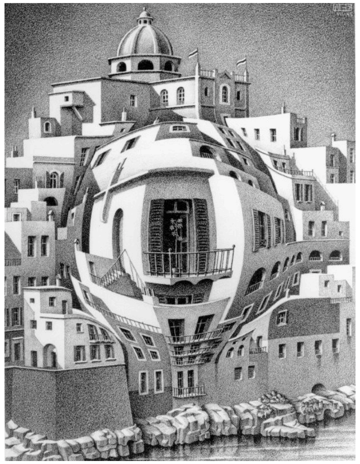
Attention

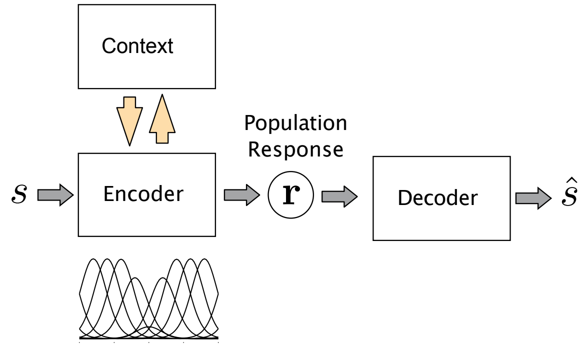
Readings:

- Maunsell & Cook, the role of attention in visual processing, 2002.
- Itti & Koch, Computational modeling of visual attention, Nat Rev Neurosci, 2001.



M. C. Escher, Balcony, 1945

When neurons and perception change



Attention

- The process by which certain information is selected for further processing and other information is discarded
- The assumption is that the brain does not have the capacity to fully process all the information it receives. Attention as a filter, or bottleneck in processing.
- 2 types: spatial attention, feature-based attention.

- Spatial attention as a spotlight, highlighting locations, moving (search), zooming in or out.

In vision, the locus of the spotlight can be the same as eye fixation (overt attention) but it doesn't have to (covert attention)

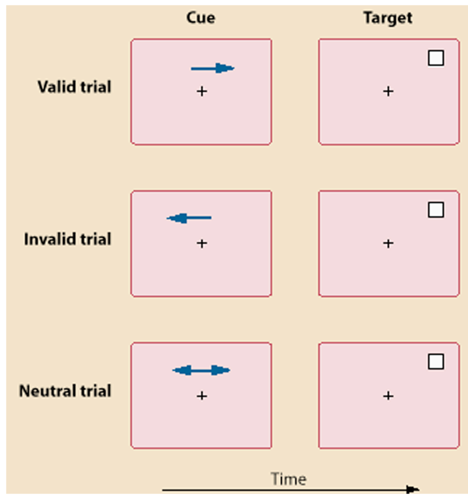
- limit to the metaphor : attention can be split in 2 locations.
- exogeneous orienting: external cue vs endogeneous orienting: task demand

Posner's Task (1980)

- focus visual attention to an area by using a cue, e.g. brief flash at given location, or arrow

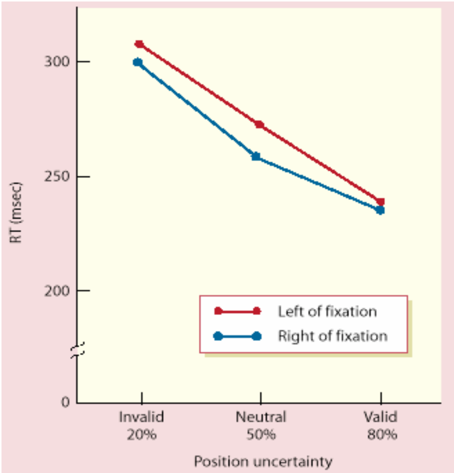
- measure reaction time to detect target when :

i) observer doesn't know where item will appear (neutral cue)
ii) observer is cued to where item will appear (valid cue)
iii) observer is wrongly cued (invalid cue)



Posner's Task (1980)

- Detection is faster for valid targets
- Detection is slower for invalid cues (inhibition of return)

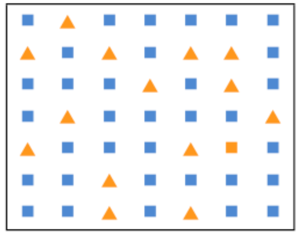


Posner, Nissen, & Ogden (1978)

Search Tasks

- task of detecting the presence or absence of a specified object (target) in the middle of other objects (distractors)
- feature search: find the red cross, find the circle
- conjunction search : find the orange square

POP-OUT



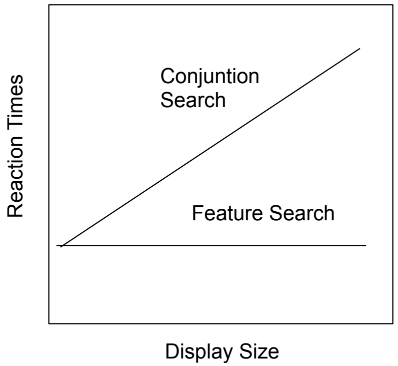
which is easier?

Feature Integration theory (FIT)

- In Feature search: RTs do not increase as a function of the display size as they in conjunction searches.
- In conjunction search, the binding problem has to be solved.
- Interpretation:

2 processes:

- a first pre-attentive stage, processes that are fast, parallel and involuntary -- Pop out.
- a second stage, attentive, serial. volitional deployment of attention.



- Later shown that these represents 2 extremes in a continuum of search difficulty (Wolfe 1996)

The idea of a saliency map

- How does the spotlight know where to go?
- Models postulate existence of a saliency map, which would represent topographically the relevance of the different parts of the visual field.
- could be built only based on bottom-up information (eg. how different is a given stimulus compared to its neighborhood?) or could include task dependent (top-down) information.
- unclear whether such a functional saliency map is implemented in a distributed manner across different cortical and subcortical areas, or whether saliency is implemented directly into the individual cortical feature maps.
- There is some evidence that neurons in LIP could encode saliency [Gottlieb et al 1998].

Are we blind outside the focus of attention?

- change blindness - unless we attend to an object, we are unlikely to perceive consciously it in any detail and detect when it is altered
demos: http://www.psych.ubc.ca/~rensink/flicker/download/

- But we are not totally blind outside the focus of attention (e.g. negative priming)

Does attention change appearance?

- Spatial attention improves detection rate, and reaction times, and also discrimination performances [Lee et al 1999].

- Attention enhances apparent contrast [Carrasco et al 2004], perceived motion coherence [Liu et al 2006], spatial frequency [Gobell & Carrasco, 2006]
Attention changes perceived size [Treue and colleagues, 2008]
Makes moving objects appear to move faster [Turatto et al 2007] ...

- Thus, attention not only enhances perception, it also distorts our representation of the visual scene according to the behavioral relevance of its components.

Neural basis : Questions

- Where does attention 'come from' ?

- Which parts of the brain does it affect ?

- What does it change in the neural responses ?
- amplitude?
- tuning?
- baseline?
- noise?
- temporal properties?

- Can we explain the perceptual changes based on the neural changes?
- Lots of (recent) data, but picture is not clear yet.

Attention changes in neural responses depends on ...

- cortical area
- neurons
- task demands

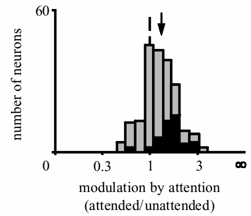


Figure 1. Typical distribution of attentional modulation for visual cortex. Responses were recorded from 197 neurons in area V4 while monkeys performed a task that directed their attention towards or away from a stimulus in the receptive field of the neuron being recorded. Most neurons responded

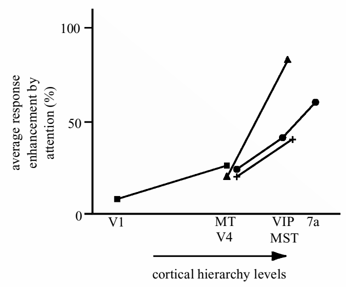


Figure 2. Average attentional modulation in visual cortical areas. The average response enhancement reported from studies that measured the effects of attention in two or more cortical areas in the same subjects while they performed a given task are shown. Positions on the *x*-axis are assigned according to the hierarchical levels defined by Felleman & Van Essen (1991). More attention modulation is found in

Attention decreases contrast response threshold

spatial attention enhances neuronal responses and decreases threshold (Ito & Gilbert 1999, McAdams & Maunsell 1999a, Motter 1993, Mountcastle et al. 1987, Roelfsema & Spekreijse 2001, Spitzer et al. 1988, Treue & Maunsell 1996).

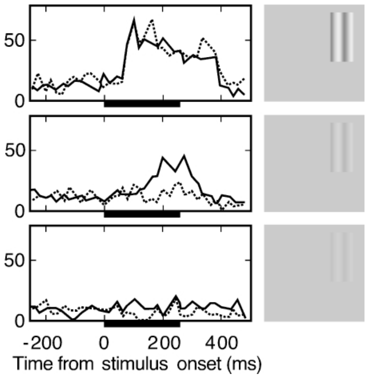


Figure 1 Responses of an example area V4 neuron as a function of attention and stimulus contrast. The contrast of the stimulus in the receptive field varied from 5% (*bottom panel*) to 10% (*middle panel*) to 80% (*upper panel*). On any given trial, attention was directed to either the location of the stimulus inside the receptive field (*solid line*) or a location far away from the receptive field (*dotted line*). The animal's task was to detect a target grating at the attended location. Attention reduced the threshold level of contrast required to elicit a response without causing a measurable change in response at saturation contrast (80%). Adapted from Reynolds et al. (2000).

Attention decreases contrast response threshold

- It is often proposed that Attention acts like an increase in stimulus contrast [Reynold and Chelazzi, 2001]

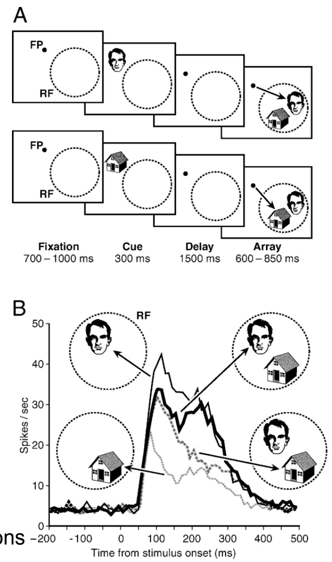
- Unlike increases in contrast, attention doesn't reduce response latency in V4 [Lee et al 2007]

Attention as Biased Competition

- Multiple Stimuli in the visual field activate population of neurons that engage in competition

- Moran and Desimone (1985) - V4 - 2 stimuli in receptive field. After some time delay, the pair response is driven almost entirely by attended stimulus.

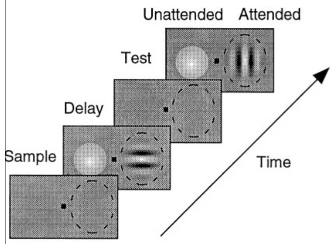
- ~ change in tuning, shrink response around attended feature



[Chelazzi et al 2001], V4, average of 76 neurons

Spatial Attention as Gain Modulation

A change in gain, not in selectivity (sharpness)



monkey performs either color task or orientation task (match to sample)

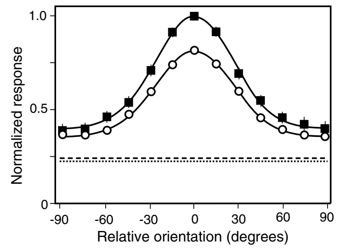
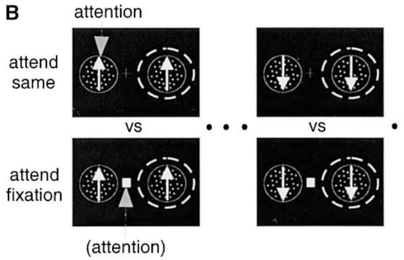
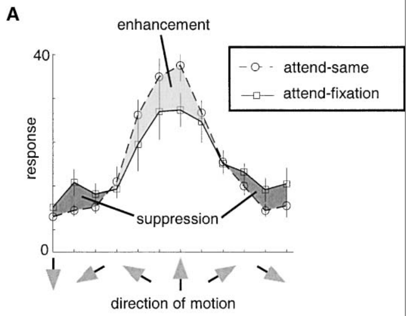


Figure 7 Attention increases tuning curves by a gain factor. Average normalized orientation tuning curves computed across a population of area V4 neurons while the monkey attended either to the location of a grating stimulus inside the receptive field (*filled squares*) or to a location in the opposite hemifield (*empty circles*). The upper curve is approximately a multiplicative version of the lower curve. Adapted from McAdams & Maunsell (1999a).

Feature-Based Attention as Gain Modulation

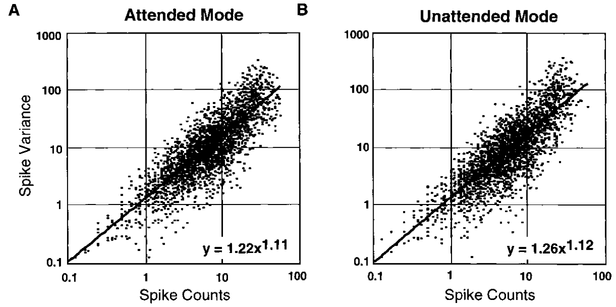


The change in gain depends on similarity between preferred direction and attended direction.



Martinez Trujillo & Treue, 1999

Not a change in Noise



[McAdams and Maunsell 1999b]

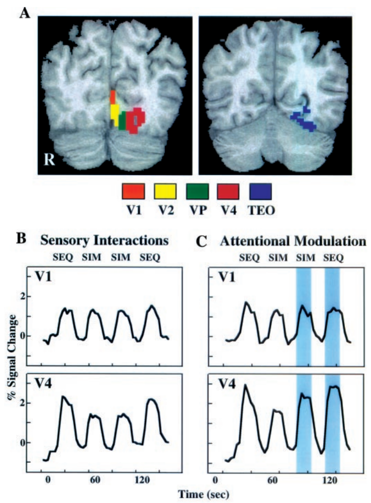
Figure 4. Population Response Variance Functions

These response variance functions were constructed by fitting power functions to the response variance data from all of the V4 neurons. The two functions are not significantly different (power: attended, 1.11; unattended, 1.12; coefficient: attended, 1.22; unattended, 1.26).

What about the baseline?

- Some studies have reported an increase in baseline.
- V2 and V4, 30-40% increase in spontaneous activity [Luck et al 1997], LIP [Colby et al 1996] before the stimulus was presented at cued location.

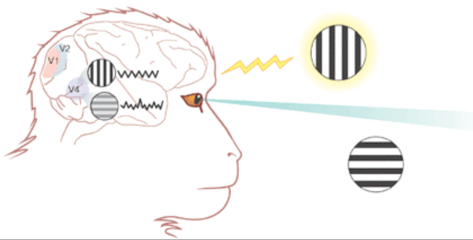
- fMRI [Kastner 1999], increases found in all visual areas, but stronger in V4.



Modulation of Oscillatory Neuronal Synchronization by Selective Visual Attention

Pascal Fries,[1*] John H. Reynolds,[1,2] Alan E. Rorie,[1]
Robert Desimone[1]

In crowded visual scenes, attention is needed to select relevant stimuli. To study the underlying mechanisms, we recorded neurons in cortical area V4 while macaque monkeys attended to behaviorally relevant stimuli and ignored distracters. Neurons activated by the attended stimulus showed increased gamma-frequency (35 to 90 hertz) synchronization but reduced low-frequency (<17 hertz) synchronization compared with neurons at nearby V4 sites activated by distracters. Because postsynaptic integration times are short, these localized changes in synchronization may serve to amplify behaviorally relevant signals in the cortex.



Attention increases Gamma synchrony

- By increasing impact on post-synaptic neurons, increase in synchrony could be a powerful way to amplify the signal