

# Visual Attention

## International Lecture Serie

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Tokyo, December 2, 2010

# 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](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 ?

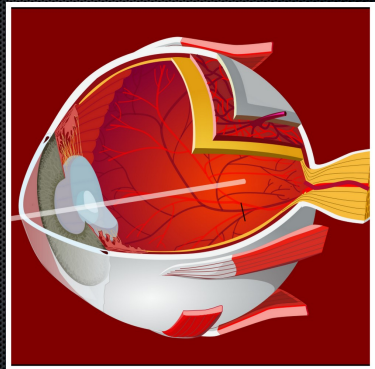
(<http://www.dothetest.co.uk/whodunnit.html>)

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 through it
- Retina receptors are not uniformly distributed over the surface of the retina
- Eye is always moving even when fixing a point (micro-tremors)

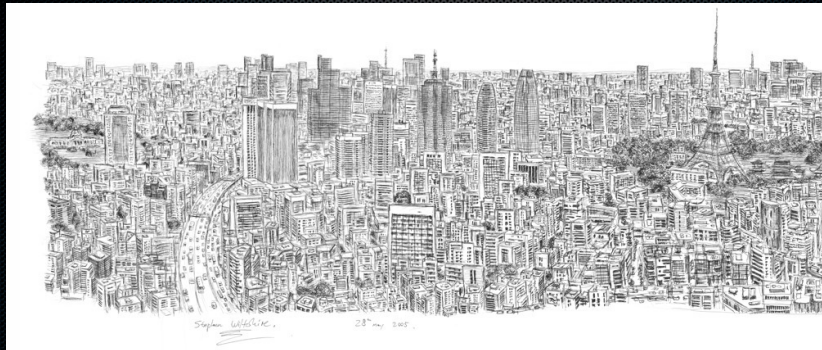


# The case of Stephen Wilshire

(Sacks, 1995)

"They were images and showed us some of the immensely complex neural 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 almost nothing about the other.

→ 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"

→ 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

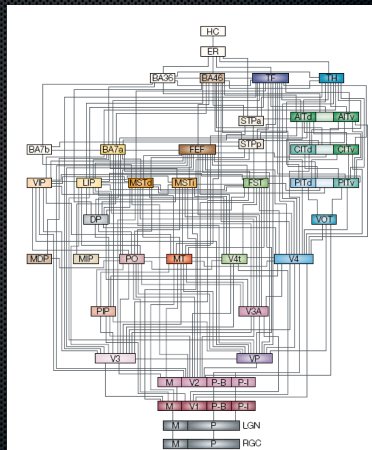


# Cortical connectivity

(Felleman and Van Essen, 1991)

## Model of cortical connectivity

- 32 cortical areas
- 10 hierarchical levels



# Main visual pathways

## The dorsal pathway

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

## The frontal pathway

- Executive control
- Temporal organization of behavior
- Visual Awareness

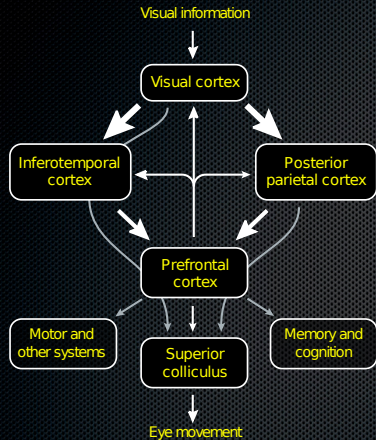
## The ventral pathway

- V1 → V2 → V4 → 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 → **spatial attention**
- Featural region of the sensory space → **feature oriented attention**
- Object as such → **object oriented attention**



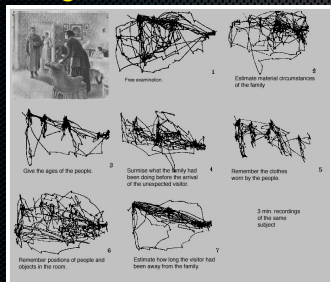
# Exogeneous and endogeneous factors

## 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.

# Facilitation 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)

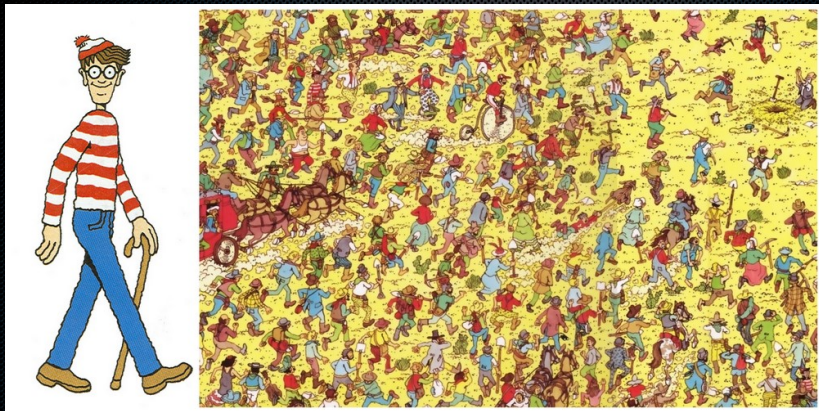
## Facilitation & suppression, spatial attributes

- "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 ?

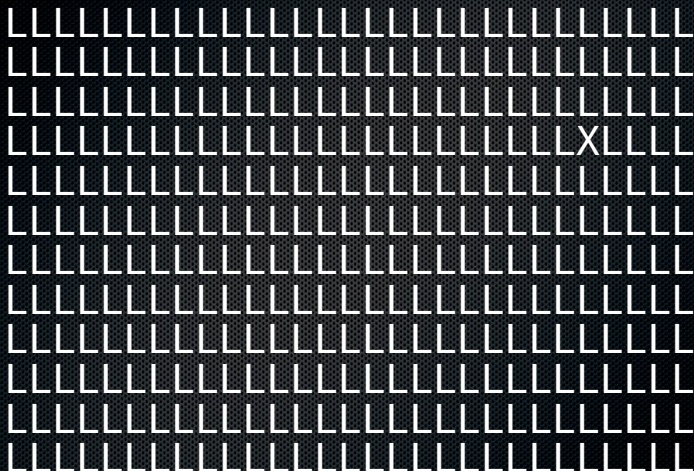


## Parallel Search



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

# Parallele Search



Still easy



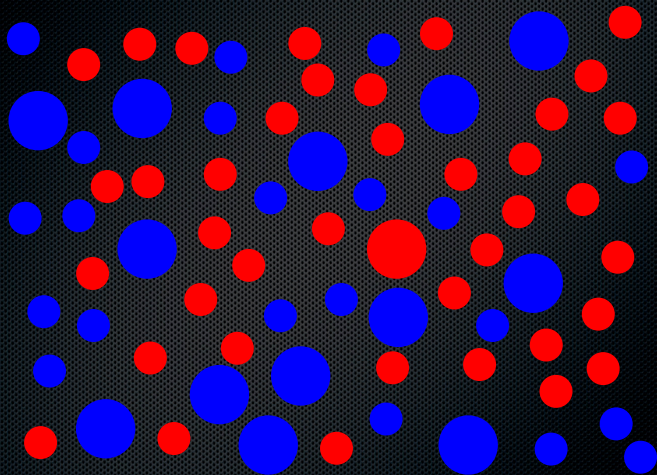


## Sequential Search

FBYCPKNRAGCJSTIVNRWHM  
CDOFAIKULWZBASUBIFOBI  
JWUEVEEQOUHEWHKAFIYJFG  
LAMEQDPZKSHBJJQUUVCYO  
FHINTDLLZSNLSGKTCNSVG  
LACRYLSJJIFMZFHATXJDZ  
JRUMNRYBPCHTNINTHEUWB  
FRUWYBNYYYPPQOQFKIGJL  
NIDBPINWAQGYPTRCLYVRU

Much harder...

# Sequential Search

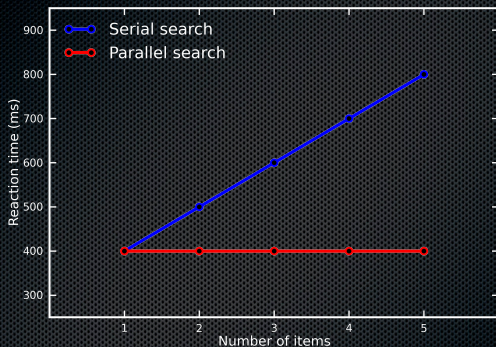




# Theories of Visual Attention

# Theories of Visual Attention

## Features Integration Theory (Treisman & Gelade, 1980)



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

- Parallel search → **Pre-attentive attention**
- Sequential search → **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)

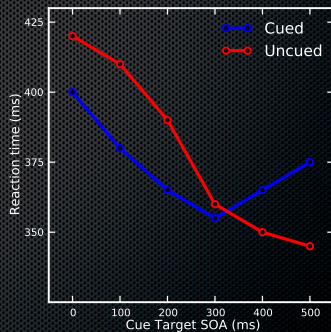
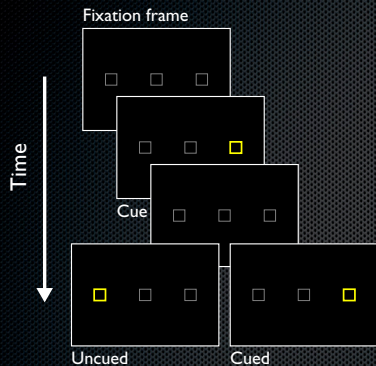
yellow blue red green blue yellow  
(黄色) (青) (赤) (緑) (青) (黄色)

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

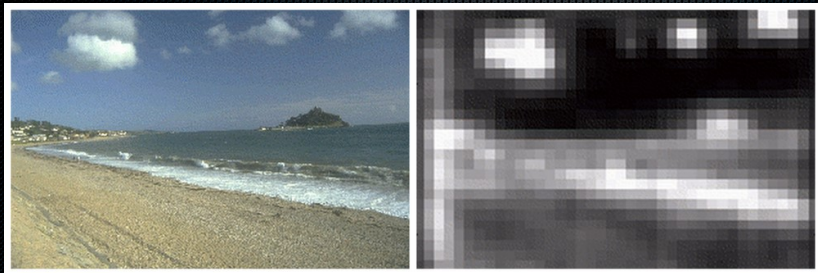
## Inhibition Of Return (IOR, Posner, 1980)

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

- Valid for mobile targets (Tipper et al., 1991)  
→ updated via perception
- Up to five indices (Pylyshin, 2004)
- Valid only when spatial working memory is available  
→ implied memorization of previously attended targets
- Appears after a time dependent of task difficulty  
→ 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)

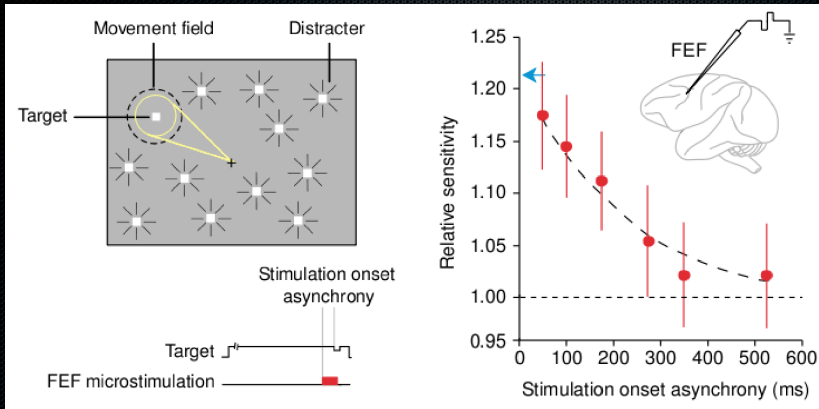
### Localization

- 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 spatially guided attention to facilitate processing of attributes
- Spatially 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  
→ To re-use *spatial attentional model*
- To memorize already attended locations
- To allow updating through perception  
→ *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.

# Bibliography

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