Visual Attention

International Lecture Serie

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Outlook

1. We see only what we look at
2. What is Attention ?
3. Visual Attention
4. Theories of Visual Attention
5. Behavioral perspectives

We see only what we look at

(Maurice Merleau Ponty, 1961)

Slow change blindness
(O'Regan, 2001)

(http://nivea.psycho.univ-paris5.fr/sol_Mil_cinepack.avi)

From J.Kevin O'Regan (http://nivea.psycho.univ-paris5.fr/)

Slow change blindness
(O'Regan, 2001)

First frame

Last frame

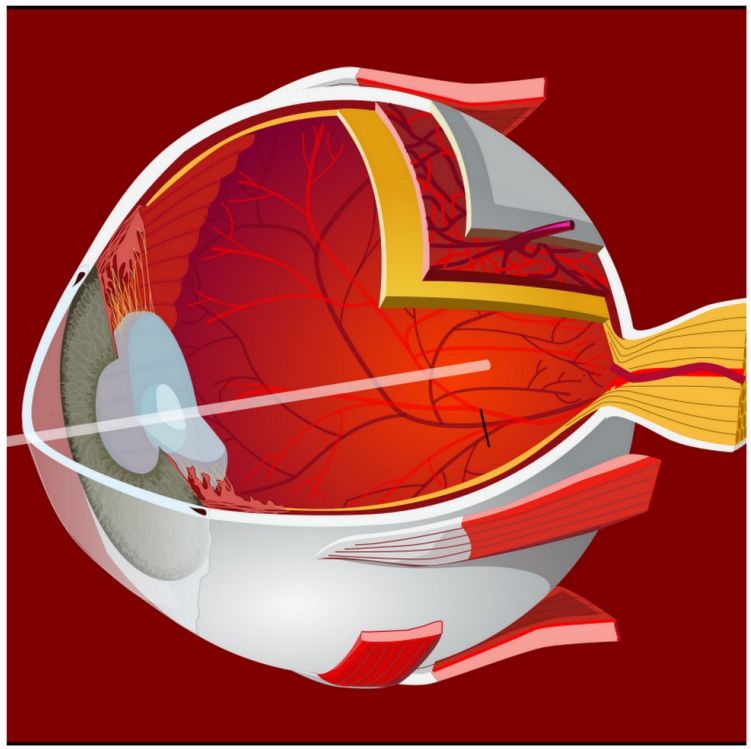
How blind are you ?

(`http://www.dothetest.co.uk/whodunnit.html`)

Transport for London campaign to *make drivers aware how easy it is to miss cyclists on the road and make cyclists understand how difficult they are to see.*

Eyes and retina

- Images on retina are formed upside-down
- There is a blind spot on the retina where optic nerves passes throught it
- Retina receptors are not uniformly distributed over the surface of the retina
- Eye is always moving even when fixing a point (micro-tremors)



The case of Stephen Wilshire
(Sacks, 1995)

"They were images and showed us some of the immensely complex neutral processes that are needed to make a visual and graphic image."

(Sacks, 1995)

What is Attention ?

What is Attention ?

Everyone knows what attention is. It is the possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration, of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others, and is a condition which has a real opposite in the confused, dazed, scatterbrained state which in French is called *distraction*, and *Zerstreutheit* in German.

W. James, 1890

Everyday attention effects

Cocktail party effect

Divided auditory attention allows you to listen to a conversation while mostly ignoring others.

Pop-out effect

Bottom-up visual processing direct your attention to salient stimuli (loud sound, moving/growing object in the visual field, intense heat, etc.)

Blindness effect

Selective attention allows you to recruit processing onto specific aspects making you virtually blind to other aspects.

Early experiments

Problem of air traffic controllers: hearing intermixed voices of pilots made the task quite difficult. Cherry conducted experiments where people have to separate sentences presented to each ear.

Dichotic listening experiment (Cherry, 1953)

- Left ear: sentence A
- Right ear: sentence B

Subjects able to report one sentence and alsmost nothing about the other.
$\rightarrow$ early selection theory (Broadbent, 1958)

Mixed dichotic listening experiments (Gray & Wedderburn, 1960)

- Left ear: cat-4-mouse
- Right ear: 3-eats-5

Subjects report "cat eats mouse" and "3 4 5"
$\rightarrow$ late selection theory (Deutsch & Deutsch, 1963)

Description

Clinical Description (Sohlberg & Mateer, 1989)

Focused	To respond discretely to a specific stimuli.
Sustained	To maintain a consistent behavioral response
Selective	To maintain attention in the face of distractors
Alternating	To shift focus of attention
Divided	To respond simultaneously to multiple tasks

Cognitive Description

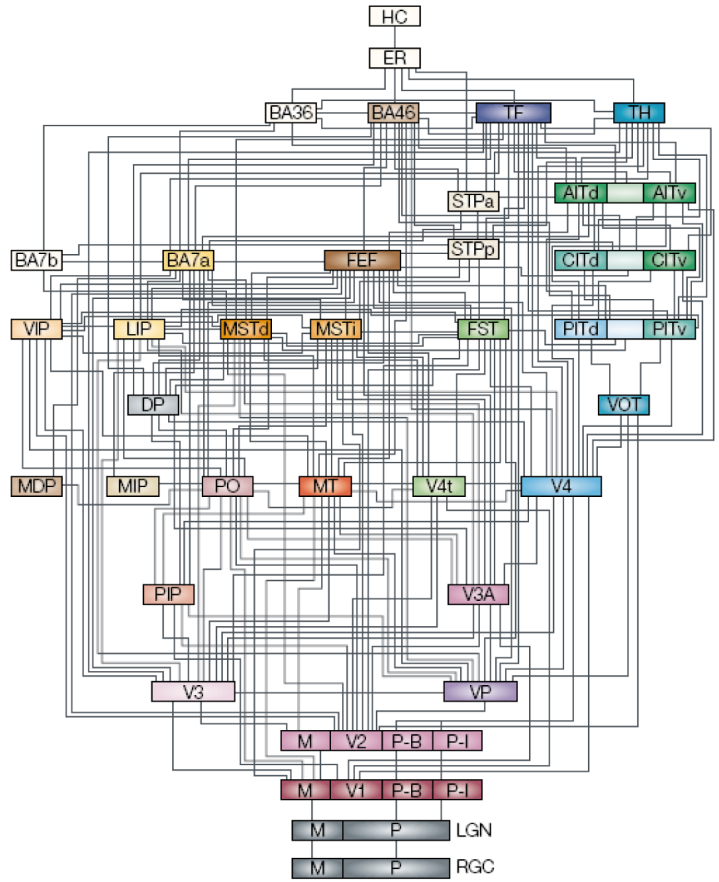
Motor	movements preparation, priming, etc.
Sensory	auditory, visual, proprioception, etc.
Overt	motor response (explicit)
Covert	cognitive response (implicit)
Top-down	goal driven, bias, etc.
Bottom-Up	stimulus driven, pop-out, etc.

Visual Attention

Cortical connectivity
(Felleman and Van Essens, 1991)

Model of cortical connectivity

- 32 cortical areas
- 10 hierarchical levels



Main visual pathways

The dorsal pathway

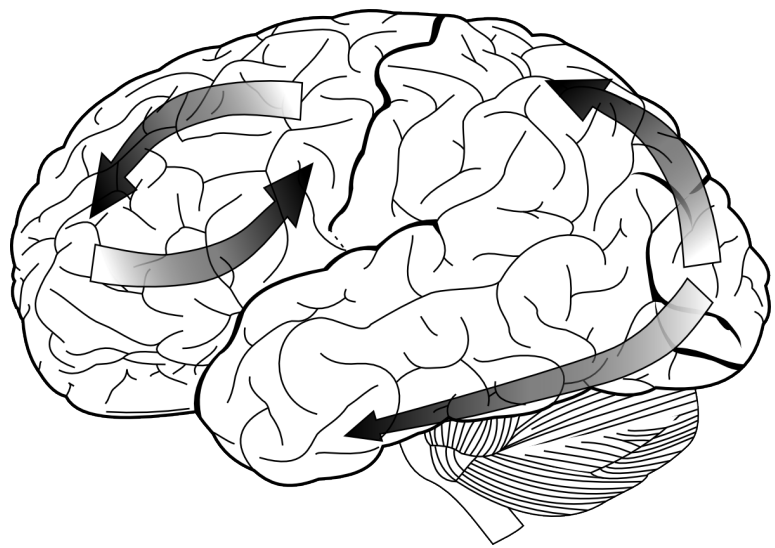
- V1 $\rightarrow$ V2 $\rightarrow$ MT $\rightarrow$ posterior parietal cortex
- *Where or How* pathway
- Motion and representation of object locations

The frontal pathway

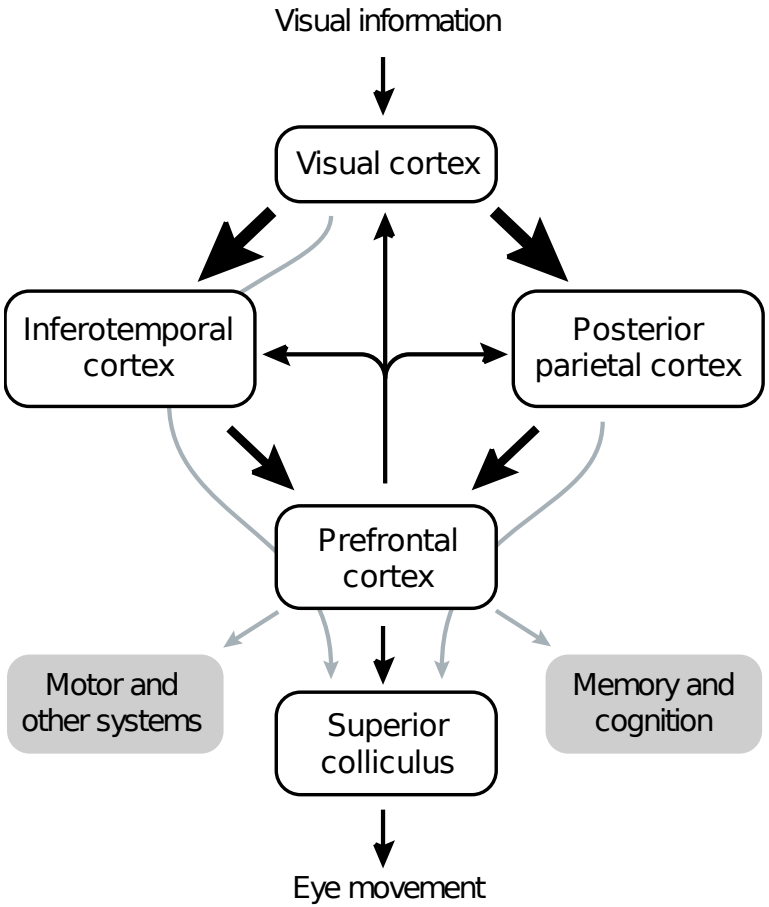
- Executive control
- Temporal organization of behavior
- Visual Awareness

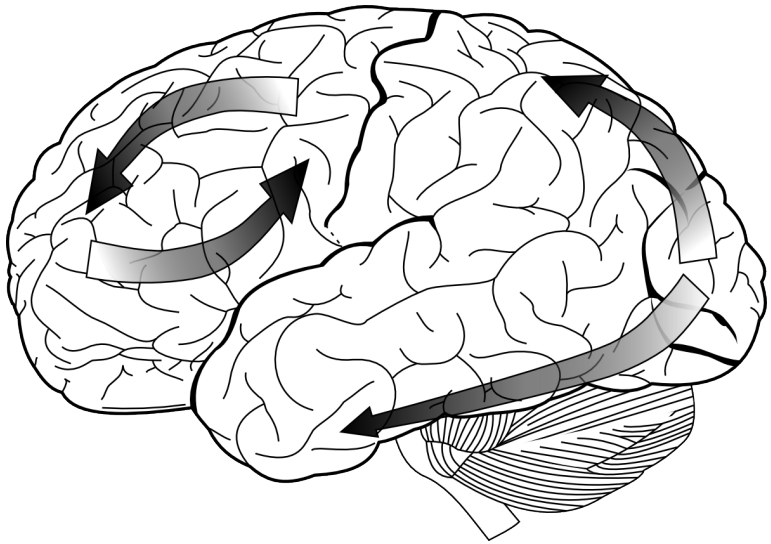
The ventral pathway

- V1 $\rightarrow$ V2 $\rightarrow$ V4 $\rightarrow$ inferior temporal cortex
- *What* pathway
- Form and object representation



Visual pathways
(Itti & Koch, 2001)





Spotlight metaphor

Behavioral level

Attention is the capacity to select a relevant region of the sensory space

- Topological region of the sensory space $\rightarrow$ spatial attention
- Featural region of the sensory space $\rightarrow$ feature oriented attention
- Object as such $\rightarrow$ object oriented attention

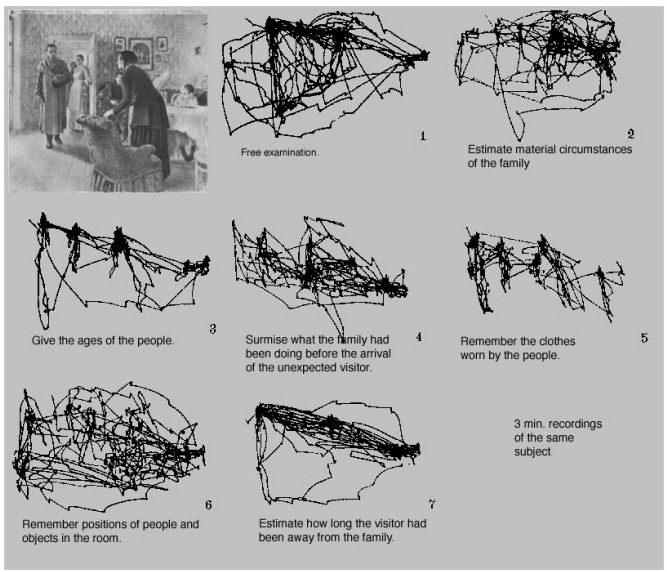
Exogeneous and endogeneous factors

Exogeneous visual attention (Desimone & Duncan, 1995)

Visual attention is driven by physical properties of stimuli

- color
- orientation
- movement
- curvature

Endogeneous visual attention (Yarbus, 1967)



Visual attention is biased by a priori knowledge and goals.

Faciitation and suppression

Facilitation & suppression, non spatial attributes

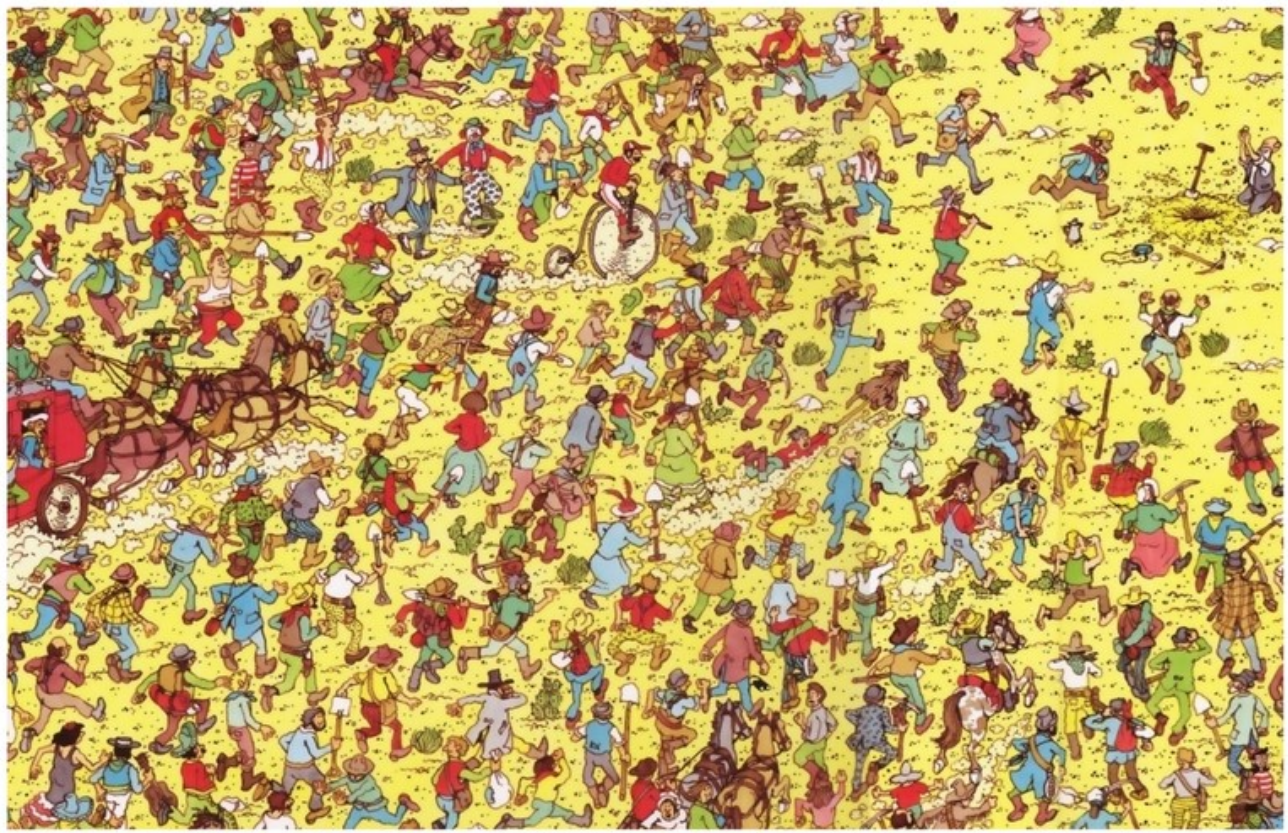
- Influence of novelty in LIP
- Influence of relevant attributes
  - IT: complex objects (e.g. faces)
  - V4: simple attributes (e.g. color, orientation)
  - MT: movements (e.g. speed, direction)

Facilitation & suppression, spatial attributes

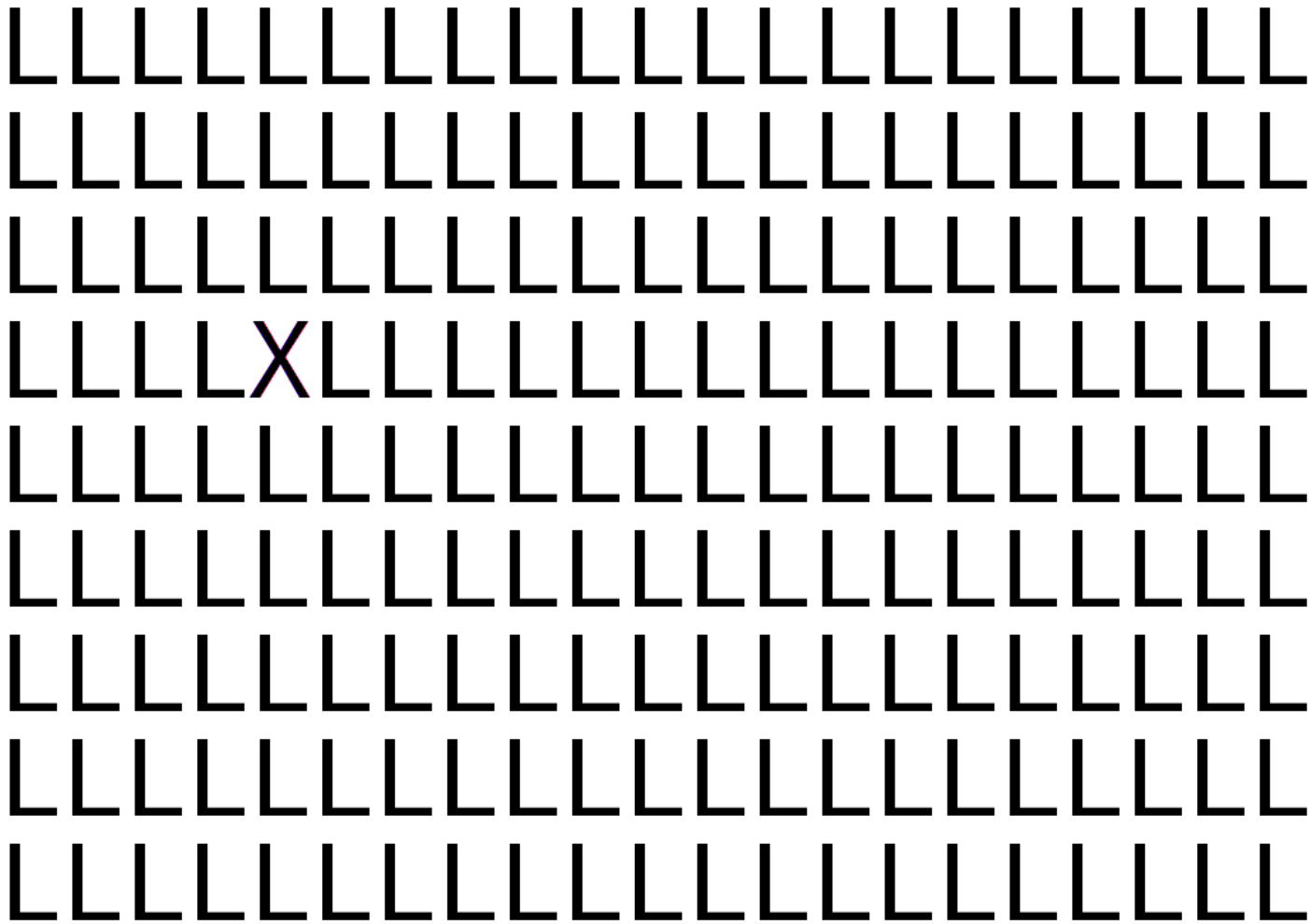
- "Directing spatial attention to a stimulus increases its effective contrast" (Reynolds et al., 1999)
- Inhibition of return (Posner et al., 1980; Klein, 2000)

Visual Search

Where is Waldo ?

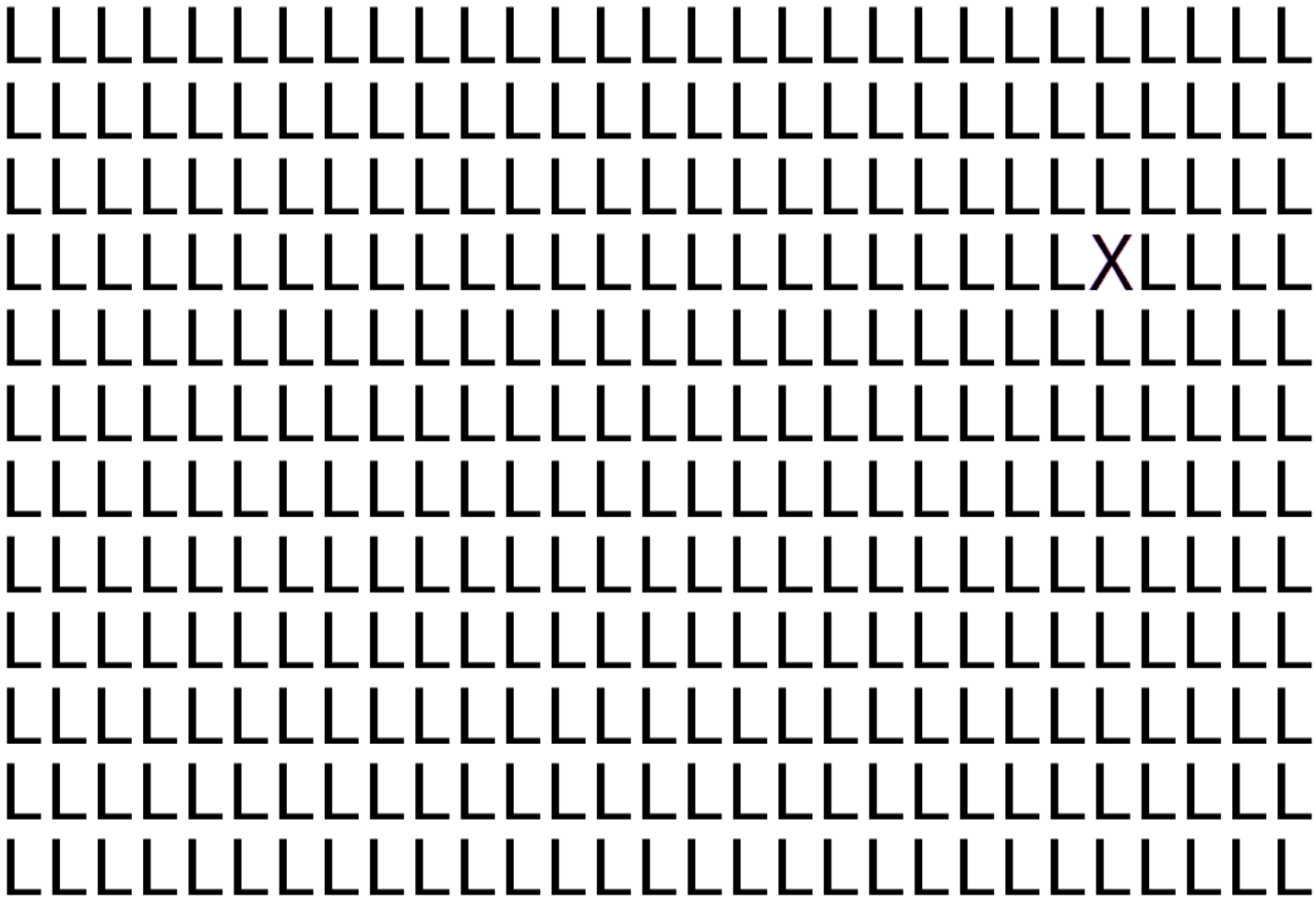


Parallel Search



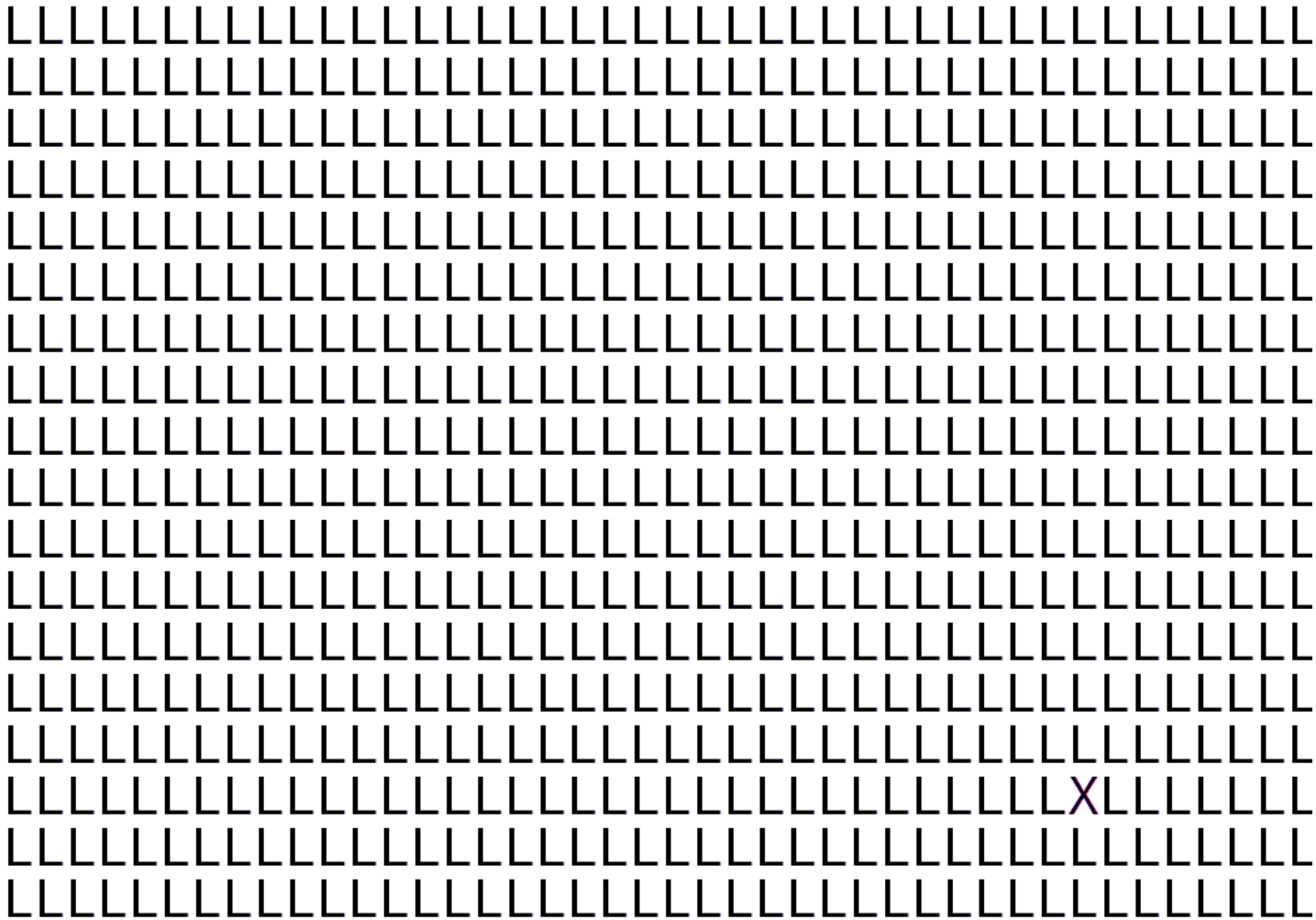
It's pretty easy to find the X among the L's.

Parallele Search



Still easy

Parallel Search



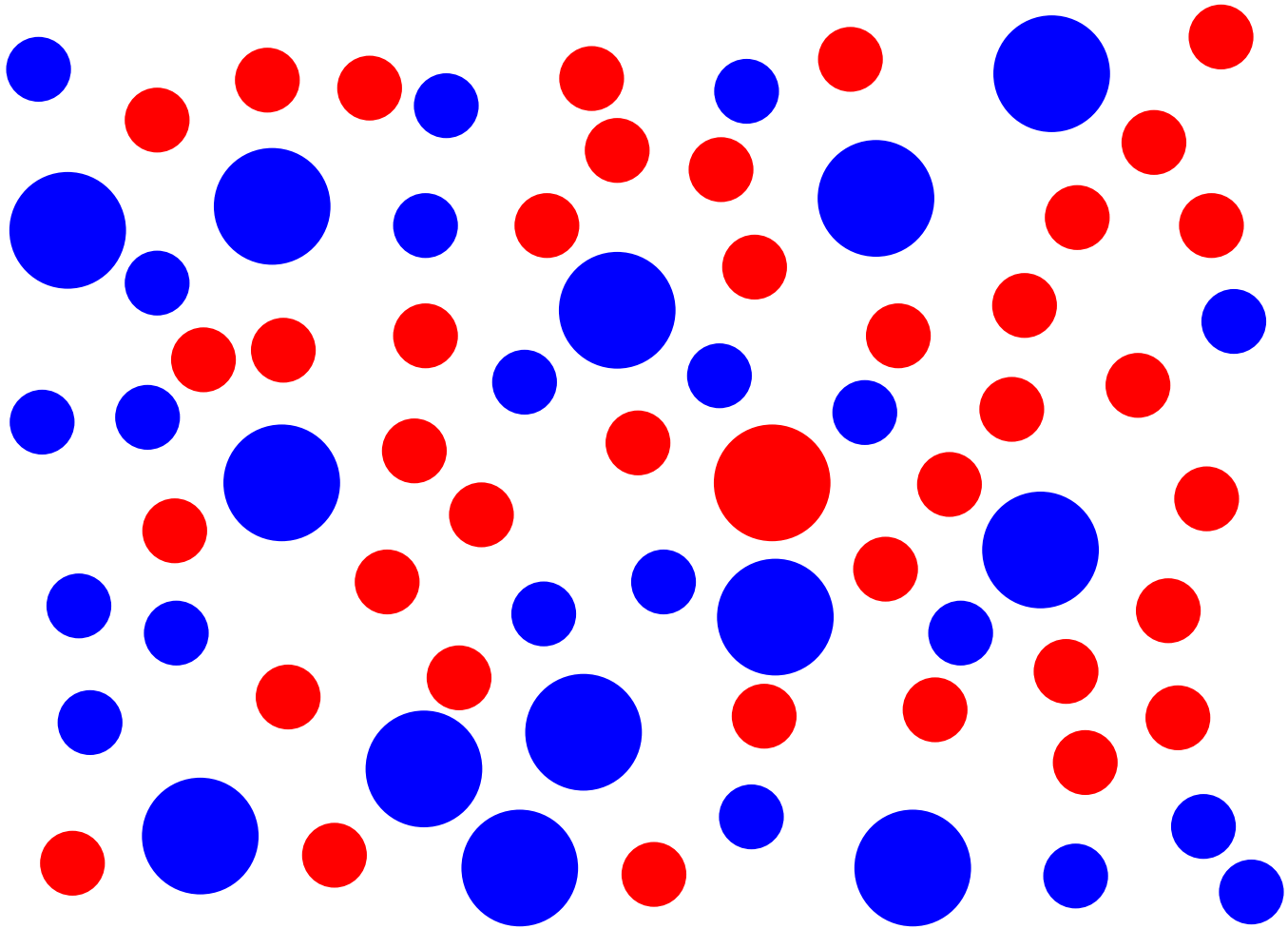
Still easy

Sequential Search

```
FBYCPKNRAGCJSTIVNRWHM
CDOFAIKULWZBASUBIFOBI
JWUEVEQOUHEWHKAFIYJFG
LAMEQDPZKSHBJJQUUVCYO
FHINTDLLZSNLSGKTCNSVG
LACRYLSJJIFMZFHATXJDZ
JRUMNRYBPCHTNINTHEUWB
FRUWYBNYYYPPQOQFKIGJL
NIDBPINWAQGYPTRCLYVRU
```

Much harder...

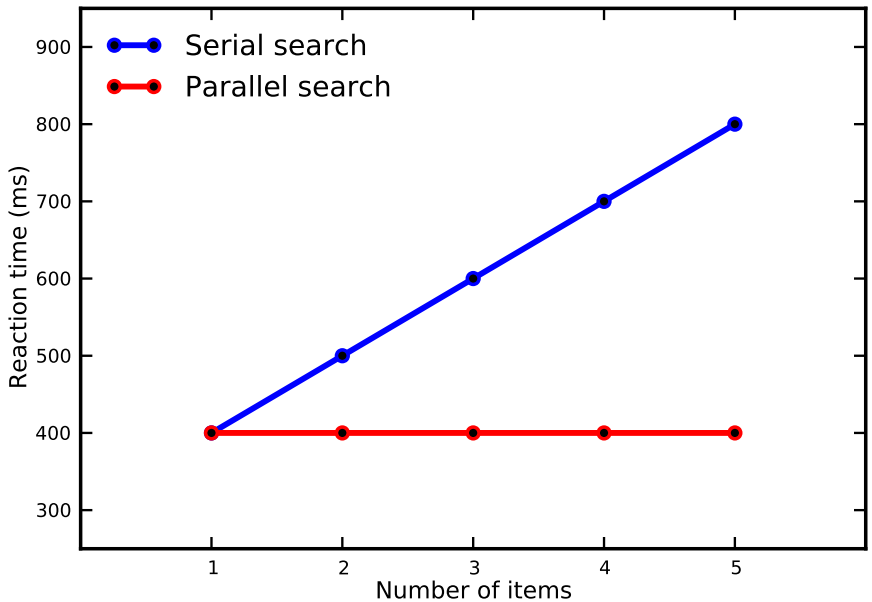
Sequential Search



Theories of Visual Attention

Theories of Visual Attention

Features Integration Theory (Treismann & Gelade, 1980)



Several primary visual features are processed and represented with separate feature maps that are later integrated into a *saliency* map.

- Parallel search $\rightarrow$ Pre-attentive attention
- Sequential search $\rightarrow$ Attentive attention

Theories of Visual Attention

Automatic vs Controlled (Stroop, 1935)

Say color of words out loud as quickly as possible

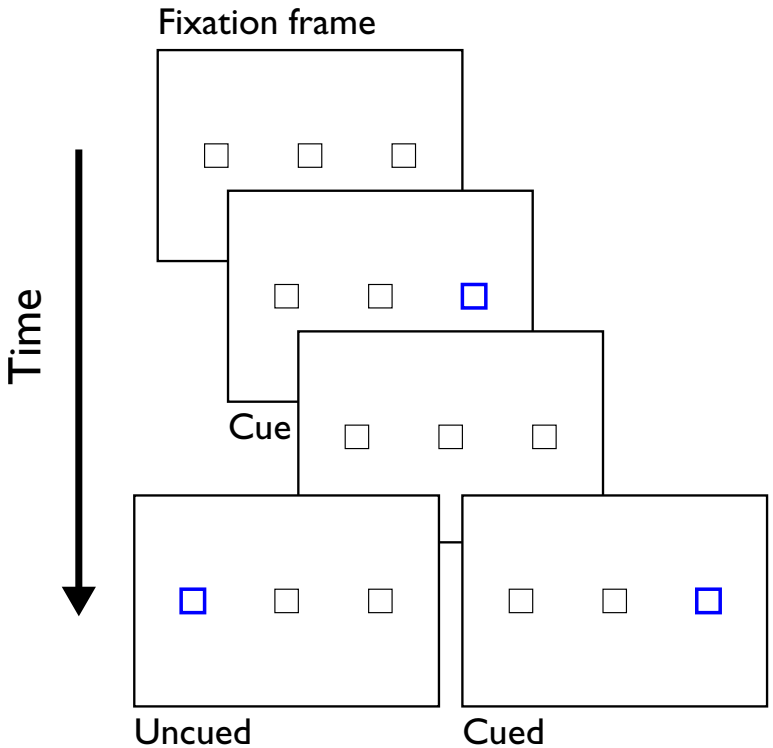
yellow	red	green	blue	red	green
(黄色)	(赤)	(緑)	(青)	(赤)	(緑)

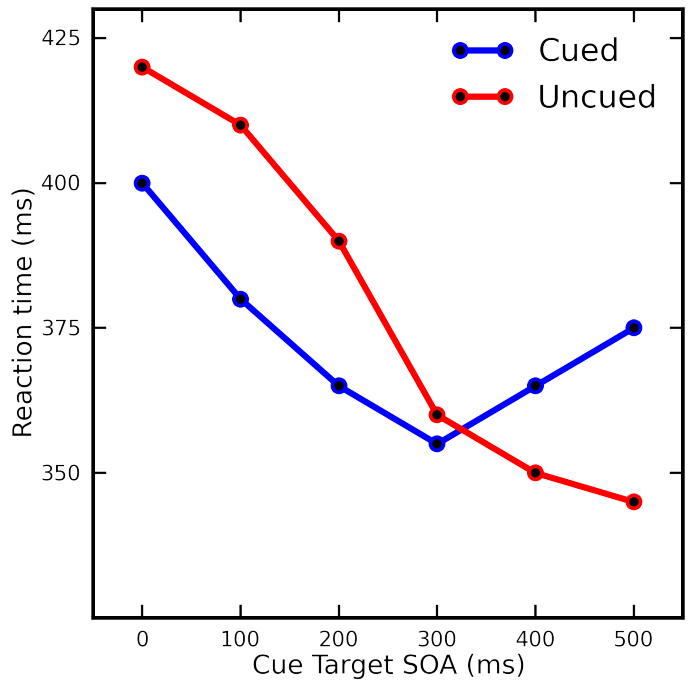
yellow	blue	red	green	blue	yellow
(黄色)	(青)	(赤)	(緑)	(青)	(黄色)

Reading is quite automatic and color naming requires control (suppression) of reading, thus it is slower.

Theories of Visual Attention

Inhibition of return (IOR, Posner, 1980)





Theories of Visual Attention

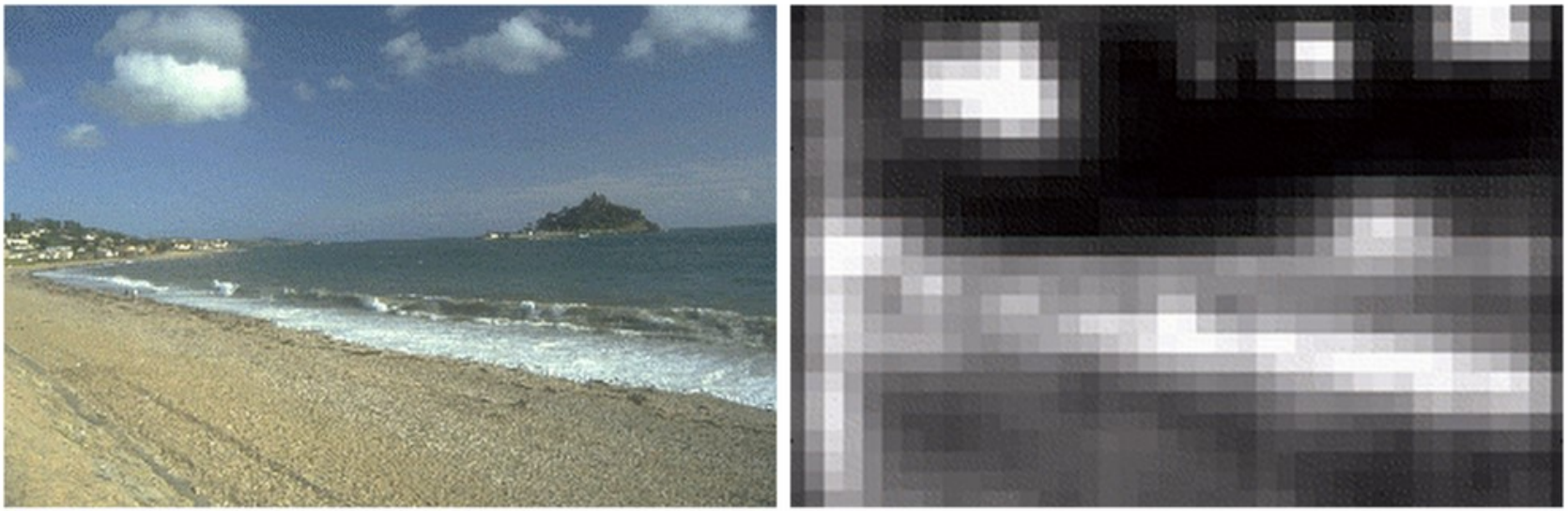
Inhibition Of Return (IOR, Posner, 1980)

"IOR operates to decrease the likelihood that a previsously inspected item in the visual scene will be reinspected" (Klein, 2008)

- Valid for mobile targets (Tipper et al., 1991)
  $\rightarrow$ updated via perception
- Up to five indices (Pylyshin, 2004)
- Valid only when spatial working memory is available
  $\rightarrow$ implied memorization of previously attended targets
- Appears after a time dependent of task difficulty
  $\rightarrow$ Neurons dynamic does not drive IOR

Theories of Visual Attention

Saliency Maps (Itti & Koch, 2001)



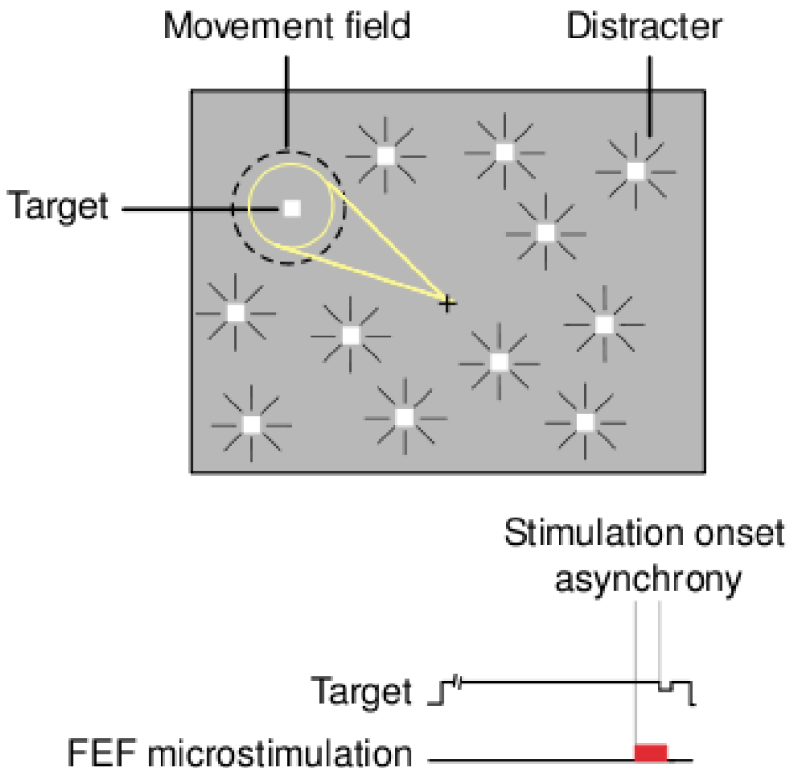
"Saliency map is a topographically arranged map that represents visual saliency of a corresponding visual scene." (Niebur, 2007)

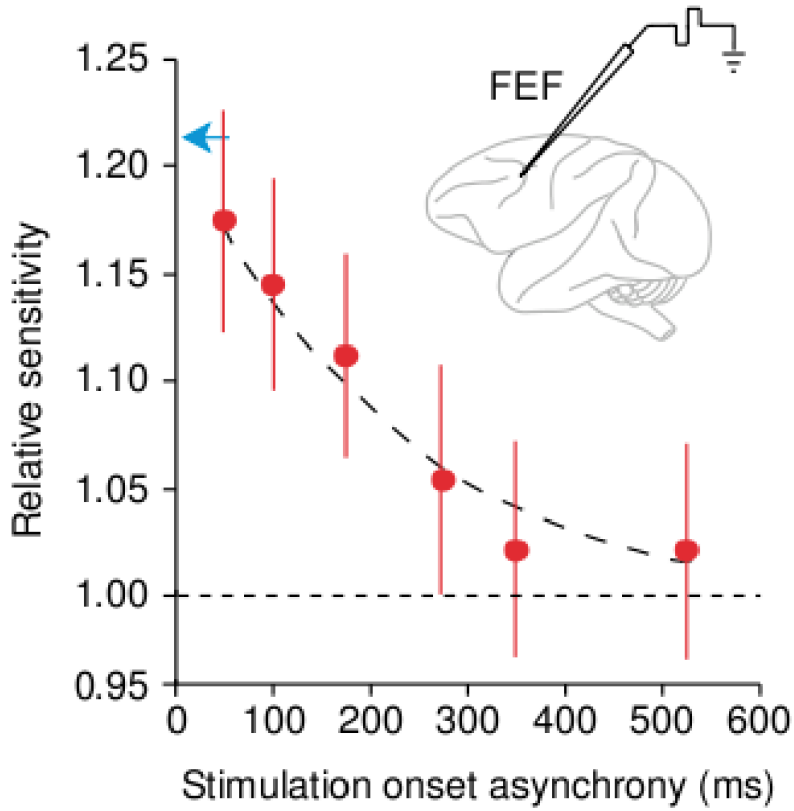
Localization

- Frontal Eye Field (FEF) ?
- LGN (Lateral Geniculate Nucleus) ?
- Superior Colliculus ?
- Distributed ?

Theories of Visual Attention

Premotor Theory of Attention (Rizzolati, 1987)





No need to postulate for two distinct control mechanisms

- One dedicated circuit for action
- One dedicated circuit for attention

The premotor theory of attention postulates that attention may derive from weaker activation of same frontal-parietal circuits.

Behavioral perspectives

Modeling perspectives

- Functional separation between *What* and *Where* pathways
- Non spatialy guided attention to facilitate processing of attributes
- Spatialy guided attention to facilitate processing of a spatial location
- Spatial attention to be deployed sequentially
- IOR to avoid attending a previously attended location

Computational perspectives

- To represent attention focus from saliency map
  $\rightarrow$ To re-use spatal attentional model
- To memorize already attended locations
- To allow updating through perception
  $\rightarrow$ Dynamic spatial working memory
- To dynamically inhibit point of attention
- To temporally control inhibition effect

Behavioral perspectives

Perception in action (Gibson, 1979)

- Without perception action would be unguided
- Without action perception would serve no purpose

Sensori-motor account on vision (O'Regan & Noë, 2001)

- Refute the hypothesis of an internal representation of the world
- The outside world serves as its own, external representation
- To master the laws of sensorimotor contingency

Deictic codes for the embodiment of cognition (Ballard et al., 1997)

- System of implicit reference (called deictic) to bind objects to cognitive programs
- External frame of reference centered at the fixation point

Conclusion

"On ne voit que ce qu'on regarde" (Merleau-Ponty, 1961)

Visual perception and attention are quite different from our unified visual experience and implies a lot of different and complex processings:

- Parallel/Serial
- Attentive/Pre-attentive
- Automatic/Controlled
- Conscious/Unconscious

The challenge for computational neuroscientist is thus to handle this complexity within a unified model in order to understand attention and makes the link to cognition.

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