

*NST II Psychology*

*NST II Neuroscience (Module 5)*

# Brain Mechanisms of Memory and Cognition – 3

## Attention; the binding problem

**Rudolf Cardinal**

Department of Experimental Psychology

*Monday 12, 19, 26 Jan; 2, 9, 23 Feb 2004; 10 am*

*Physiology Main Lecture Theatre*

*Slides will be at [pobox.com/~rudolf/psychology](http://pobox.com/~rudolf/psychology)*

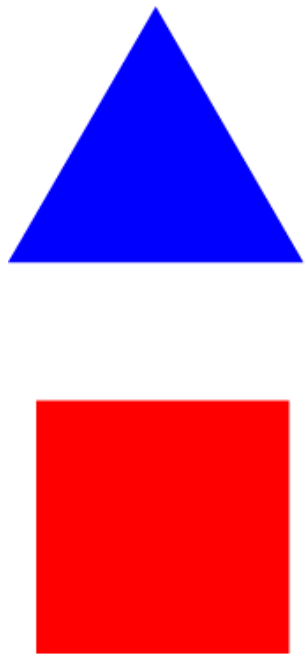


*Binding*

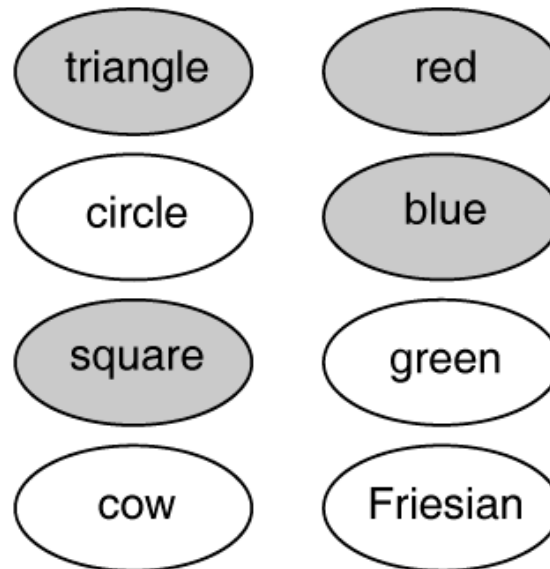
# An example of a binding problem

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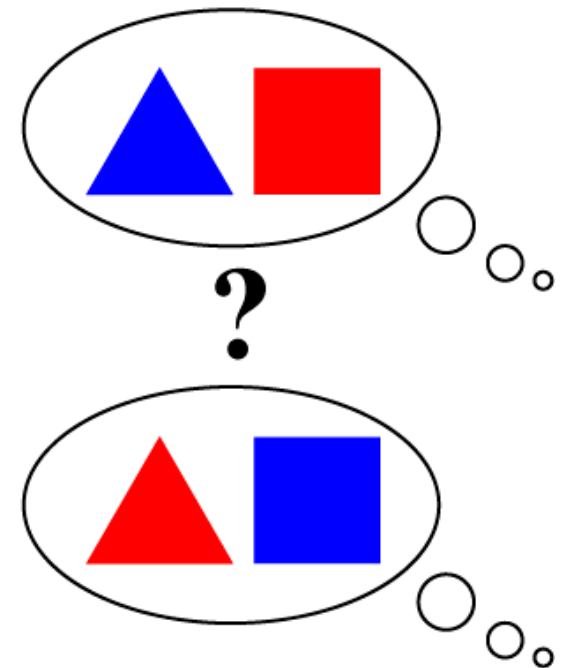
Visual scene



'Feature detectors'



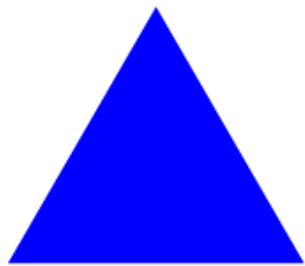
A binding problem



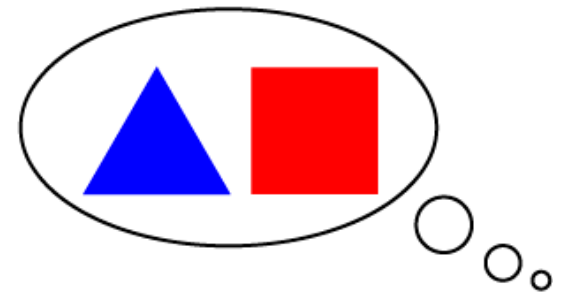
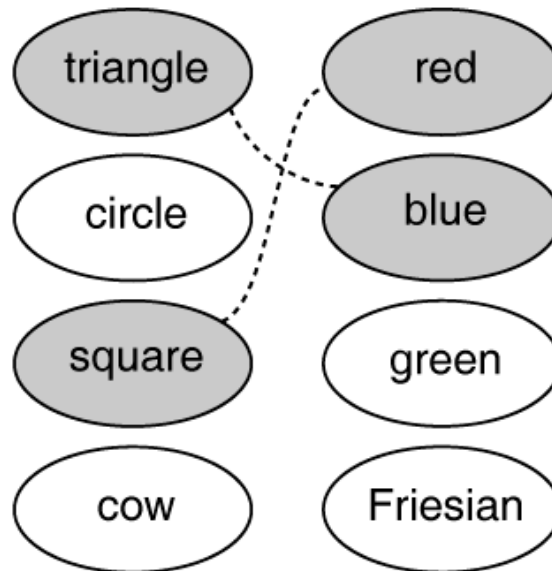
# What needs to happen...

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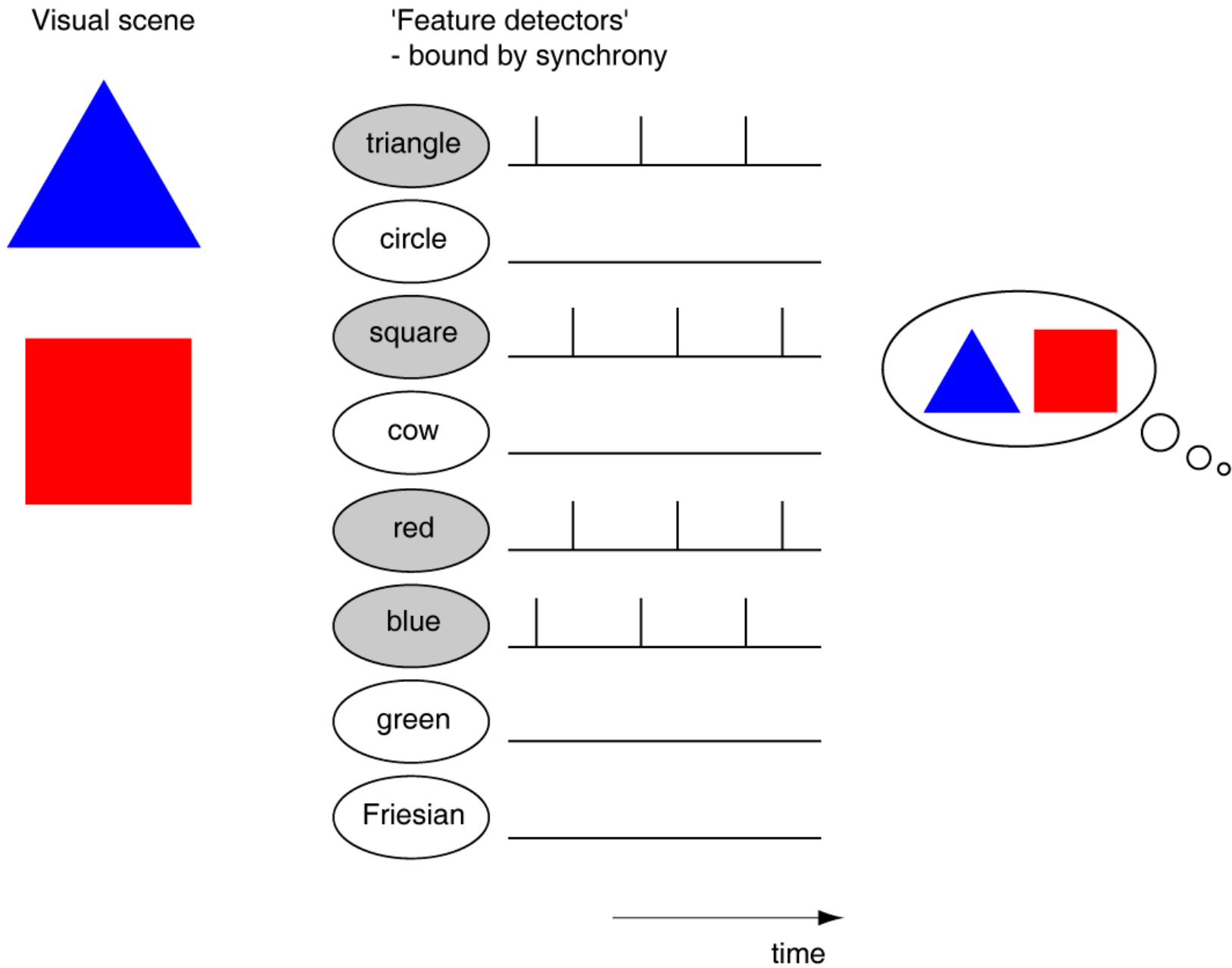
Visual scene



'Feature detectors'  
- bound together appropriately



# Binding by synchrony

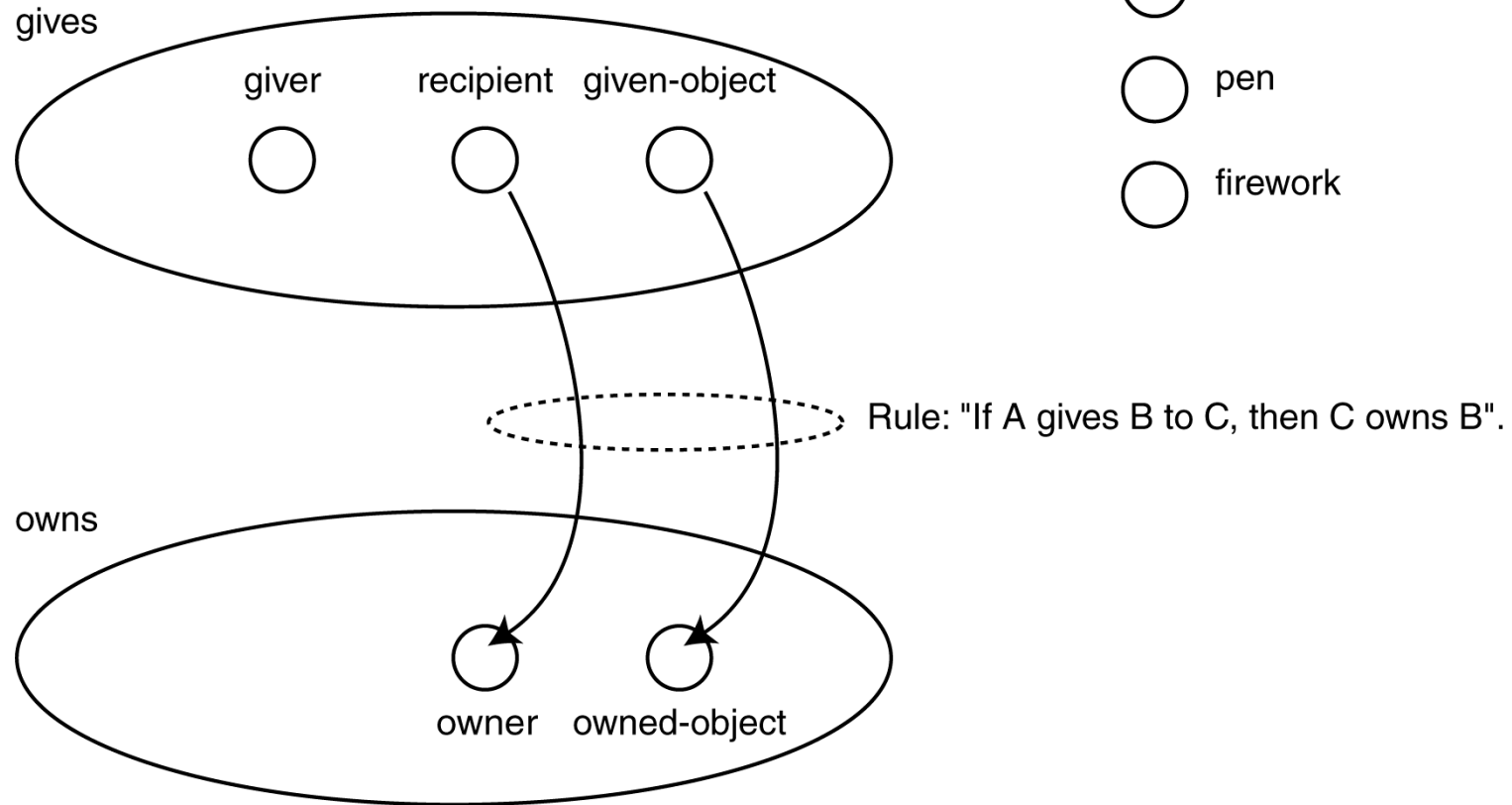


# Reasoning by dynamic binding? (1 - the static bit)

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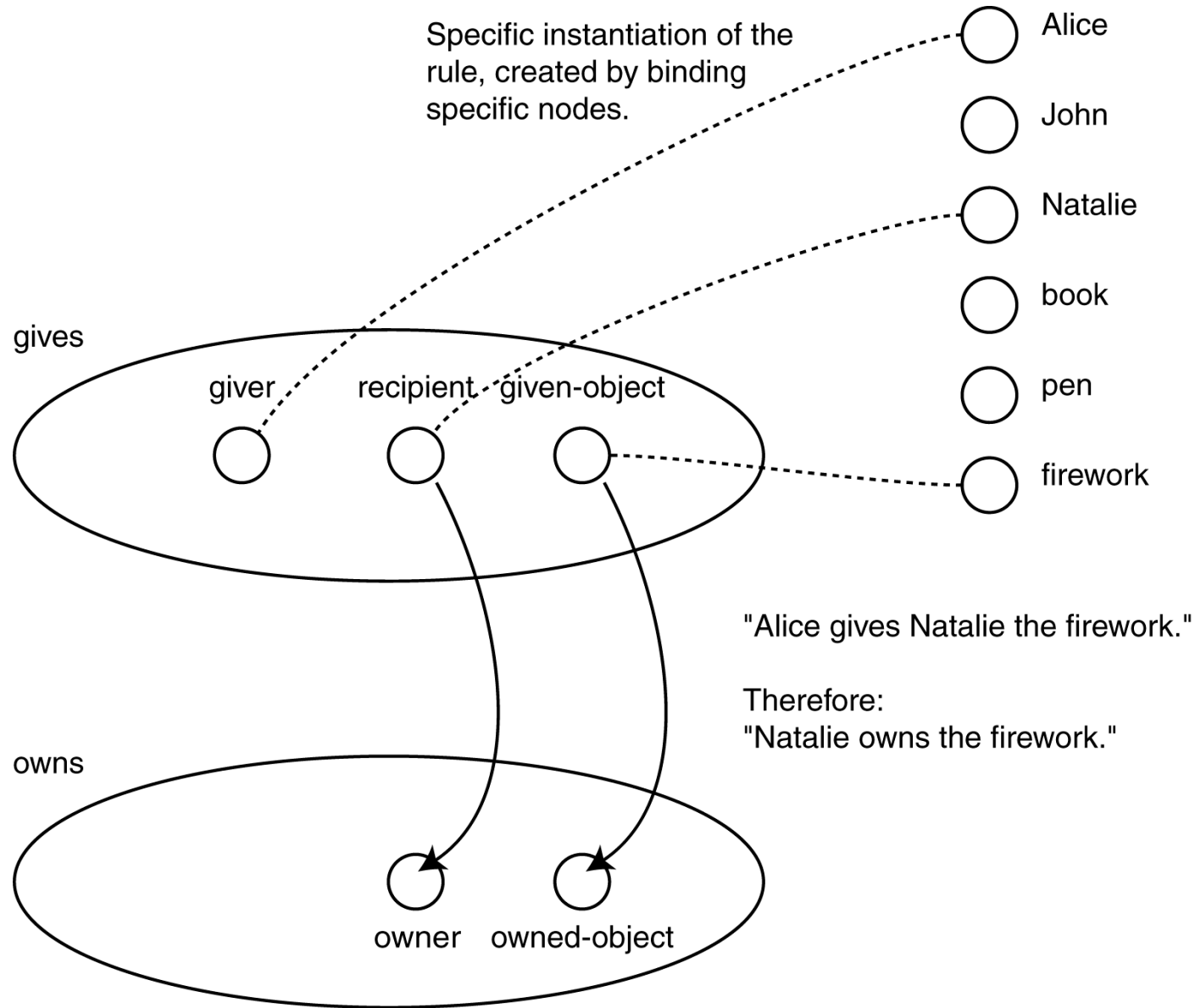
Available to be dynamically bound as 'fillers' to the rules (by **synchronizing** with the 'giver', 'recipient', 'given-object' etc. nodes).

- Alice
- John
- Natalie
- book
- pen
- firework



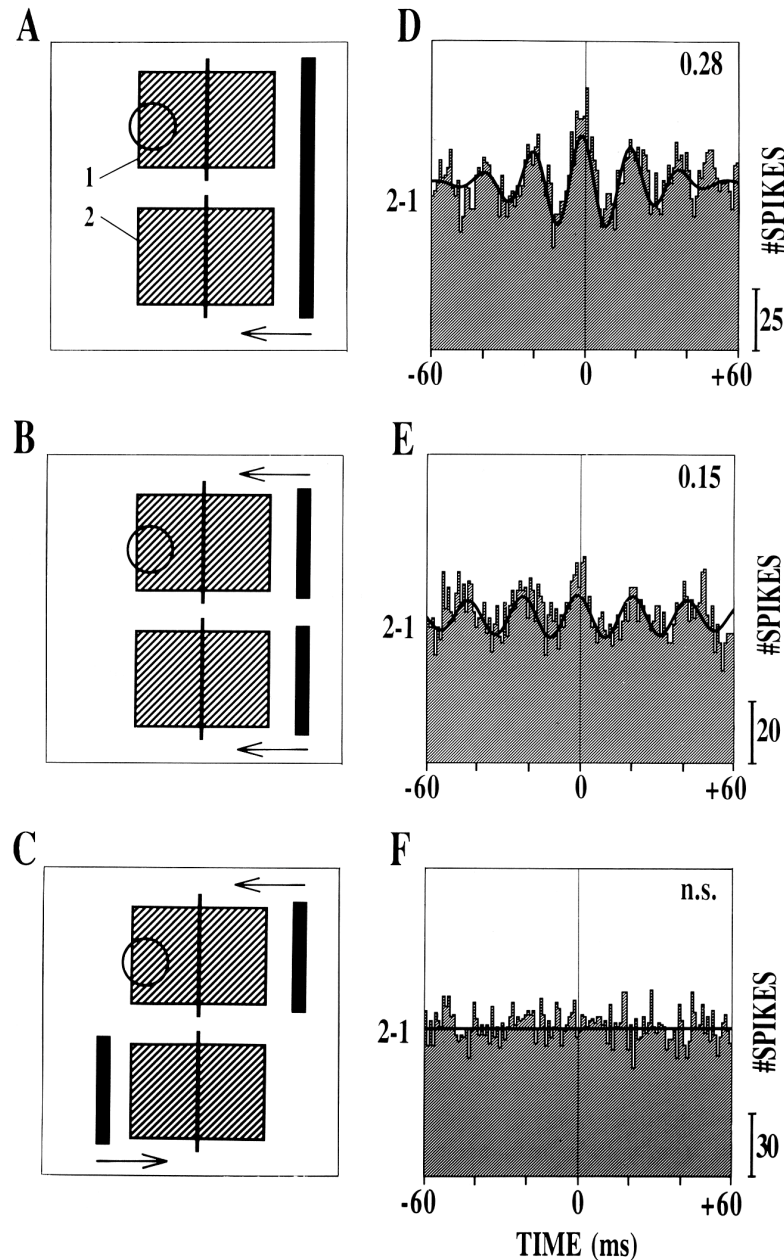
*based on Shastri & Ajjanagadde (1993)*

# Reasoning by dynamic binding? (2 - the dynamic bit)



*based on Shastri & Ajjanagadde (1993)*

# Evidence for synchrony: cat visual cortex (1)



- Two sites a long way (7 mm) apart in area 17 (V1).

- Responses to a long bar covering both receptive fields (A), two short bars moving in the same direction across the receptive fields (B), or two short bars moving in different directions (C).

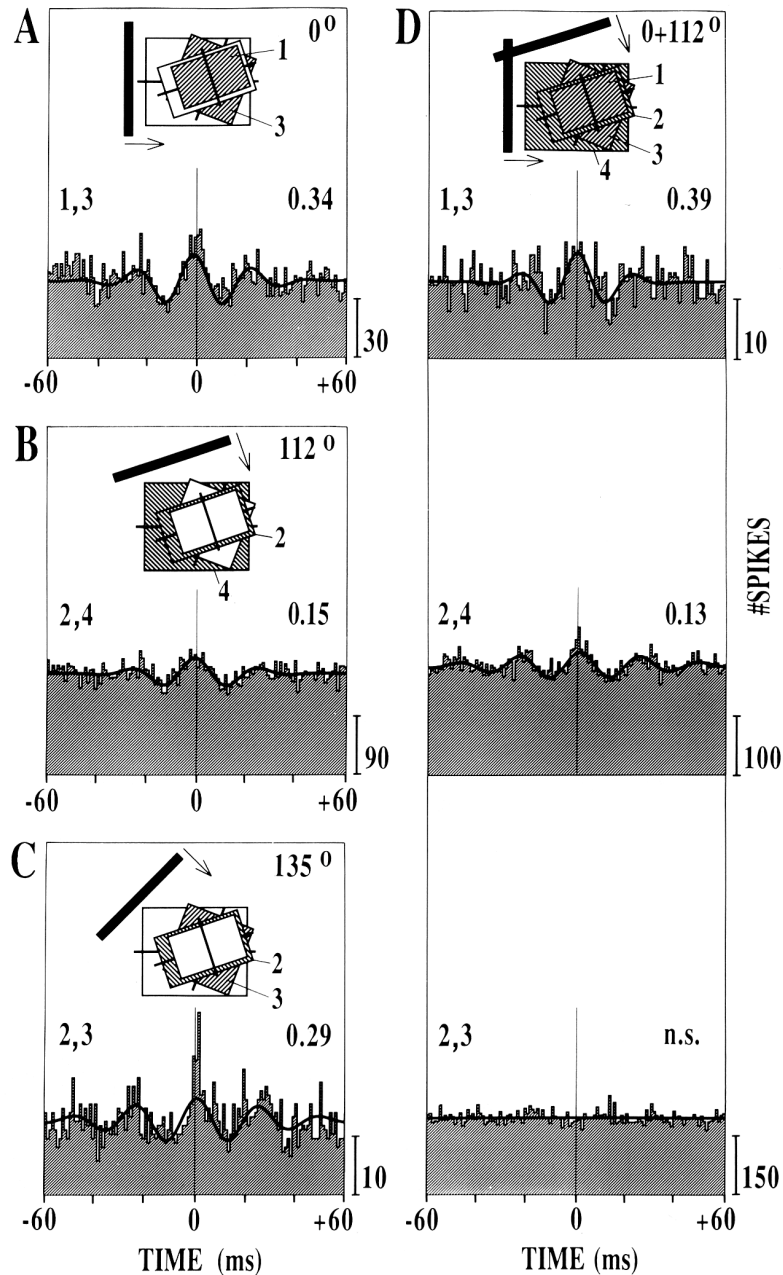
- Cross-correlation functions (right-hand side) indicate **synchrony** between the two sites in conditions A and B, but not C.

- Conditions A and B match Gestalt criteria for perceptual grouping (i.e. perceiving the bars as one object).

*from Singer (1995) / Engel et al. (1992)*



## Evidence for synchrony: cat visual cortex (2)



- Four sites in area 17 (V1). Different groups of cells prefer different orientations (shown in insets).
- If a moving bar of light activates several cells, they synchronize (A, B, C).
- But if two bars are used, the cells **split**: some prefer one bar, some the other (D).
- In this case, cells that respond to bar 1 are mutually synchronized; cells that respond to bar 2 are mutually synchronized; but the group that respond to bar 1 are *not* synchronized with those that respond to bar 2.
- There are then **two populations, defined by synchrony**, each responding to one visual stimulus.

*from Singer (1995) / Engel et al. (1991)*

## *Attention:*

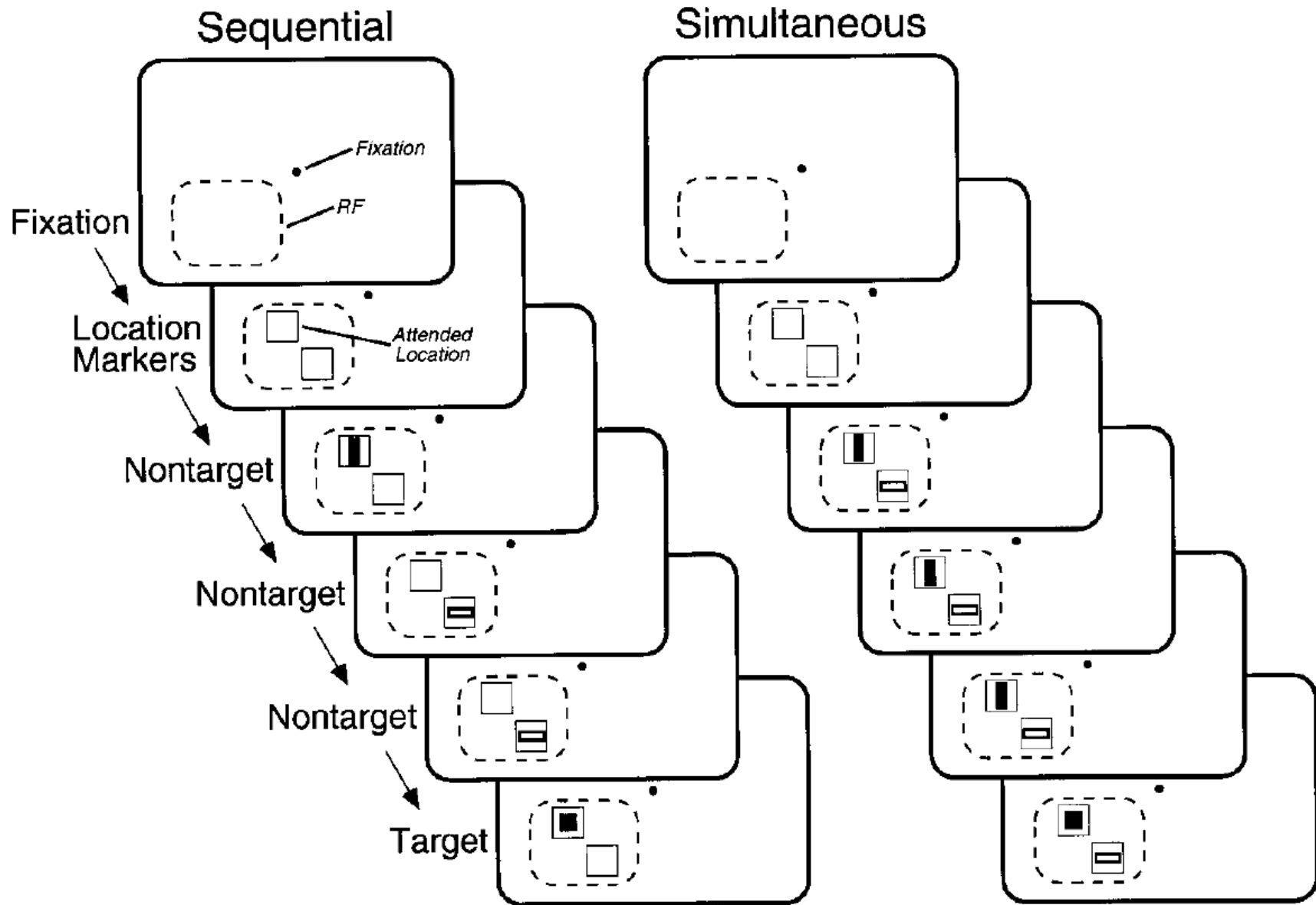
*'The taking possession by the mind in clear and vivid form of one out of what seem several simultaneous objects or trains of thought.'*

*James (1890)*

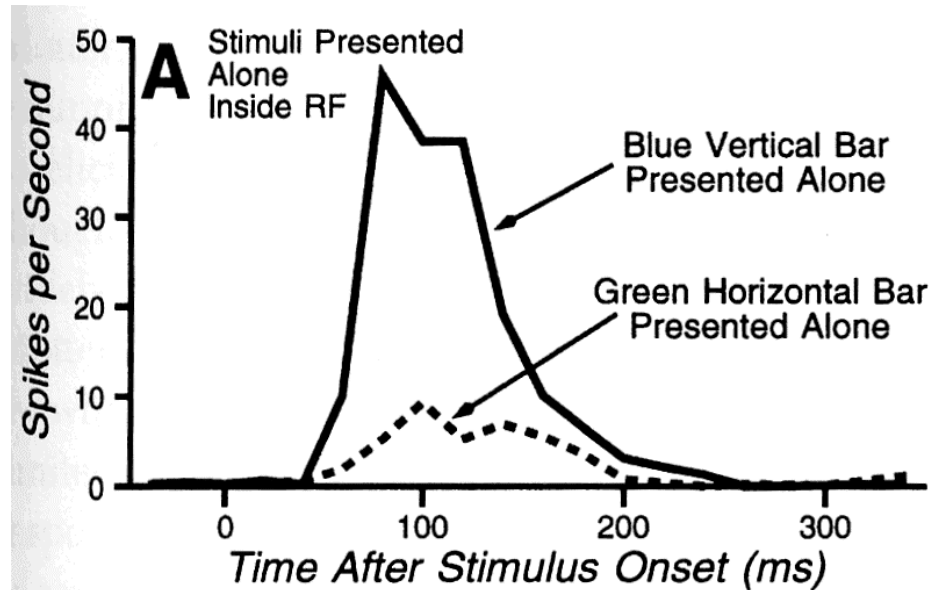
*Attentional enhancement and  
suppression of firing*

# Monkeys can attend to a location in order to detect targets...

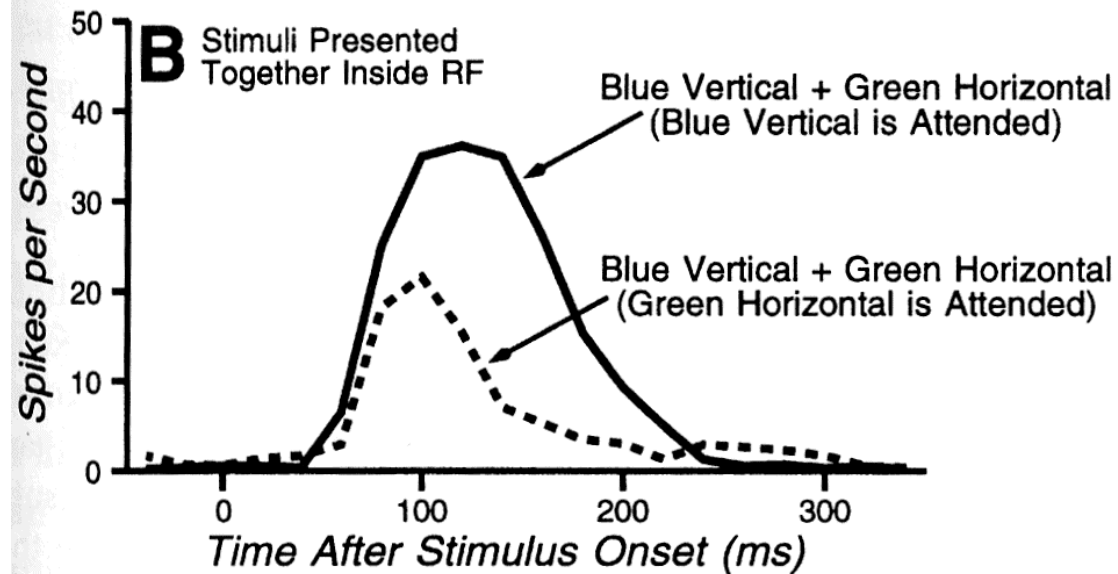
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# Modulation of V4 responses by attention



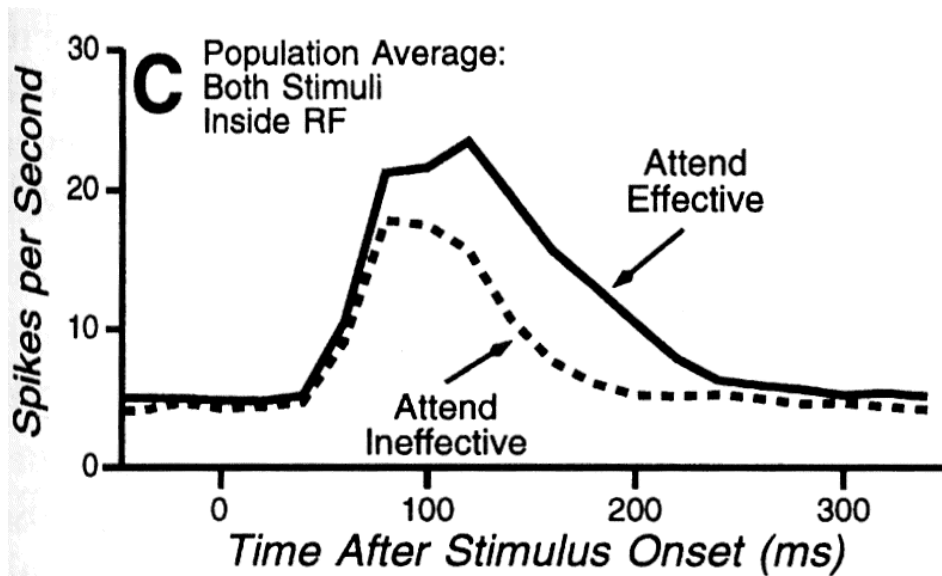
This cell prefers blue vertical bars to green horizontal bars.



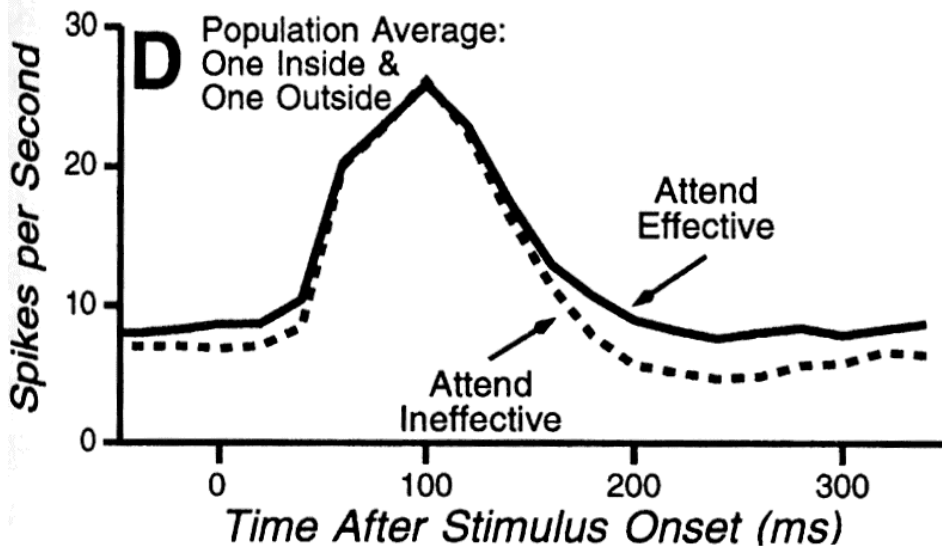
When *both* a blue and a green stimulus are present, the response depends strongly on which stimulus is being attended to.

*Luck et al. (1997)*  
*J Neurophysiol 77: 24*

# Attentional modulation depends on competition in the RF?



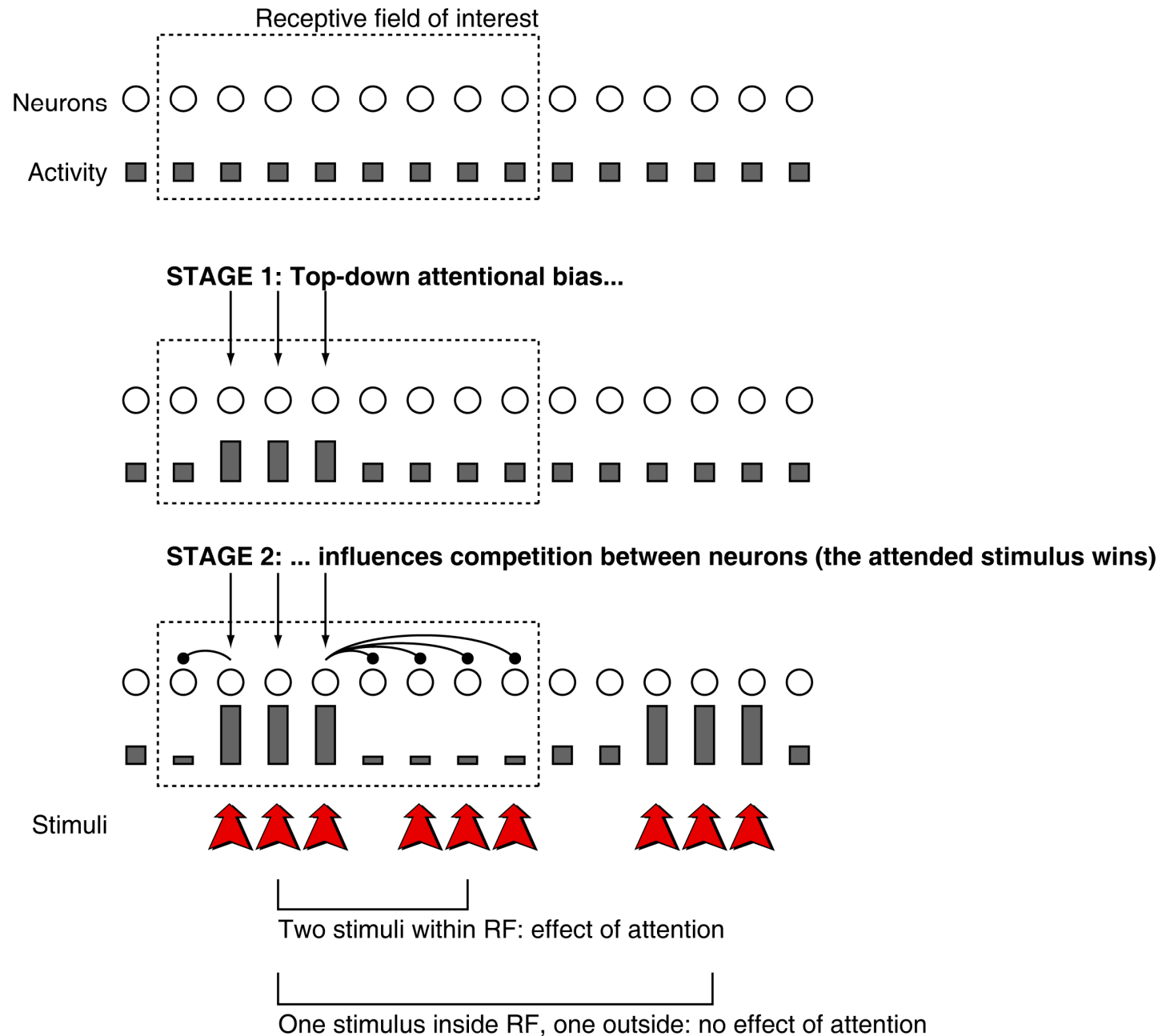
When there are *two* stimuli inside the receptive field of a cell, the response depends on which stimulus is being attended to.



If there is only one stimulus inside the RF (whichever one it is), the response *doesn't* depend on which stimulus is being attended to.

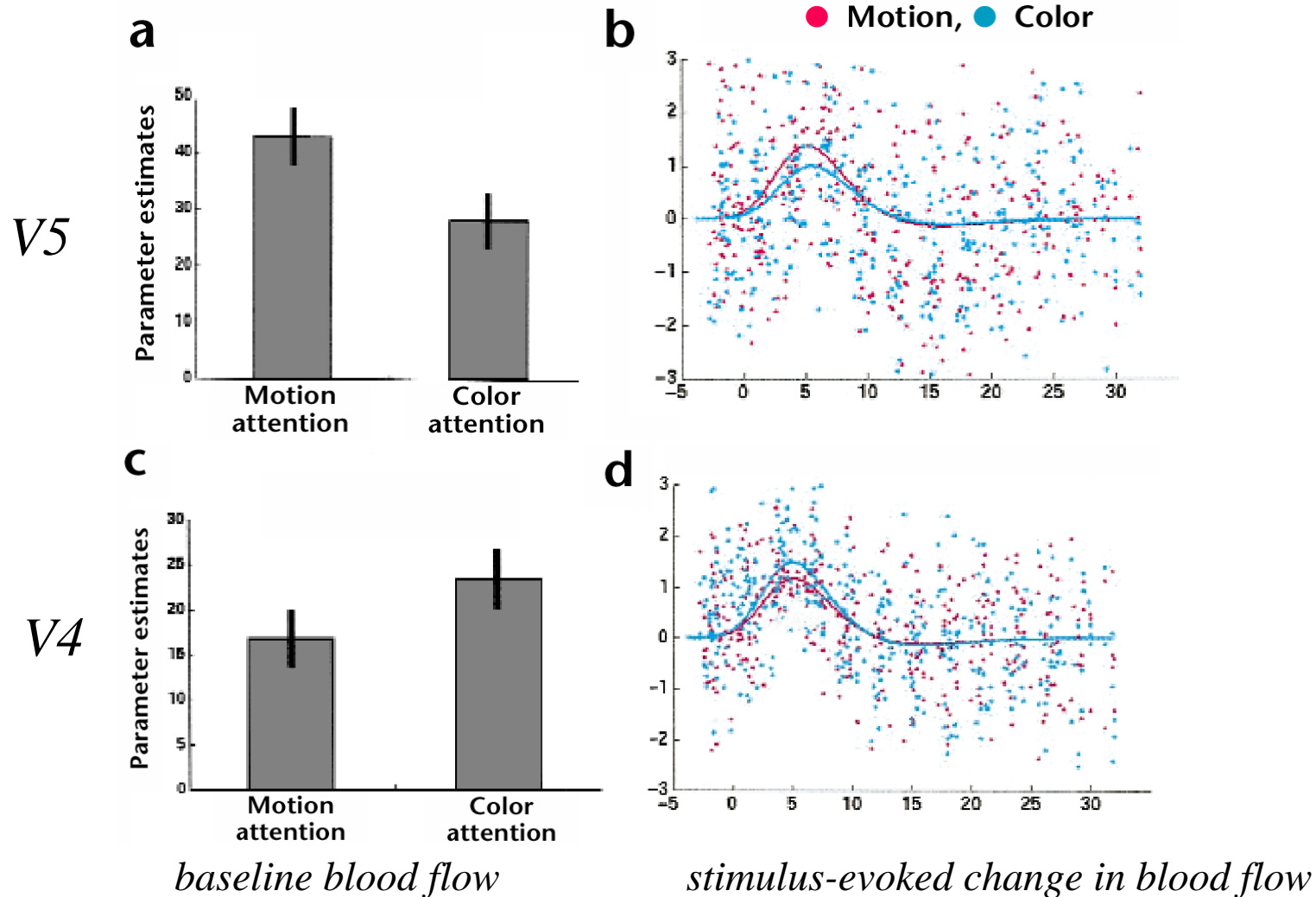
*Luck et al. (1997)*  
*J Neurophysiol 77: 24*

# Therefore... one view of the Luck et al. (1997) model



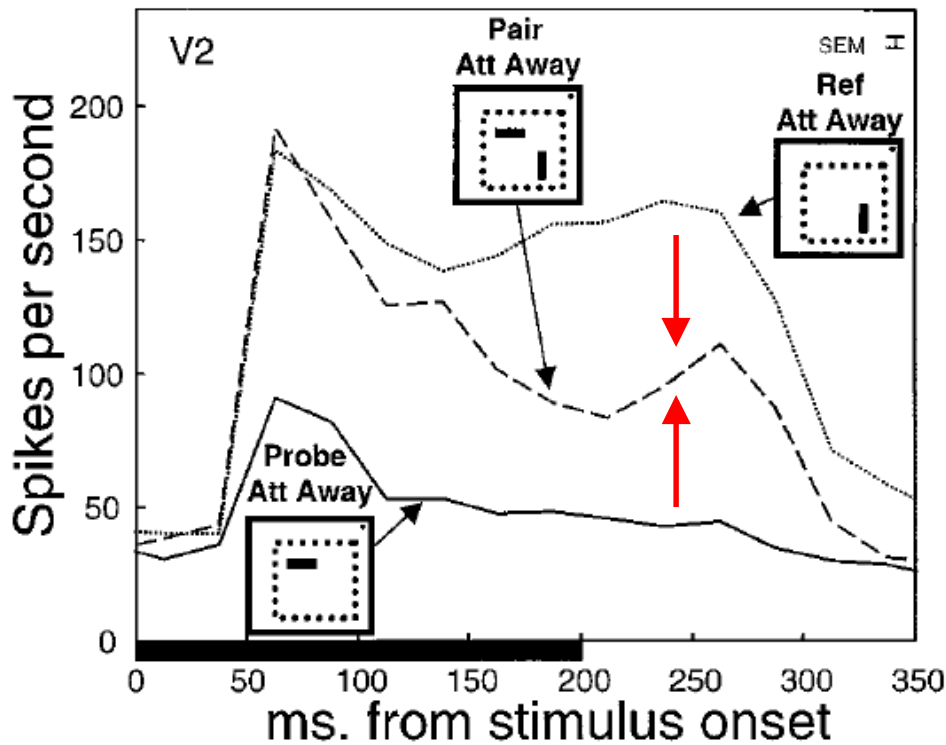
# Evidence for attentional modulation in the absence of stimuli

- Monkeys: e.g. Luck *et al.* (1997) — attention increased baseline firing
- Humans: e.g. Chawla *et al.* (1999) — attention increased baseline blood flow (in V4 for attention to colour, and V5 for attention to motion)

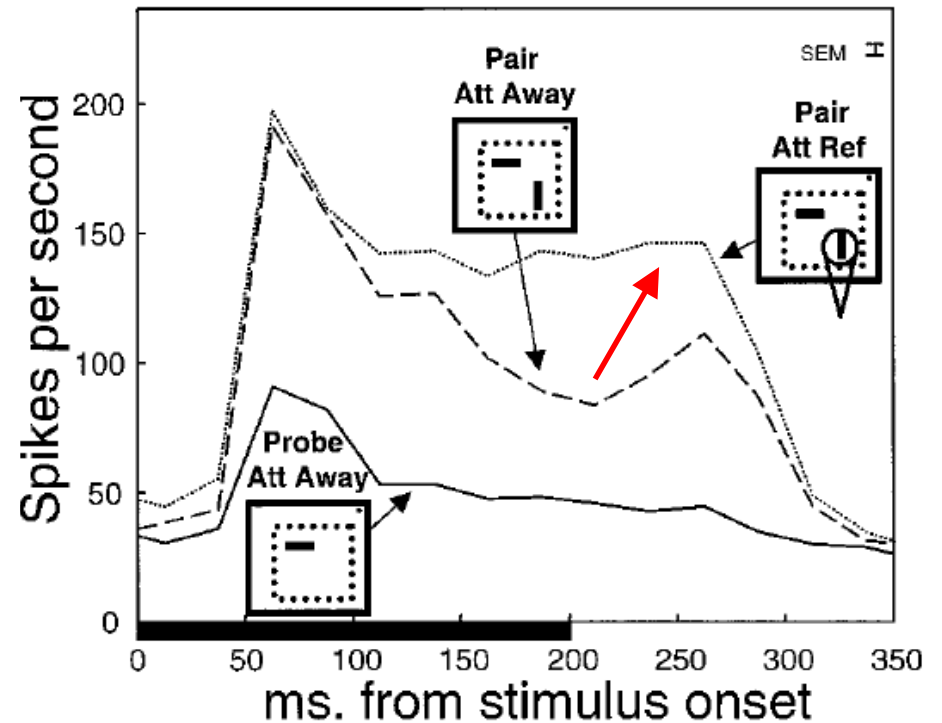




# Evidence for stimulus competition in the absence of attention

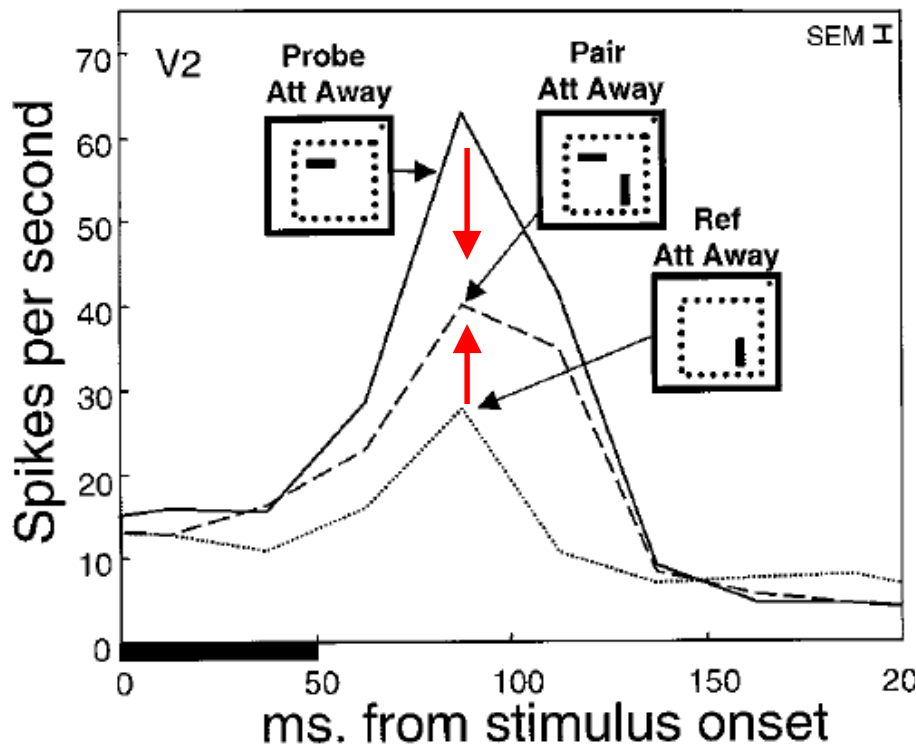


*NO ATTENTION.*  
The response to two stimuli ('pair') is **not** the best of the response to each alone ('pair', 'ref'); it is intermediate, i.e. they **compete**.

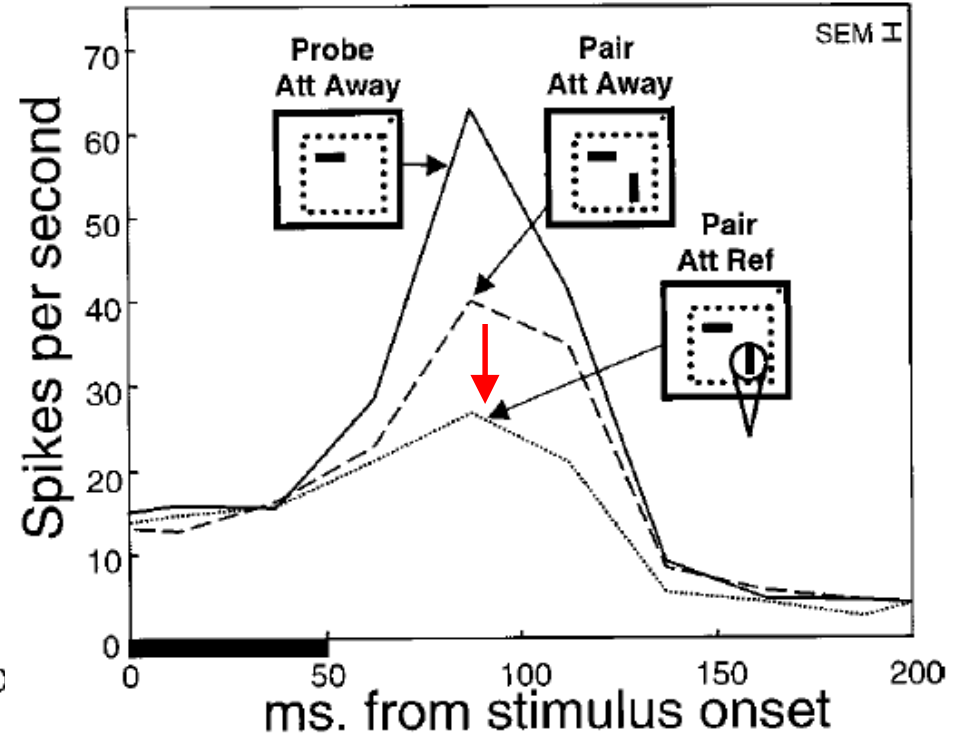


*If one stimulus is attended to, the effects of competition against that stimulus are eliminated.*

# Attention increases the *influence* of stimuli (even if inhibitory)



*NO ATTENTION.*  
*Again, two stimuli compete.*



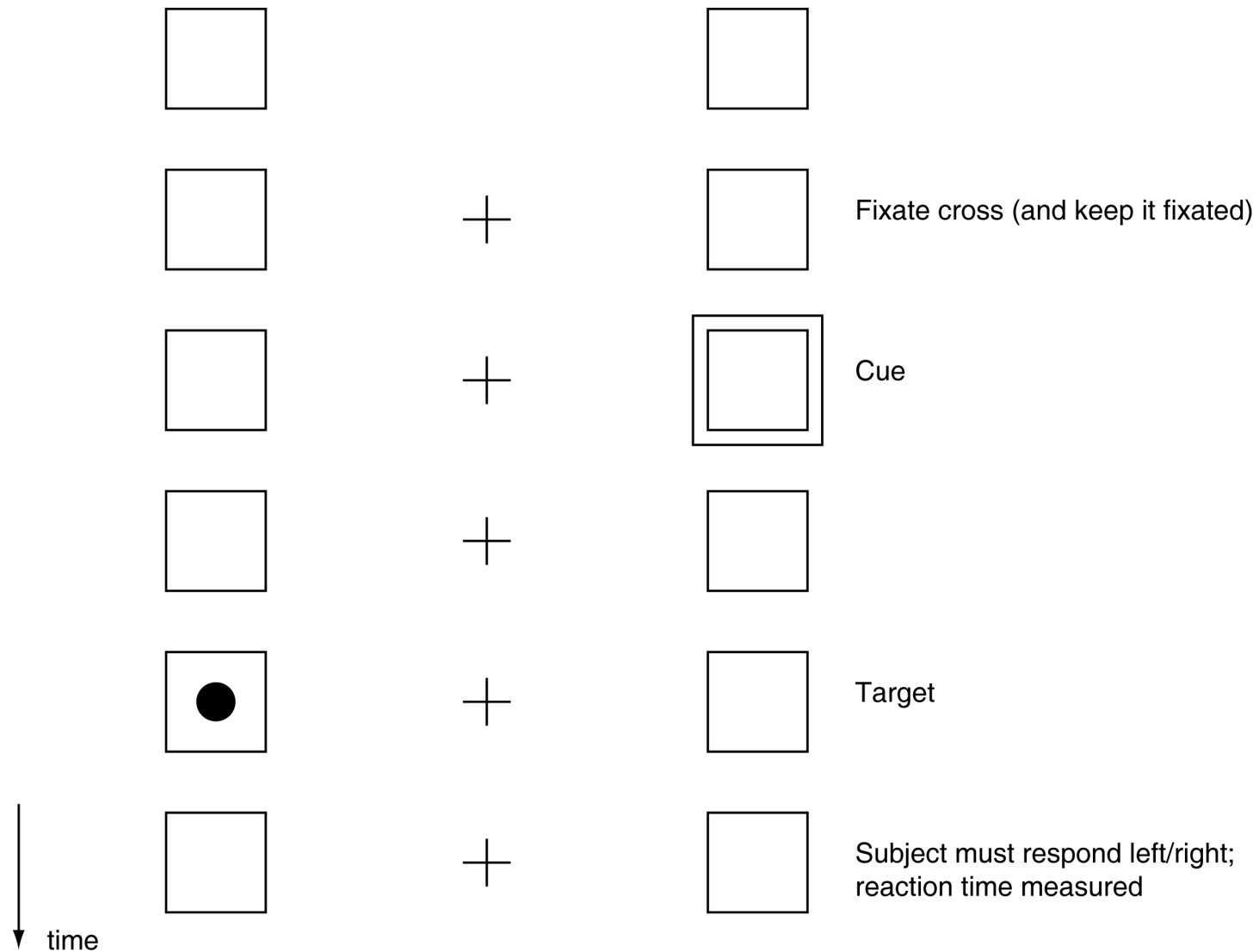
*Again, if one stimulus is attended to, the effects of competition against that stimulus are eliminated.*

*If the less-preferred stimulus is attended to, the neuron's response to the pair is **diminished**. Attention enhances the **influence** of the stimulus, not simply the response?*

# *Networks of attentional control*

# Cued spatial orienting paradigm (Posner et al. 1984)

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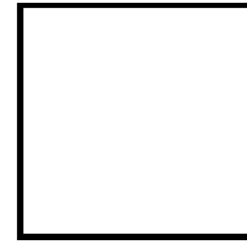
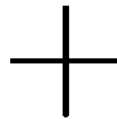
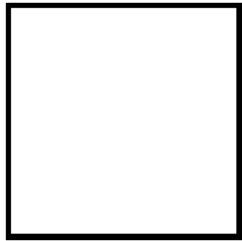


*Cue may be valid (same side as target) or invalid (opposite side, as shown here).*

# Cued spatial orienting paradigm (Posner et al. 1984)

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*Invalid - DISENGAGE, MOVE, ENGAGE*



# Posterior parietal lesions impair the DISENGAGE operation

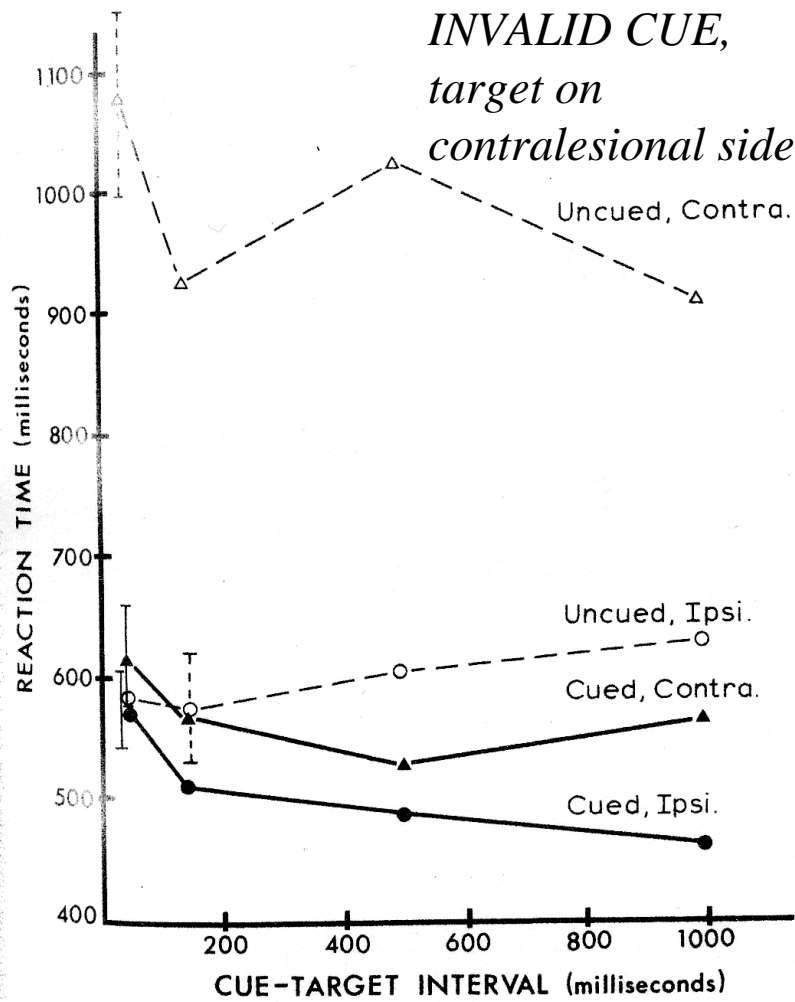


Figure 2. Reaction time for six right parietal patients in the main experiment. Solid lines are for targets on the cued side, and dashed lines are for targets on the uncued side. Triangles are contralateral targets, and circles are ipsilateral targets. Bars indicate  $\pm 1$  SE for representative points.

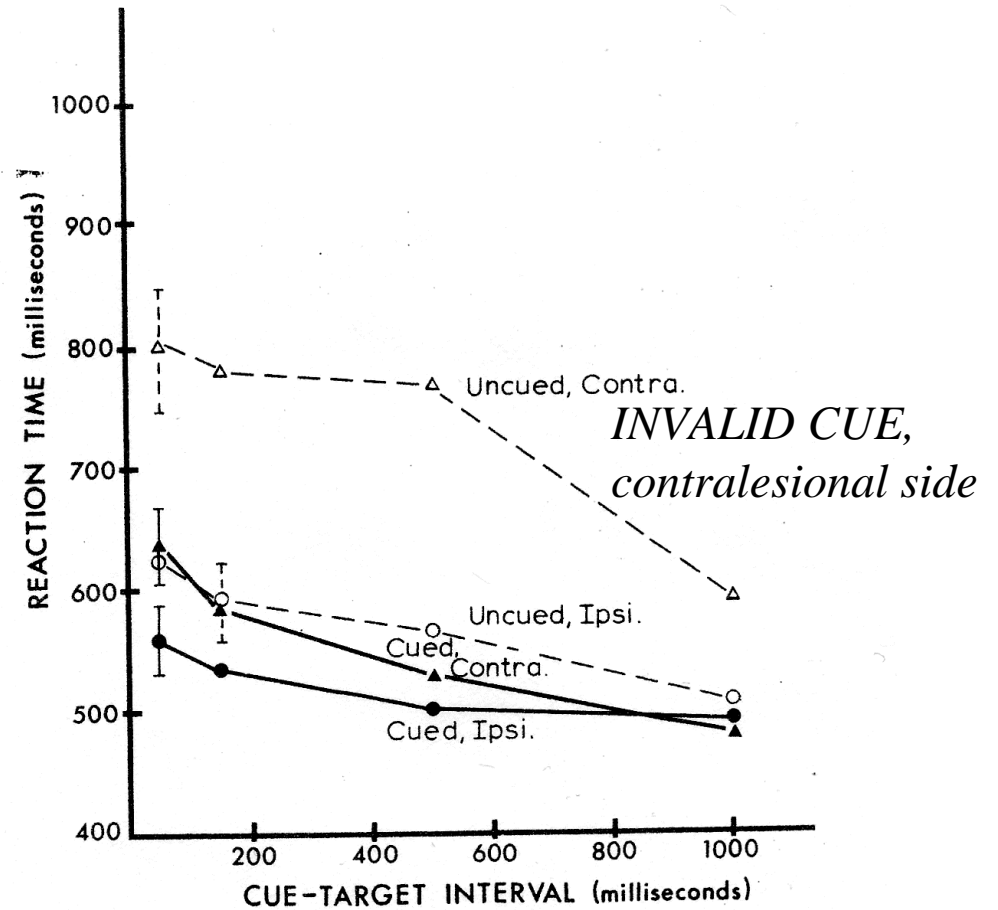


Figure 3. Reaction times for seven left parietal patients in the main experiment. Solid lines are targets on the cued side, and dashed lines are for targets on the uncued side. Triangles are contralateral targets, and circles are ipsilateral targets. Bars indicate  $\pm 1$  SE for representative points.

## The 1980s model...

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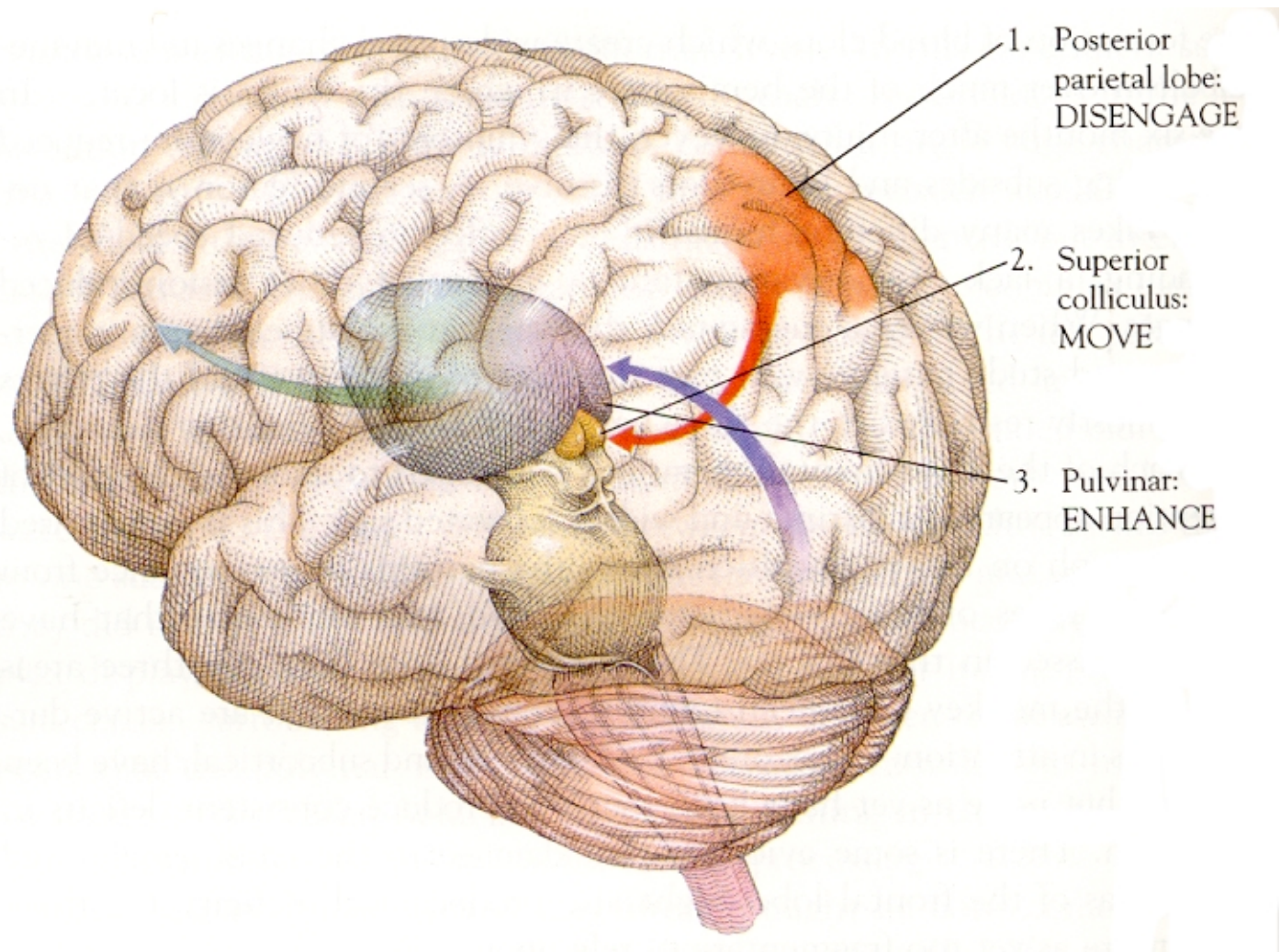
- Posterior parietal cortex: DISENGAGE. Lesioned subjects are slower if their attention was previously engaged elsewhere.
  - Relevance to **neglect** caused by lesions of posterior parietal cortex (e.g. temporo-parietal junction). Failure to disengage from targets on the ipsilesional side, and can't get attention to targets on the contralesional side.
- Superior colliculus (midbrain): MOVE. Lesioned subjects are slower for both valid and invalid cues. (The SC is known to be important for orienting and eye movement control.)
- Pulvinar (thalamus): ENGAGE. Lesions impair the ability to engage contralateral targets. Lesioned monkeys are *slow* to respond to contralesional stimuli, but are *faster* than normal following an invalid (contralateral) cue - i.e. the cues don't engage attention.

*Humans: e.g. Posner & Petersen (1990)*

*Monkeys: e.g. Desimone et al (1990)*

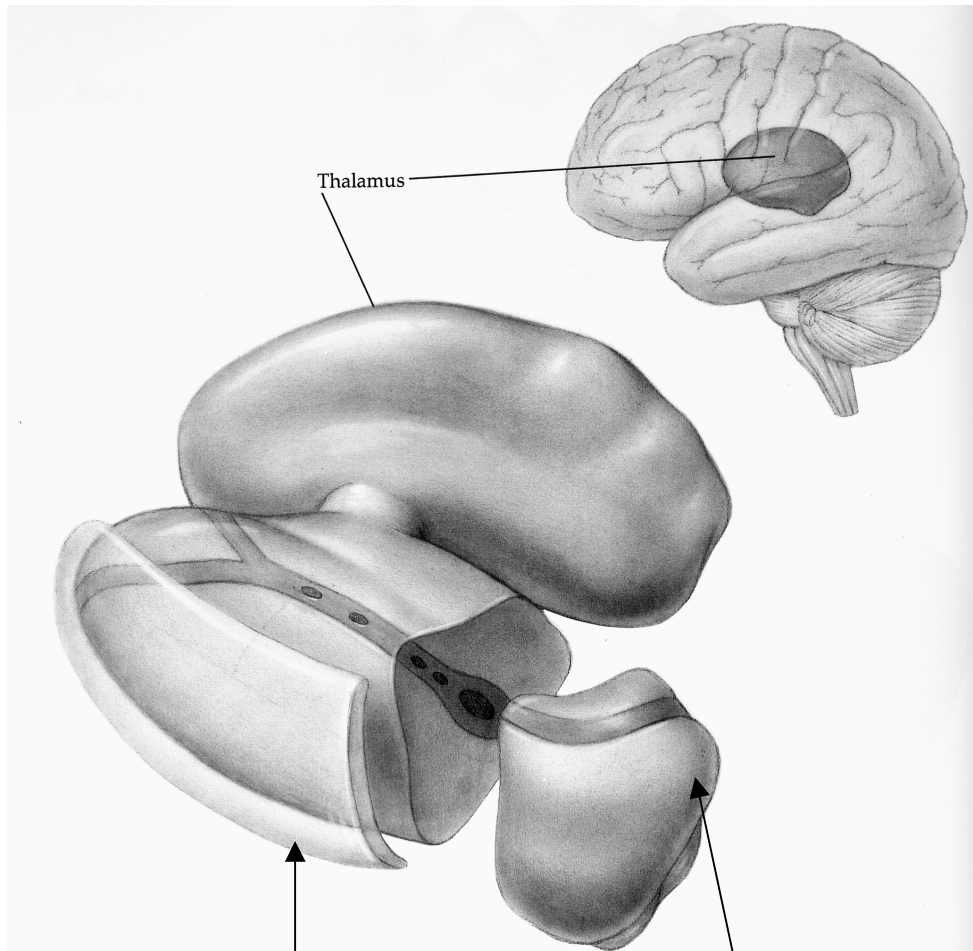
# A network for attentional control

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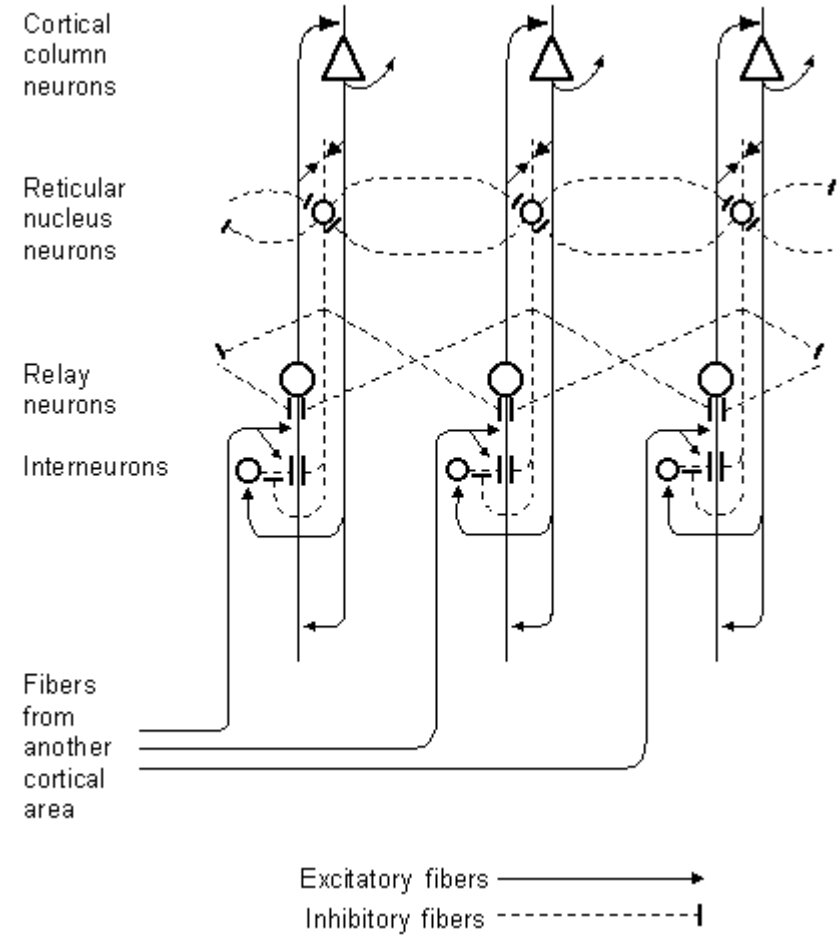


# What does the thalamus contribute to attention?



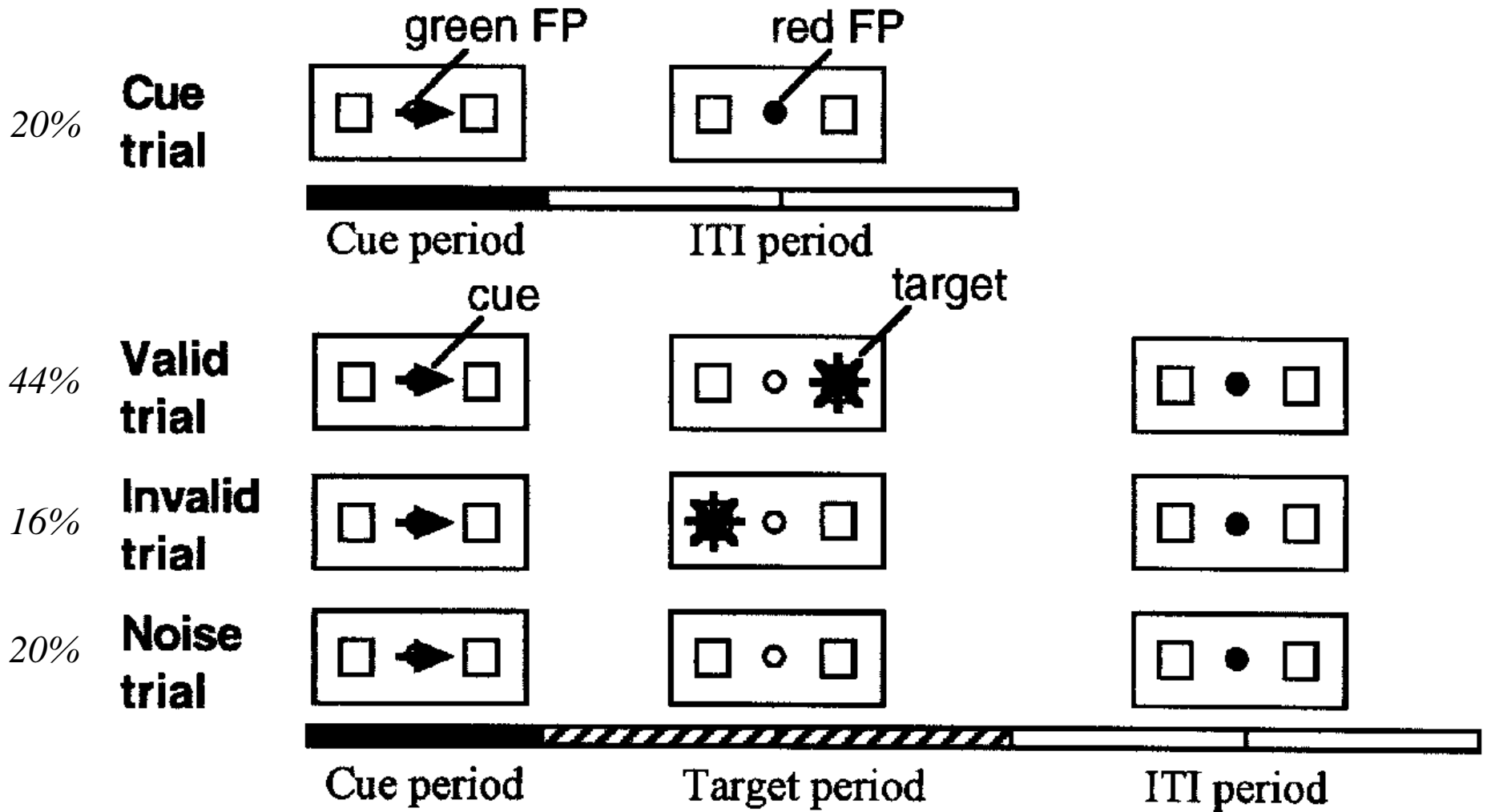
*reticular nucleus  
(partly cut away)*

*pulvinar*

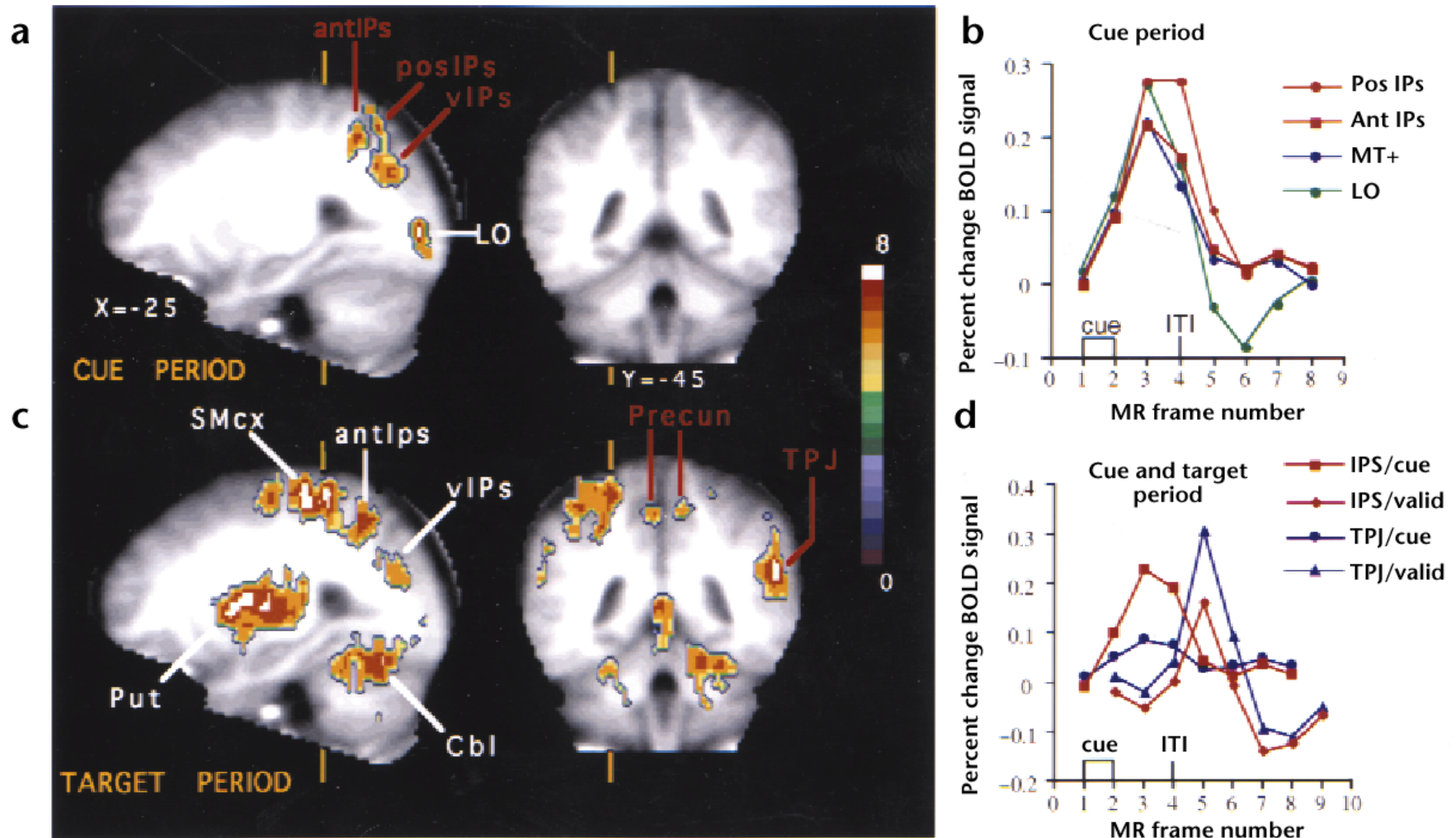


*LaBerge (2000a, b)*

# Voluntary ('top-down') versus 'bottom-up' attention



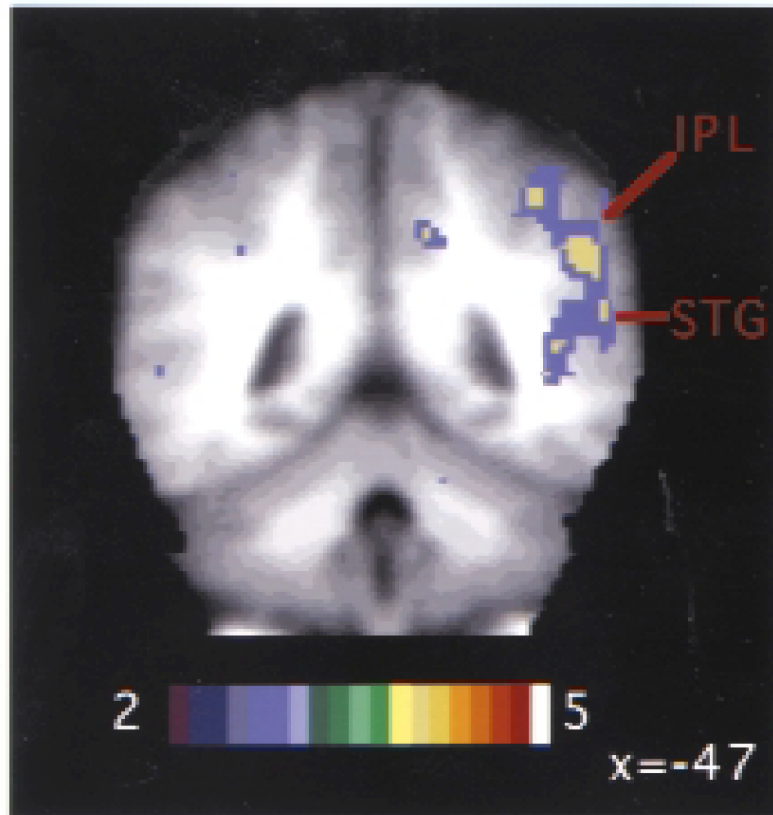
# Voluntary ('top-down') attention and the IPS



*The intraparietal sulcus (IPS) responds to the cue (a correlate of directing attention to a particular location). Several regions are active when the target arrives...*

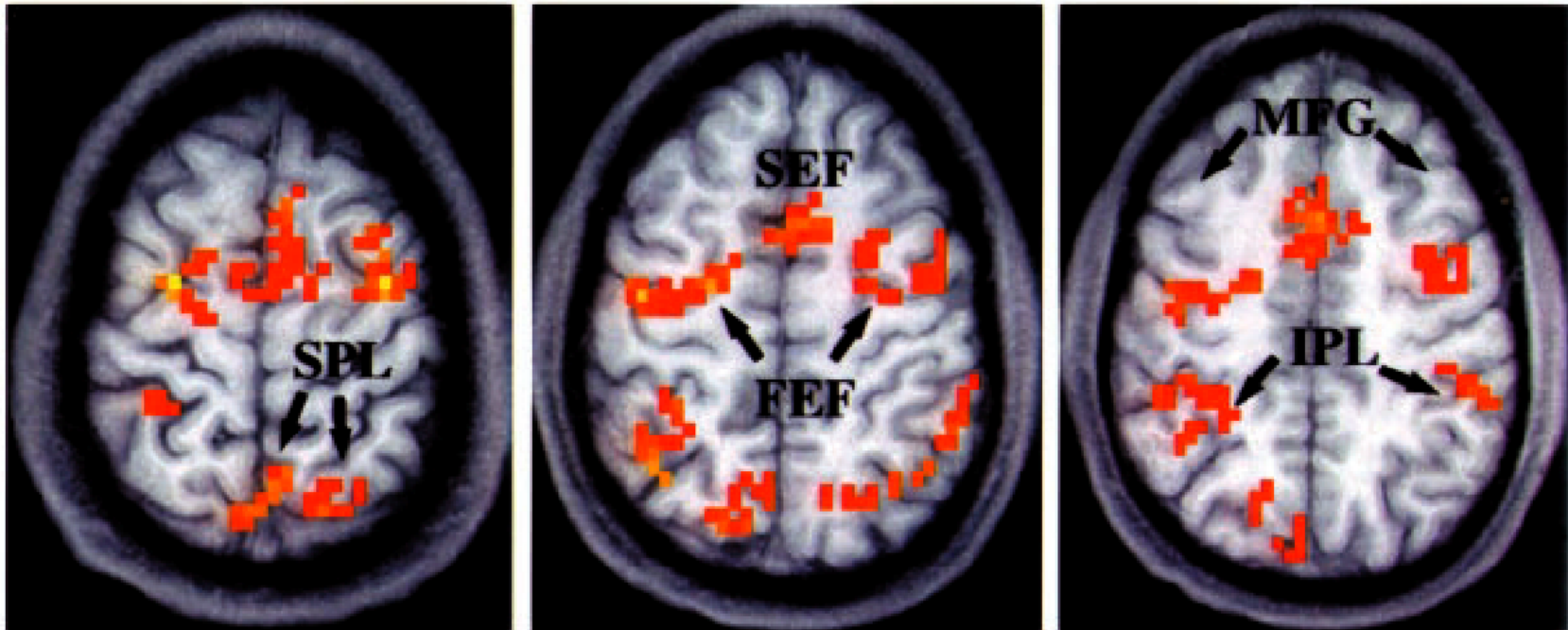
## 'Bottom-up' attention and the TPJ

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*... but the temporo-parietal junction (TPJ) region, including inferior parietal lobule (IPL) and superior temporal gyrus (STG), is selectively activated when unexpected targets arrive (INVALID minus VALID cue conditions).*

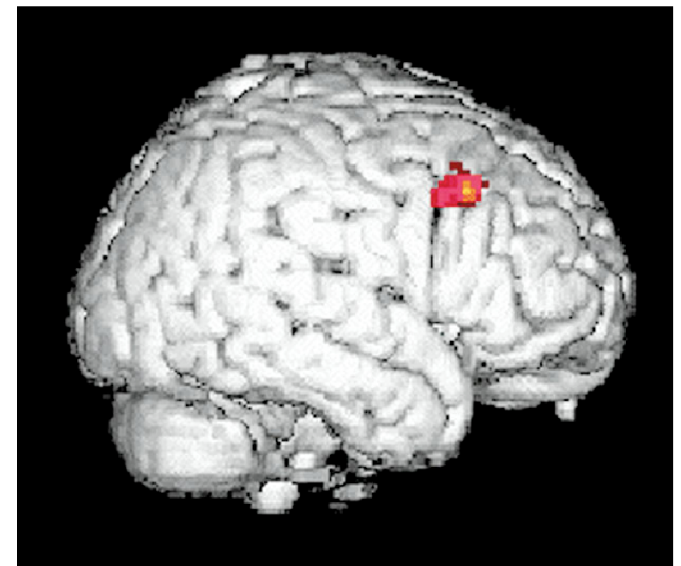
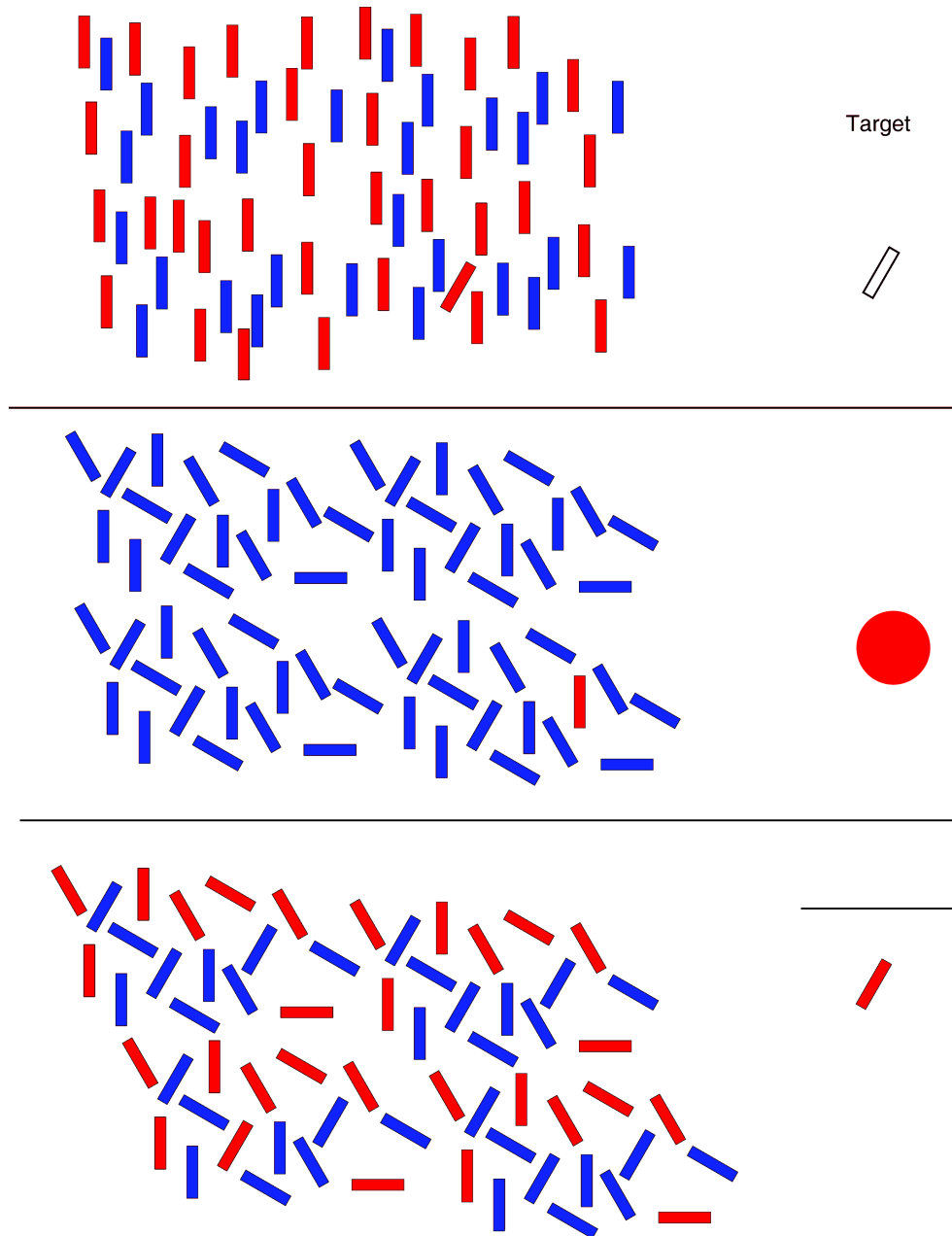
'Top-down' from frontal lobe: frontal eye fields, cingulate...



*Attending to a peripheral stimulus (while looking at a central fixation point) MINUS looking at a central fixation point*

*Kastner et al (1999)*

# 'Top-down' from the frontal lobe: dorsolateral PFC



**Fig. 2.** The area activated by the conjunction task relative to the feature tasks shows no effect of stimulus presentation rate and is located in right BA 8 [Talairach coordinates are (42 22 40), and the Z score is 4.22].

*Rees et al. (1997)*

