What is the role of visual attention?

Old view: Attention “welds” preattentive features into more complex structures. The accumulation of these structures is then the basis for visual perception

But: 1) A lot of the “welding” is already done at the preattentive (rapid) level
2) If structures accumulate, why can we fail to see large changes (change blindness)?
Intuition: *Accumulation of information*
So why should change blindness exist?

Proposal: Attention is needed to perceive change in an object.

Under normal circumstances, a change creates a motion transient, which draws attention. When change is made same time as another event, transients interfere with drawing of attention, causing change to become “invisible”.

How does attention enable change perception?

Recap: Initial stages of visual processing

1. Transduction stage (light to pixels) - minimal interactions
2. Primary processing (pixels to edges) - local inhibition/excitation
3. Secondary processing (proto-objects) - local grouping/interpretation
Coherence theory

1. Without attention, proto-objects are volatile, i.e., have limited coherence in space and time. Thus, they are replaced by any new stimuli.

Coherence theory—(cont’d):

2. Focused attention acts as a metaphorical hand that “grabs” selected proto-objects and makes them coherent across time as well as space. As such, they maintain an identity, and thus can be perceived to change.
Coherence theory— (cont’d):

3

Once attention is released, objects “dissolve” back into proto-objects

- There is no buildup of information after attention is withdrawn from items (see also Wolfe, 1999)
Exploring Attentional Mechanisms

Can use experimental techniques and theories to explore the nature of visual attention

Example: Use them to explore aspects like:

- **capacity** — how many items are “held” at a time?
- **speed** — how fast are attended objects formed?
- **coding** — what are the “primitives” of attention?
- **guidance** — what attracts visual attention?
Attentional Capacity

**Approach: Visual Search for Change**
- use images that change back and forth in time, like the scene examples
- **but** images that are much simpler in content
  - can control the number of items, the type of change, etc.

**Visual Search for Change** (Rensink, 2000c)
- on half the trials, one of the items changes (target)
- observer must report if change present or absent

[Diagram of Visual Search for Change process]

Focused attention holds onto item, allowing change to be seen
Measure: Reaction time (RT) vs. set size

RT is a linear function of number of items

\[ \text{search slope} = \frac{\Delta \text{reaction time}}{\Delta \text{# of items}} \]

Determination of attentional capacity:

The number of items held by attention across a gap

\[ \text{hold} = \frac{\text{alternation rate}}{\text{search rate}} \]

To determine capacity (maximum hold):

1. Find search speeds for **various display times**
   - the longer the display, the more items held
   - loading will eventually **saturate**
2. **Asymptotic value of hold = attentional capacity**
Results: Search for presence of change (orientation)
(task: look for horizontal items changing to vertical)

![Graph showing the relationship between display time (ms) and number of items changing. The graph shows a constant rate of 110 ms/item and an asymptote of 5.5 items.]

Visual Search for Absence of Change
-on half the trials, one of the items doesn't change (target)
-observer reports if a nonchange is present or absent

![Diagram illustrating the visual search for absence of change. Displays alternate until the observer responds. Focused attention holds onto an item, allowing change to be seen.]

**Results:** Search for **absence of change (orientation)**
(task: look for items that remain horizontal or vertical)

- **Asymptote:** 1.4 items

- **Constant rate:** 320 ms / item

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Search for **presence of change (orientation)**
- capacity is ~ 5 items
- similar to limits found via other techniques
  (e.g. item tracking)

Search for **absence of change (orientation)**
- capacity is ~ 1 item

**Why?**
**Hypothesis:** Attention pools information from 4-5 links into a single *nexus*

(a) Searching for presence of change

If change present, nexus value = 1
If change absent, nexus value = 0

Thus, present vs absent is 1 vs 0 — strong signal

(b) Searching for absence of change

If nonchange present, nexus value = 4
If nonchange absent, nexus value = 5

Thus, present vs absent is 4 vs 5 — weak signal
(b) Searching for absence of change

If nonchange present, nexus value = 1
If nonchange absent, nexus value = 0

Present vs absent is 1 vs 0 — strong signal

Note: Limitation is not just in comparison operation

If several items in memory, could check them all:

But for absence of change, capacity is only 1...

Thus, attended items (items in memory) are not independent — linked via nexus
All attended items form a single integrated structure
- coherence field\textsuperscript{a} (Rensink, 2002)

Places severe limits on what can be seen in a dynamic display

-> If attended items are part of a single field, may not be possible to keep changing items separate.

May only be able to see one change at a time

\textsuperscript{a}Sequence contains a simultaneous change

\textsuperscript{b}Sequence contains no simultaneous changes

Observer asked to report if sequence contains a simultaneous change
Thus, observers have difficulty distinguishing one change from two changes.

- Observers cannot see more than one change at a time
- All attended items are linked together in some way
  - pooled into a single *nexus*
  - form a single *coherence field*
Summary

**Attention loads up over time**
loading rate = 8 items/sec

**Attention has a capacity of 5 items**
- similar to other estimates of attentional capacity
- demonstrates that visual detail is not built up
  - otherwise, capacity estimate would be unlimited

**Only one object can be attended at a time**
- info can be collected from up to 5 items
- pooled into a single attentional nexus
- these then form parts of a single coherence field

Implications for Display Design

1. **Rapid Pickup of Information**

   → maximum amount of information that can be picked up at any instant is from 4-5 items
     - only a small amount from each item

   → can use flicker paradigm to find the basic units of visual attention.
     - units = properties which have capacity of 4-5
     - items that are compounds will take longer to see

   → switches to new (coherent) objects should be minimized
     - each switch can take c. 300 ms
2. Conveying Information via Dynamic Means

→ No attentional distraction from other parts of display
  - would create change blindness

→ Keep important sources of information together
  - minimize eye movements -> less change blindness

→ Only one dynamic information source at a time
  - can’t separate two simultaneous changes

→ Only a limited amount of information can be conveyed
  - perception of dynamic patterns requires attention, and
    attention is severely limited in capacity.
  (e.g. blindness to more than one movement parameter)