Attention - Overview

Definition

Theories of Attention

Neural Correlates of Attention
• Human neurophysiology and neuroimaging
• Single cell physiology – cellular mechanisms

Deficits of Attention
• Unilateral neglect
Attention

Everyone knows what attention is. It is the taking possession of 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...

- William James (1890)

Circa 1880
Attention: Two Components

Tonic attention (vigilance): setting arousal level, detection efficiency, signal-to-noise ratio. – brainstem reticular formation, basal forebrain, locus coeruleus, etc.

Selective attention: space-, object-, modality-selective attention. – temporal and parietal cortex.
What Does Attention Do?

1. Maintaining alertness and vigilance

2. Orienting to sensory events
   - overt vs. covert

3. Selection of sensory events
   - early vs. late selection

4. Detecting targets
   - limits on capacity
   - processing bottlenecks

5. Controlling access to memory and awareness
Where Does Attention Take Place?

Different sensory modalities (vision, audition etc.).

Attention is a distributed function.

Different processes – different anatomical substrates.
Attention as Competition for “Neural Resources”

Top-down Feedback Mechanisms: Fronto-Parietal Attentional Network

Competition among Multiple Stimuli for Representation in Visual Cortex

Output to:
Memory & Motor Systems

Bottom-up Sensory-Driven Mechanisms

Kastner and Ungerleider, 2000
Attention: A Covert Spotlight?

Helmholtz’ experiment:  Attention selects information
The Cocktail Party Effect

Shadowing - selective listening

Cherry’s dichotic listening experiments
However, even unattended information can “break through” and produce a shift in attention or orienting. Treisman’s attenuation theory.
Where Does the Selection Occur (Early or Late)?

*Early selection*: before full analysis of input
*Late selection*: at or after semantic encoding
Spatial Attention: Posner Task

Target might appear here:

- A

Fixation Point

Cue 75% accurate

Attention switches to here (but eyes don’t move)

or here:

- A
Attention and Orienting

Voluntary orienting (expectancy) results in faster reaction times.

Attention affects perceptual information processing, attention is spatial $\rightarrow$ “mental spotlight”
Find the T:
Find the T:
Find the T:
Find the T:
Find the T:
Find the T:
Find the T:
Find the T:
Find the Blue T:
Find the Blue T
Find the Blue T:
Find the Blue T
Searching a Scene

“pop-out”

conjunction-search
(sequential spotlight)
Treisman’s Attention Model
Competition and Visual Search

Interpretation of Treisman’s results:

Feature search requires look-up within one feature map (bottom-up saliency-based mechanisms).

Conjunction-search requires coordination of multiple feature maps in register, serial search under guidance of visual attention (top-down influences of spatial or object-based attention). “Multiple objects are competing for neural representation.”
Inhibition of Return

Localized exogenous cues (light flash) can lead to faster performance at that location (within 250 msec) – then there is an inhibitory aftereffect (inhibition of return).
The Saliency Map


Saliency map = encoding “visual conspicuity”, or saliency.

Two mechanisms:
-fast, parallel pre-attentive extraction of visual features.
-slow, sequential focal attention, winner-take-all, inhibition-of-return.
The Saliency Map
The Saliency Map

Input image

Linear filtering

- colors
- intensity
- orientations

Center-surround differences and normalization

- Feature maps

Linear combinations

Saliency map

Winner-take-all

Inhibition of return

Attended location
The Saliency Map: Application

Street signs
The Saliency Map: Application

“Replication” of Treisman’s experiments:
## Stroop Task

<table>
<thead>
<tr>
<th>Blue</th>
<th>Yellow</th>
<th>Red</th>
<th>Green</th>
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# Stroop Task

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****** ****** ****** ******

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Stroop Task

Blue   Yellow  Red   Green
Green  Yellow  Green  Yellow
Yellow  Green  Blue  Blue
Red    Blue    Red    Green
Stroop

• Failure of selective attention
• Race model
  – Word name is processed automatically
  – Color is not so automatic
  – Both arrive at the same time, we have a hard time attending to the relevant stimulus attribute
  – Doesn’t happen upside down
Stroop Task

Green Red Blue
Blue Blue Green Yellow
Yellow Green Yellow Green
Green Red Blue
Blue
Sharing Attention: Dual Tasks

- Do two things at once: can they be performed at the same time?
- Do they interfere?
- Experiment has 3 conditions
  - Task A alone
  - Task B alone
  - Task A and B together at the same time
Sharing Attention: Dual Tasks

• Example:
• Pat head and rub belly
• Now speed up just your belly
• If you can’t do it, it suggest that they share the same processing capacity
• Same brain area?
Sharing Attention: Dual Tasks

Example:
Task A: Can read 30 pages an hour when not watching tv
Task B: Can recite 85% of Gilligan’s lines before he does when not reading at the same time.

Can you watch Gilligan and still read as quickly? (Assume you adjust your reading speed to maintain the same comprehension level)
Attention – Neurophysiology

Hillyard’s experiments – dichotic listening: attention-dependent effect on ERP amplitude.

Early or late?

Study by Woldorff et al., localization of an early (20-50 ms latency) attention effect using ERP(F)/MRI.)
P1 Attention effect (current density)
Attention – Neuroimaging

Previous imaging studies revealed: changes in neural activity related to attentional shifts (parietal lobe) and attention-related specific activation of extrastriate areas (color, form, motion). No changes in V1.

Recent fMRI studies (e.g. Somers et al., 1999):

- Selective visual attention modulates neural activity in extrastriate cortex, as well as in V1.
- Attentional modulations in V1 are spatially specific.
- “Window of attention can be spatially complex”, hints at object-selective attention.
Attention – Neuroimaging

Flattening of the occipital lobe (Somers et al., 1999)
(a) and (b): Stimulus
(c) and (d): Topography
(e) and (f): Attentional Modulation
Attention – Top-Down

Most “natural” visual scenes are composed of multiple objects.

Receptive fields in higher visual areas are large (up to 25 degrees) and typically contain multiple objects at one time.

This creates a problem for neurons encoding specific object features...
Attention – Top-Down

Red alone
No attention
50 spikes/s

Blue alone alone
No attention
10 spikes/s

Violet alone
No attention
30 spikes/s

Red & blue together
No attention
30 spikes/s

Ambiguous response
Attention – Top-Down

Ambiguity in neural response can be reduced by:

a) Referencing spatial (retinal) location

b) Attentional modulation of firing rate
Attention – Top-Down

Un-ambiguous response

Prediction
(a) Input gating

V4 neuron's receptive field

"Attend to the left."

Intermediary neuron (inhibitory)

(b) Neuron gating

Red-preferring cells

Mutual inhibition

Green-preferring cells
Cellular Basis of Attention

Note: visual input does not change (fixation point), what changes is the focus of covert attention

Moran and Desimone, 1985
Other examples of attention-related modulations of neural activity:

1) Parietal ("where") pathway: increased firing to attended stimuli (area 7a), and to remembered locations where stimuli had been present. Also, responses occur to inferred motion.

2) Temporal ("what") pathway: increased firing to attended stimuli (IT) particularly during active discrimination, or to remembered stimuli (working memory)

The prevalence of these effects makes it difficult to distinguish state-dependent (endogenous) and input-driven (exogenous) components of “normal” neuronal responses. Are different cells specialized for each component?
Cellular Basis of Attention

Neuronal responses in IT during a delayed-match-to-sample task.

Task:

Chelazzi et al., Nature 363, 345, 1993
Cellular Basis of Attention

Neuronal responses in IT (20 trial average, smoothed mean firing rate)

Chelazzi et al., Nature 363, 345, 1993
Cellular Basis of Attention

Model

Chelazzi et al., Nature 363, 345, 1993
**Attention and Synchronization**

Steinmetz et al., 2000:

**Task:** Monkeys trained to switch attention between a visual (“dimming detection”) and a tactile (“raised letters”) task.

**Recording:** multiple neurons (neuron pairs) in SII (secondary somatosensory cortex), contralateral to hand involved in tactile task.

**Results:** Most neurons in SII increase firing rate with attention to tactile task. A proportion of neuron pairs (17%) showed increased cross-correlation (synchrony) with attention.
Attention and Synchronization

SII neuron pair:

increased correlations for tactile task over visual and chance
Attention and Synchronization

But are attentional effects on synchronization cell-specific?

Experiments by Fries et al., 2001.

Simultaneous recordings of MUA and LFP, in primate area V4.
Attention and Synchronization

Response histogram, showing stimulus-evoked responses. No clear attentional effects, either during stimulus period or during delay period.
Attention and Synchronization

delay period

Blue: no attention
Red: attention

stimulus period
Two Disorders of Attention

Unilateral neglect

Balint syndrome
Symptoms of Unilateral Neglect

- left hemiparetic arm
- anosagnosia - unawareness / denial of illness.
- rightward gaze deviation
- no obvious hemianopia
- Visual extinction to double simultaneous stimulation (DSS)
- Tactile extinction to DSS
- Constructional apraxia: deficit in constructional and drawing tasks
  - apraxia: disorder of skilled movement
- allesthesia: (gross) mislocalization of stimulation
Unilateral Neglect

- A deficit in perceiving and responding to stimulation on one side.
- Not a visual or motor defect (hemianopia or hemiparesis)!
- Two components: spatial neglect, bodily neglect.
- Typical lesion site: unilateral parietal-occipital junction, (dorsal) parietal cortex (Brodmann's area 7, 40)
- Side opposite to lesioned hemisphere (contralesional side) is affected.
Unilateral Neglect: Lesion Sites

Lesion sites (frontal and parietal) from 7 patients with left-sided neglect

Husain et al., Nature 385, 154, 1997
Unilateral Neglect

Behavioral components of unilateral neglect:

1. **Perceptual** component: sensory events on one side have diminished impact on awareness (extinction).

2. **Motor** component: hemispatial exploratory weakness (manual exploration tasks)

3. **Motivational** (limbic) component: “nothing important is expected to be happening” on the affected side.
Unilateral Neglect

Figure 7  (a) Examiner's model of two flowers depicted either as parts of a single object (above) or as two separate objects (below). (b) Copies by a patient with left unilateral neglect. (From Marshall & Halligan, 1993.)
Unilateral Neglect
Unilateral Neglect
Unilateral Neglect

Eye movements from a patient with left unilateral neglect, during visual exploration
Unilateral Neglect: Frames of Reference

“On the side opposite to”: In what frame of reference does neglect occur (space, object, world)?

How do we define LEFT?

Reference Frame: system for representing locations relative to some standard coordinate system

Neglect affects multiple reference frames
Unilateral Neglect: Frames of Reference

Neglect patient JM’s copying of a daisy presented in different orientations.

Spatial or object-centered?
Bisiach’s patient (unable to recall half of the piazza del duomo) – representations are affected, not just acute visual input (“unilateral neglect of representational space”)
What Causes Unilateral Neglect?

1. Neglect results from damage to the attentional orienting system. Attention is mostly deployed to the right.
2. Neglect is caused by a failure to construct a complete mental representation of contralesional space.
Unilateral Neglect: Patient J.R.

Patient cannot completely cross out local components of global forms (Navon figures)

From Nature, 373, 1995, 521ff
Unilateral Neglect: Patient J.R.

However, patient can adequately describe the figure shown in (a) and mark its corners; patient then cannot cancel all the dots (b); patient can reconstruct figure from memory (c).

From Nature, 373, 1995, 521ff
Unilateral Neglect: Patient J.R.

Patient cannot cancel all imaginary components of a drawn square (a); performance is better without vision (blindfolded) (b).

Note the contrast between exogenously (input) driven and endogenously (memory) driven task!

From Nature, 373, 1995, 521ff
Unilateral Neglect: Patient J.R.

Patient cannot cancel all dots in (a), but can reproduce a circle of dots (driven by an internal global representation) (b). After drawing the circle, again dots cannot be canceled on the left (c).

From Nature, 373, 1995, 521ff
Marshall and Halligan summarize J.R.’s deficit as follows:

“Conscious perception of the whole does not automatically lead to visual awareness of all the parts. [...] J.R. can perceive the whole forest but cannot use that percept to search for and cut down the tress on the left thereof.”
Unilateral Neglect: Summary

• A unilateral attention deficit
• LH- strong right bias; RH- possible bilateral control (can direct left or right)
• Attention operates on representations, neglect can affect multiple representations
• Brain represents space in multiple frames of reference
• Posterior parietal cortex critical for attention
Balint Syndrome

Main component: visual disorientation (simultanagnosia). Inability to attend to more than a very limited (and unstable) sector of the visual field (a single object) at any given moment (the rest is “out of focus”). Percept of a spatially coherent scene is lost.

Lesion: Most often, bilateral occipito-parietal lesions