Attention: Behavioral studies and overview


William James (1890)

“Everyone knows what attention is. It is the taking possession by the mind in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought....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.”

Limited capacity

"Selection takes place in order to protect a mechanism of limited capacity" (Broadbent, 1971)

"If the brain had infinite capacity for information processing, there would be little need for attentional mechanisms" (Mesulam, 1985)

- Broadbent: limit in semantic categorization / identification
  - attenuation of non-selected information
- Posner: consciousness

What is attention for?

- Traditional account
  - “selection” due to system limitations
- Allport's answer(s)
  - Constraints on “behavioral coherence”
  - Perceptual-motor control
  - Emphasis on diversity of attentional functions
Early vs. late selection

- Is "bottleneck" before or after categorization/recognition?
- Tacitly assumes series of stages
  - early one is sensitive to spatial locations/relationships
  - later one involves (spatially invariant) "recognition"
- Staged assumption hard to reconcile with neurophysiology
  - parallel "what" vs. "where" pathways
  - spatial information is relevant throughout processing
  - top-down influences on "lower-level" processing (e.g., figure-ground)

Controlled vs. automatic processes

- Access to shared "central controller" (Shiffrin & Schneider, 1977)
  - Controlled processes require attention (slow, effortful, conscious)
  - Automatic processes do not (fast, parallel, unconscious)
  - False dichotomy (Ryan, 1983) except, perhaps, "load dependency"
- Stroop
  - reading interferes with color naming
  - but color naming interferes with novel shape naming (MacLeod)
- Multiple Resources?
  - unconstrained ("resource" as theoretical soupstone; Navon, 1984)

Dual-task performance

Shafer (1975)

Reading aloud (visual-vocal) + audio typing (auditory-manual)
  - Strong interference
Copy typing (visual-manual) + speech shadowing (auditory-vocal)
  - No interference

Feature Integration Theory (Treisman)

- Load dependency (increase in RT with increasing number of items)
  - elementary features processed in parallel
  - conjunctions processed sequentially (need attention)
- Allport: useful, but not a general account of attentional phenomena
Attention network

- posterior parietal cortex (spatial representations)
- frontal eye fields (eye movement planning)
- posterior cingulate cortex (effort)
- thalamic nuclei (shifts of attention)
- basal ganglia (motor responses)
- superior colliculus (eye movements)
- midbrain reticular formation (arousal)

Posner: disengage, switch, engage

Attentional modulation of neural activity

- Spatially selective enhancement effect (SSEE)
  - Priority assignment for potential control of action
- Not much evidence for inhibition of non-attended stimuli
  - Doesn't look like selection
- Inhibition does operate over actions
  - Inhibition of return

Neuropsychology: Hemispatial neglect

- Damage to right posterior parietal cortex (usually)
- Ignore contralesional region of space
  - fail to dress/shave/eat on left
  - fail to orient or respond to stimuli in "bad" field
  - impairment of actions into contralesional space
- Influenced by various types of knowledge
  - modulated by objects (e.g., groupings, words)
  - affects internal representations (imagery)
  - mixture of reference frames (retinotopic, body-centered, allocentric)

Attention as selection for action

- Effective action must be directed toward one (or a very few) objects in the world
- Properties of relevant objects must determine action parameters
- Properties of irrelevant objects must not interfere
Constraints on attentional system

- Unpredictability and time constraints
- Multiple goals
- Multi-functional systems
- Behavioral coherence (coordination)
- Maintaining vs. shifting attentional engagement
  - exogenous vs. endogenous control
- Neural implementation

Biased competition (Desimone & Duncan)

- Visual objects compete for representation, analysis, control
- Competition is biased toward information that is currently relevant to behavior

"attention is an emergent property of many neural mechanisms working to resolve competition for visual processing and control of behavior."

Experimental paradigms

- Probe reaction times (RTs)
- Overlapping tasks
- Priming, categorical encoding, and selective response
- Spatial selection and interference
- Non-spatial selection and negative priming
- (Object-based attention)

Neural basis for competition

- Separation of (ventral) "what" and (dorsal) "where" pathways
  - creates "binding problem"
  - can be solved by simultaneity, but at the cost of multiplicity
- Objects compete to be represented in the ventral pathways
  - "receptive fields [in the ventral pathway] can be viewed as a critical visual processing resource, for which objects in the visual field must compete"
- Object positions compete to be represented in the dorsal pathway
  - "what" and "where" competitions must constrain each other to stay consistent
- Actions compete for (behavioral) control
Top-down control (bias)

"Some kind of short-term description of the information currently needed must be used to control competitive bias in the visual system, such that inputs matching that description are favored in the visual cortex"

- Mediated by prefrontal cortex
  - locations: dorsal prefrontal
  - object features: ventral prefrontal

- Operates by influencing competition with attentional network (dorsal) and object descriptions (ventral)

Biased competition theory

1. At several points between input and response, objects in the visual field compete for limited processing capacity and control of behavior.

2. This competition is biased in part by bottom-up neural mechanisms that separate figures from their background (in both space and time) and in part by top-down mechanisms that select objects of relevance to current behavior. Such bias can be controlled by many stimulus attributes, including selection by spatial location, by simple object features, and by complex conjunctions of features.

3. Within the ventral stream, top-down biasing inputs resolve competition mainly between objects located within the same receptive field. These mechanisms may work in a similar fashion for both object and spatial selection.

4. Because many spatially mapped structures contribute to competition, unilateral lesions will often cause neglect and extinction syndromes that do not necessarily imply a specific role in attentional control.

5. The top-down selection templates for both locations and objects are probably derived from neural circuits mediating working memory, perhaps especially in prefrontal cortex.

6. Objects act as wholes in neural competition. The construction of object representations from the conjunction of many different features appears, in many cases, to occur in parallel across the visual field before individual objects are selected and, hence, prior to any attentional binding.

7. Attention is not a high-speed mental spotlight that scans each item in the visual field. Rather, attention is an emergent property of slow, competitive interactions that work in parallel across the visual field.