NST II Psychology
NST II Neuroscience (Module 5)

Brain Mechanisms of
Memory and Cognition – 3

Attention; the binding problem

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Monday 12, 19, 26 Jan; 2, 9, 23 Feb 2004; 10 am
Physiology Main Lecture Theatre
Slides will be at pobox.com/~rudolf/psychology
Binding
An example of a binding problem

Visual scene

'tFeature detectors'

triangle

circle

square
cow

'red

'blue

green

Friesian

A binding problem

?
What needs to happen...

Visual scene

'Feature detectors'
- bound together appropriately

triangle
red

circle
blue

square
green

cow
Friesian
Binding by synchrony

Visual scene

‘Feature detectors’
- bound by synchrony

triangle

(circle

square

cow

(red

blue

(green

(Friesian

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

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

Rule: "If A gives B to C, then C owns B".

based on Shastri & Ajjanagadde (1993)
Reasoning by dynamic binding? (2 - the dynamic bit)

Specific instantiation of the rule, created by binding specific nodes.

Alice
John
Natalie
book
pen
firework

gives

giver recipient given-object

"Alice gives Natalie the firework."

Therefore:
"Natalie owns the firework."

owns

owner owned-object

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...

Luck et al. (1997)
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

**Receptive field of interest**

**Neurons**

**Activity**

**Stage 1:** Top-down attentional bias...

**Stage 2:** ...influences competition between neurons (the attended stimulus wins)

**Stimuli**

Two stimuli within RF: effect of attention

One stimulus inside RF, one outside: no effect of attention
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)

**V5**

**V4**

*baseline blood flow*  
*stimulus-evoked change in blood flow*
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.

Reynolds et al. (1999)

If one stimulus is attended to, the effects of competition against that stimulus are eliminated.
Attention increases the influence of stimuli (even if inhibitory)

Again, two stimuli compete.

NO ATTENTION.
Again, two stimuli compete.

Reynolds et al. (1999)
Networks of attentional control
Cued spatial orienting paradigm (Posner et al. 1984)

Fixate cross (and keep it fixated)

Cue

Target

Subject must respond left/right; reaction time measured

Cue may be valid (same side as target) or invalid (opposite side, as shown here).
Cued spatial orienting paradigm (Posner et al. 1984)

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 ±1 SE for representative points.

**INVALID CUE,**
target on contralateral side

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 ±1 SE for representative points.

Posner et al. (1984)
The 1980s model...

- **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

1. Posterior parietal lobe: DISENGAGE
2. Superior colliculus: MOVE
3. Pulvinar: ENHANCE
What does the thalamus contribute to attention?

LaBerge (2000a, b)
Voluntary (‘top-down’) versus ‘bottom-up’ attention

Corbetta et al. (2000)
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...

Corbetta et al. (2000)
‘Bottom-up’ attention and the TPJ

... 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).

Corbetta et al. (2000)
‘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

‘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)