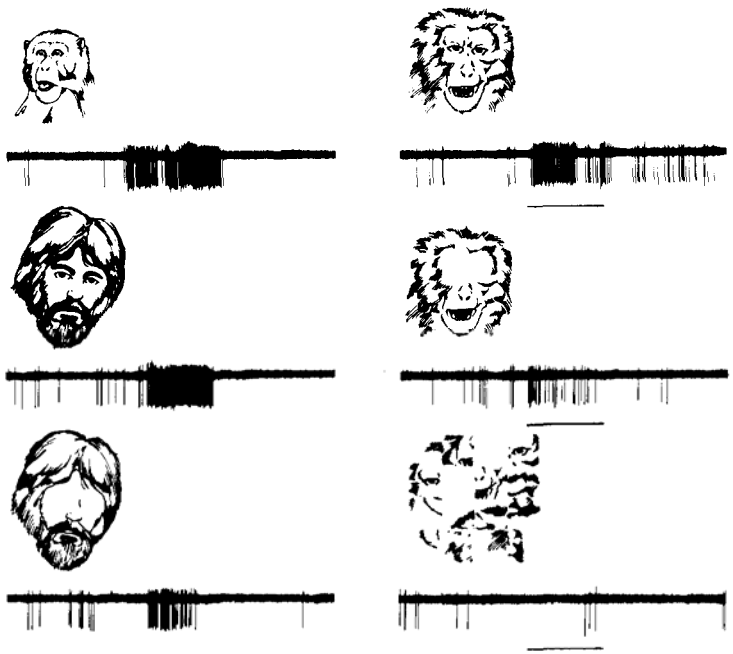


Area V1 – where visual processing starts in the cortex

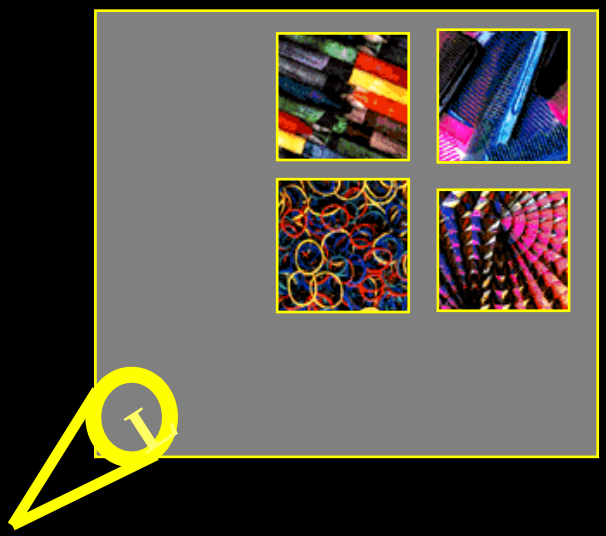




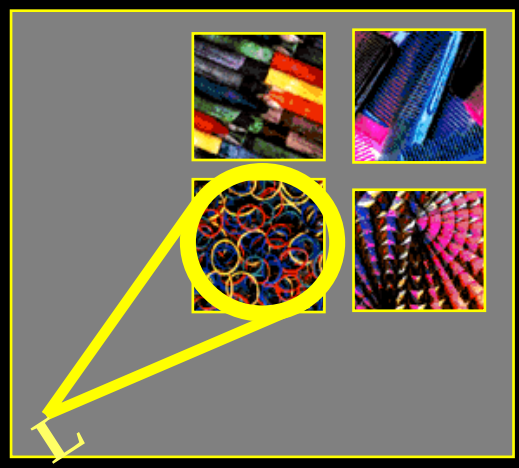
Area TE – where it ends



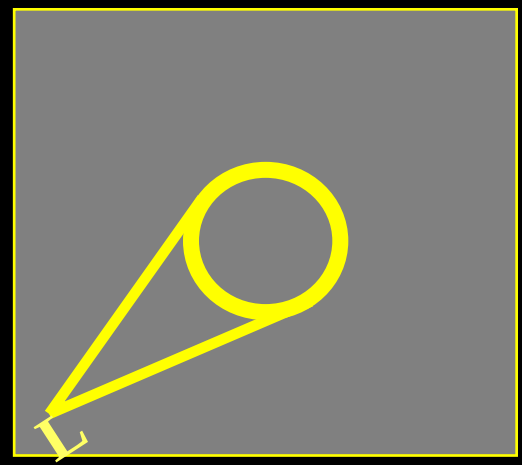
Stimulation w/o attention



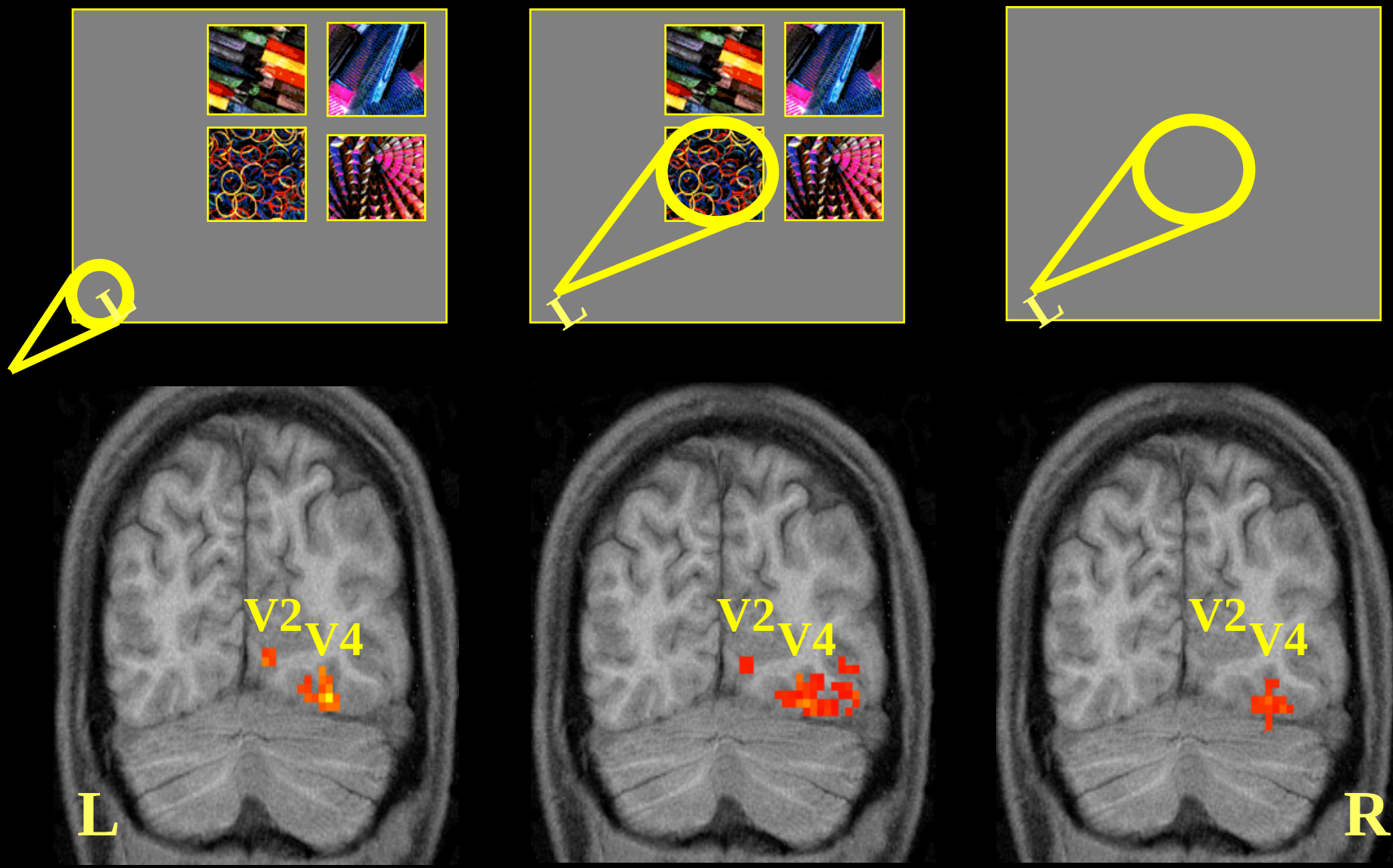
Stimulation with attention



Attention without Stimulation



Activation in Visual Areas:



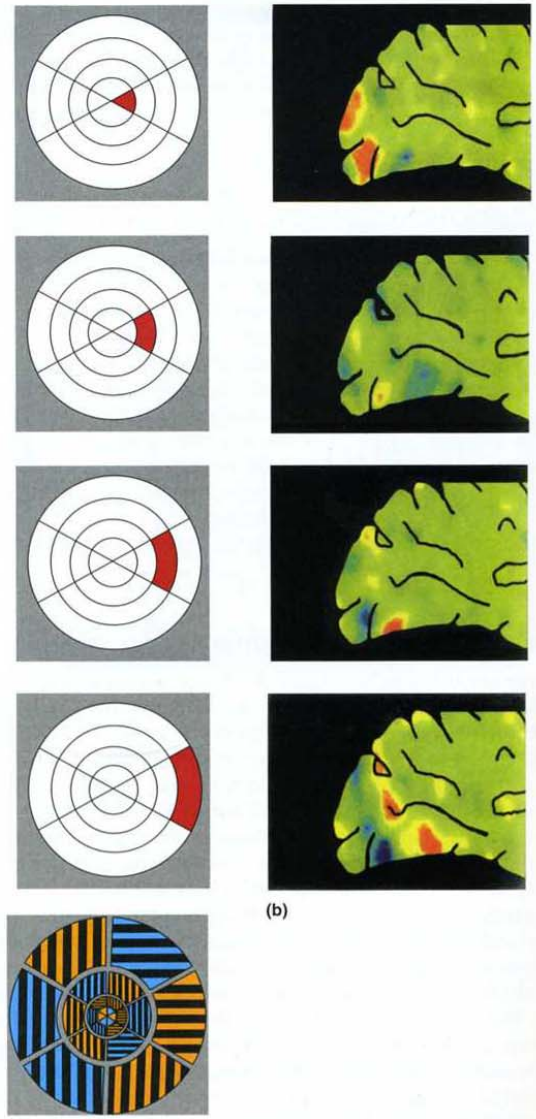
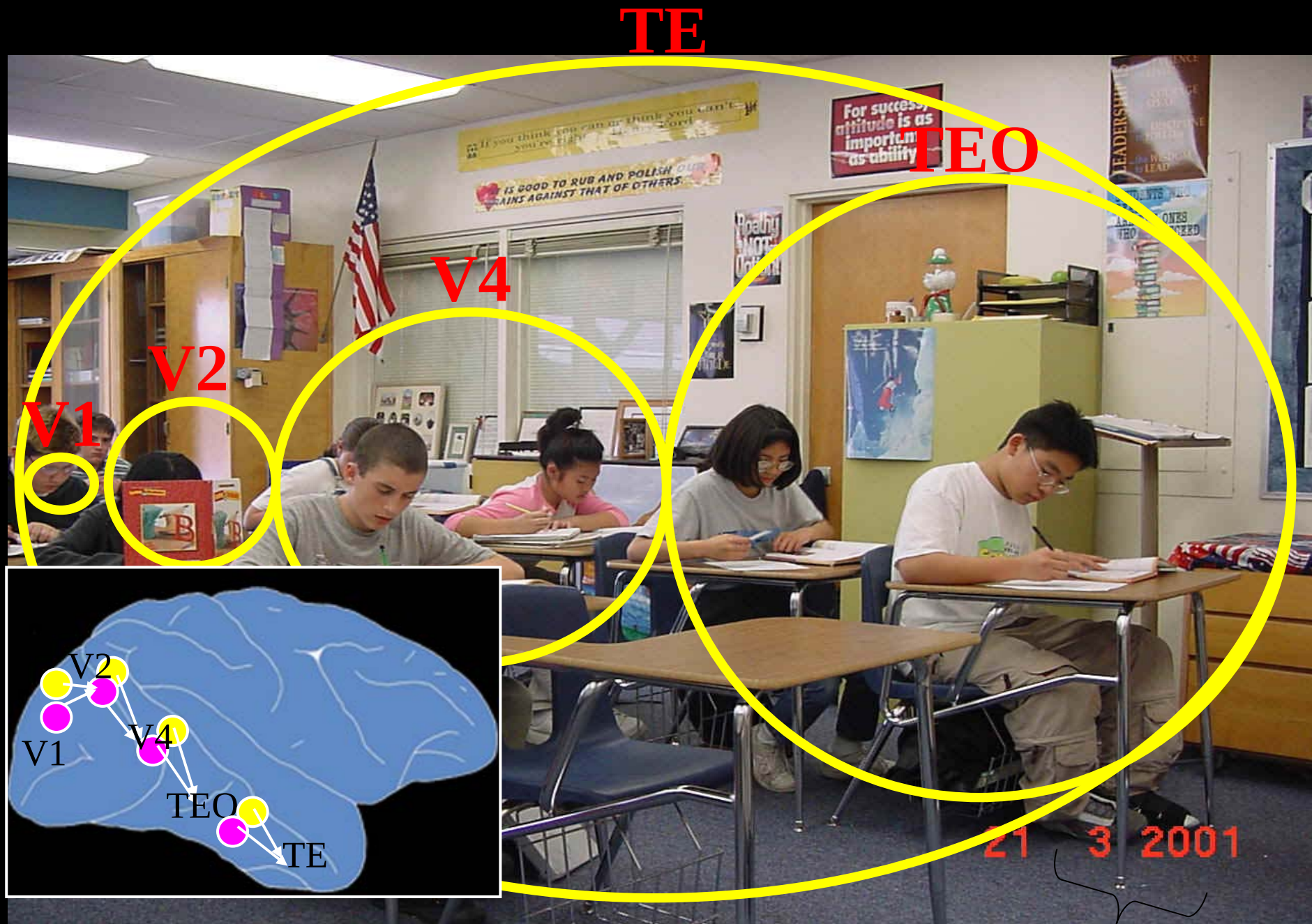
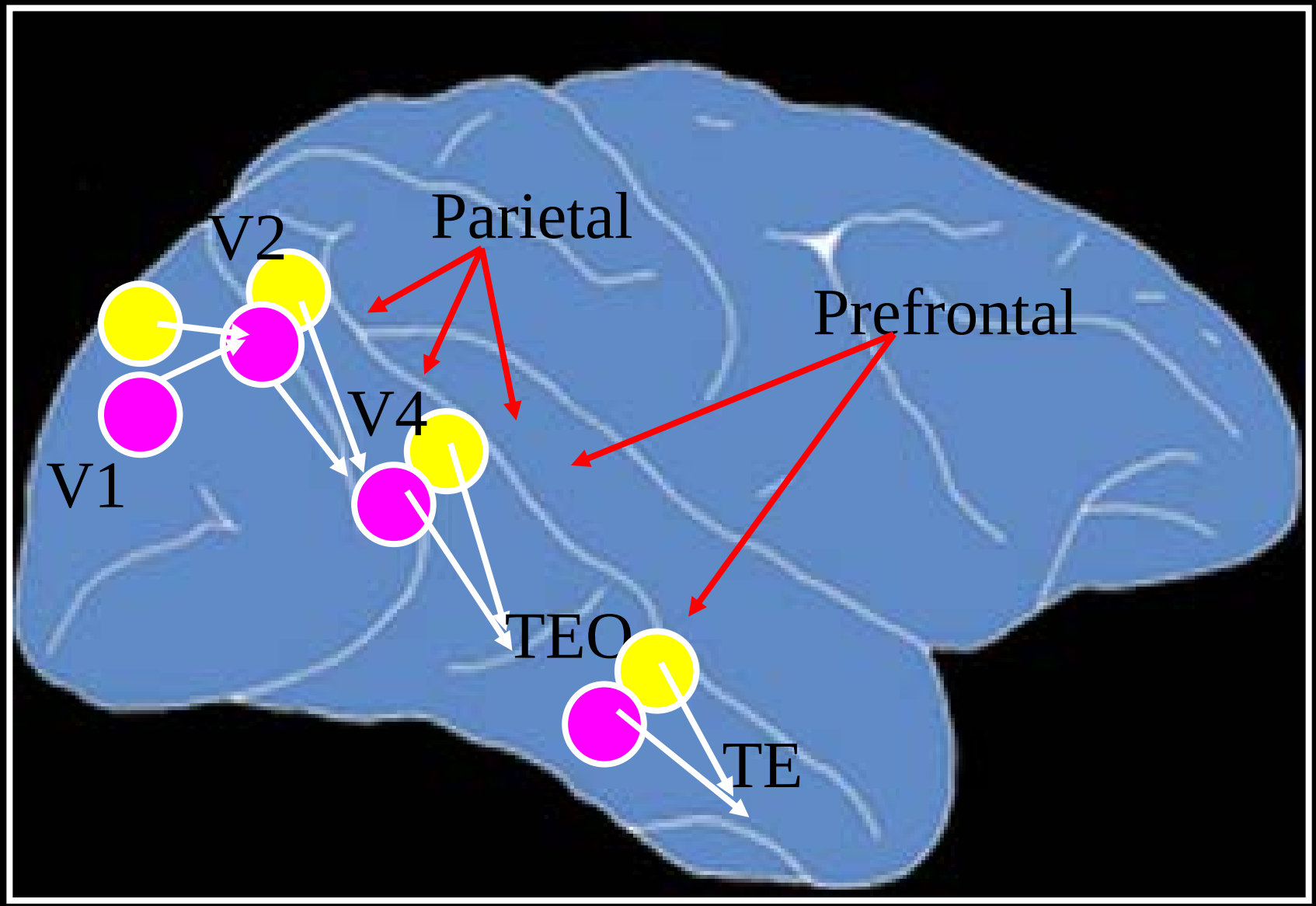


FIGURE 21.5
The spotlight of attention. (a) The visual stimulus. The stimulus (bottom frame) consisted of blue and orange line segments arranged into sectors radiating out from the central fixation point. The orientation and color of each sector changed every 2 seconds. The four bull's-eye patterns indicate in red the sector that a subject was instructed to attend to. **(b)** Enhanced activity in visual cortex. The visual stimuli elicited activity in multiple visual cortical areas, but patches of enhanced activity were associated with the attended sector. In these images, enhanced activity is indicated by yellow and red. (Source: Courtesy of J. A. Brefczynski and E. A. DeYoe.)

Animals Use Attention for Flexible Behavior Too!


TE
TEO
V4
V2
V1
V2
V4
V1
TEO
TE


V2
Parietal
Prefrontal
V4
V1
TEO
TE

Effects of Attention on Area V4

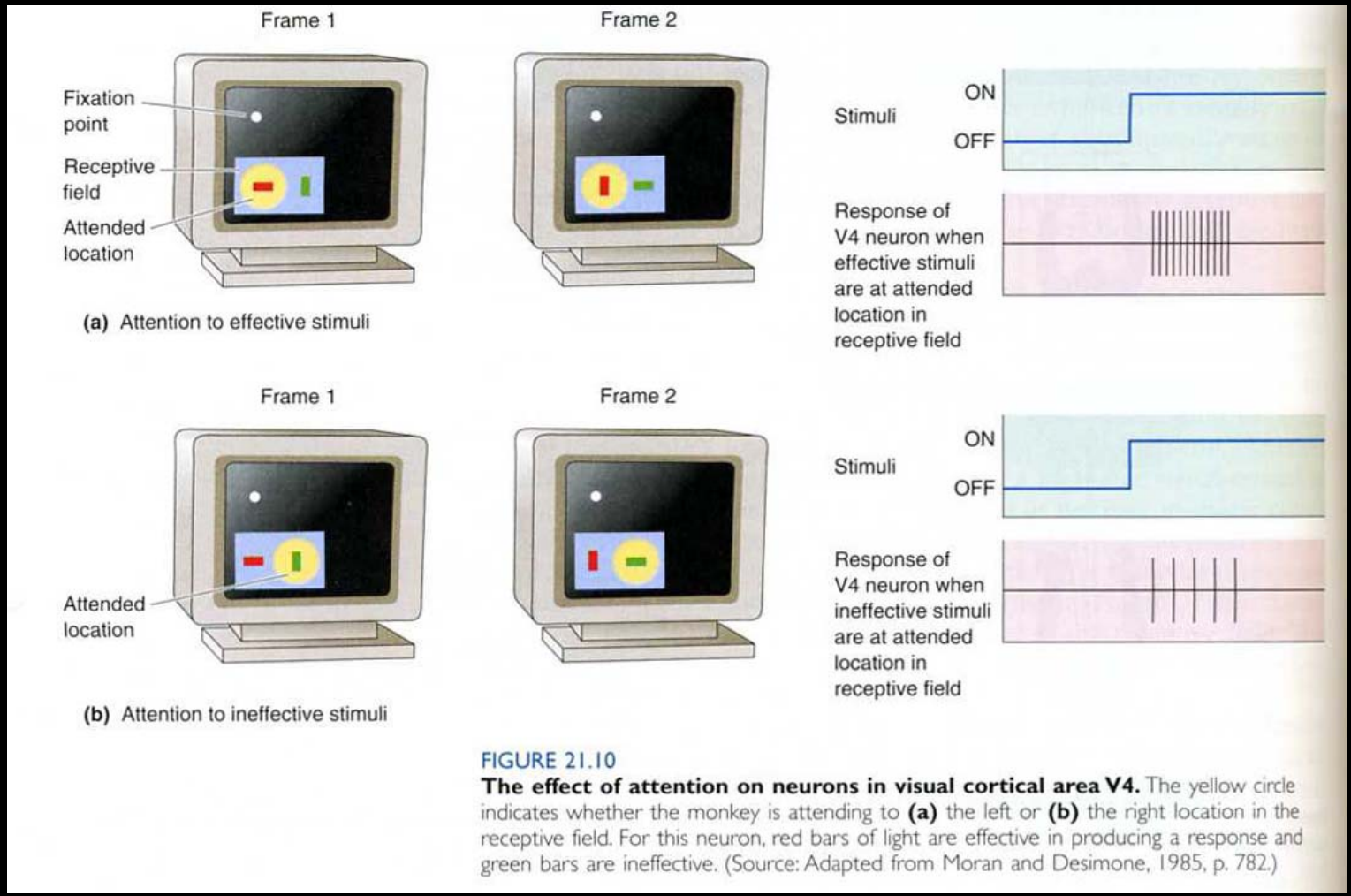
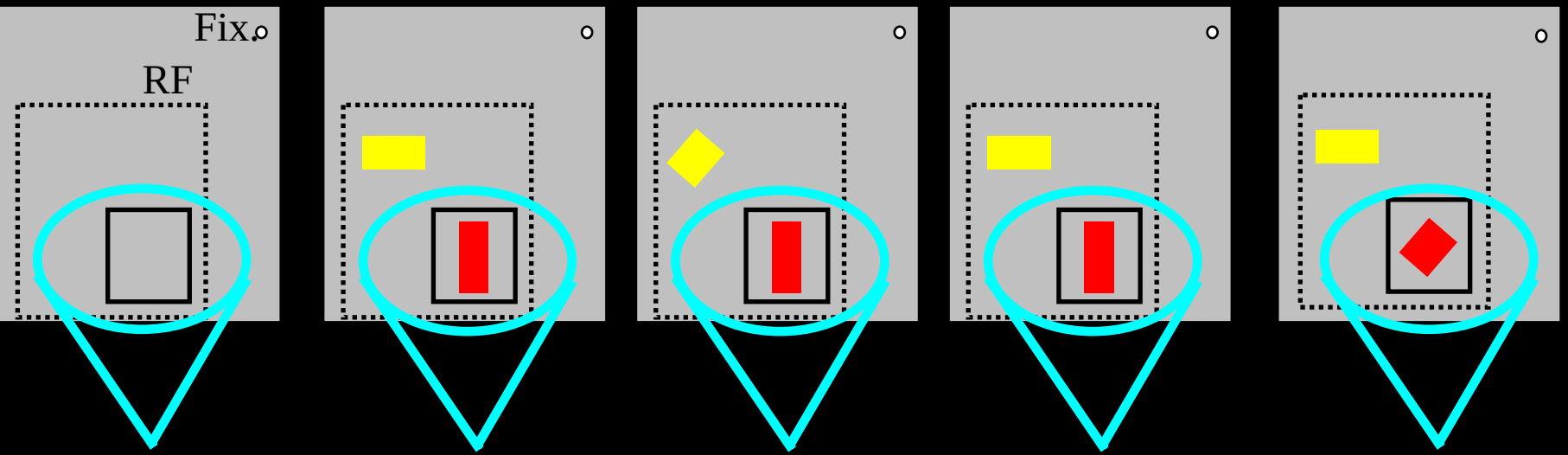


FIGURE 21.10
The effect of attention on neurons in visual cortical area V4. The yellow circle indicates whether the monkey is attending to **(a)** the left or **(b)** the right location in the receptive field. For this neuron, red bars of light are effective in producing a response and green bars are ineffective. (Source: Adapted from Moran and Desimone, 1985, p. 782.)

Spatial Attention Task

Instruction Trials



Response/Reward

Cue box

Potential target & distracter 200 ms

Blank delay 500 ms

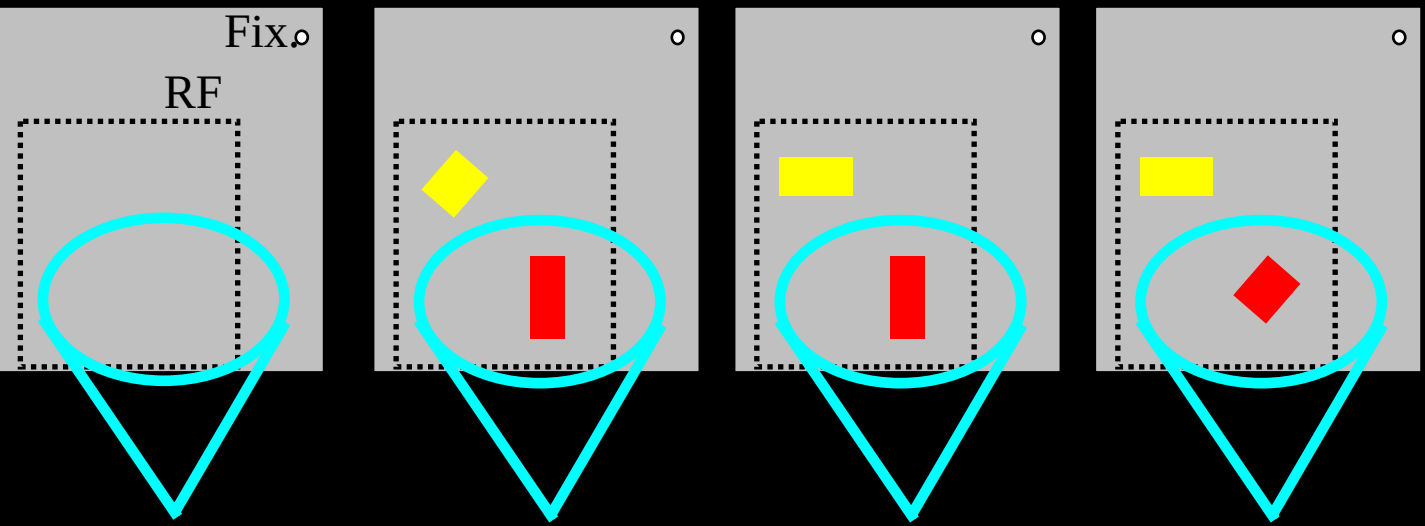
Potential target & distracter

Potential target & distracter

Target & distracter

Spatial Attention Task

Data Acquisition Trials

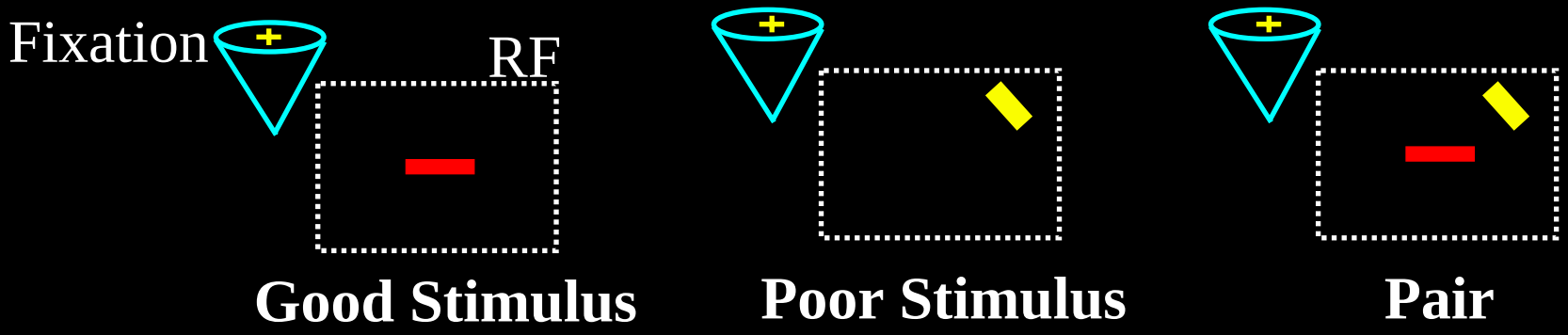


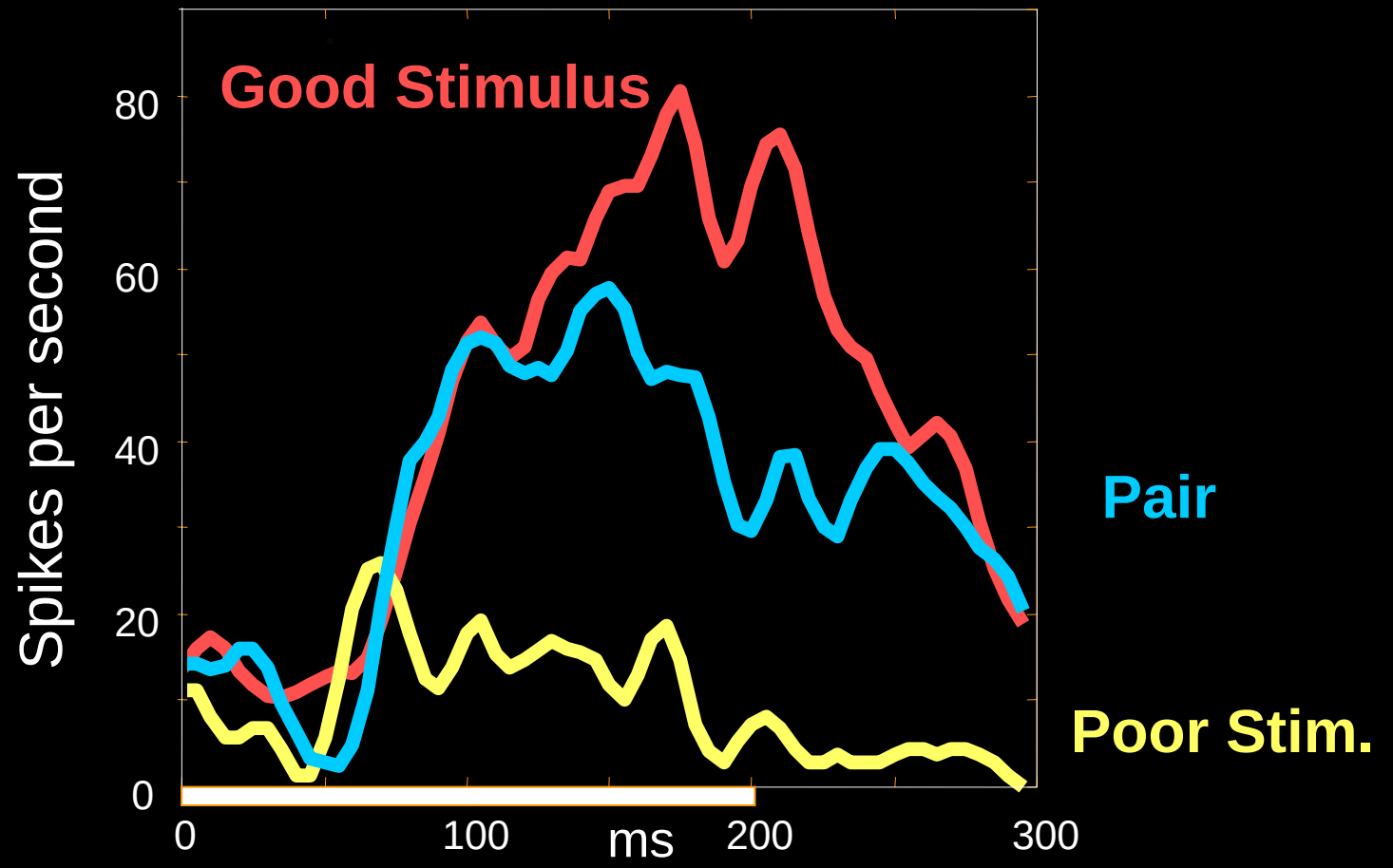
Potential target & distracter

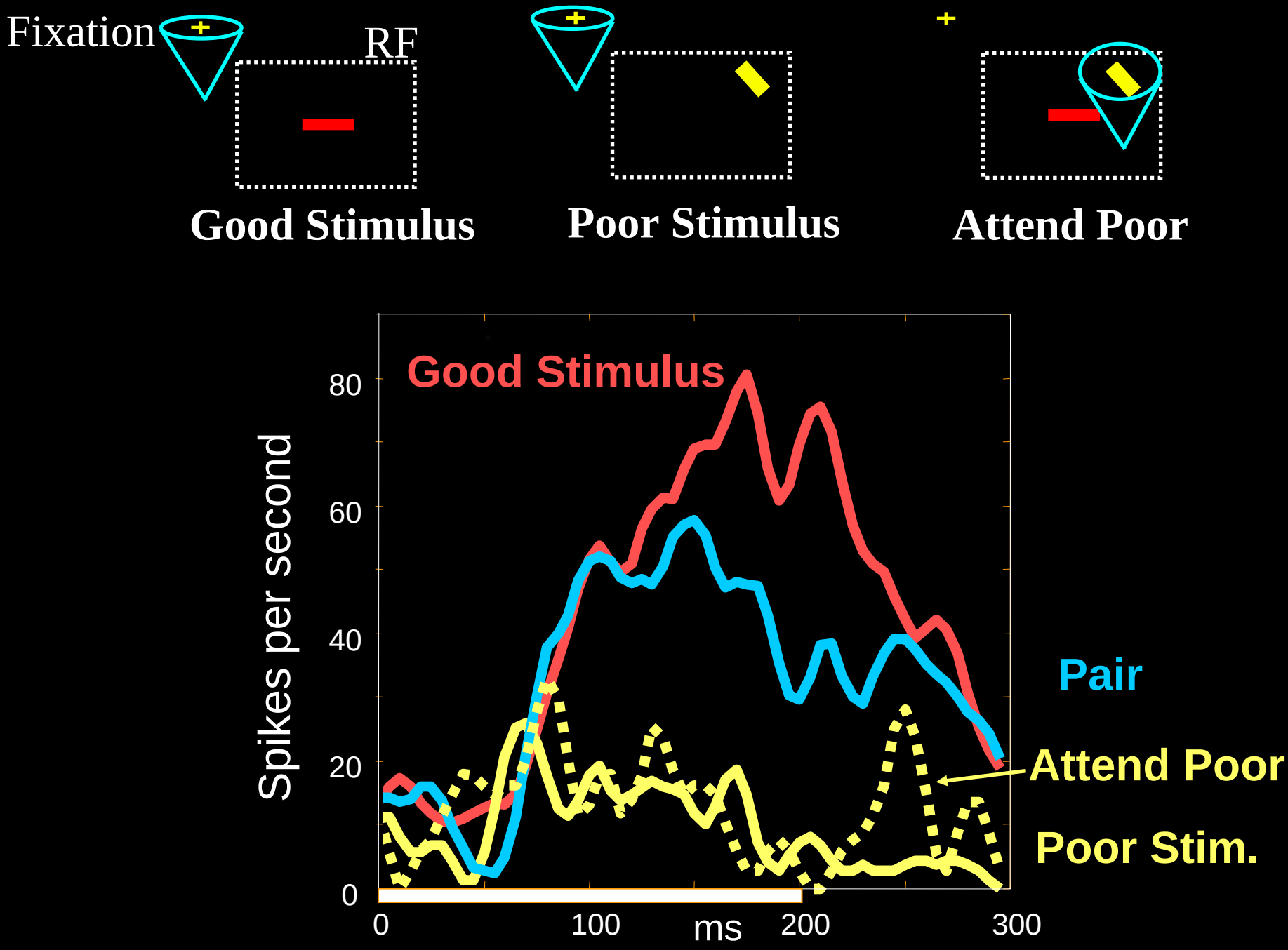
Potential target & distracter

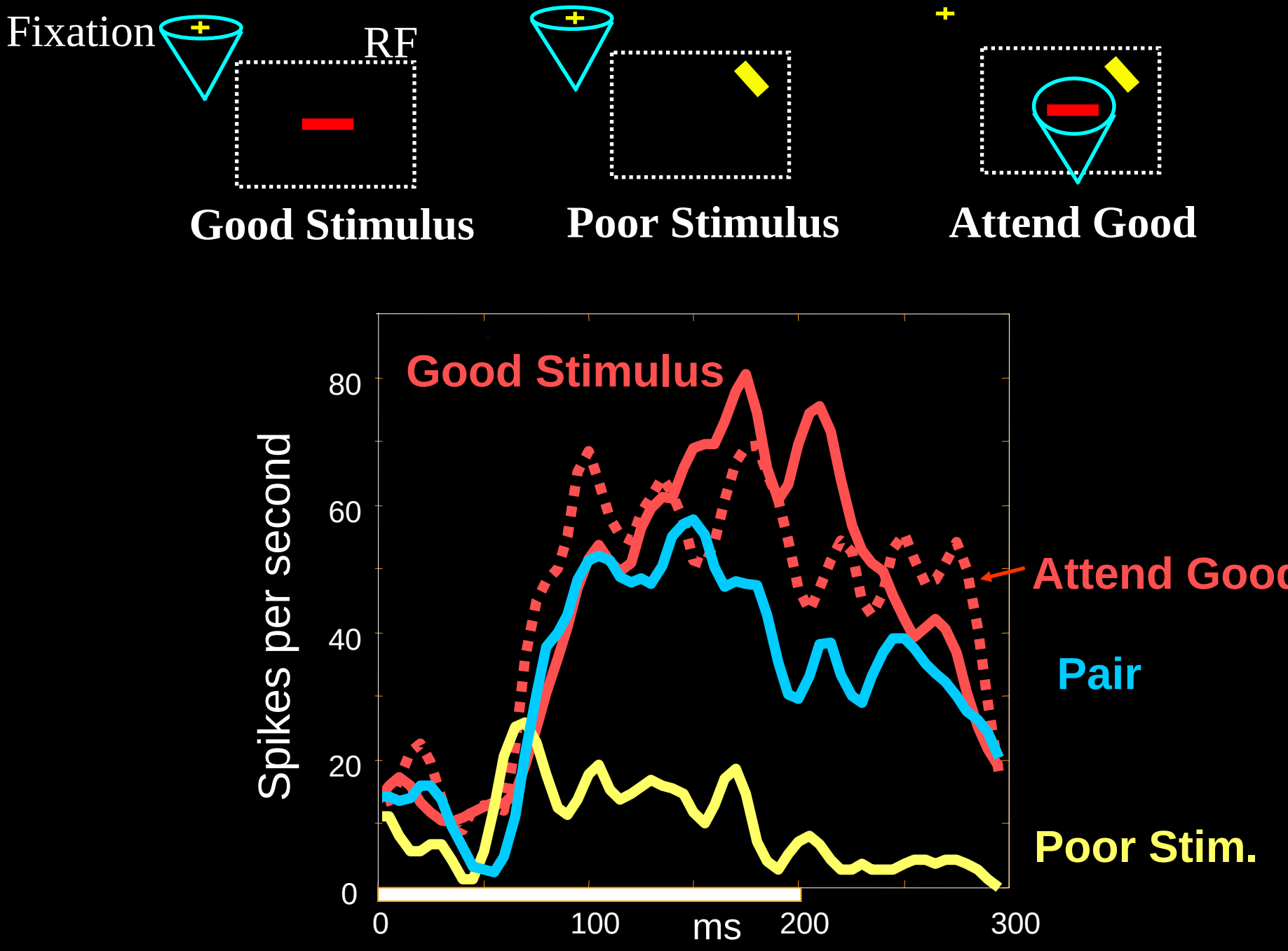
Target & distracter

Response/Reward


Fixation
RF
Good Stimulus
Poor Stimulus
Pair

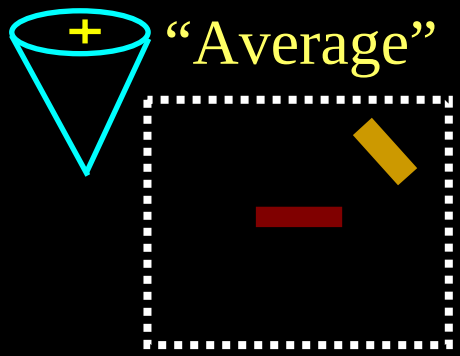

Good Stimulus
Spikes per second
80
60
40
20
0
0
100
200
300
ms
Pair
Poor Stim.


Fixation
RF
Good Stimulus
Poor Stimulus
Attend Poor
Good Stimulus
Spikes per second
80
60
40
20
0
0
100
200
300
ms
Pair
Attend Poor
Poor Stim.


Fixation
RF
Good Stimulus
Poor Stimulus
Attend Good
Good Stimulus
Spikes per second
80
60
40
20
0
0
100
ms
200
300
Attend Good
Pair
Poor Stim.

Without Attention

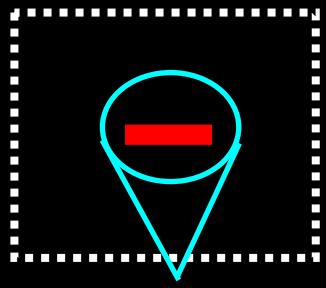
Fix. “Average”



Pair

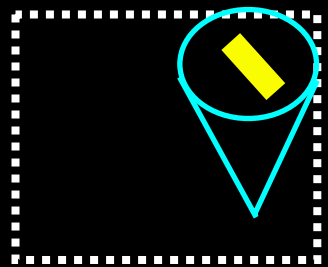
With Attention

\+ “Red”

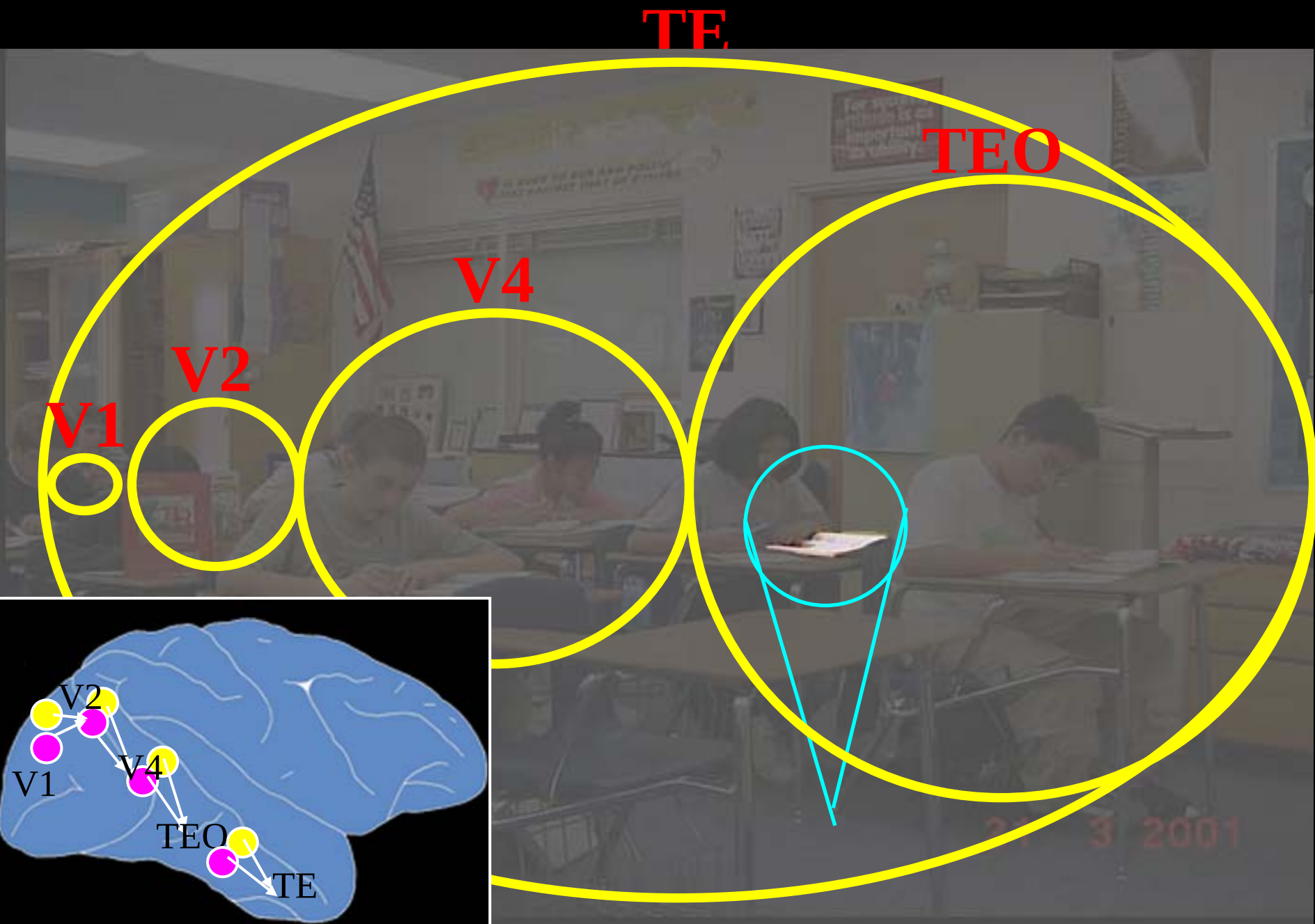


Pair

\+ “Yellow”



Pair


TE
TEO
V4
V2
V1
V2
V1
V4
TEO
TE

Attention to Features

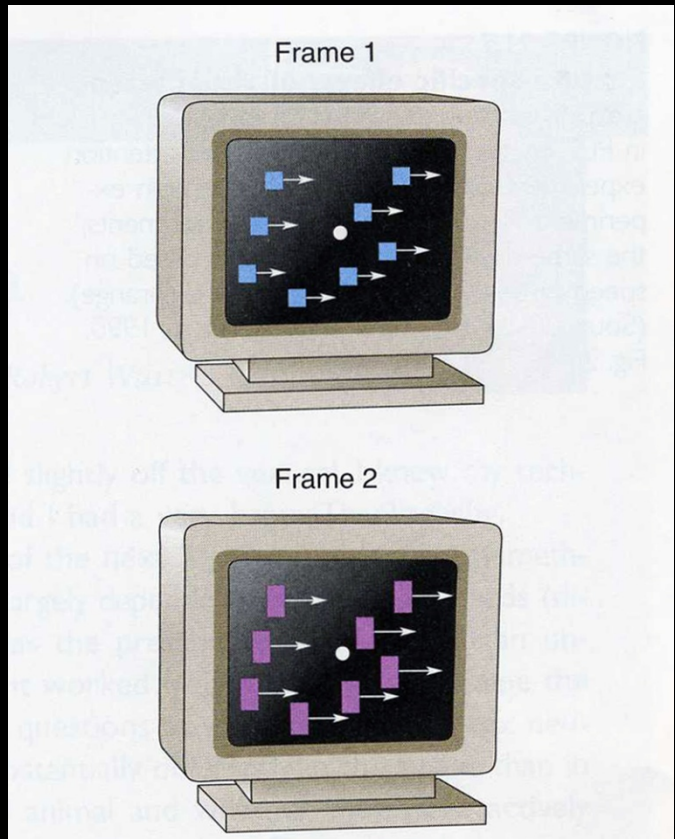
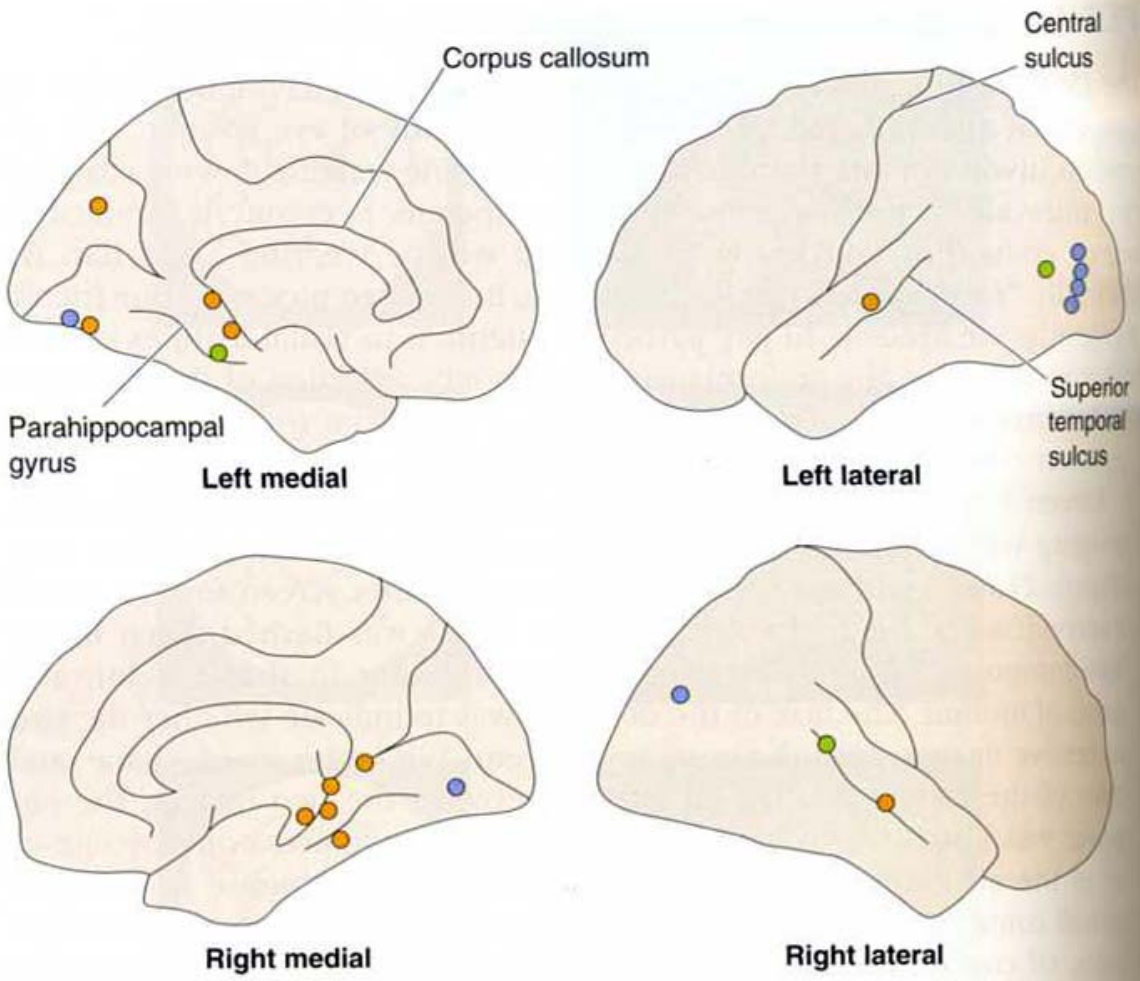


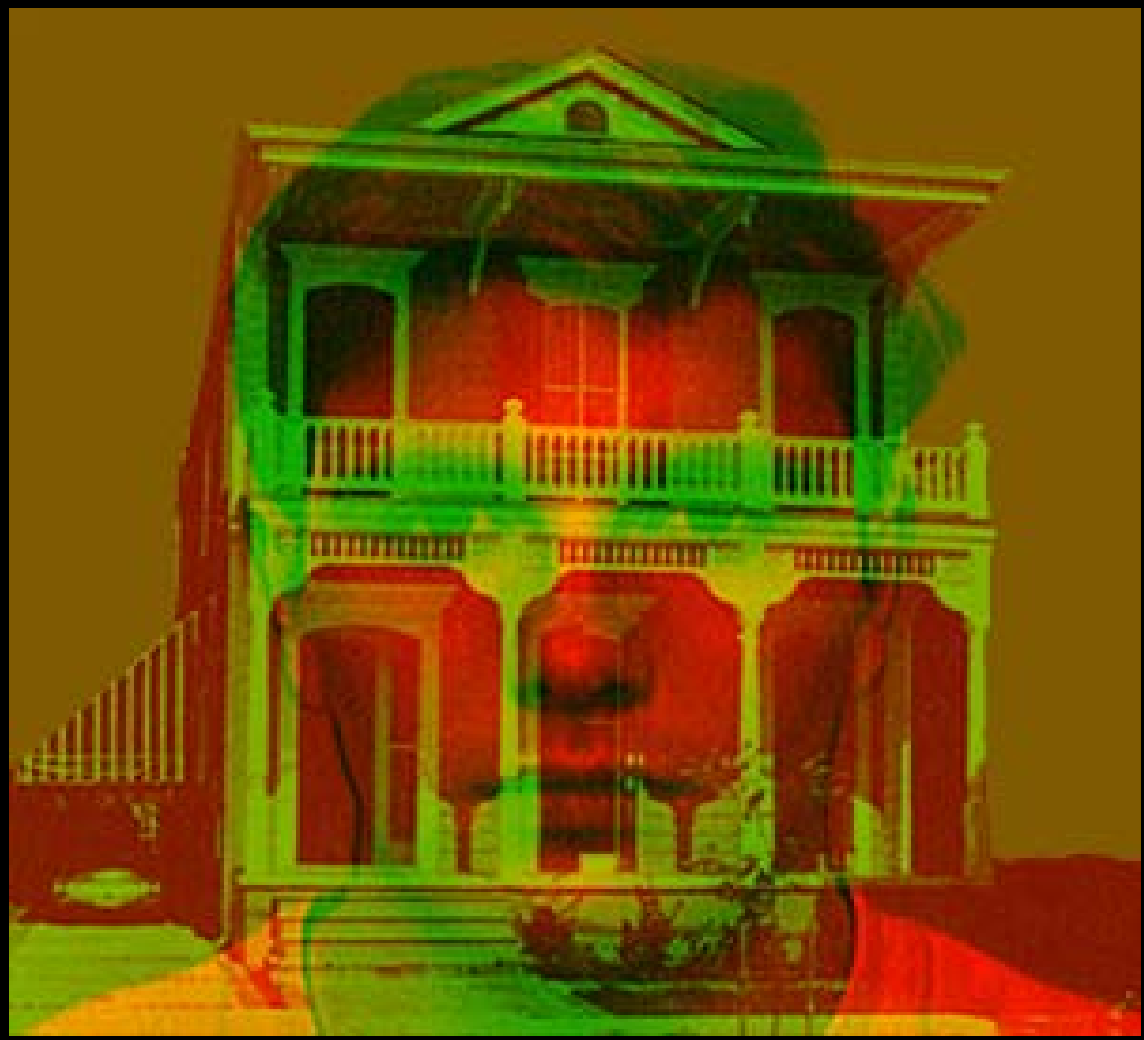
FIGURE 21.6
Stimuli used to measure attention to features. The observer sees two frames, each containing moving elements that can change in shape, color, and speed of motion. The observer responds by indicating whether the stimuli are the same or different. (Source: Adapted from Corbetta et al., 1990, Fig. 1.)

Attention to Features

FIGURE 21.7
Feature-specific effects of visual attention. Symbols indicate where brain activity in PET images was higher in selective-attention experiments relative to divided-attention experiments. In selective-attention experiments, the same-different judgments were based on speed (green), color (blue), or shape (orange). (Source: Adapted from Corbetta et al., 1990, Fig. 2.)

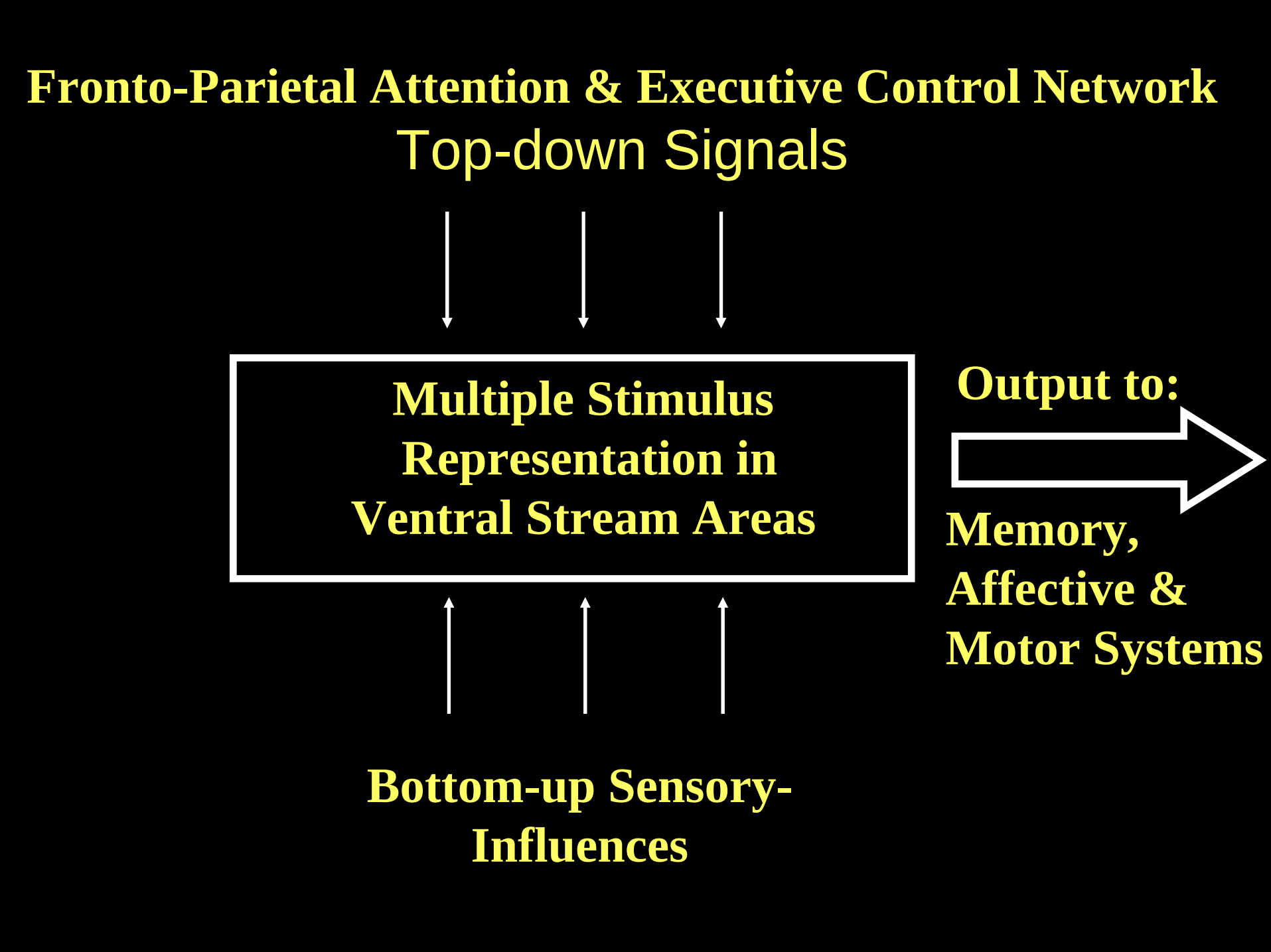


Attention to Features: Faces vs Houses (Kanwisher)

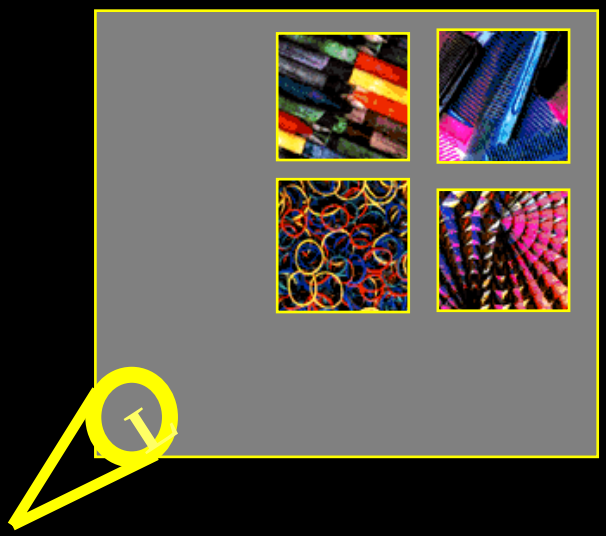


The neural basis of visual attention

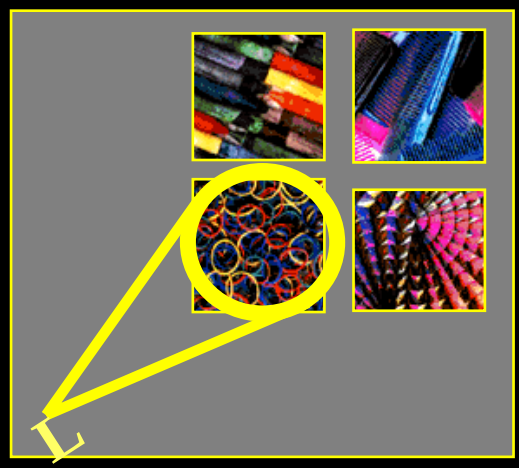
The fronto-parietal system for attentional control


Fronto-Parietal Attention & Executive Control Network
Top-down Signals
Multiple Stimulus Representation in Ventral Stream Areas
Output to:
Memory, Affective & Motor Systems
Bottom-up Sensory-Influences

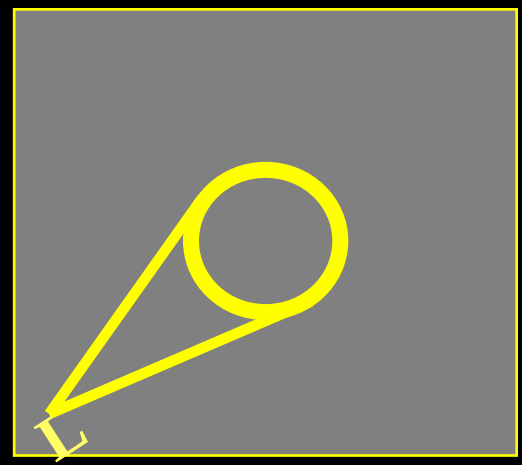
Stimulation w/o attention



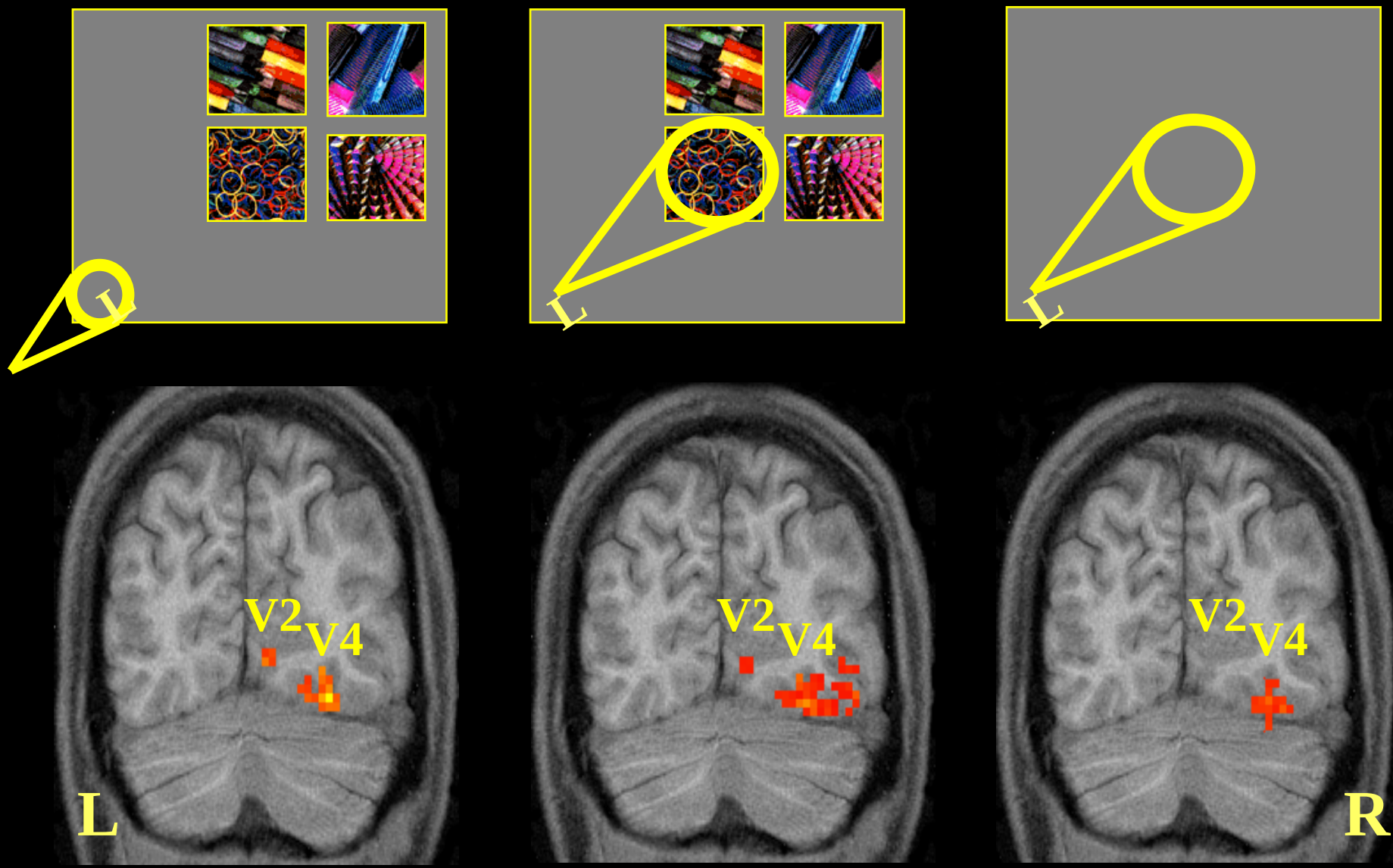
Stimulation with attention



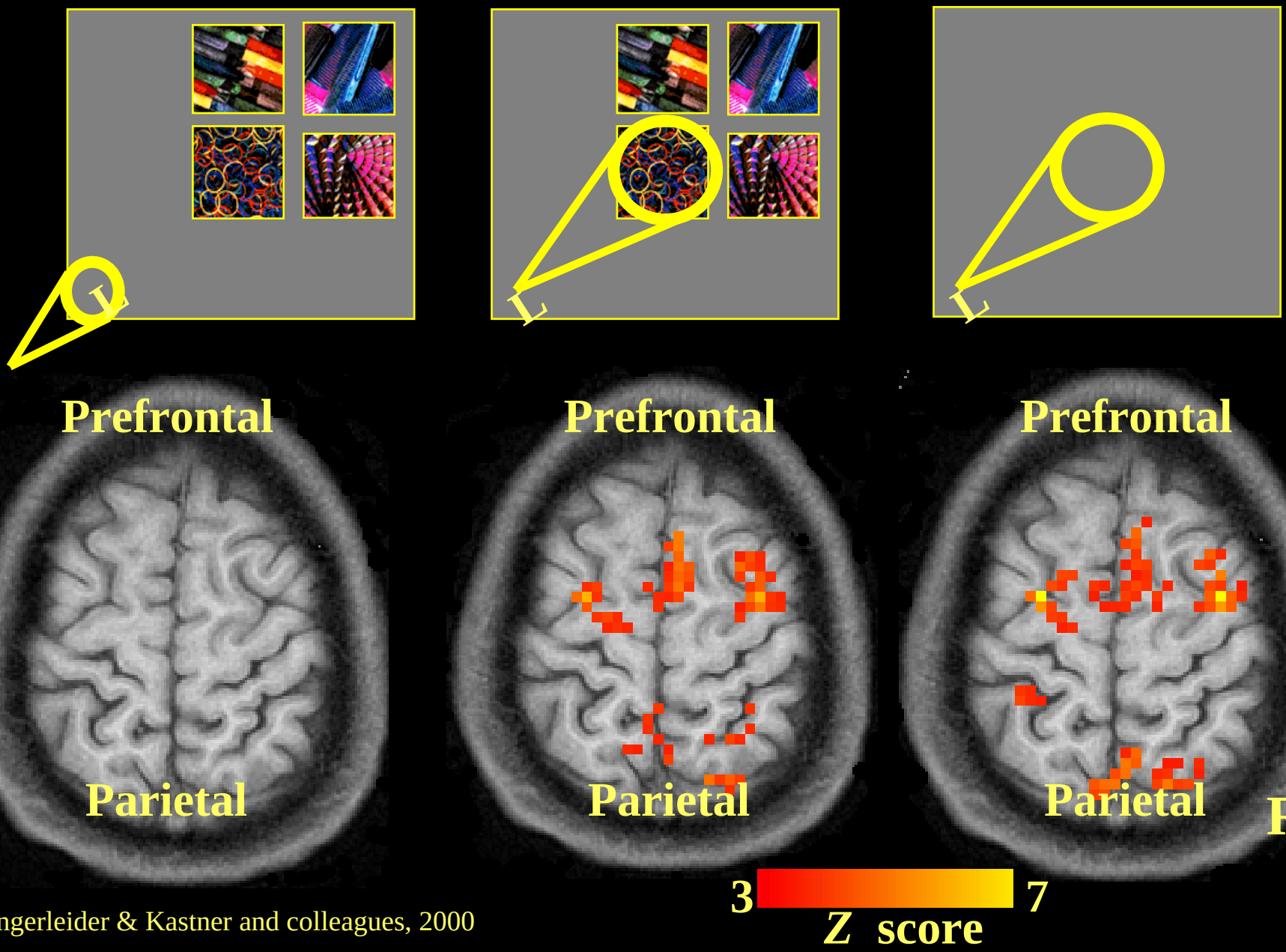
Attention without Stimulation



Activation in Visual Areas:

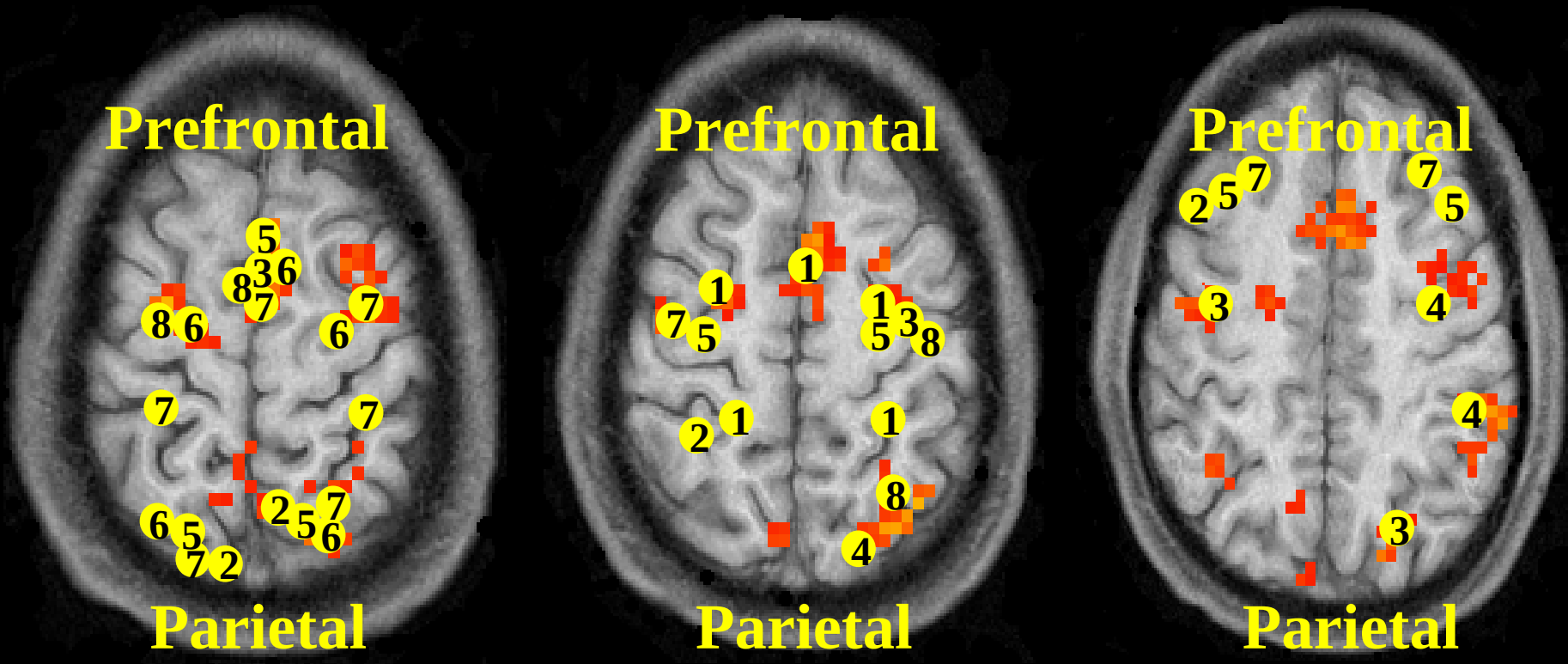


Activation in Prefrontal and Parietal Areas:

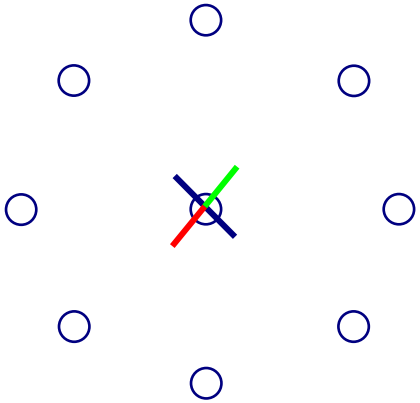


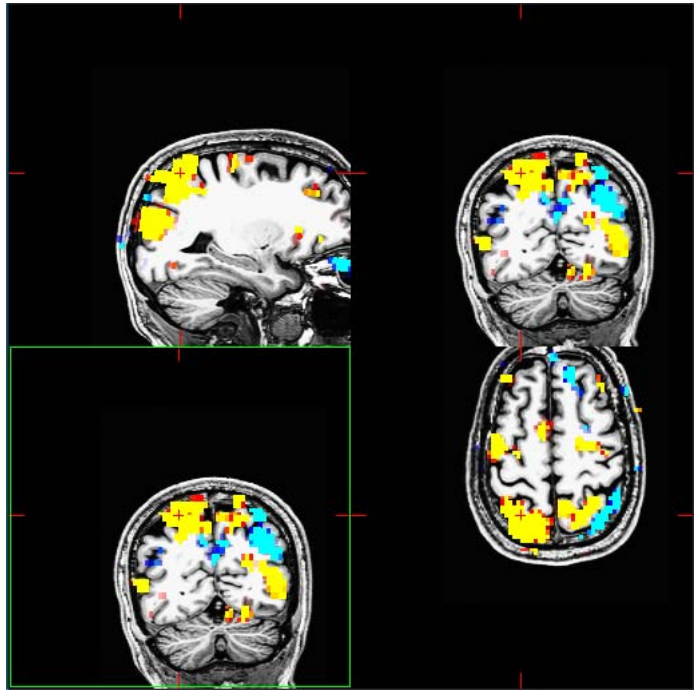
Ungerleider & Kastner and colleagues, 2000

Numersous brain imaging studies reveal large prefrontal and parietal network for top-down control.



[1] Corbetta et al, 1993
[2] Fink et al, 1997
[3] Nobre et al, 1997
[4] Vandenberghe et al, 1997
[5] Corbetta et al, 1998
[6] Culham et al, 1998
[7] Kastner et al, 1999
[8] Rosen et al, 1999

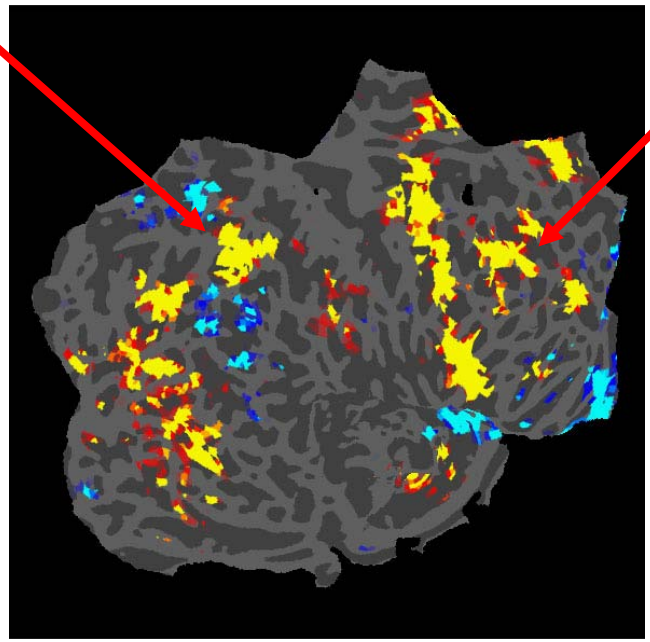


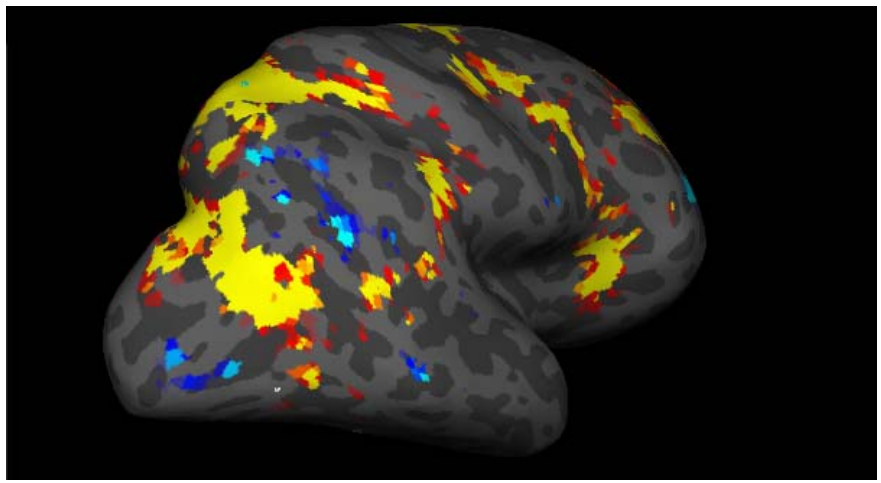


Peripheral > Central

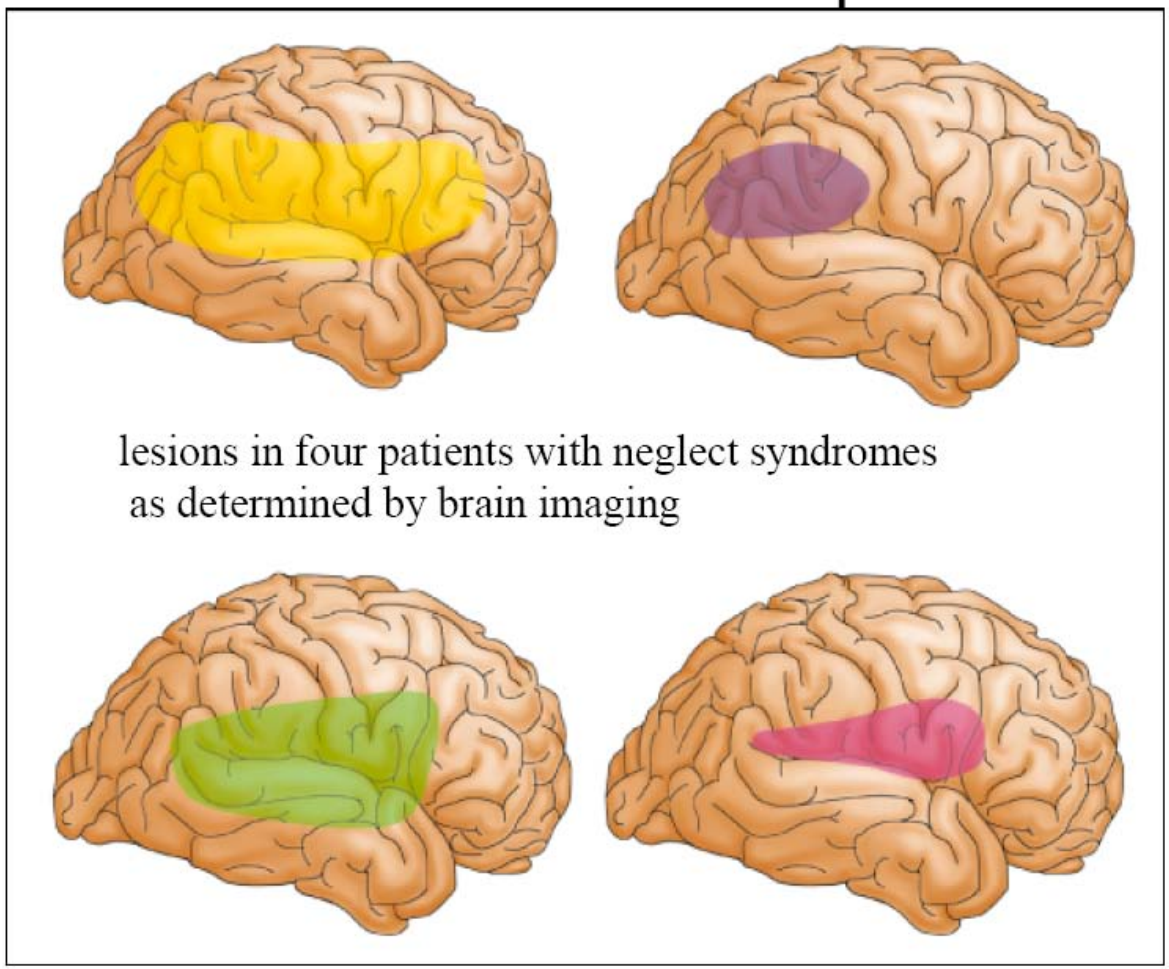
Parietal

DLPFC





Damage to Right Inferior Parietal Cortex (temporal-parietal junction) Causes Neglect



lesions in four patients with neglect syndromes as determined by brain imaging

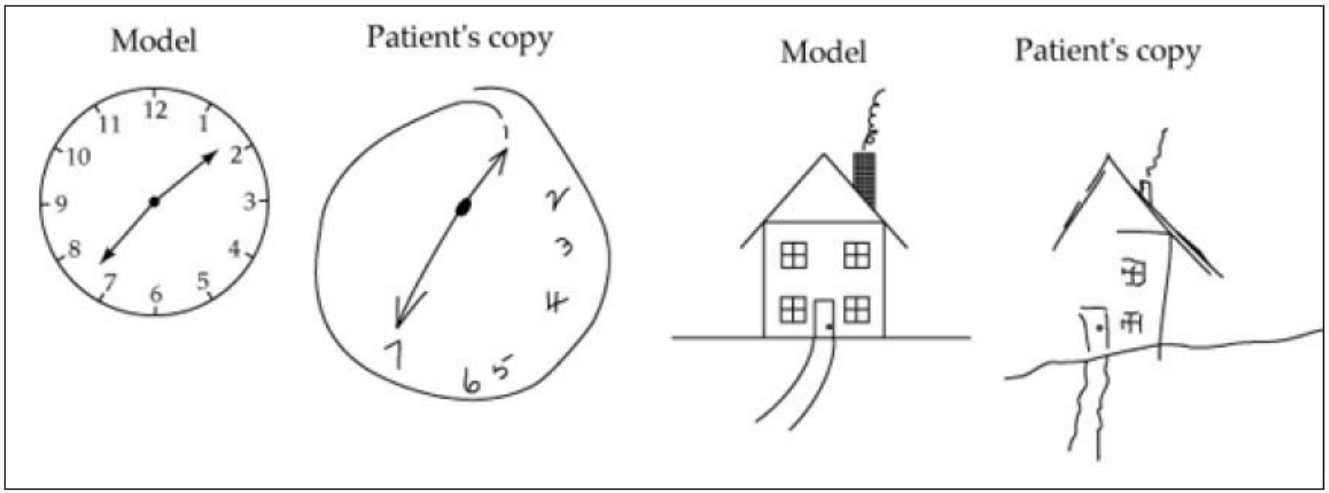
Contralateral Neglect Syndrome

- Most often seen after large areas of damage to right side parietal lobe
  - frequent consequence of stroke on right side of brain and thus neglect of everything on the left
- Patients ignore everything on side opposite to lesion
  - not blindness: patients can recognize and name objects
    - Doctor wiggles a finger; patient sees the finger
    - If doctor doesn't move the finger, patient is oblivious
  - patients just don't pay attention; i.e. 'neglect'
  - may even believe that the left side of one's body is someone else's

Neglect Syndrome

Testing of Contralateral Neglect Syndrome

patient ignores and does not copy left side of drawing



Even when asked to draw an object from memory with eyes closed, they draw only the right side

Neglect Syndrome

Figure 7.41 The late German artist Anton Raederscheidt's self-portraits painted at different times following a severe stroke, which left him with neglect to contralesional space.

Monkey Neurophysiology

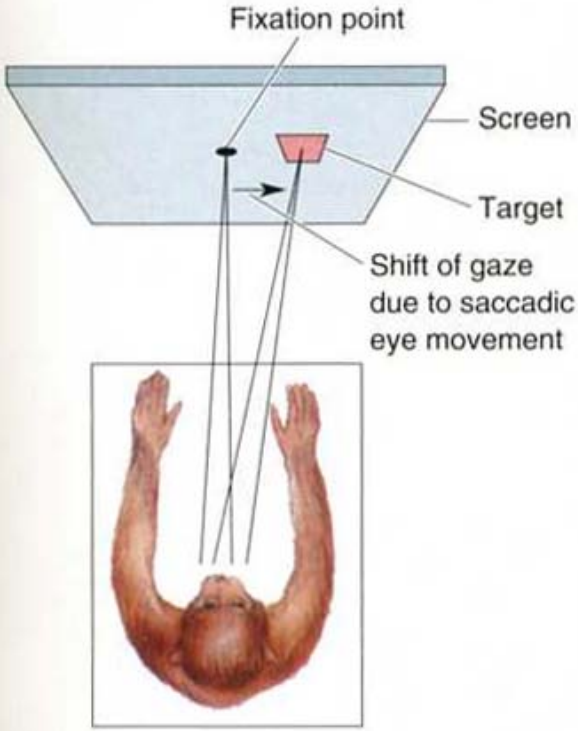


FIGURE 21.8
A behavioral task for directing a monkey's attention. While recordings are made from the posterior parietal cortex, the monkey fixates on a point on a computer screen. When a peripheral target appears (usually in a neuron's receptive field), the animal makes a saccade to the target. (Source: Adapted from Wurtz, Goldberg, and Robinson, 1982, p. 128.)

Enhancement of Neural Responses with Attention: Spatially Specific, but not limited to a particular motor response (attention vs intention)

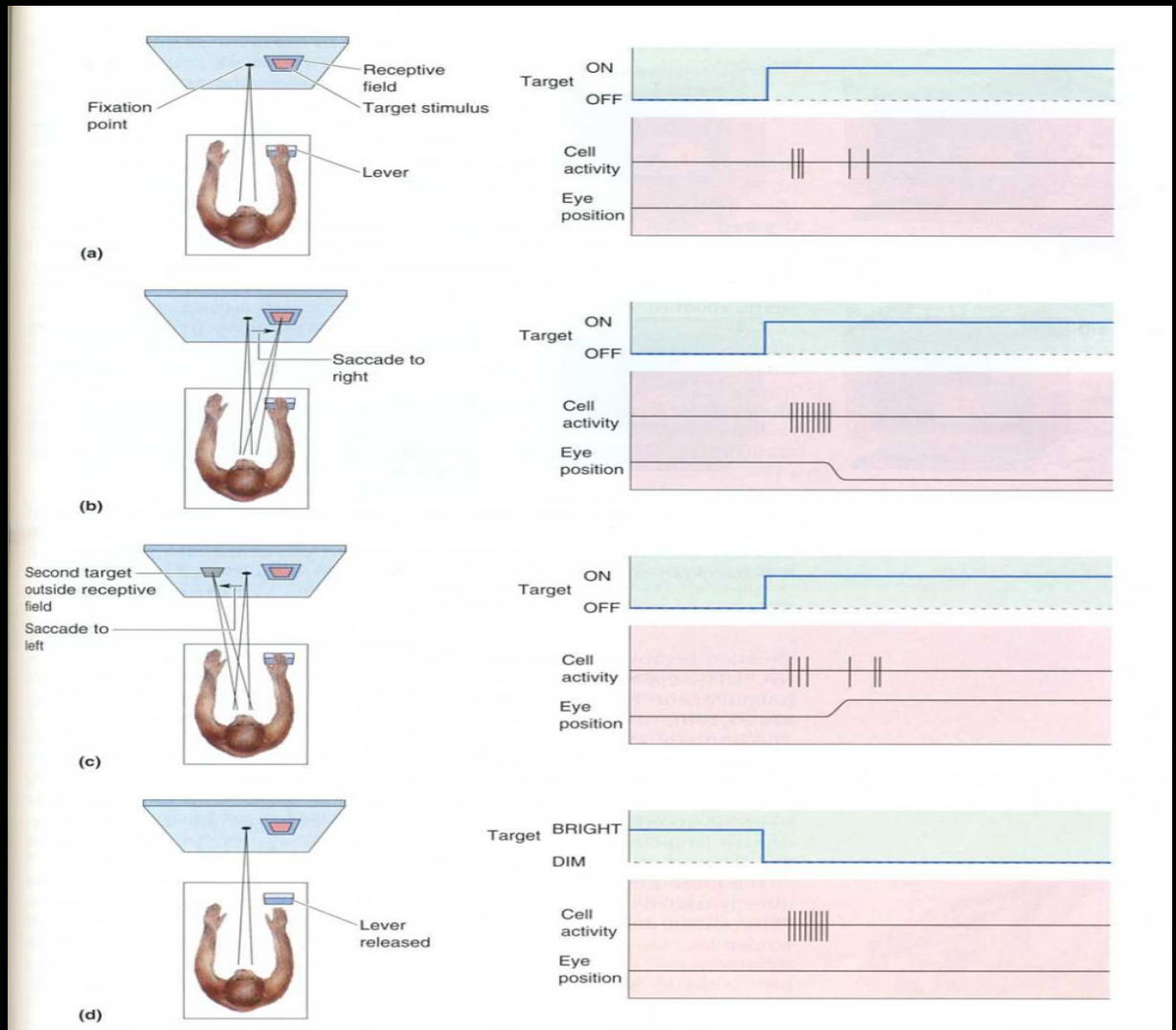
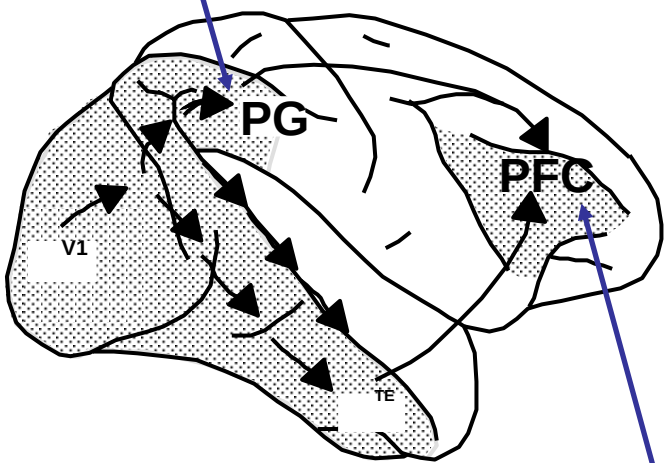
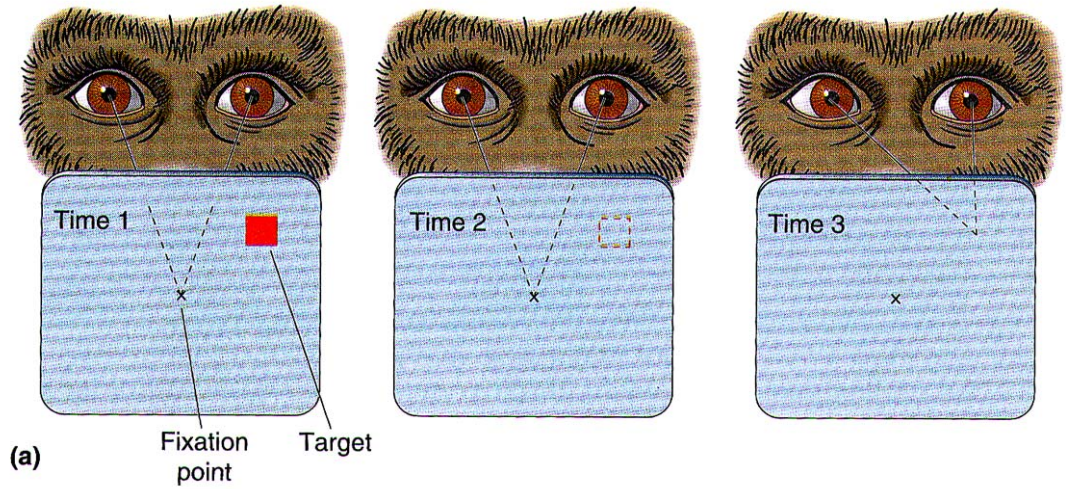


FIGURE 21.9
The effect of attention on the response of a neuron in posterior parietal cortex. **(a)** A neuron in posterior parietal cortex responds to a target stimulus in its receptive field. **(b)** The response is enhanced if the target presentation is followed by a saccade to the target. **(c)** The enhancement effect is spatially selective, because it is not seen if a saccade occurs in response to a stimulus not in the receptive field. **(d)** Enhancement is also seen when the task requires the animal to release a hand lever when the peripheral spot dims. (Source: Adapted from Wurtz, Goldberg, and Robinson, 1982, p. 128.)

Sustained Activity During Sustained Attention and Memory in Prefrontal and Parietal Cortex

Anderson,
Goldberg
Colby

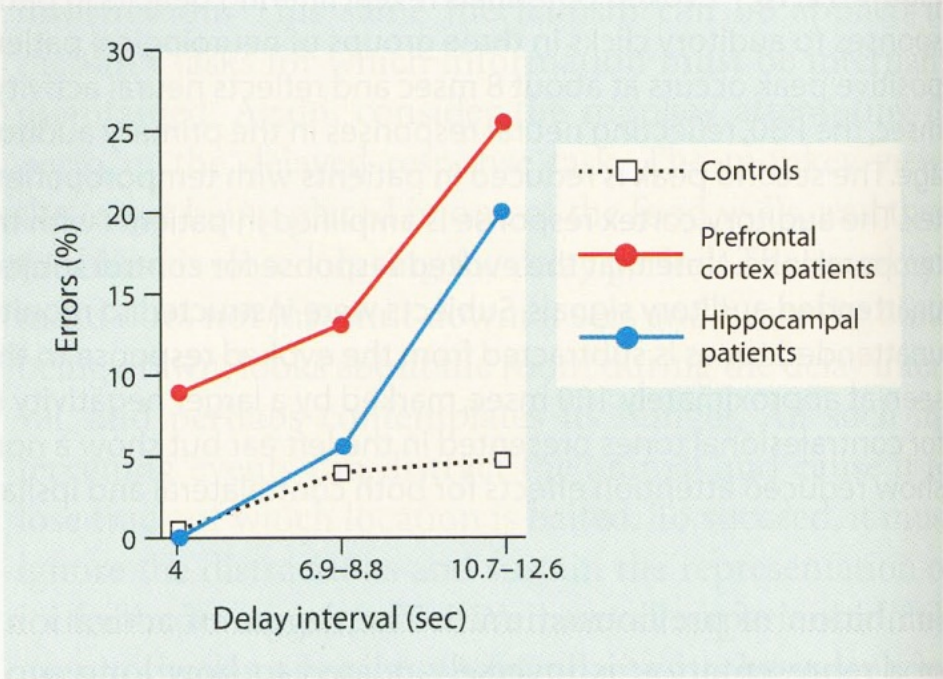




Miller, Fuster,
Goldman-Rakic, Schall,
etc

Distractibility After Prefrontal Lesions

Figure 12.20 Susceptibility to distraction in patients with lateral prefrontal lesions. Subjects performed a delayed auditory matching to sample task. Unrelated distractor tones were presented during the delay period. The group with prefrontal lesions made more errors for all delay conditions, and the deficit became greater as the number of distractors increased. Patients with hippocampal damage were impaired only at the longest delay, consistent with the role of this structure in long-term memory formation. Adapted from Chao and Knight (1995).



Expansion of Prefrontal Cortex Over Evolution

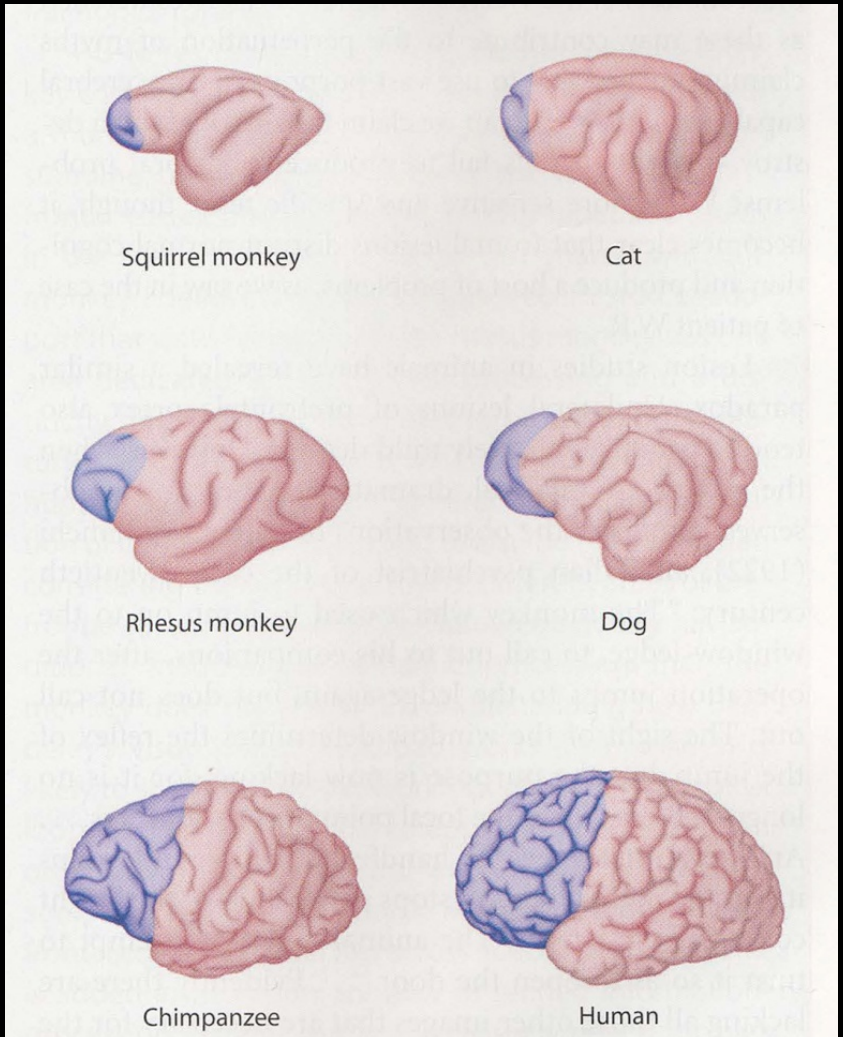
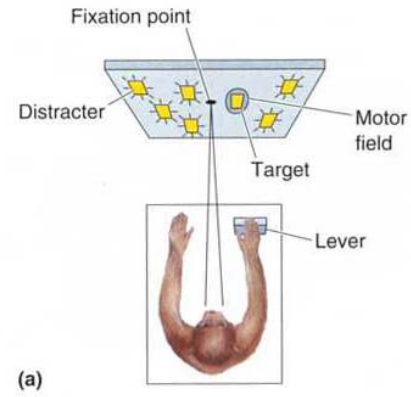


Figure 12.2 The shaded areas show the extent of prefrontal cortex in six species. Note how small this region is in the cat, dog, and squirrel monkey. It is greatly enlarged in humans. The brains are not drawn to scale. Adapted from Fuster (1989).

FEF electrical stimulation: Behavior



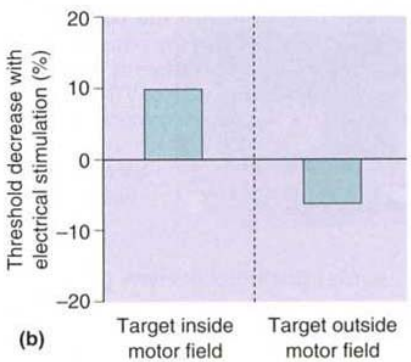
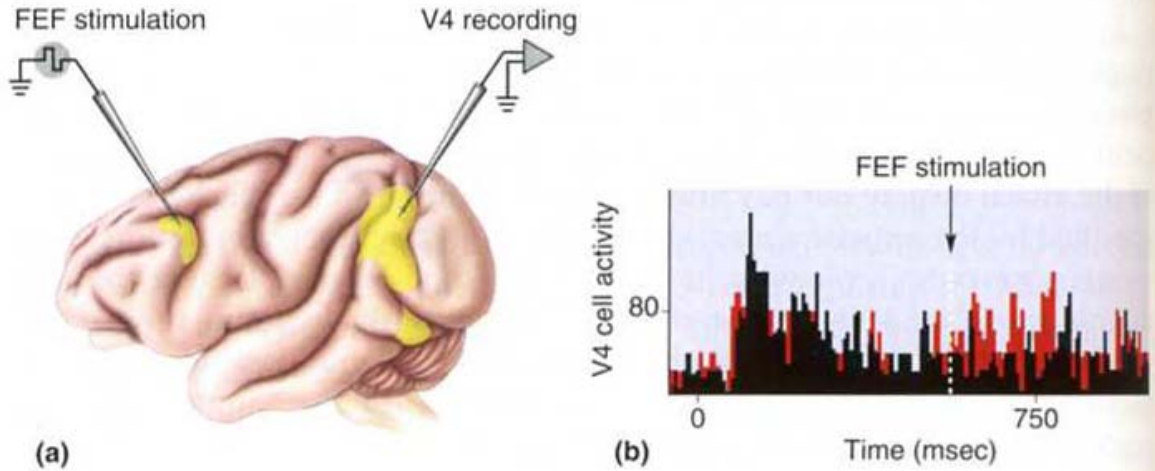
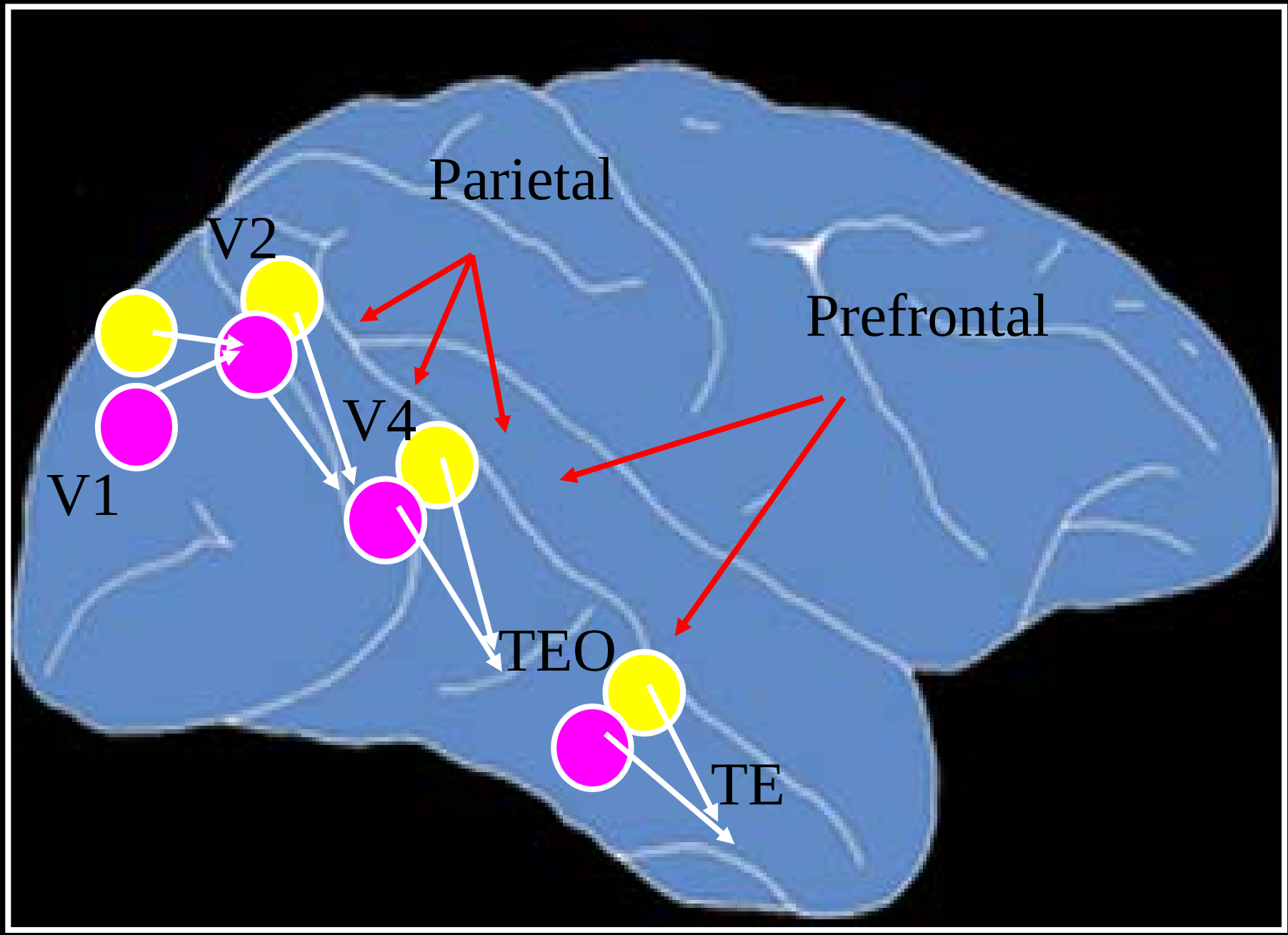


FIGURE 21.13
The effect of FEF stimulation on perceptual thresholds. (a) A monkey views spots on a visual display; all spots blink on and off except for the target spot. The monkey releases a lever if the target spot dims. **(b)** If the target spot is in the motor field of neurons under study, electrical stimulation in the FEF reduces the threshold light difference needed to detect that the target spot dimmed. If the target is outside the motor field, electrical stimulation slightly increases the threshold. (Source: Adapted from Moore and Fallah, 2001, Fig. 1.)

FEF electrical stimulation: Effects on Visual Responses

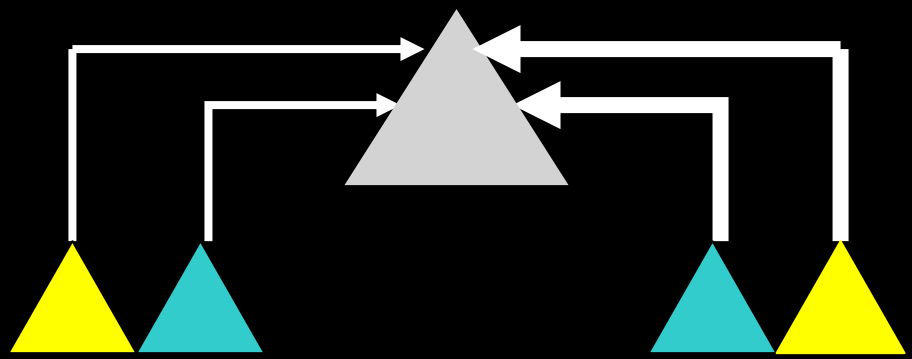
FIGURE 21.14
The effect of FEF stimulation on neuron activity in area V4. (a) A small electrical current is passed into the FEF while the activity of a neuron in V4 is recorded. A stimulus is presented in the V4 receptive field at time zero, and FEF stimulation occurs after a delay. **(b)** The V4 response was greater on trials with FEF stimulation (red) than on trials without (black). (Source: Adapted from Moore and Armstrong, 2003, p. 371.)

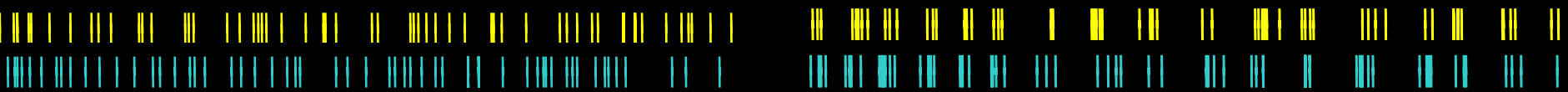



Parietal
V2
Prefrontal
V4
V1
TEO
TE

How can attention increase the effectiveness of neural pathways for behaviorally relevant stimuli at the expense of distracters?

Temporal synchrony: Cells receive many inputs. Those that are synchronized in time will be most effective in driving the cell.





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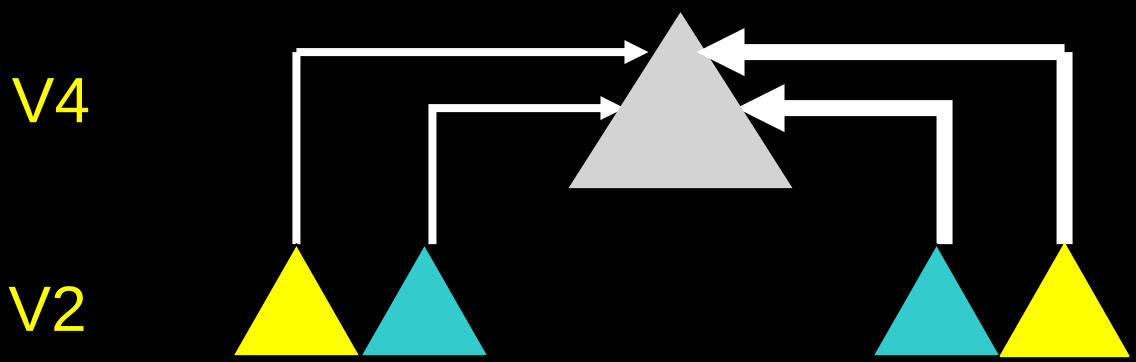

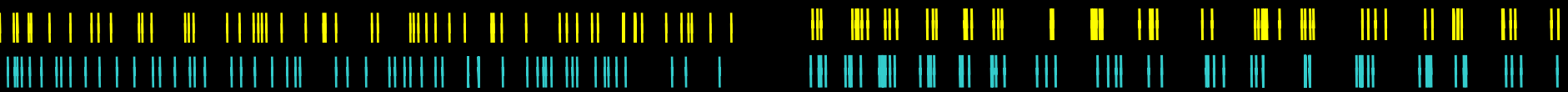

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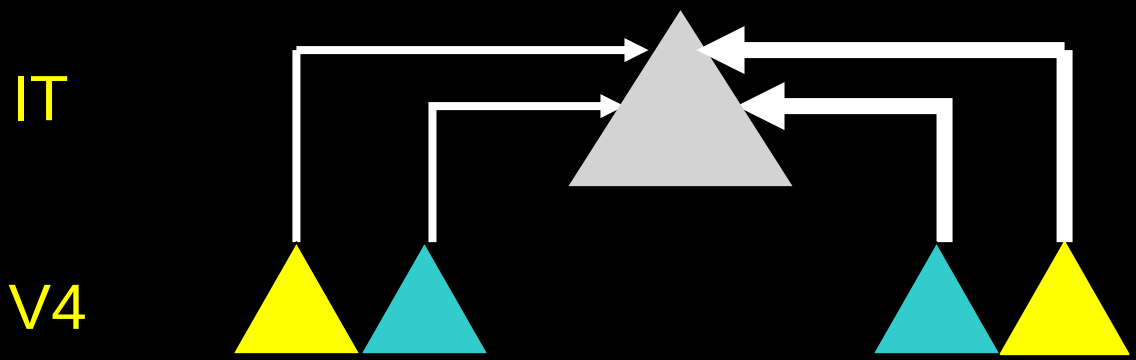
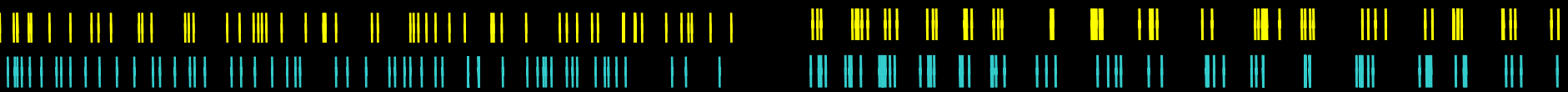
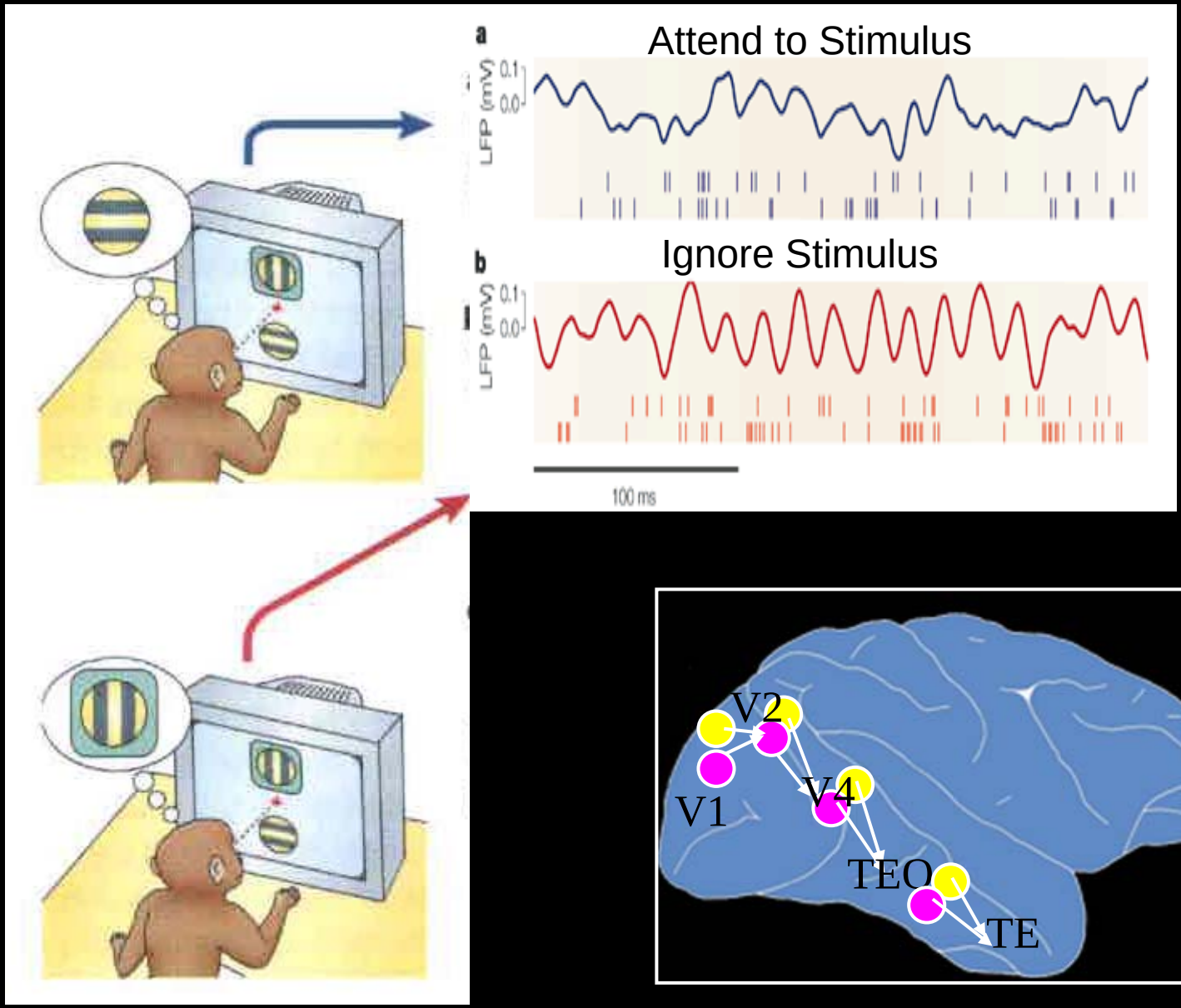
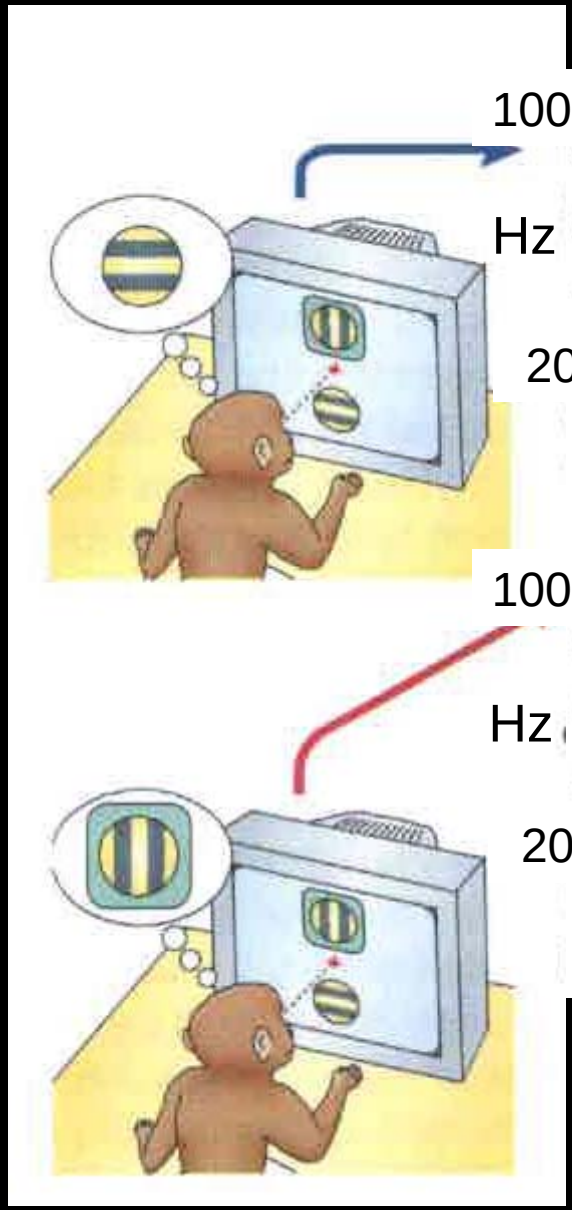
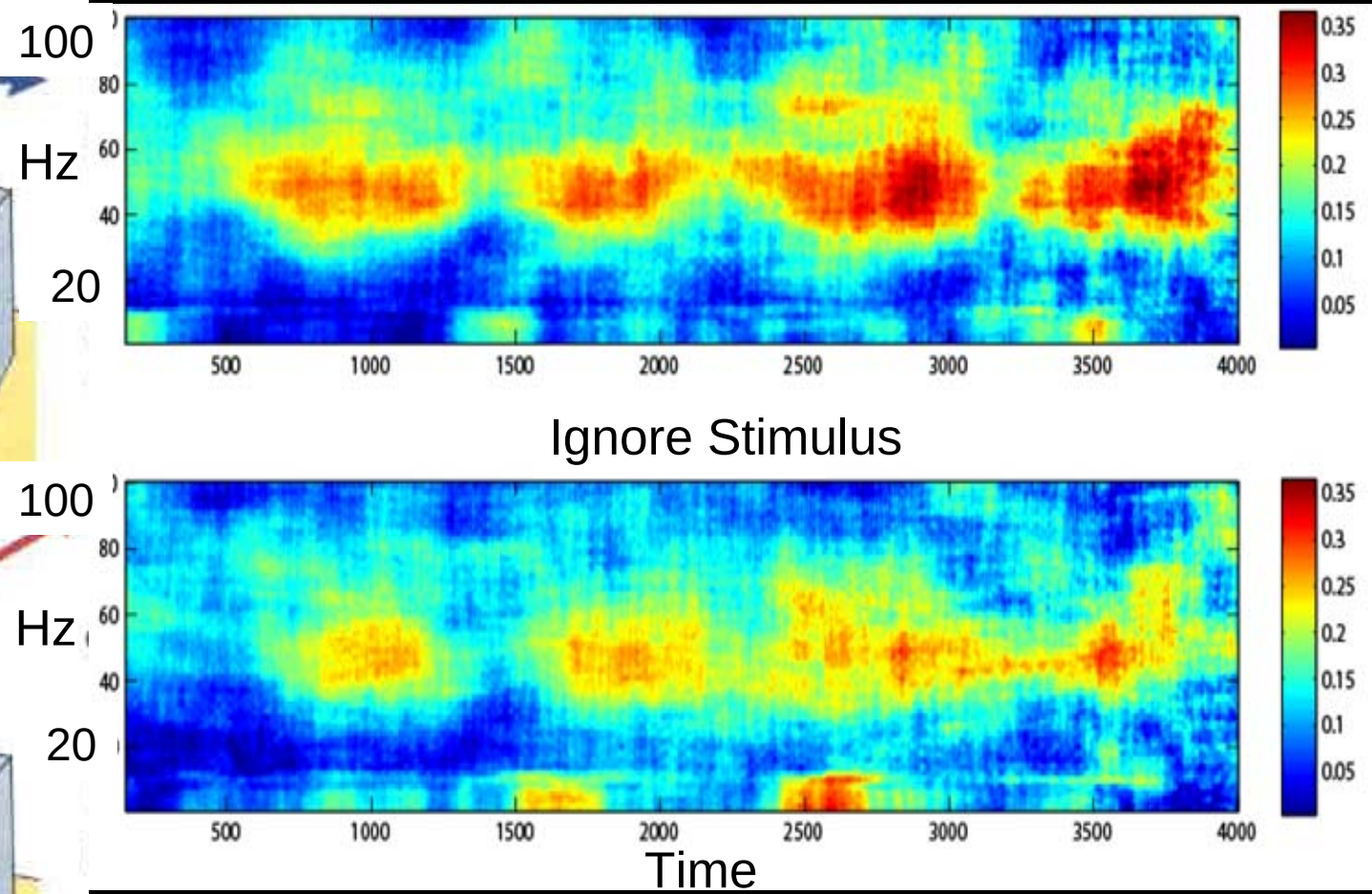




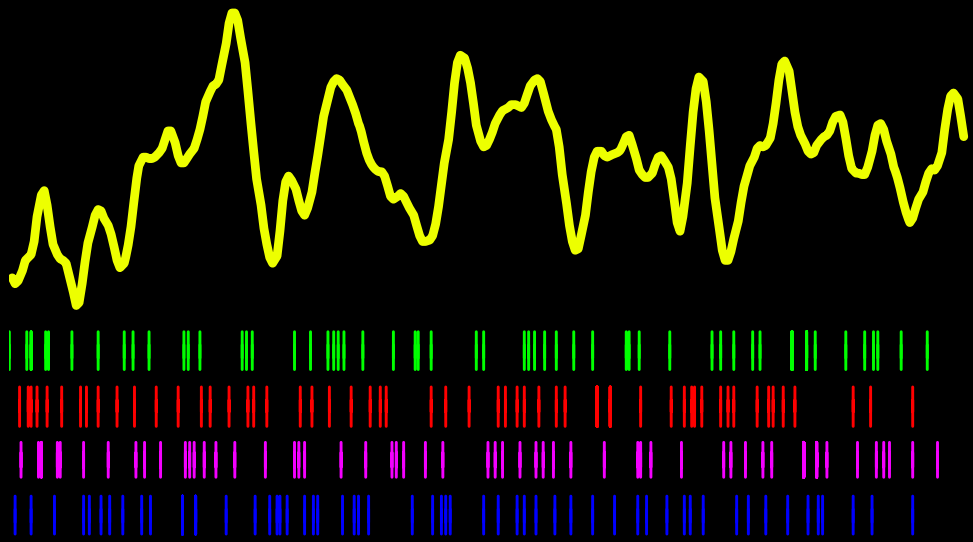

Attend to Stimulus
a
LFP (mV)
0.1
0.0
Ignore Stimulus
b
LFP (mV)
0.1
0.0
100 ms

V2
V1
V4
TEO
TE

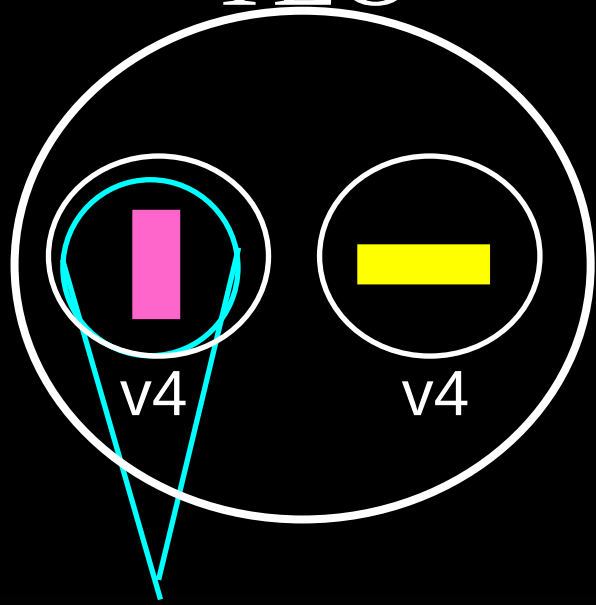



100
Hz
20
80
60
40
500
1000
1500
2000
2500
3000
3500
4000
0.35
0.3
0.25
0.2
0.15
0.1
0.05
Ignore Stimulus
100
Hz
20
80
60
40
500
1000
1500
2000
2500
3000
3500
4000
0.35
0.3
0.25
0.2
0.15
0.1
0.05
Time

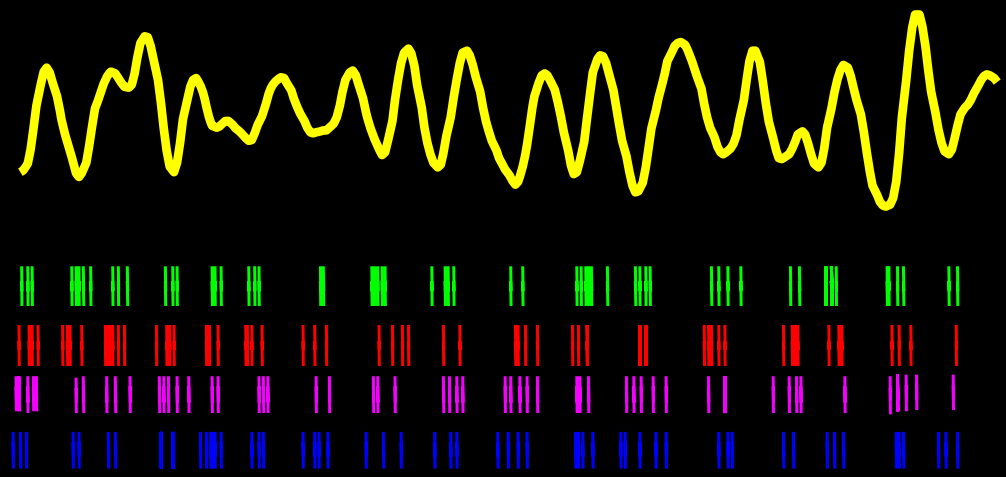
Unattended stimulus

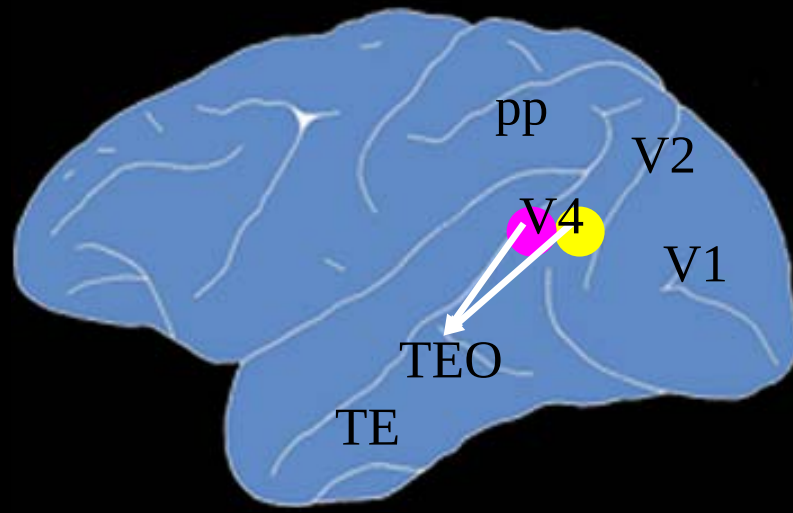


TEO

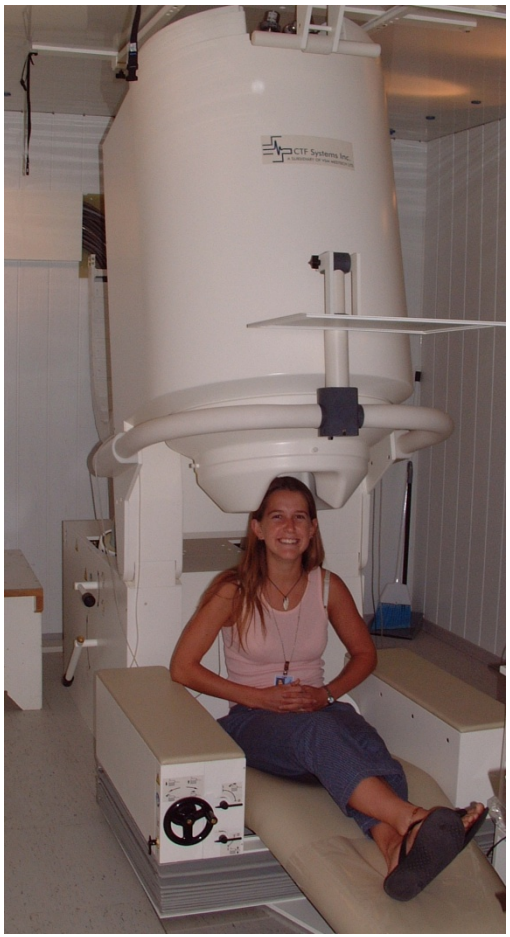


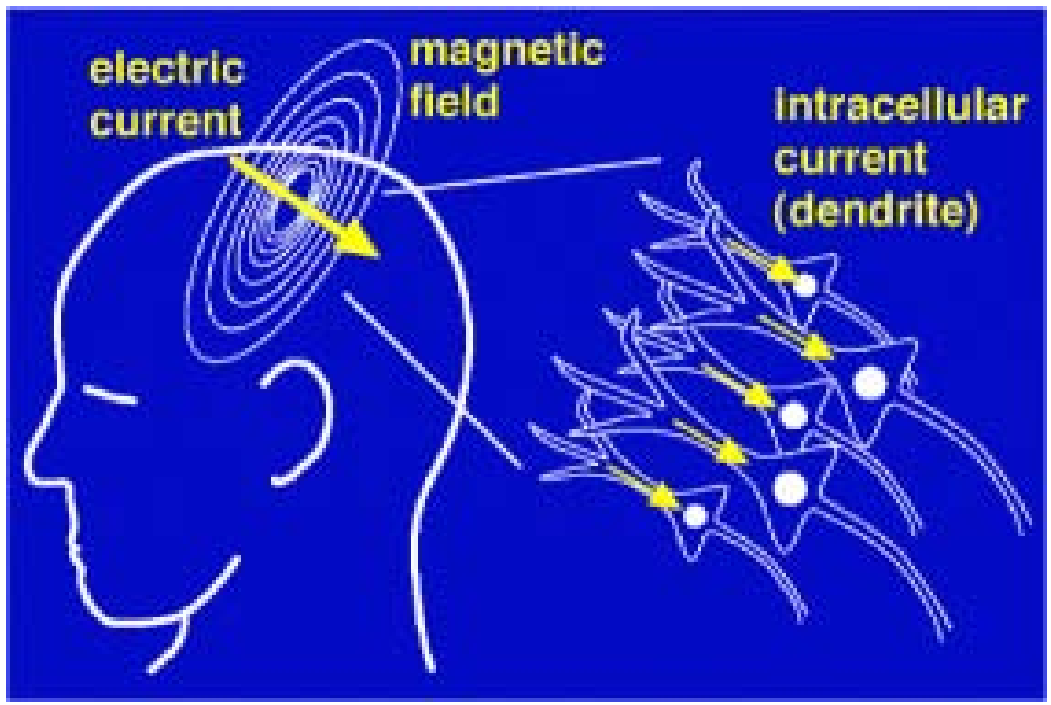
Attended stimulus



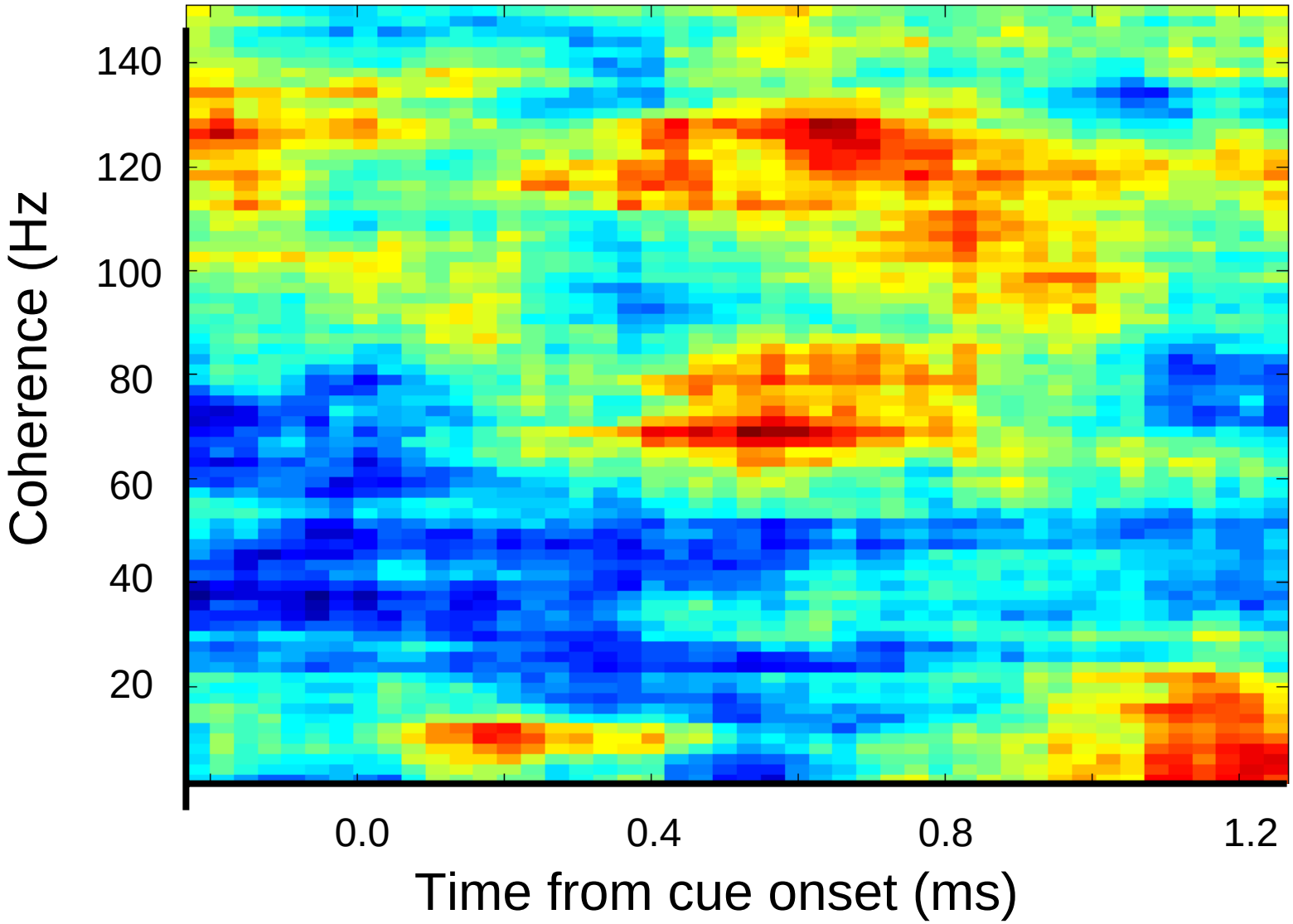


Magnetoencephalography

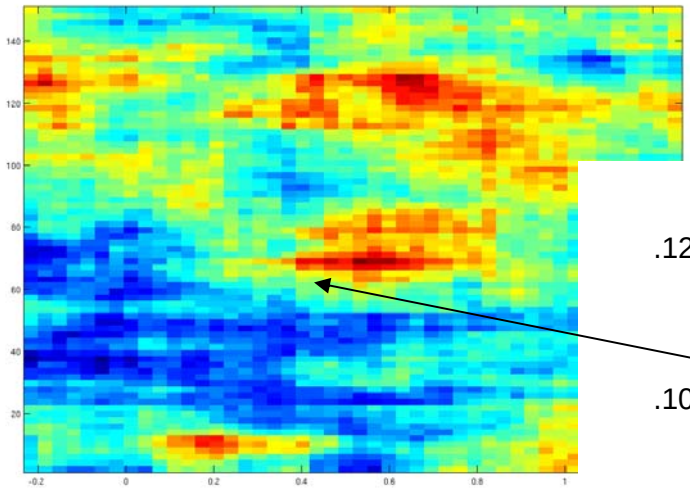


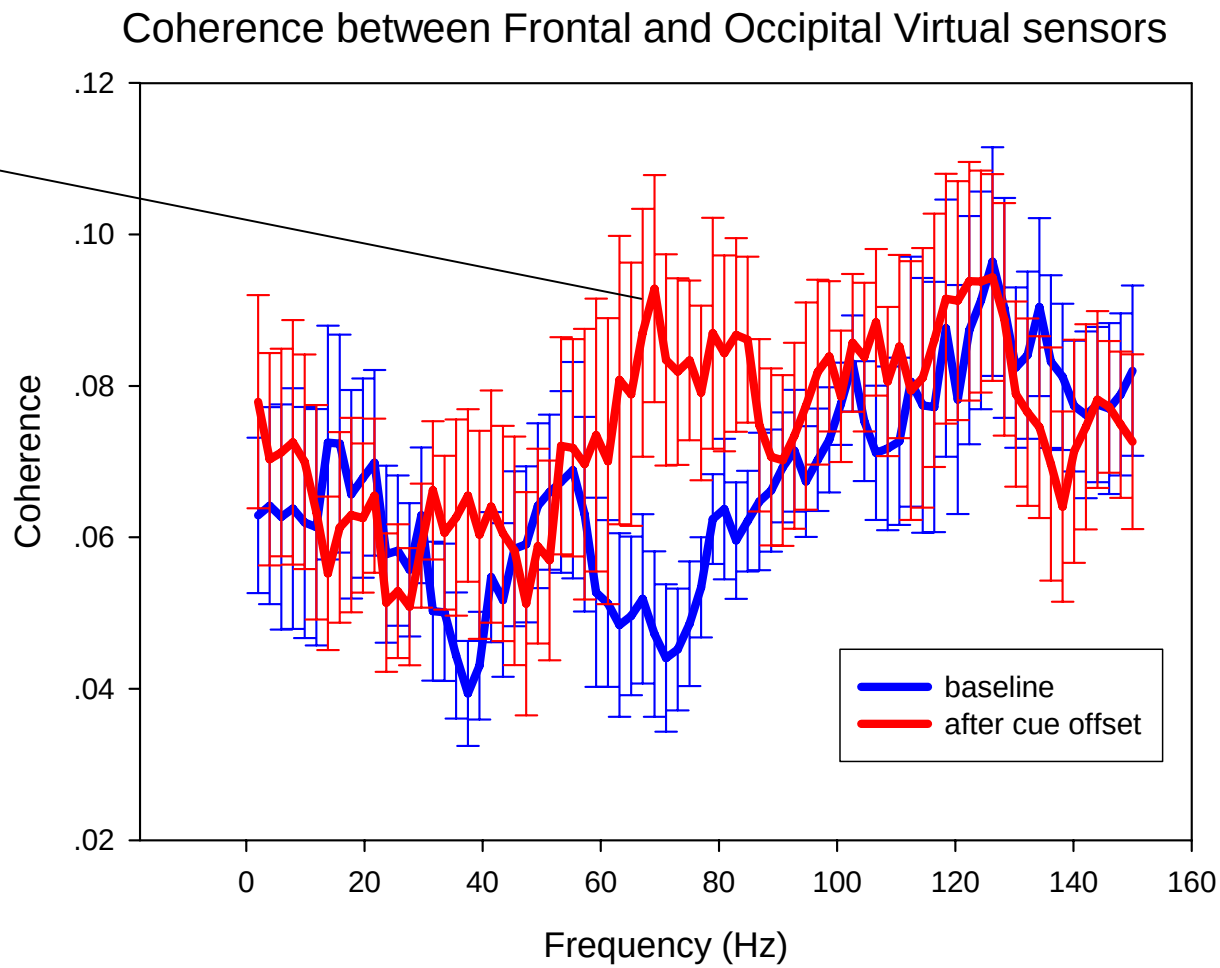


Coherence between frontal and occipital virtual sensors, time-locked to attentional cue



Frontal-Visual Cortex Coherence With Attention





Gamma (30-90 Hz), t(9) = 2.543, P < .05

MEG Task Design

Time

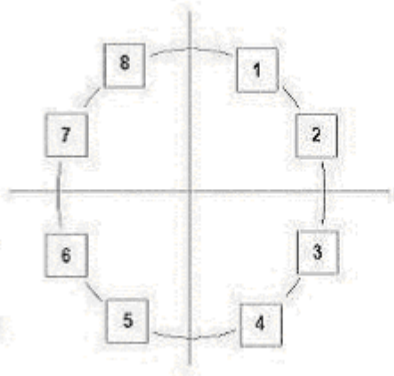
Color Change

Stimulus Onset

Cue Offset

Cue Onset

Central Fixation



0 0.5 1.0 1.5 3.7 4s

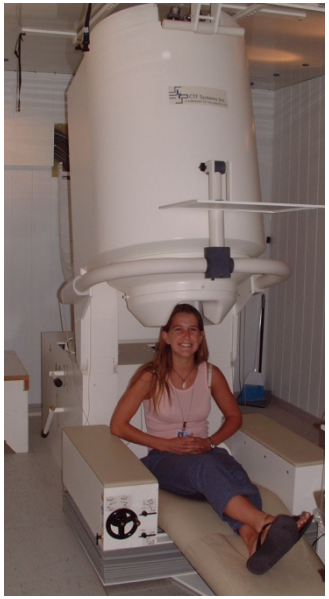
Fixation

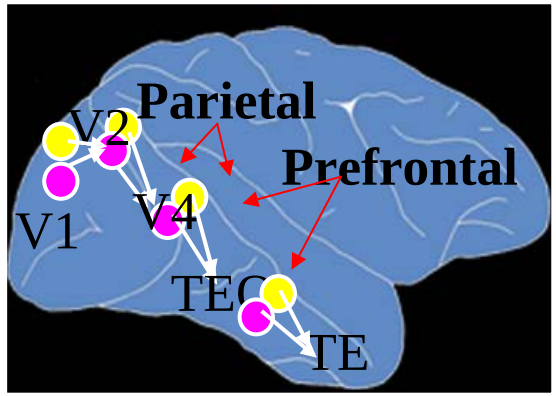
Cue Onset

Cue Offset

STIM Onset

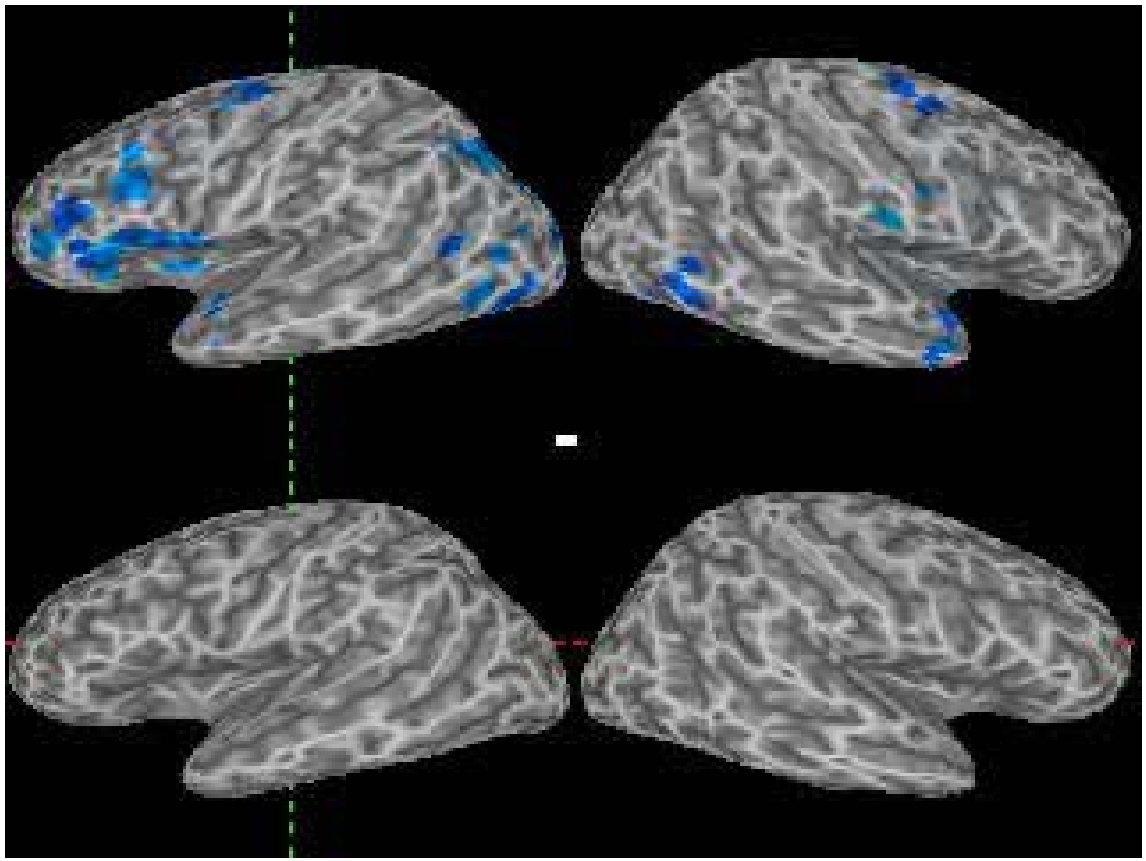
Color Change



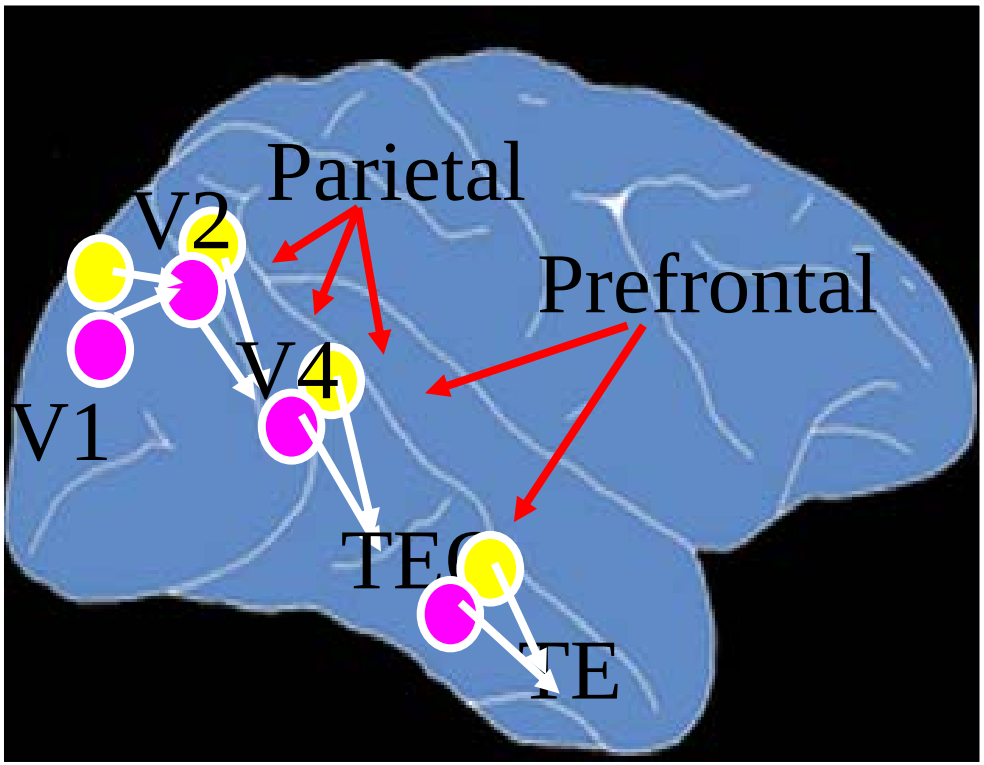


Low

High



Attention and Executive Control: It Takes A Brain



Chapter 21 Review Questions

- What differences are there between the conscious states of a person with neglect syndrome and a split-brain individual who can only describe things in the right visual field?
- In what ways is unilateral spatial neglect different from blindness in half of the visual field?
- How would you use fMRI or PET imaging to look for brain areas involved in directing selective attention in humans?
- What neural mechanism(s) could be responsible for the receptive field changes observed in area V4 in response to shifts in attention?
- How are shifts in attention and eye movements related?
- How might feedback from the frontal eye fields modulate the responses of neurons in visual cortex?
- How would a system for guiding attention to features differ from a system directing attention to different locations?