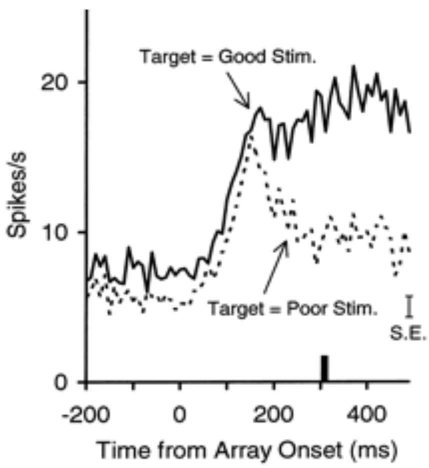
Attention

The systems level of attention

Suggested reading:

- Hamker, F. H. (2003) The reentry hypothesis: linking eye movements to visual perception. Journal of Vision, 11:808-816.
- Hamker, F. H. (2005) The Reentry Hypothesis: The Putative Interaction of the Frontal Eye Field, Ventrolateral Prefrontal Cortex, and Areas V4, IT for Attention and Eye Movement. Cerebral Cortex, 15:431-447.

Attention: The systems level of attention



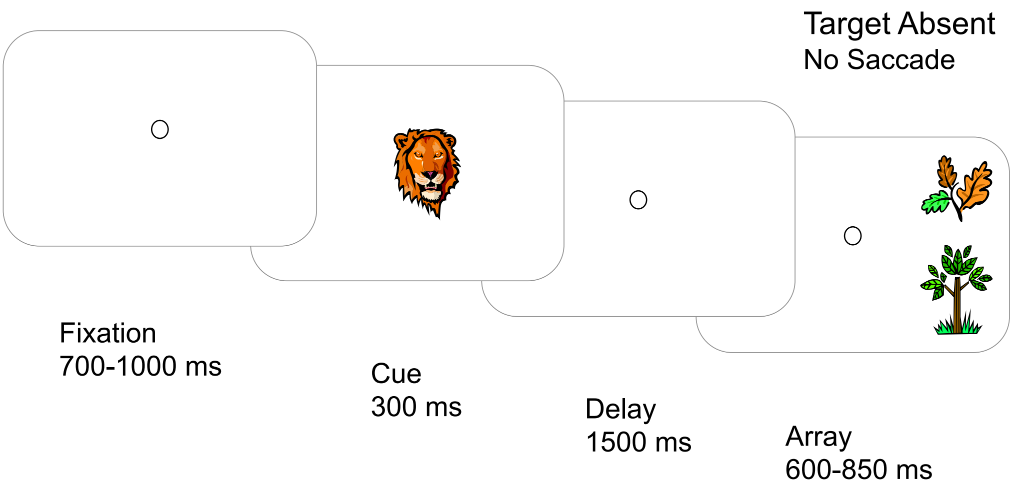
Contents:

- Why do we need attention?
- Visual search – experimental observations
- Effects of a eye-movements on attention
- The occulomotor system
- Integrated competition
- The role of the frontal eye field
- Anti-saccade task
- Parallel vs serial search

Why do we need attention?

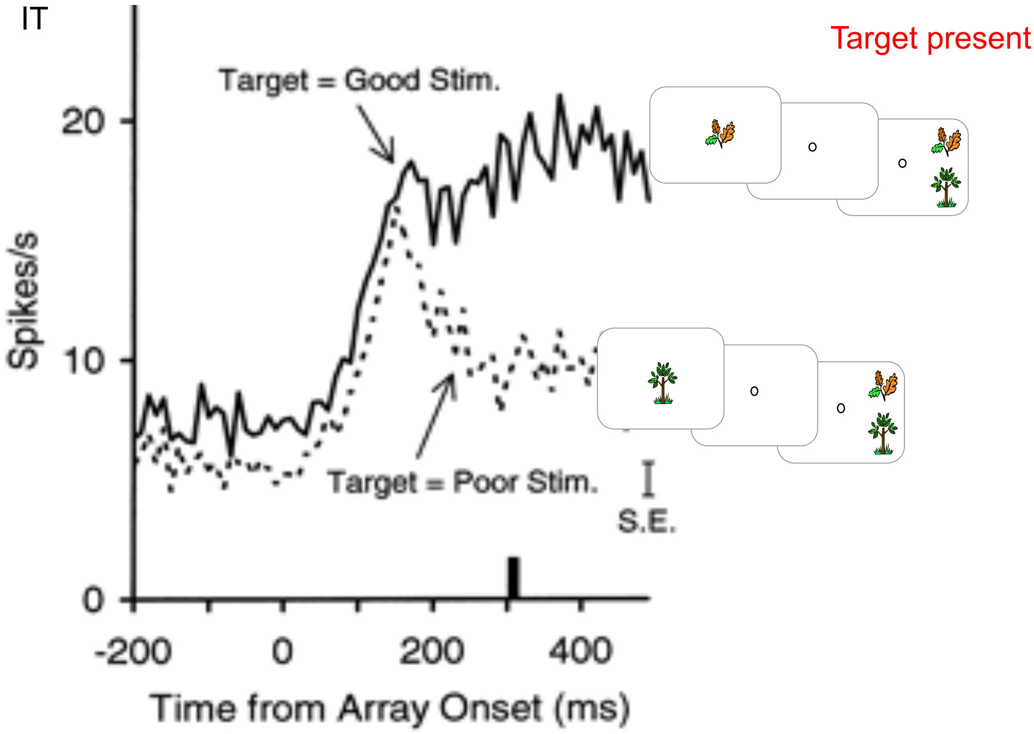
Aus: Simons & Chabris (1999) Perception, 28:1059-1074.

Visual Search – experimental observations



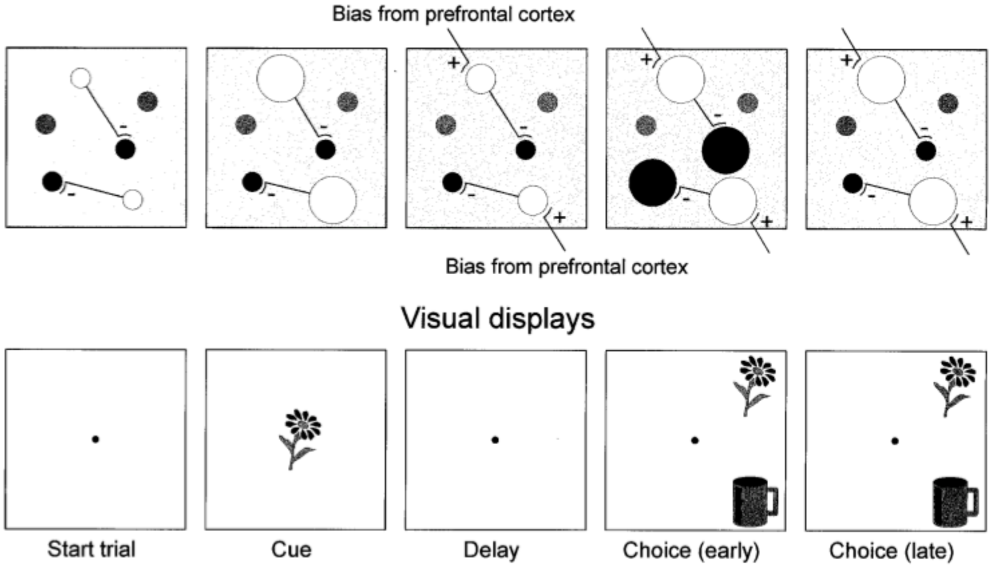
Chelazzi, Duncan, Miller & Desimone
J. Neurophysiol. (1998)

Visual Search – experimental observations



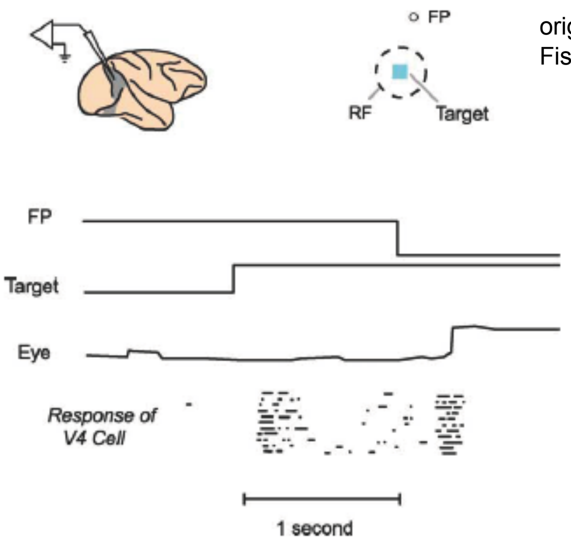
Classical Interpretation

<u>Biased Competition</u>
Desimone and Duncan, 1995
Chelazzi et al., 1998
Chelazzi et al., 2001



Effects of a eye-movements on attention

Effects of a saccade on the neural firing rate of V4 cells:

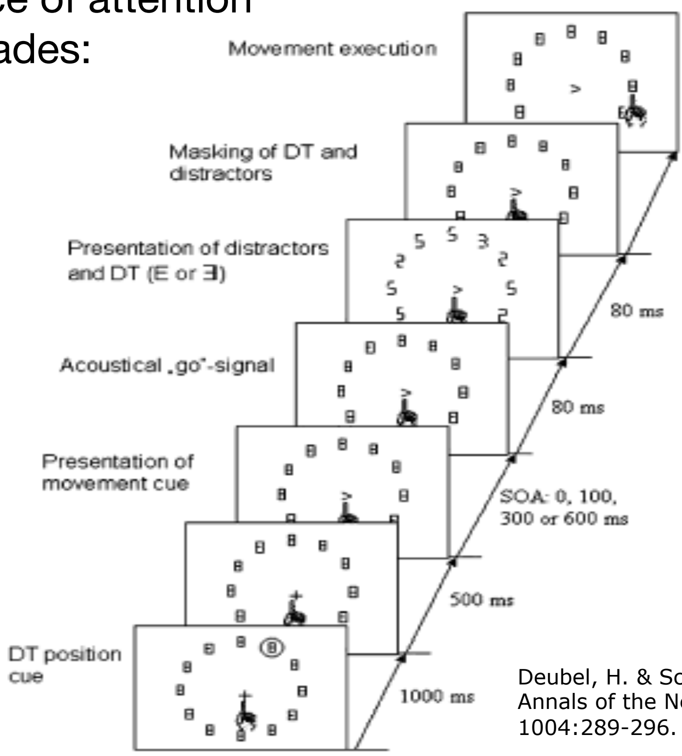


original data from Fischer & Boch (1981)

Source: Moore et al., (2003) Neuron.

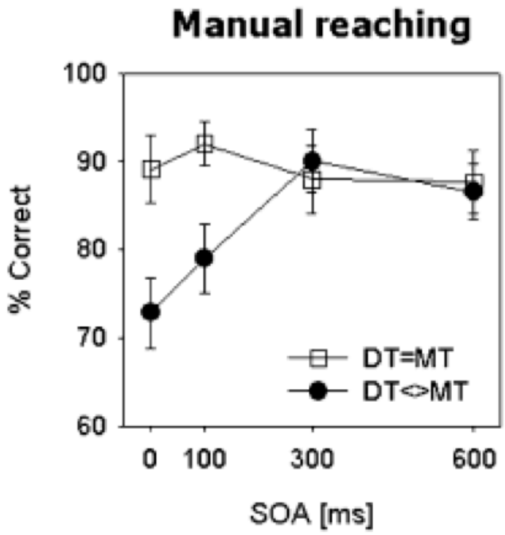
Effects of a eye-movements on attention

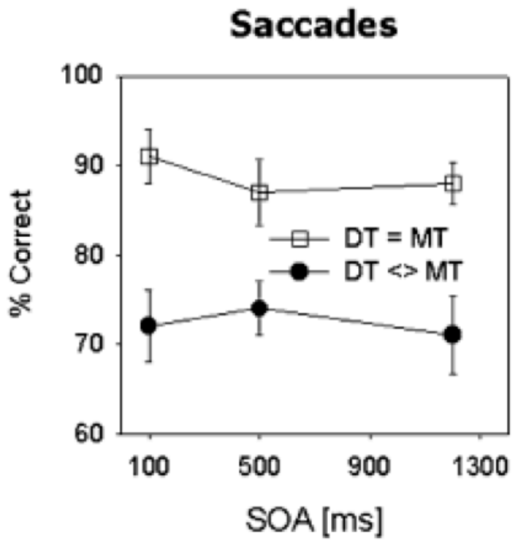
Interference of attention with Saccades:



Deubel, H. & Schneider, W.X. (2003). Annals of the New York Academy of Sciences, 1004:289-296.

Effects of a eye-movements on attention

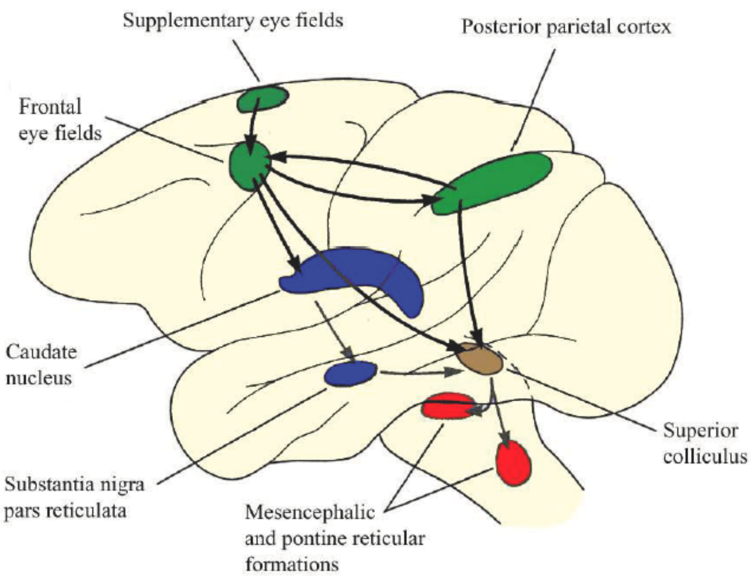




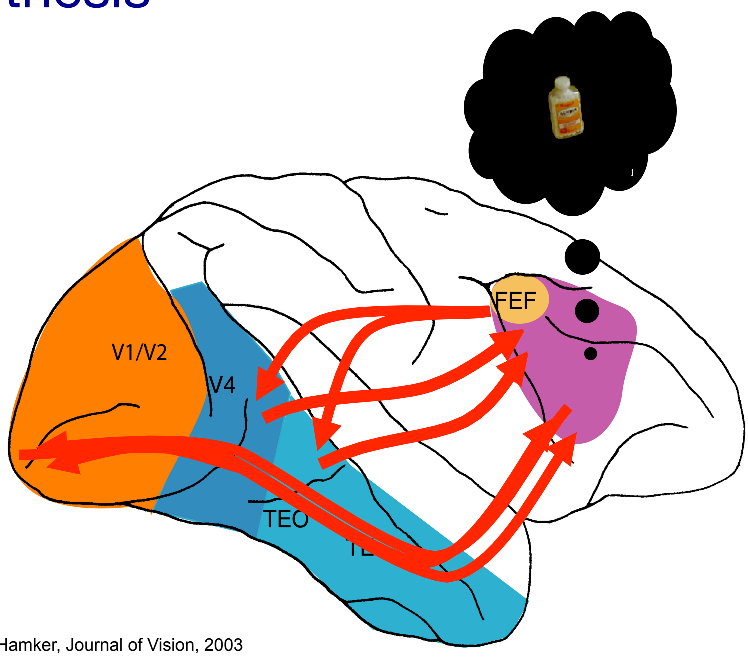
Deubel, H. & Schneider, W.X. (2003).
Annals of the New York Academy of Sciences,
1004:289-296.

The execution of a saccade is always under on-line control. Attention cannot be decoupled from the saccade. Reaching, however, can be done off-line.

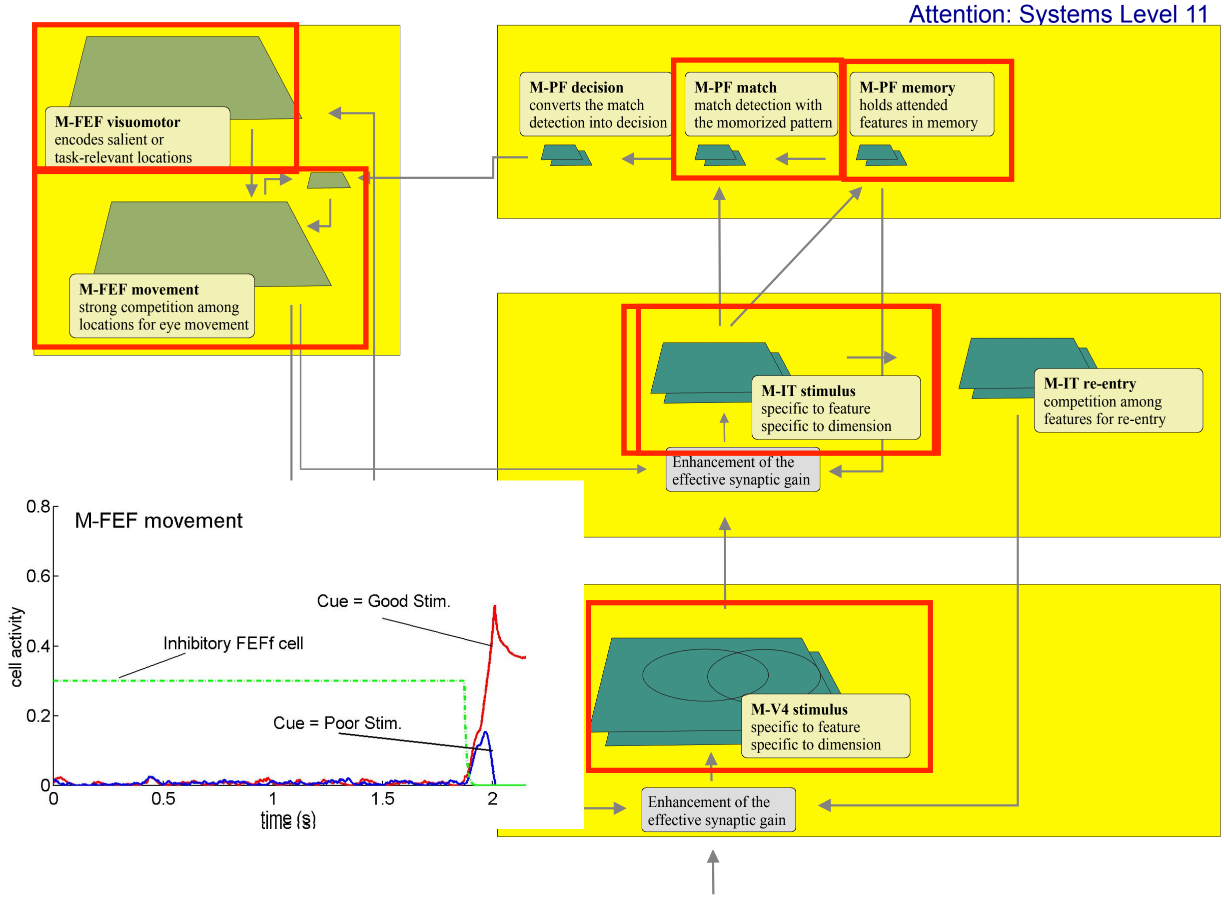
The occulomotor system



Integrated Competition or the Reentry Hypothesis



Hamker, Journal of Vision, 2003
Hamker, Cerebral Cortex, 2005.



Integrated Competition - Equations

V4

$$\tau \frac{d}{dt} r^{V4}_{d,i,x} = I^{\uparrow}_{d,i,x} + I^{\leftrightarrow}_{d,i,x} + I^{\downarrow}_{d,i,x} - (r^{V4}_{d,i,x} + 0.1) I^{inb}_{d,x} - B r^{V4}_{d,i,x}; \quad B = 0.08, \ \tau = 0.01\,\mathrm{s}$$

$$I^{\uparrow}_{d,i,x} = w^{\uparrow} I_{d,i,x} \cdot S_{d,i,x}; \quad w^{\uparrow} = 0.9$$

$$I^{\leftrightarrow}_{d,i,x} = I^{\uparrow}_{d,i,x} \cdot \sigma(A - r^{V4}_{d,i,x}) \sum_j w_{ij} r^{V4}_{d,j,x}$$

$$I^{\downarrow}_{d,i,x} = I^{\uparrow}_{d,i,x} \cdot \sigma(A - r^{V4}_{d,i,x}) w^{\mathrm{ITt,V4}} r^{\mathrm{ITt}}_{d,i} + I^{\uparrow}_{d,i,x} \cdot \sigma(A - r^{V4}_{d,i,x}) w^{\mathrm{FEFm,V4}} r^{\mathrm{FEFm}}_{x}; \quad w^{\mathrm{ITt,V4}} = 20, \ w^{\mathrm{FEFm,V4}} = 10$$

$$I^{inb}_{d,x} = w_{inb} \sum_i r^{V4}_{d,i,x} + w^{RF}_{inb} z^{V4}_{d}; \quad w_{inb} = 1.3, \ w^{RF}_{inb} = 0.5$$

$$\tau^{RF}_{inb} \frac{d}{dt} z^{V4}_{d} = \sum_x \max_i [r^{V4}_{d,i,x}] - z^{V4}_{d}; \quad \tau^{RF}_{inb} = 0.2\,\mathrm{s}$$

Integrated Competition - Equations

IT

$$\tau \frac{d}{dt} r^{\mathrm{ITs}}_{d,i} = f(I^{\uparrow}_{d,i,x}) + f(I^{\leftrightarrow}_{d,i,x}) + f(I^{\downarrow}_{d,i,x}) - (r^{ITs}_{d,i} + 0.1) I^{inb}_{d} - B r^{\mathrm{ITs}}_{d,i}$$

$$f = \max_x; \quad B = 1.8$$

$$I^{\uparrow}_{d,i,x} = w^{\uparrow} r^{V4}_{d,i,x}; \quad w^{\uparrow} = 0.9$$

$$I^{\leftrightarrow}_{d,i,x} = I^{\uparrow}_{d,i,x} \cdot \sigma(A - r^{ITs}_{d,i}) \sum_j w_{ij} r^{ITs}_{d,j}$$

$$I^{\downarrow}_{d,i,x} = I^{\uparrow}_{d,i,x} \cdot \sigma(A - r^{ITs}_{d,i}) w^{\mathrm{PFwm,ITs}} r^{\mathrm{PFwm}}_{d,i} + I^{\uparrow}_{d,i,x} \cdot \sigma(A - r^{ITs}_{d,i}) w^{\mathrm{FEFm,ITs}} r^{\mathrm{FEFm}}_{x} \quad w^{\mathrm{PFwm,ITs}} = 10, \ w^{\mathrm{FEFm,ITs}} = 10$$

$$I^{inb}_{d} = w_{inb} \sum_i r^{ITs}_{d,i} + w^{RF}_{inb} z^{ITs}_{d} \quad w_{inb} = 0.14, \ w^{RF}_{inb} = 1.5$$

$$\tau^{RF}_{inb} \frac{d}{dt} z^{ITs}_{d} = \sum_i r^{ITs}_{d,i} - z^{ITs}_{d} \quad \tau^{RF}_{inb} = 0.1\,\mathrm{s}$$

Integrated Competition - Equations

FEF

$$\tau \frac{d}{dt} r_x^{FEFv} = I_x^{\uparrow} - r_x^{FEFv} I^{inh} - B r_x^{FEFv}; \quad B = 0.3$$

$$I_x^{\uparrow} = w^{V4s} \sum_d \max_i (r_{d,i,x}^{V4s}) + w^{FEFm} r_x^{FEFm}; \quad w^{V4} = 0.5, \; w^{FEFm} = 0.2$$

$$I^{inh} = w_{inh} \max_x (r_x^{FEFv}); \quad w_{inh} = 0.5$$

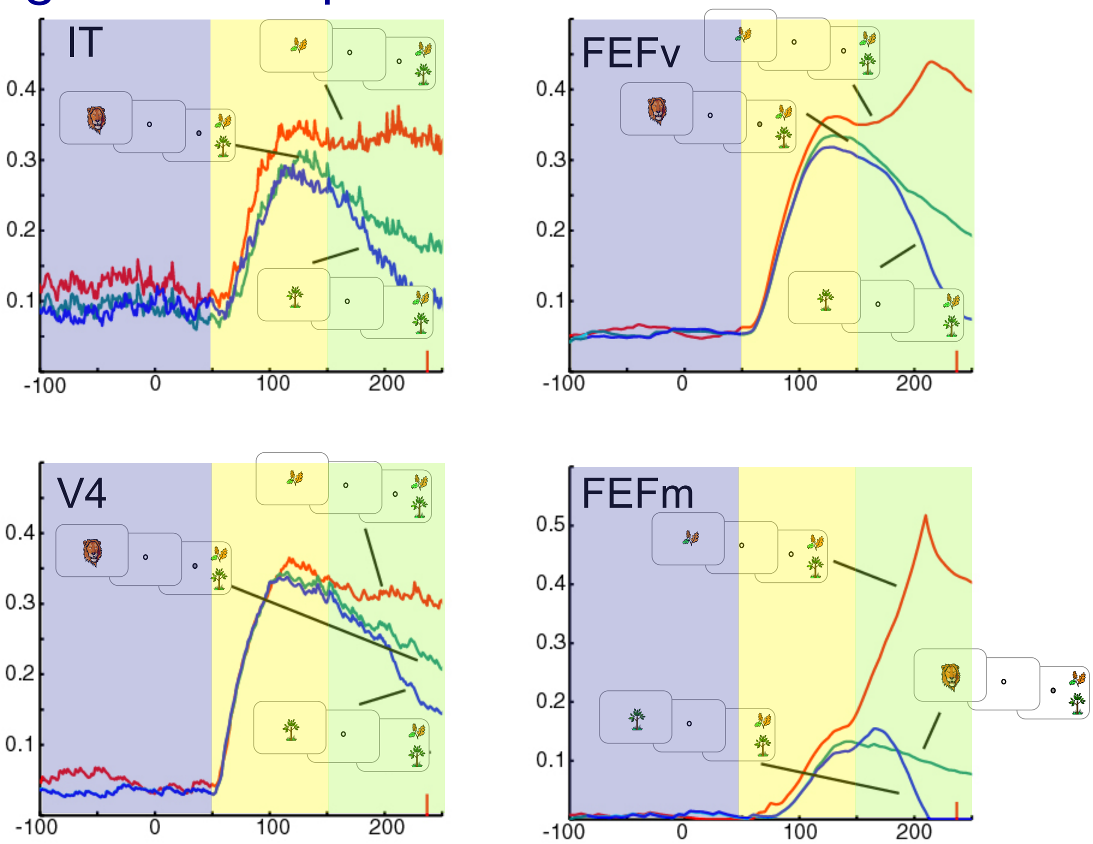
$$\tau \frac{d}{dt} r_x^{FEFm} = I_x^{\uparrow} + I_x^{\leftrightarrow} - r_x^{FEFm} I_x^{inh}$$

$$I_x^{\uparrow} = r_x^{FEFv} - \sum_{x' \neq x} w_{x,x'}^{FEFv} r_{x'}^{FEFv}; \quad w_{x,x'}^{FEFv} = 0.15$$

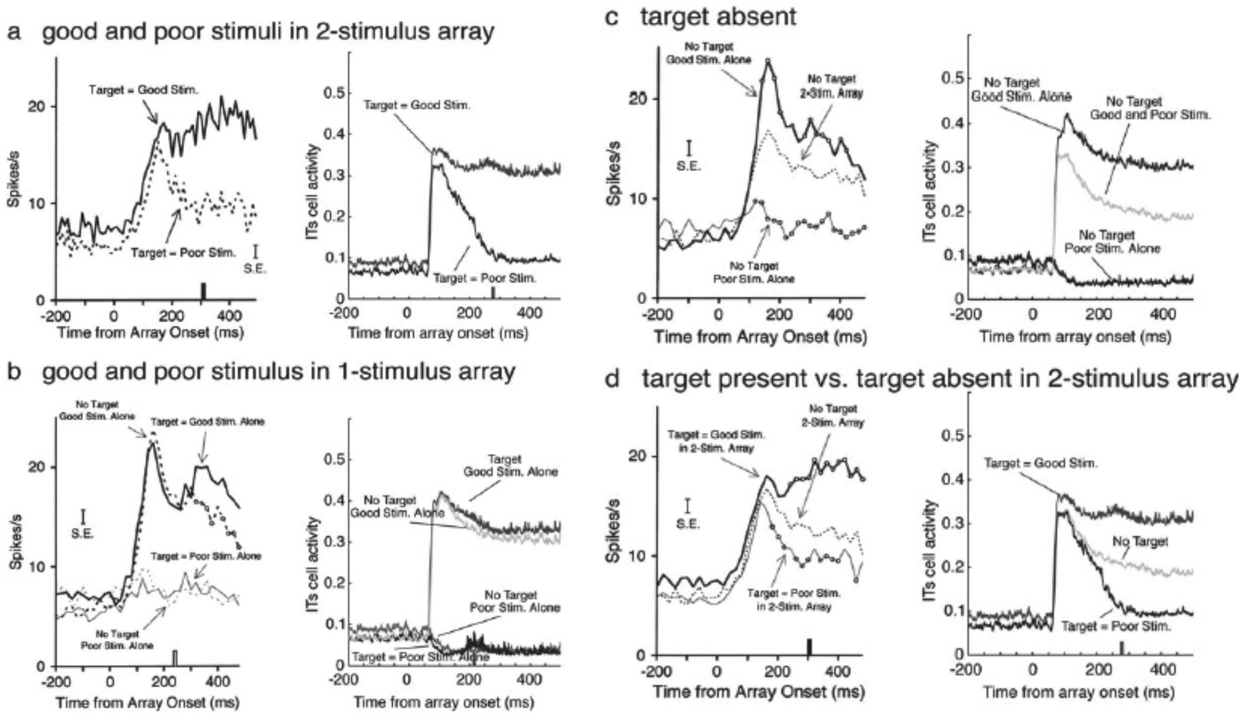
$$I_x^{\leftrightarrow} = w^{FEFm} r_x^{FEFm}; \quad w^{FEFm} = 0.2$$

$$I_x^{inh} = w_{inh} \max_x (r_x^{FEFm}) + \sum_{x' \neq x} w_{x,x'}^{map} r_{x'}^{FEFm} + r^{FEFf}; \quad w_{inh} = 0.5, \; w_{x,x'}^{map} = 3.6$$

Integrated Competition – simulation results

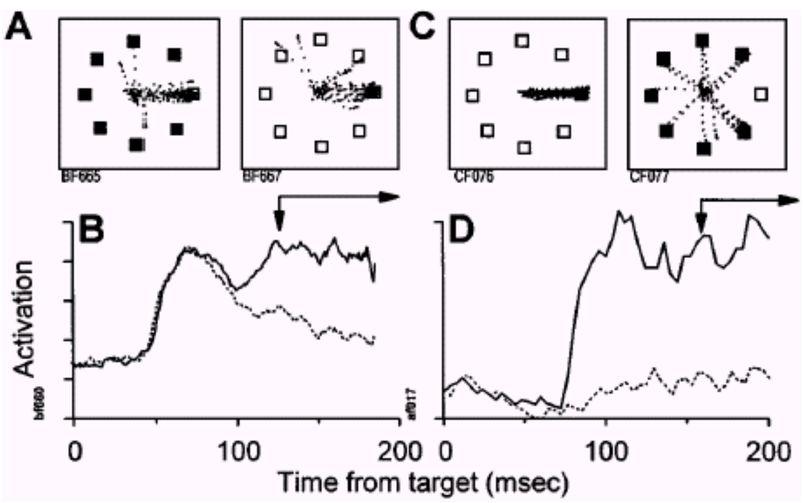


Integrated Competition - Comparison with data



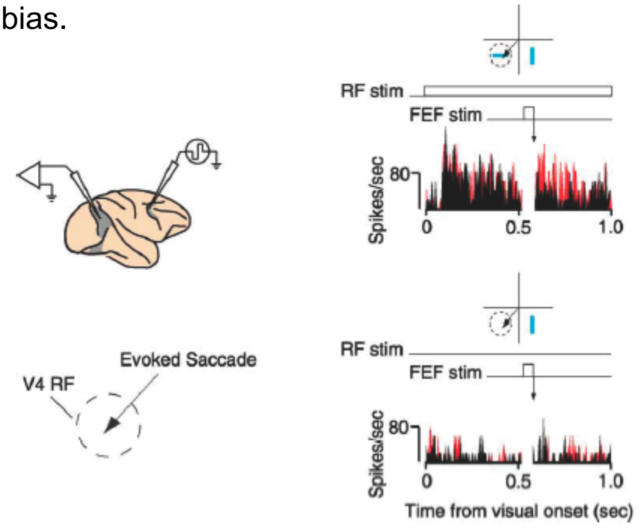
The role of the frontal eye field

Neurons in the frontal eye field selectively fire towards a behaviorally relevant stimulus, e.g. if it is defined by its saliency (A und B), or by its color after many training trials (C und D).



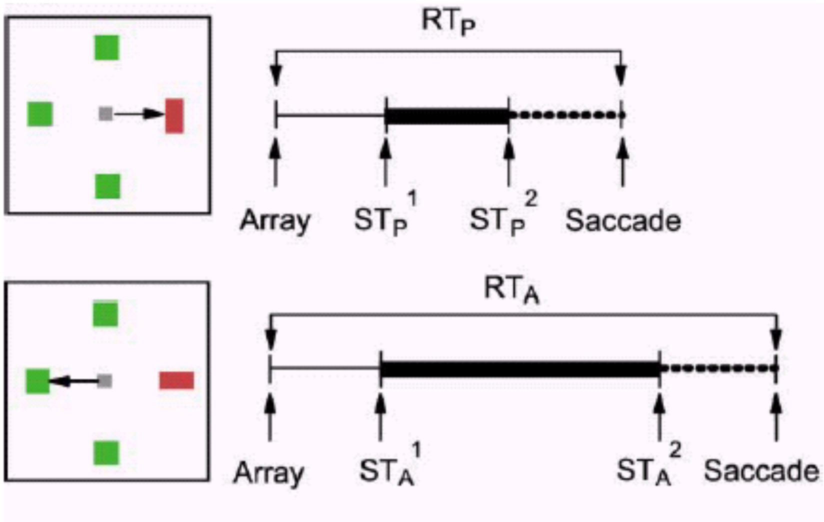
The role of the frontal eye field

Anatomical projections and graded responses seen in LIP, SC and FEF suggest that these areas participate in a distributed network that drives visual attention. However, it is of interest which of those areas drives the spatial bias.



Moore, T., Armstrong, K.M. (2003) Selective gating of visual signals by microstimulation of frontal cortex. Nature, 421:370-373.

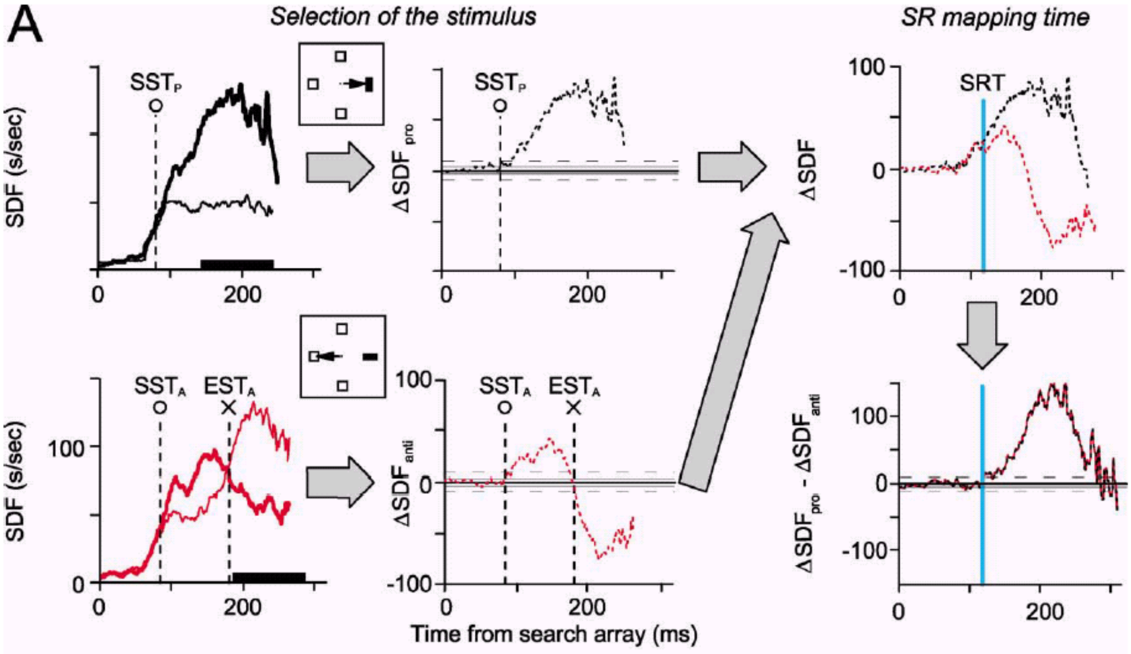
Anti-saccade task



A vertical and salient stimulus indicates a pro-saccade and a horizontal an anti-saccade. The reaction time (RT) can be divided into a coding phase (thin line), stimulus-response selection-phase (thick line), und stimulus-response preparation-phase (dotted line).

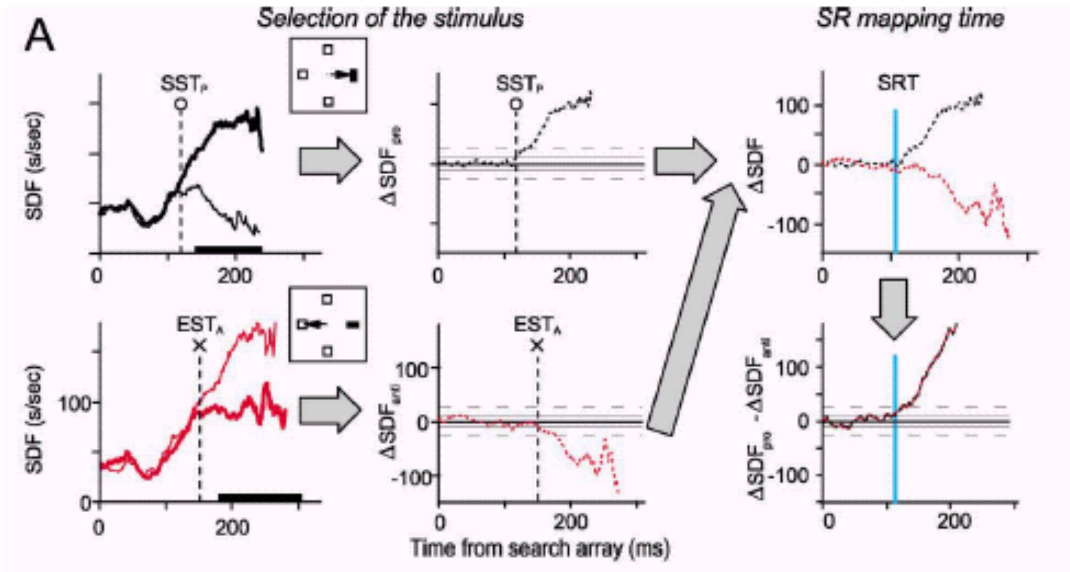
Sato TR, Schall JD. (2003) Effects of stimulus-response compatibility on neural selection in frontal eye field. Neuron 38:637-648.

Anti-saccade task



Comparison of the neural activity in the pro-and anti-saccade in a (so called) type I neuron with little „movement-related activity.

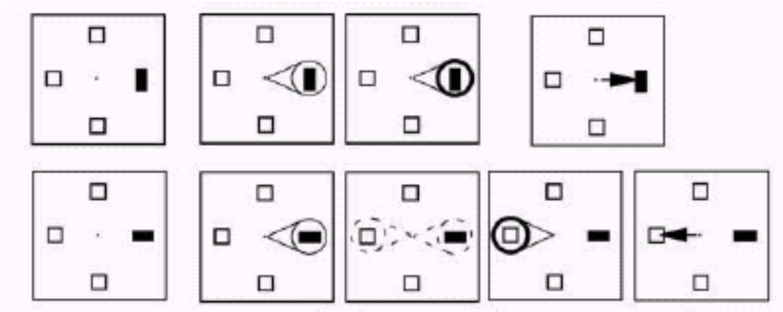
Anti-saccade task



Comparison of the neural activity in the pro-and anti-saccade in a type II neuron with little visual- but high movement-related activity.

Anti-saccade task

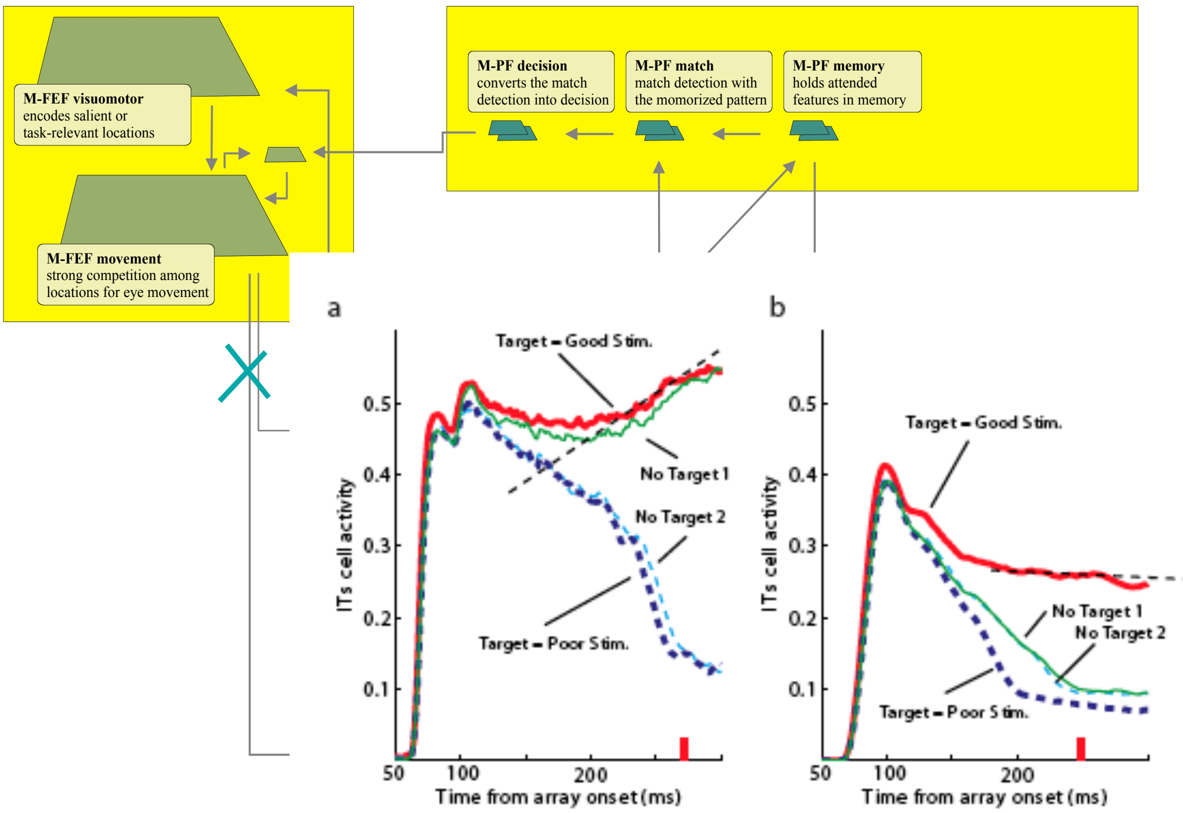
Visual selection model:



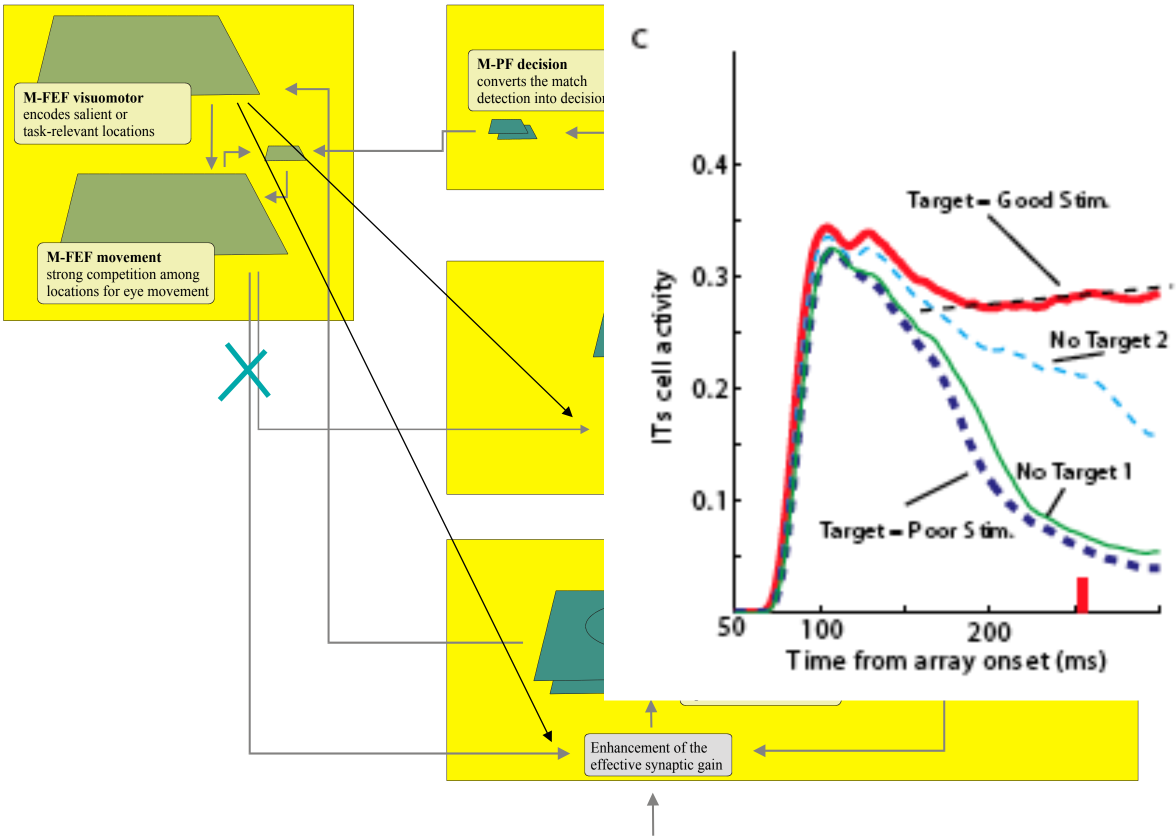
Sato TR, Schall JD. (2003) Effects of stimulus-response compatibility on neural selection in frontal eye field. Neuron 38:637-648.

Schall and colleagues suggest, that attention will be first directed onto the salient task-relevant stimulus and then onto the saccade target. The selection among the type I neurons could direct attention onto the salient stimulus in order to support the read out of its orientation and then attention would move towards the saccade target.

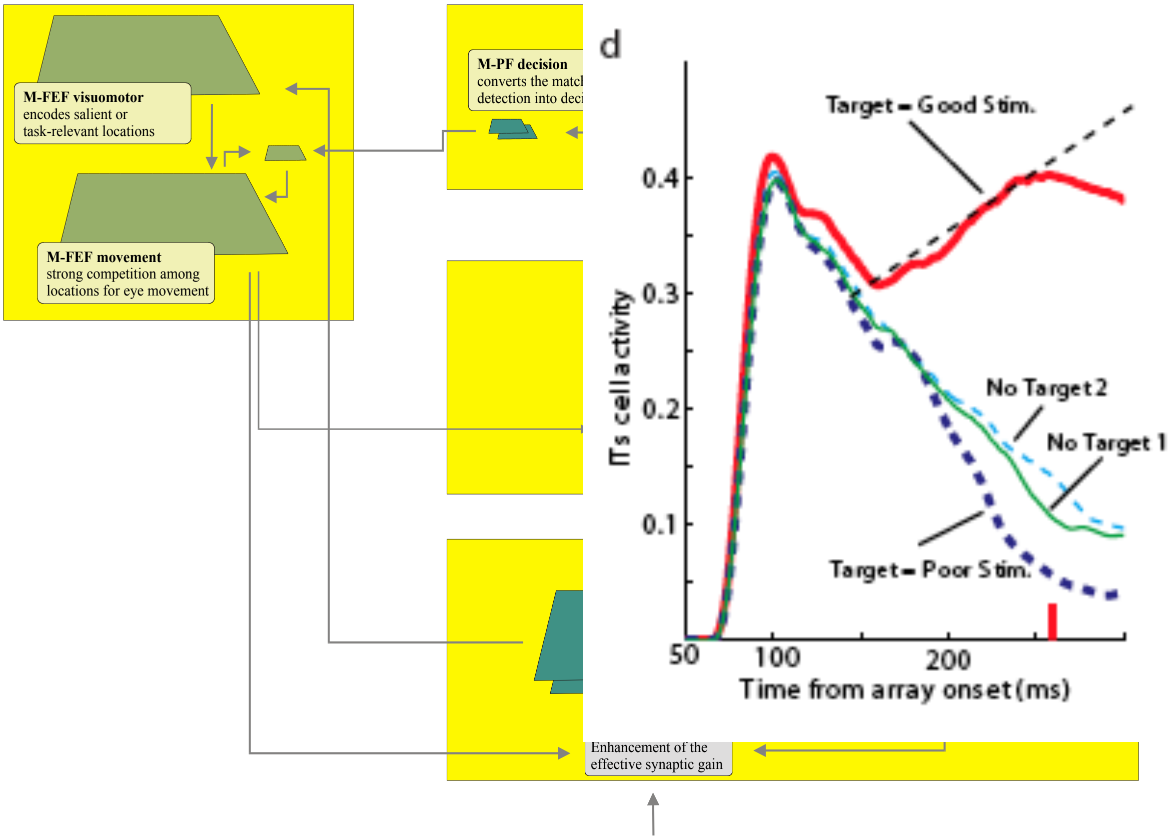
Alternative model: No spatial feedback



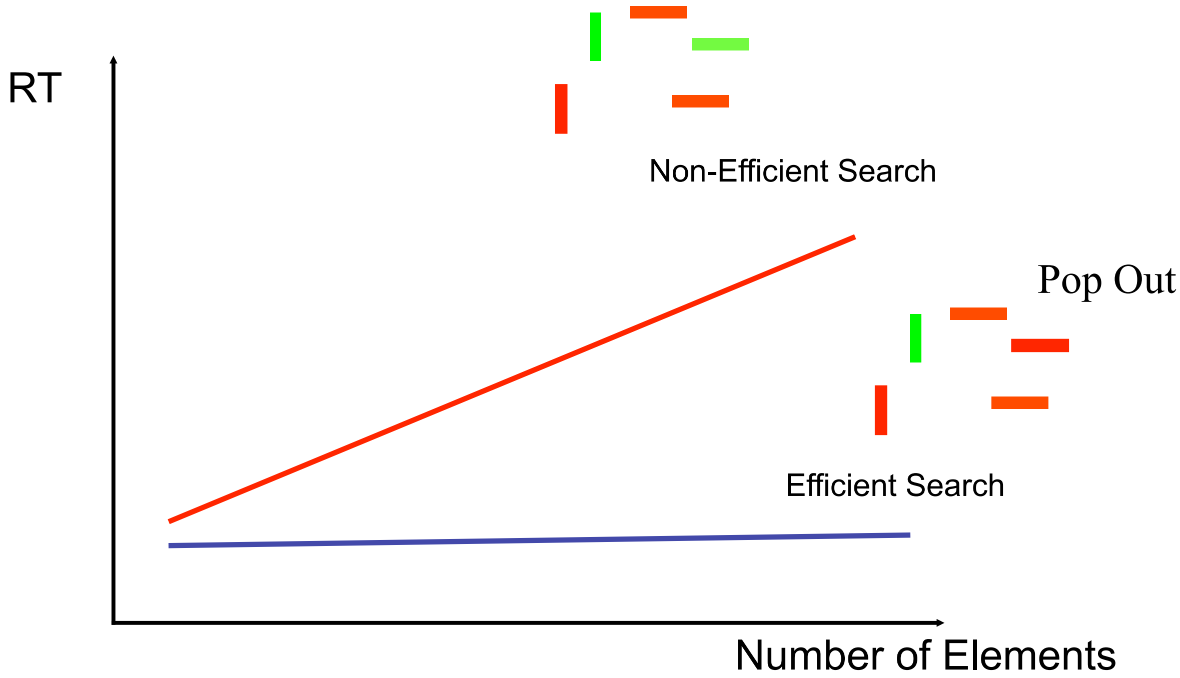
Alternative model: FEFv feedback



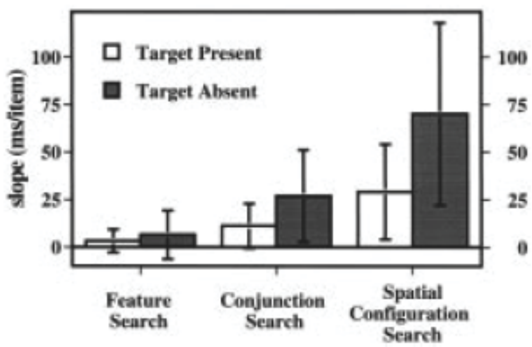
Alternative model: FEFm feedback



Parallel vs serial search



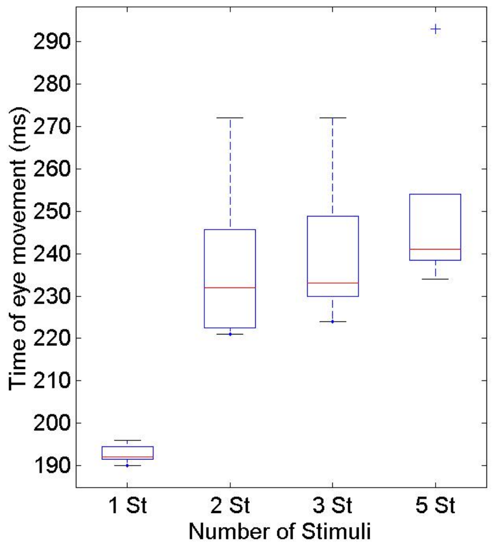
Parallel vs serial search

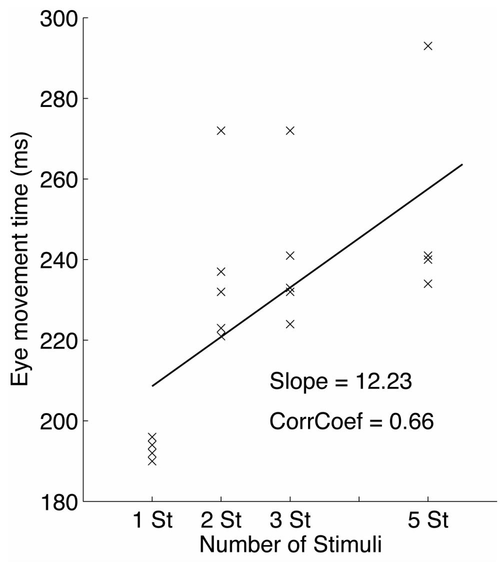


From: Wolfe, J. M. (1998). What can 1 million search trials tell us about visual search. Psychological Science, 9, 33-39.

Parallel vs serial search

Saccade latency increases with set size:

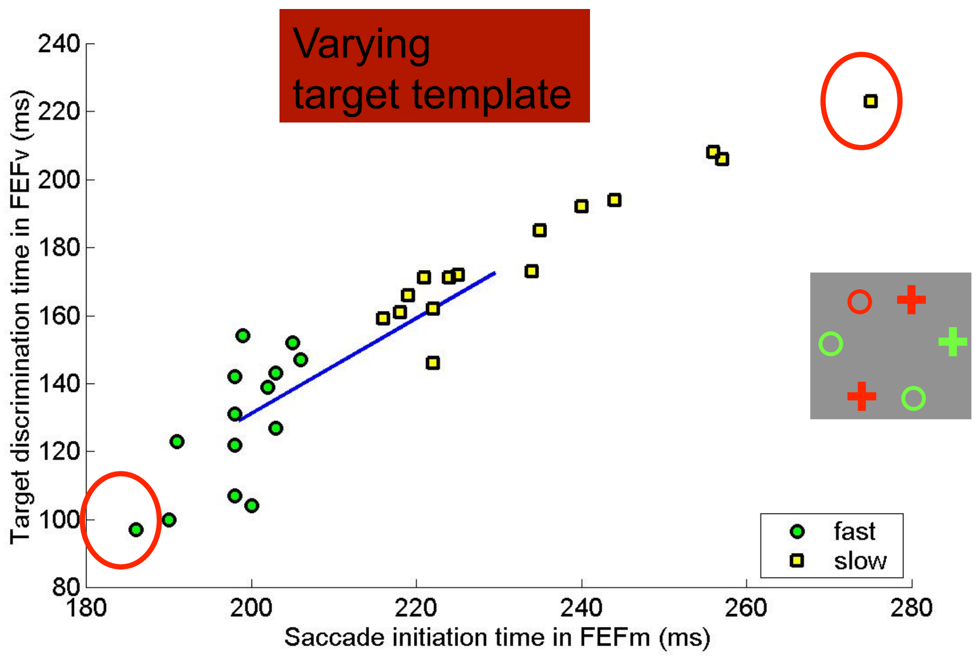




Shallow search slopes can be explained by a parallel process

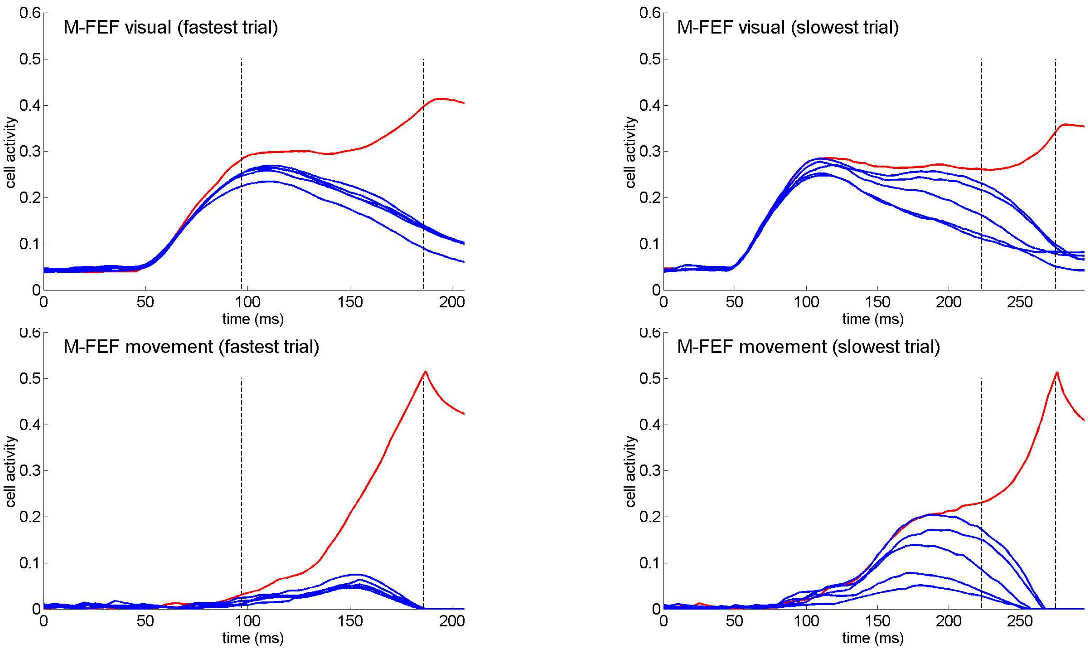
Parallel vs serial search

Physiological mechanism of set-size effects:



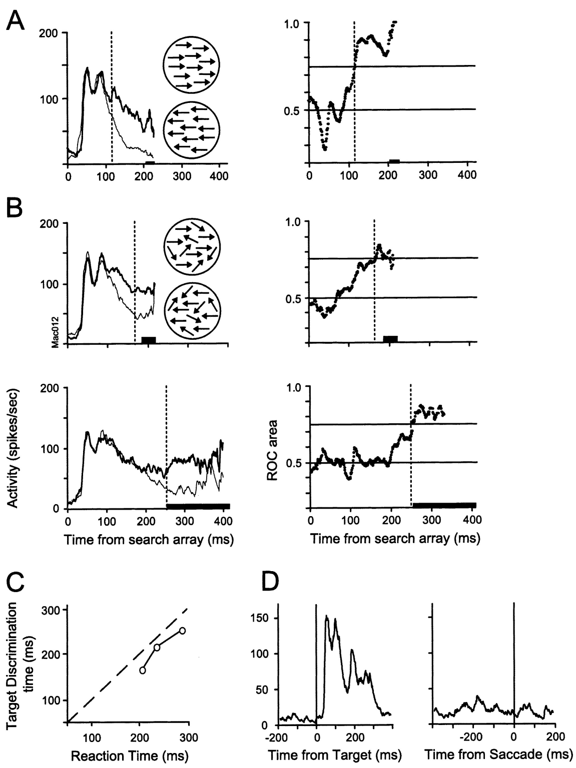
Parallel vs serial search

Physiological mechanism of set-size effects:



Parallel vs serial search

Comparison with
frontal eye field data



Sato T, Murthy A, Thompson KG, Schall JD. (2001) Search efficiency but not response interference affects visual selection in frontal eye field. Neuron. 30:583-591.

Discussion

Typically attention is defined as a separate mechanism that controls the “information” flow whereas other mechanisms actually process the “information”.

The presented model suggests that “information control” and “information processing” are part of the same neural processes.

References:

- Chelazzi L, Duncan, J, Miller EK, Desimone R (1998) Responses of neurons in inferior temporal cortex during memory-guided visual search. J Neurophysiol 80:2918-2940.
- Chelazzi L, Miller EK, Duncan J, Desimone R (2001) Responses of neurons in macaque area V4 during memory-guided visual search. Cereb Cortex 11:761-772.
- Desimone, R., Duncan, J. (1995) Neural mechanisms of selective attention. Annual Review of Neuroscience, 18:193-222.
- Deubel, H., Schneider, W. X. (1996) Saccade target selection and object recognition: Evidence for a common attentional mechanism. Vision Research, 36:1827-1837.