Attention systems

Posner, M.I. and Peterson, S.E. (1990). The attention systems of the human brain. *Ann. Rev. Neurosci.* **13**:25–42.

A. Orienting

Posterior parietal lobe

1. Reduced ability to shift attention covertly
2. Especial defect in the ability to disengage from an attentional focus to a contralateral target

Superior colliculus and/or surrounding areas

1. Reduced ability to shift attention.
2. Shift is slowed whether or not attention is first engaged anywhere (suggests a computation involved in moving attention is impaired).
3. Patients with lesion return to former target locations as readily as to fresh locations; normal subjects have a reduced probability of returning attention to recently examined locations.

Thalamus, particularly lateral pulvinar

1. Defect in covert orienting.
2. Difficulty in engaging attention on a contralateral target so as to avoid being distracted by events at other locations.

- Slowed responding to a contralateral target even when patients given plenty of time to orient there; parietal/midbrain lesions show nearly normal responses once attention has been cued to a location.
- Alert monkeys with thalamic lesions made faster-than-normal responses to ipsilateral targets after being cued to contralateral side, as if the contralateral cue was not effective in engaging their attention.
- Worse than normal when given a contralateral target, regardless of the side of the cue.
- Lesioned animals have difficulty responding to contralateral targets when there is a competing event in the ipsilateral field..
- When required to filter our irrelevancies, humans show metabolic increases in the pulvinar contralateral to the field required to do the filtering.

Suggests:

1. Parietal lobe disengages attention from its present focus;
2. midbrain moves the index of attention to the target;
3. pulvinar is involved in reading out data from the indexed locations.

Hemispheric differences

Attention can be concentrated on a narrow or a wide area.
RHS is biased towards global processing (low spatial frequencies), LHS towards local processing.
This bias may develop, perhaps with language; the degree of lateralization may differ between literate and illiterate normals.

Pattern recognition

A search for single visual features operates in parallel; a search for a conjunction of attributes is slow, attention-demanding and serial. Attention provides a high priority to attended features in a way that overrides even the distance between objects in a display.

Neglect (posterior parietal lobe lesions) is a defect of attention, not recognition. Defects can frequently be corrected by cuing attention to the neglected side; the cues appear to provide time for the damaged parietal lobe to disengage attention.

Patients who neglect the left-most letters of a random string frequently report a word correctly. Cues improve the performance of normals for nearby letters in a random string, but do not affect letters that make up words. An area of the **left ventral occipital lobe** (the "visual word form area") responds selectively to strings of letters that are either words or orthographically regular nonwords. It seems likely that this area operates without attention.

******* The posterior attention system can interact with the ventral visual pattern recognition system through the thalamus; this interaction requires about 90ms. Cells in V4 begin to respond to unattended items within their receptive field but shut these unattended areas off after 90ms. *******

Patients with right parietal lesions also fail to report the contralesional side of visual images, a deficit which arises at the time of scanning the image (i.e. turn the image round and they neglect the *new* left side).

Activation of the superior parietal lobe is particularly associated with visual imagery, such as imagining one is walking along a familiar route. Many other areas are activated, most of them common to other verbal and arithmetical thoughts, but the superior parietal lobe is closer to being unique to imagery. This suggests the neural mechanisms of attending to a visual image are similar to those used when attending to an external location.

B. Detection

A general alert state is distinct from one in which attention is clearly oriented and engaged in processing information.

Detecting a target produces interference with most other cognitive operations. Monitoring many spatial locations or modalities produces little or no interference over monitoring a single modality, unless a target occurs.

The importance of engaging the focal attention system in the production of widespread interference suggests there is a unified system involved in the detection of signals, which allows a wide range of arbitrary responses.

Midline frontal areas, including the **anterior cingulate gyrus**, are active during semantic processing of words. Blood flow in the anterior cingulate gyrus increases with the number of targets to be detected; it seems particularly sensitive to the operations involved in target detection. It contains alternating bands of cells connected to the posterior parietal lobe [posterior attention system] and the dorsolateral prefrontal cortex [language tasks]. Lesion data suggests the anterior cingulate gyrus is important in aspects of attention, including neglect.

Is attention a single unified system? Patients with parietal lesions are slowed at orienting to a visual cue when shadowing a stream of auditory information. A language task had bilateral effects, rather than effects contralateral to the lesion, suggesting it involved some but not all of the mechanisms used in visual orienting. This is compatible with the view that visual orienting involves systems separate but interconnected with those for language processing. Visual cues have a greater effect on a linguistic shadowing task when presented to the right visual field, suggesting the common system is lateralized to the left hemisphere. [Fits with connections listed above.]

There might be a **hierarchy** of attention systems in which the anterior system can pass control to the posterior systems when it is not busy.

C. Vigilance

In letter and word matching experiments, the passive activation of internal units representing the physical form of a letter, its name and even its semantic classification (e.g. vowel) appear to take place at about the same rate regardless of whether subjects are alert and expecting a target or not. The alert state produces more rapid responding, but this increase is accompanied by a higher error rate. *It is as though the build-up of information about the classification of the target occurs at the same rate regardless of alertness, but in states of high alertness the selection of a response occurs more quickly*, based on a lower quality of information, thus resulting in an increase in errors. This suggests that alertness affect the rate at which attention can respond to the stimulus.

The ability to develop and maintain the alert state depends heavily on the integrity of the **right cerebral hemisphere**. An area of the midfrontal cortex is most active in auditory, visual and somatosensory vigilance

conditions. The higher metabolic activation in the right prefrontal cortex is accompanied by reduced activation in the anterior cingulate. “If one views the anterior cingulate as related to target detection, this makes sense. In tasks for which one needs to suspend activity while waiting for low probability signals, it is important not to interfere with detecting the external signal. Subjectively, one feels empty-headed, due to the effort to avoid any thinking that will reduce the ability to detect the next signal.”

The noradrenaline system of the **locus coeruleus** may be crucial in the alert state. Lesions of the right cerebral hemisphere, but not the left, lead to depletion of NA on both sides; the effects are strongest with lesions near the frontal pole. (These findings are consistent with the idea that NA pathways run through frontal areas, dividing as they go backwards; thus an anterior lesion would have a larger effect.)

In the posterior visual system, the greatest NA innervation is found in the posterior parietal lobe, the pulvinar and the superior colliculus, i.e. the posterior attention system. This fits with other evidence that suggests the *NA pathways provide the basis for maintaining alertness, and that they act most strongly on the posterior attention systems of the right cerebral hemisphere.*

D. Waffle

… during sleep, is ongoing neural activity interpreted semantically by networks primed by daily activity? … split-brain work suggests the presence in the left hemisphere of an interpreter system that attempts to impose explanations for our behaviour … schizophrenia may be a failure of the anterior attention system of the left hemisphere to impose the normal inhibitory pattern on the left lateralized semantic network … attention-deficit disorder may be linked to the right hemisphere mechanisms discusses …