ASSC 4, Brussels, Belgium

Change Detection, Attention, and the Contents of Awareness

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- Part 1: **Intentional** detection of change (Rensink)
- Part 2: **Incidental** detection / attn capture (Simons)
- Part 3: New findings and new issues (everyone)

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Part 1: Intentional Search for Change

- **Change blindness**
  - basic phenomenon
- **Representation of scenes**
  - virtual representation
- **Attentional system**
  - attentional capacity; binding problem
- **Nonattentional systems**
  - implicit perception of change

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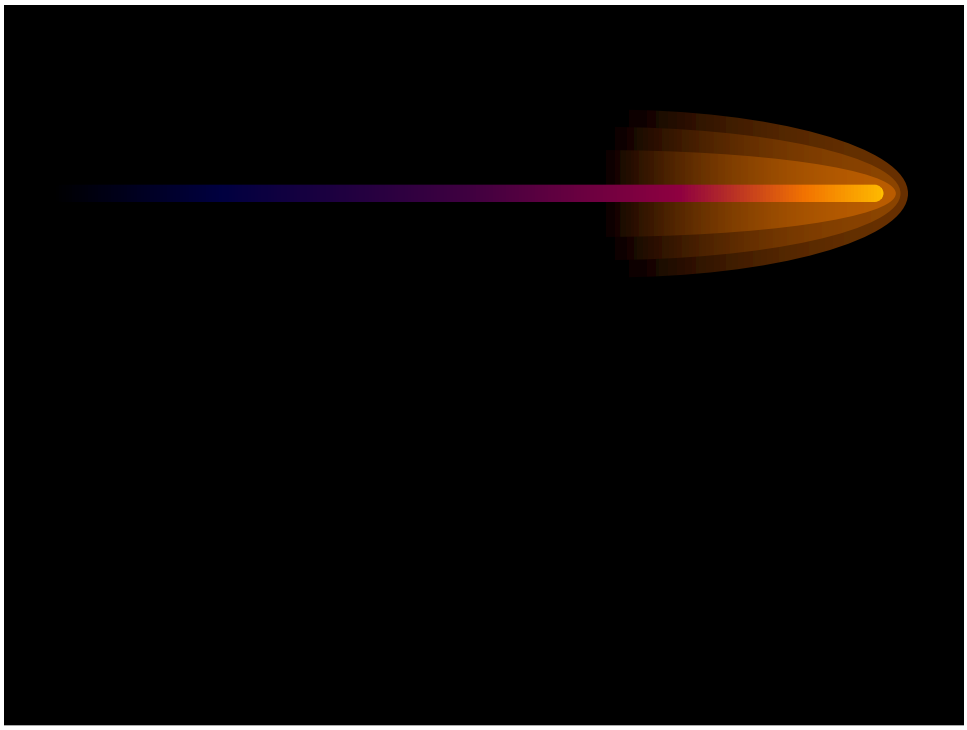

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1. Change Blindness

1.0 How Do People See Scenes?

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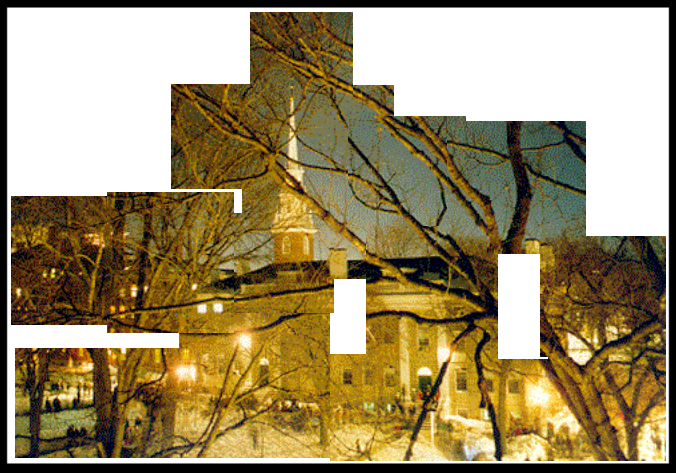
Visual buffer: accumulates information



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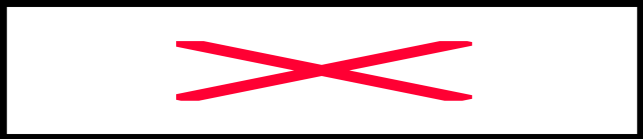
Question:

How is this accumulation implemented?

Suggestions:

- shift retinal contents (e.g., Trehub, 1991)
- data fusion (e.g., Clark & Yuille, 1990)



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1.1. Looking Again at the Basic Assumptions

Questi

Hov **cumulated?**

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Why believe we accumulate detailed information?
- always seems easy to notice changes...

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But is this always true?

Make change during brief blank interval between original and changed images

(flicker paradigm - Rensink et al., 1997)

Demo

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This is known as change blindness

- induced for changes simultaneous with:

- image flicker (e.g., Rensink et al., 1995, 1997)
- saccades (e.g., Grimes, 1996; Henderson, 1997)
- eyeblinks (O'Regan, Deubel, et al., 1999)
- "splats" not on change (Rensink et al., 2000)
- movie cuts (Levin & Simons, 1997)
- real-world interruptions (Simons & Levin, 1998)

Proposal: All these have the same cause

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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 other event, transients interfere with drawing of attention, causing change to become “invisible”.

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1.2 Coherence Theory

Background assumptions

- Complex pre-attentive structures (**proto-objects**) are formed rapidly across the visual field.
  - 3D slant (Enns & Rensink, 1991)
  - object completion (Rensink & Enns, 1998)
- These are what attention has rapid access to, **not image properties**.
  - lower-level structures (pixels, etc.) are **pre-empted** by higher-level structures. (Rensink & Enns, 1995, 1998)

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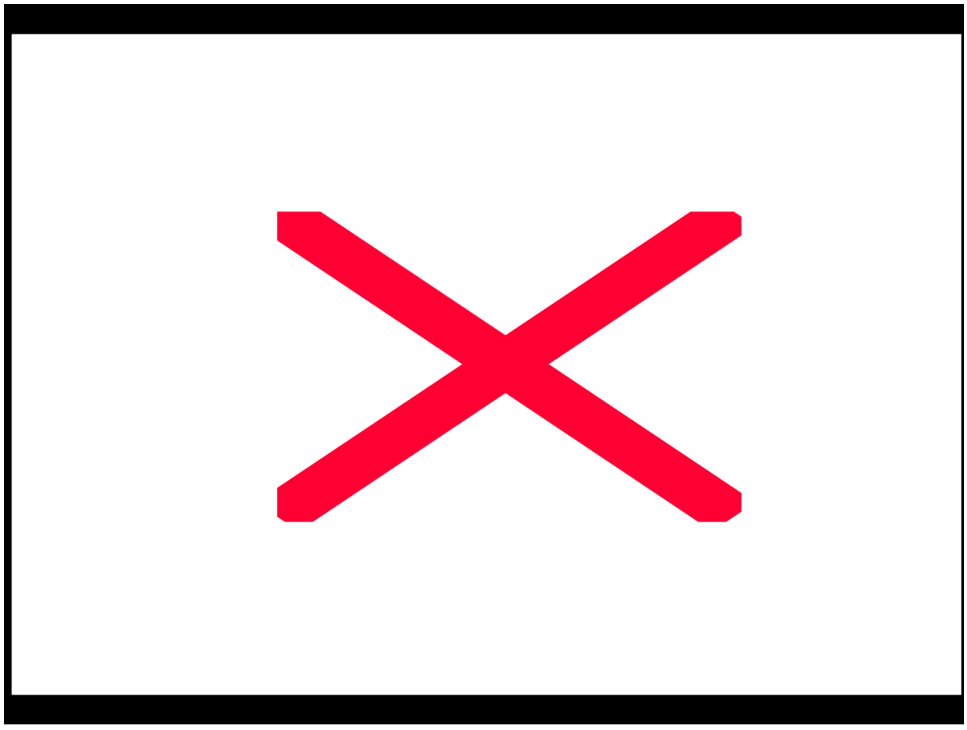

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Proposal – Coherence theory

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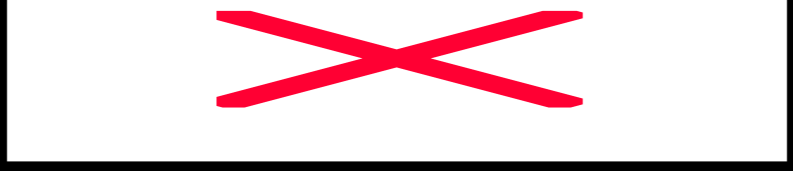

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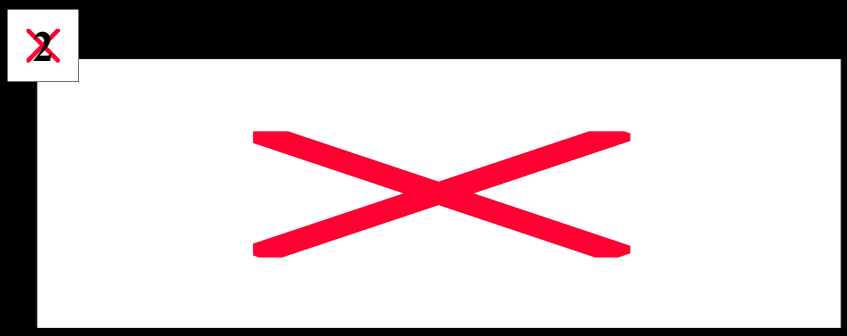
Coherence theory— (cont'd):



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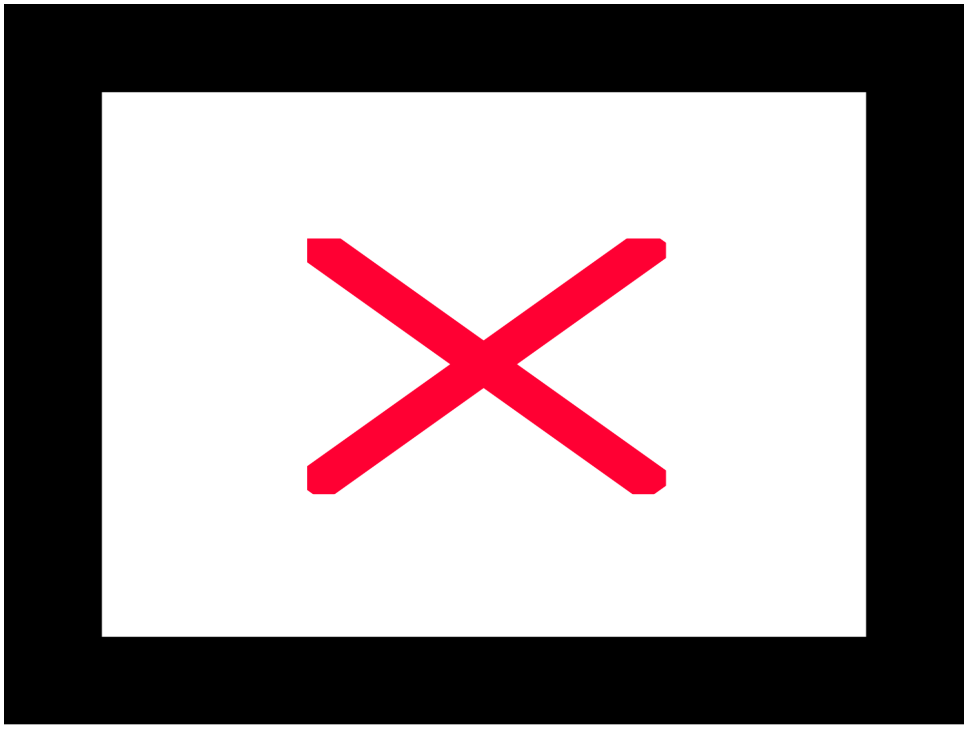

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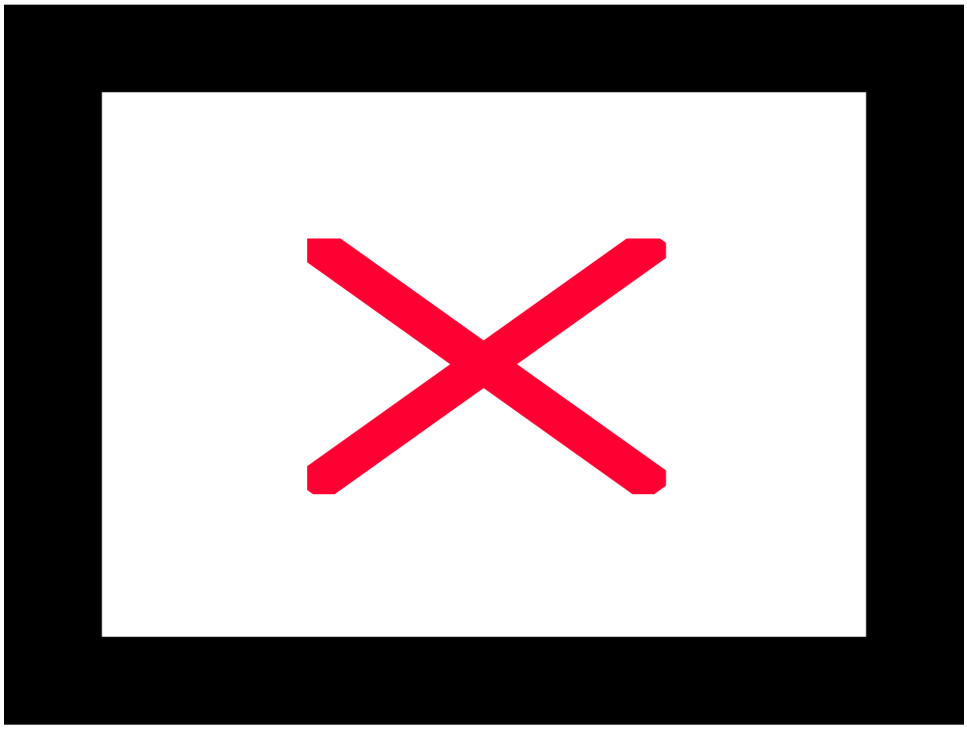

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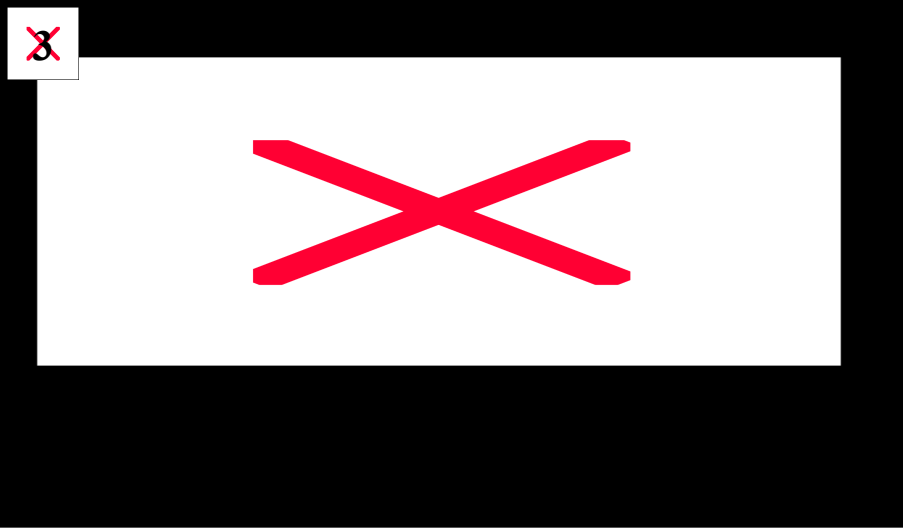
Coherence theory— (cont'd):



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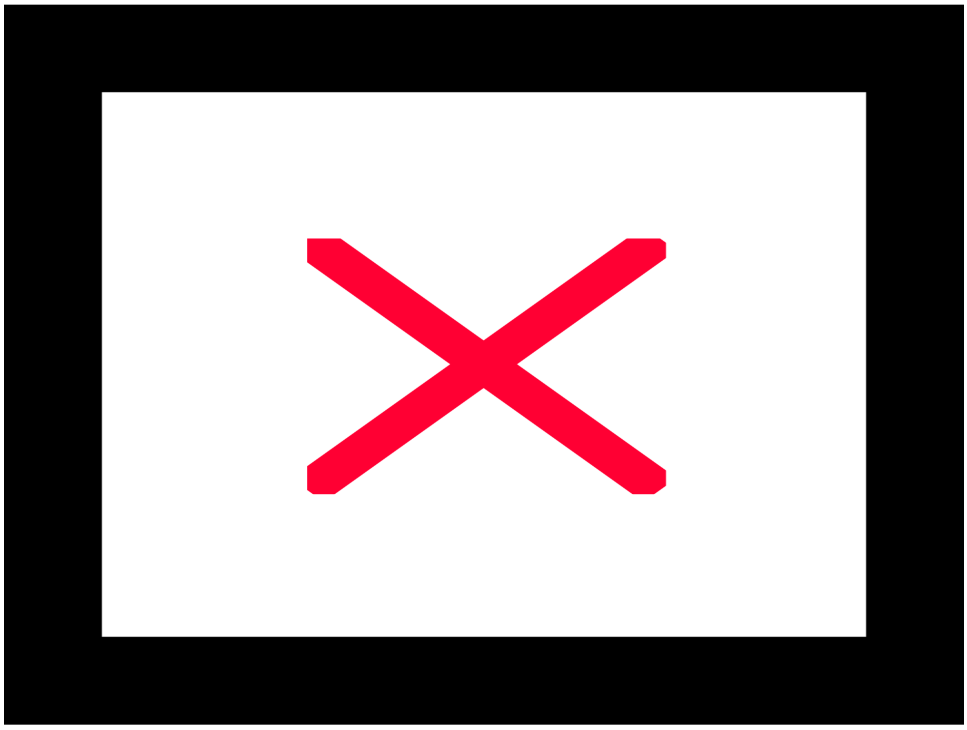

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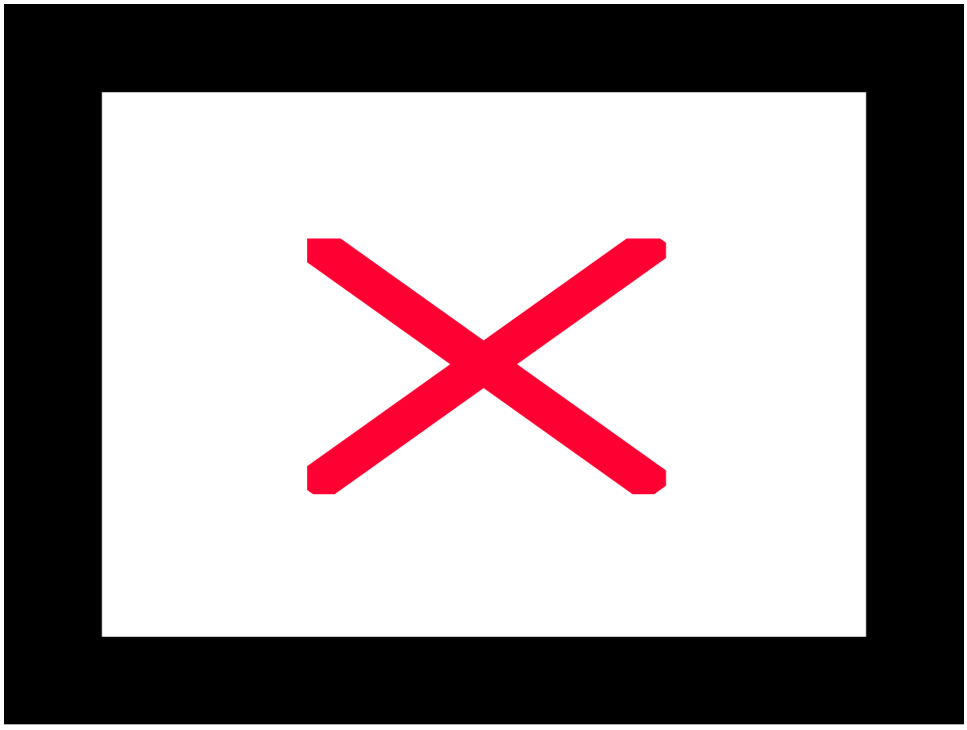

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Important points (Section 1)

- Attention is needed to see change.
  - otherwise, **change blindness** results
- Unattended proto-objects are volatile, but still provide context for interpreting attended objects.
  - **low-level** representation isn't sparse
  - only **stable** representations are sparse.

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2. Seeing

2.0 Implications for scene perception

Older view: scene perception carried out by a sequence of operations:

pixels > edges > regions > objects > scenes > …

-> Build up a complete description of scene

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However...

Change blindness shows that we can only integrate what we attend to

And we can't attend to much

Thus, can't form representations that are both detailed **and** complete.

-> **have coherent representation of only a few objects at any moment**

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If only a few object representations exist
at any given instant...

Why do we have the impression of perceiving lots of coherent objects simultaneously?

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2.1 Virtual Representation (Rensink, 2000)

Observation:

- Although objects are simultaneously present, do not need to be simultaneously **represented**
- All that is needed is that the properties of each object can be **accessed when requested.**

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This is **virtual representation**
- coherent representations
are formed "just in time"

If co-ordination is successful, it will appear to higher levels as if representation is "real", i.e., as if all items present simultaneously.

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Can this work for the visual system? **Yes!!**

-can always **obtain information from the world**
- use the world itself as a memory
(Stroud, 1955; Brooks, 1988)

-to build a coherent representation of an object, focus eyes and attention on appropriate location whenever that object is needed

-only 1-2 independent objects needed for a task at any given time

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Note 1:

-although world is an **external memory**, it is **not an external representation** (as proposed by Brooks, 1988; Noë et al, 2000)

- representations needed at early levels for various purposes

- e.g., compensating for object occlusion

- linking together elements in the image that are related in the scene

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Note 2:

- using the world as an external memory means that **perception is not carried out in isolation** in the perceiver—rather, the perceiver and environment form a **partnership**.

- environment can act not only as **external memory** but as an **external processor**
  - embedded cognition (see Clark, 1997).

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2.2 Triadic Architecture (Rensink, 2000)

Question:

How might a virtual representation be implemented in the human visual system?

Need to do this in a way that is compatible with what is known about the visual system.

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- **Nonattentional** extraction of aspects of scene (I):
  - **Gist**: abstract meaning of scene (farm, harbor, etc.)
    - obtained within 200 ms (Biederman, 1974)
    - obtained without attention (Oliva & Schyns, 1997)

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- **Nonattentional** extraction of aspects of scene (I):
  - **Gist**: abstract meaning of scene (farm, harbor, etc.)
    - obtained within 200 ms (Biederman, 1974)
    - obtained without attention (Oliva & Schyns, 1997)
  - Possibly derived via statistics of low-level structures (e.g. Swain & Ballard, 1991; Oliva & Torralba, 2000)

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- **Nonattentional** extraction of aspects of scene (II):
  - **layout**: arrangement of items in the scene.
    - nonvolatile (Simons, 1996; Sanocki & Epstein, 1997)
    - can be learned without attention (Chun & Jiang, 1998)

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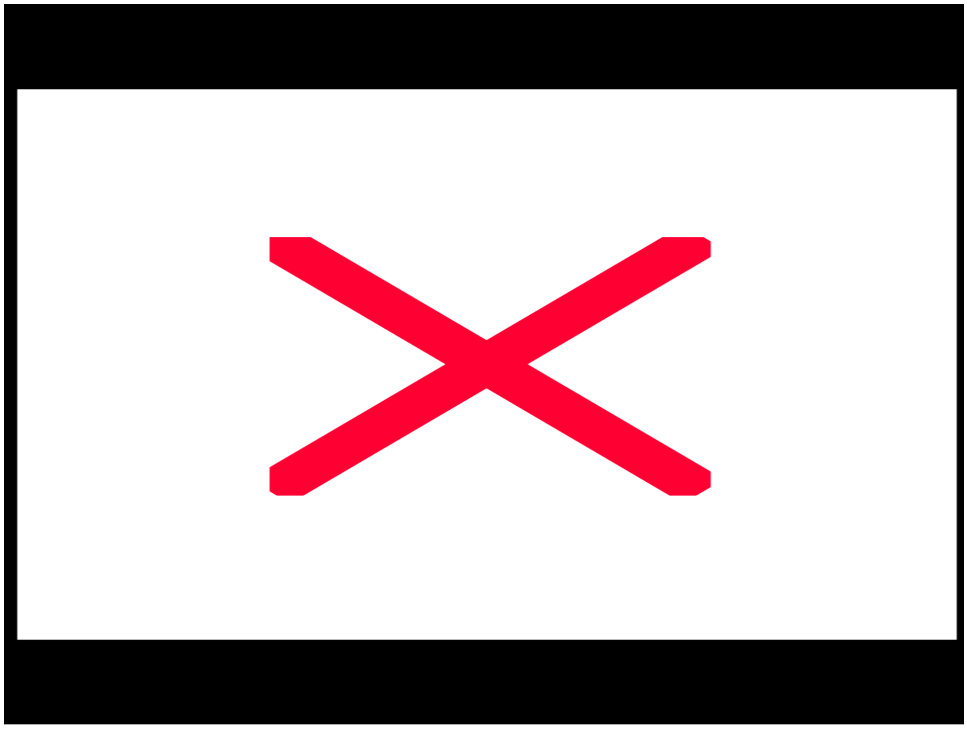

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Important Points (Part 2)

- Our impression that many coherent objects are represented simultaneously is only an impression.
  - scenes represented via **virtual representation**
- **Attention not a central processing "gateway"**
  - stream specialized for **coherent objects**

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3. Visual Attention

Change blindness is not just an interesting effect in its own right.

Can use the experimental techniques and theoretical structure to find out more about **attention itself**.

- **capacity** — how many items are "held" at a time?
- **speed** — how fast are attended objects formed?
- **selectivity** — how well can properties be selected?

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Approach: Visual Search for Change

Visual Search:

- display is an array of identical items (distractors)
- on half the trials, one of the items differs (target)
- observer must report if target present or absent

target absent

target present

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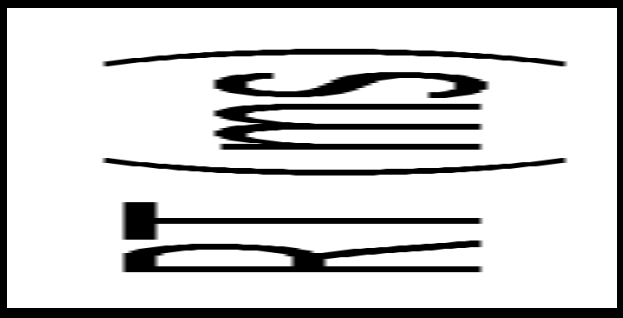
Measure: Reaction time (RT) vs. set size

RT often a linear function of number of items



search slope = Δ (reaction time) / Δ (# of items)

target-absent slope usually 2x target-present slope
-> **serial, self-terminating search**

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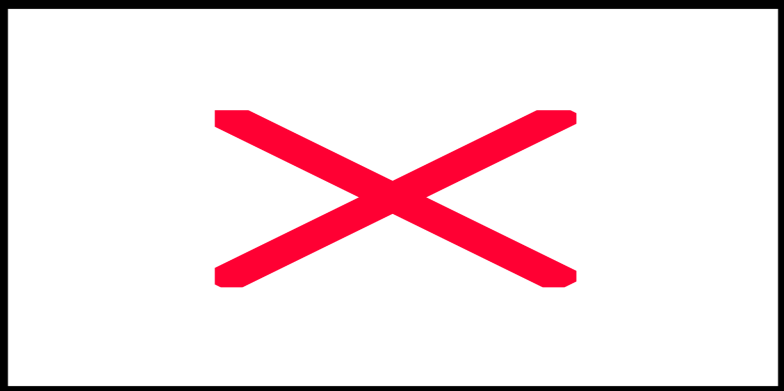
Visual search for change (Rensink, 1998, 2000)

- display is an array of flickering non-changing items
- on half the trials, one of the items changes (target)
- observer must report if target present or absent



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Example: To determine attentional capacity

- if only 1 item held by attention,
  search slope = alternation time

- if 10 items held by attention,
  search slope = alternation time / 10

- more generally, if n items held by attention,
  search slope = alternation time / n

items held = alternation time / search slope

Capacity = maximum number of items held

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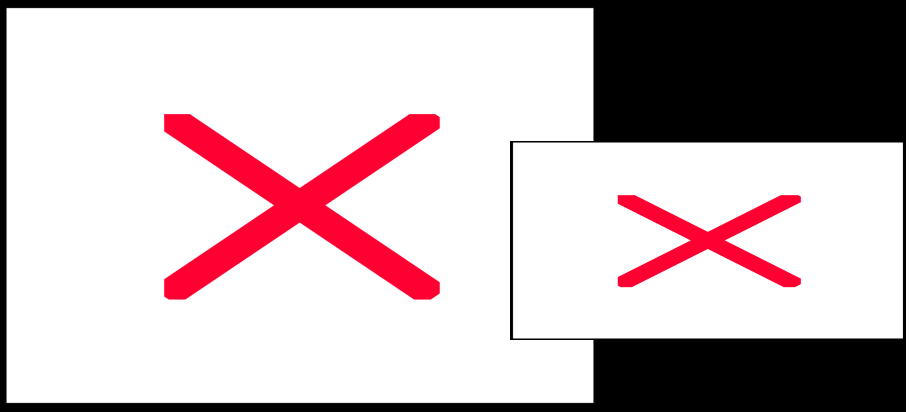
*Results: Search for orientation **change***
(changing target, nonchanging distractors)



Focused attention can hold on to ≤ 5.5 items

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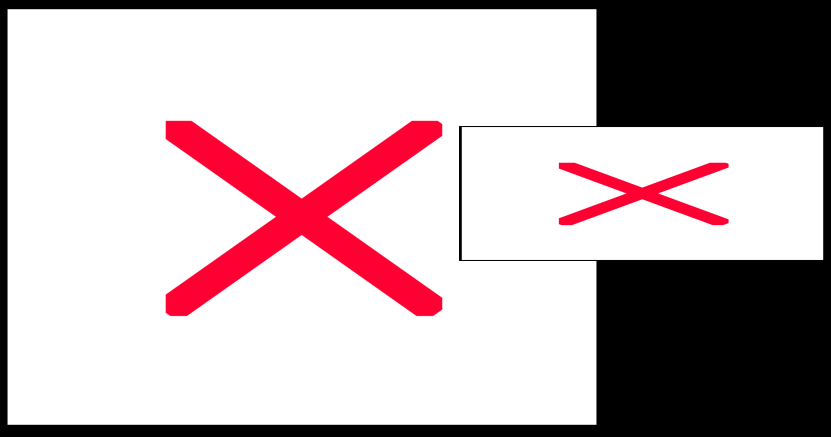
Dependence on ISI (Rensink et al., 2000)



Focused attention can hold on to 4 items

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Results:

- Attention loads up over time
  - loading rate = 8 items/sec
- Attention has a capacity of about 4 items
  - similar to other estimates of attentional capacity
- Demonstrates that visual detail is not built up
  - otherwise, capacity estimate would be unlimited

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What about search for <u>absence</u> of change?

- targets remain constant
- nontargets continually changing orientation

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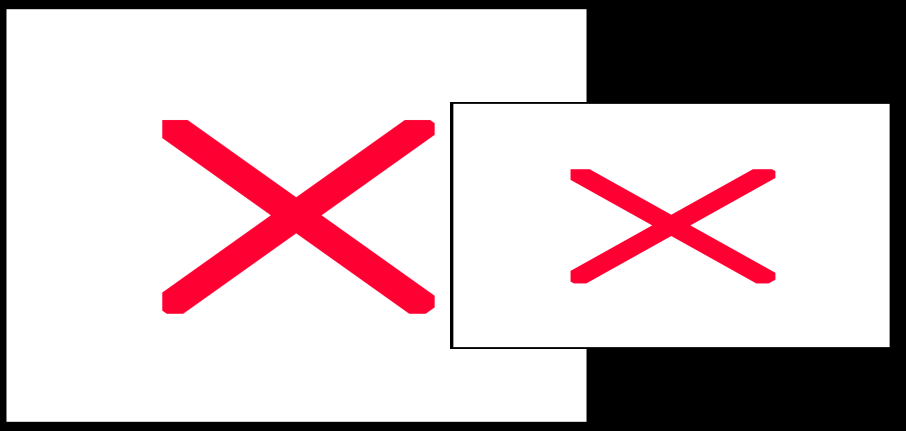
*Results: Search for **absence of change***
(non-changing target, changing distractors)



Focused attention can hold on to only 1 item

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Why is there a search asymmetry?

Reminiscent of asymmetry in "classic" visual search
- detecting presence of feature (change)
is much easier that detecting absence

Asymmetry explained via **pooling** of signal
over image (Treisman & Gormican, 1985)

- detecting presence: 1 vs 0
- detecting absence: n vs n-1

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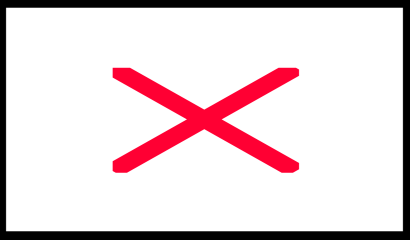
Hypothesis: *Information from 4-5 links pooled into a* ***single nexus***

(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

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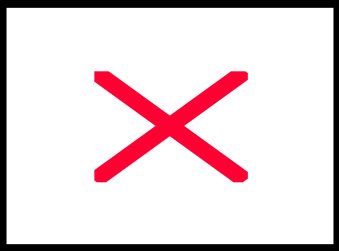
(b) Searching for absence of change



If nonchange present, nexus value = 4

If nonchange absent, nexus value = 5

Thus, present vs absent is 4 vs 5 — weak signal
-check links one at a time to get strong signal

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What about search for <u>conjunction</u> of change?

- nontargets continually change on **<u>one</u>** dimension (orientation **<u>or</u>** contrast sign)
- target continually changes on both dimensions (orientation **<u>and</u>** contrast sign)

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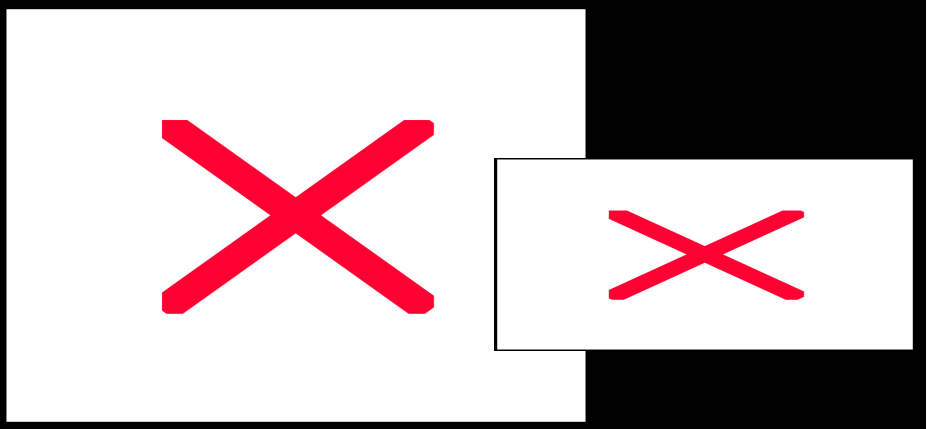
*Results: Search for **conjunction of change***
*(target changes in orientation **and** contrast)*



Focused attention can hold on to only 1 item

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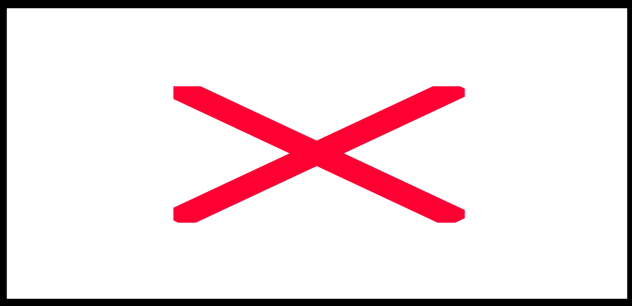
Binding of attended items is incomplete:



Information from each item is not held separately—features are pooled into nexus

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Binding problem: how to correctly assign visual properties to different objects

- if only one object represented at a time, no problem with assignment of properties

-> **If only one collection point (nexus), all attended properties assigned to that object**
- further distinctions (e.g. binding of parts) inaccessible to higher levels

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Binding problem becomes irrelevant
(cf. problem of integrating saccades)

- only appears that than one object is represented simultaneously

Problem becomes one of gating:
- when to allow which properties into the coherence field?

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Important points (Section 3)

- Only one nexus (object) can be attended at a time; inputs funnelled in from 4 links (parts).
- Binding problem may be largely irrelevant.
  In its place is the **gating problem**:
  - which items/properties to put into coherence field?

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4. Nonattentional Streams

Virtual representation implies an important role for **nonattentional streams** in vision

These streams not primarily concerned with explicit perception of change (coherence theory)

-> Mapped out via **implicit** detection of change?

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4.1 Implicit Detection of change — visuomotor

- Bridgeman et al. (1975) — **oculomotor response**
  - target moves while observer saccades to it
  - eye makes corrective saccade, even though observers have no explicit perception of change
- Goodale et al. (1986) — **manual pointing**
  - target moves while observer saccades to it
  - hand reaching towards target corrects its trajectory, even though observers have no explicit perception of change

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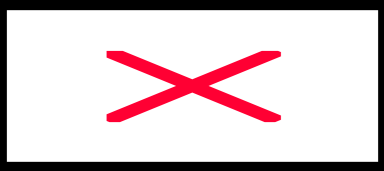
4.2 Implicit Detection of change — perceptual

- Fernandez-Duque & Thornton (2000)
  - observers view 2-display sequence; each display is a simple array of rectangles
  - observers tested on two items: the item changed, and the item diagonally across from it



  - If observer did not notice change, asked to **guess which item changed**.

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Results

- Observers could guess **better than chance** (55-63%) even though change was not consciously noticed
  - (a form of blindsight in normal observers)
  - ➞ **involvement of limited-capacity system**
- No attentional priming at location of unnoticed change
  - ➞ **involvement of purely nonattentional system**

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4.3. Visual awareness without visual experience

Origin - spontaneous reports by observers in original flicker experiments that they were **aware** of the change long before they **visually experienced** it.

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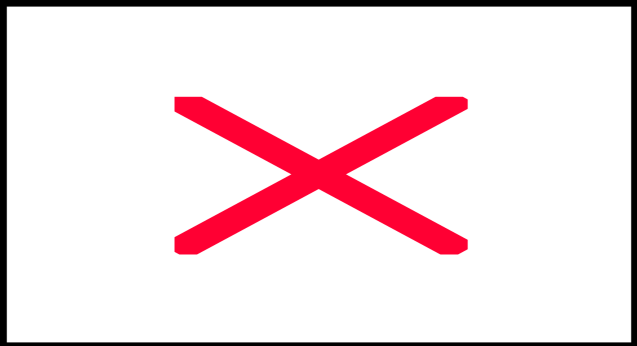
- Rensink (1998, 2000)
  - observers view continuous flicker sequence (natural images)
  - asked to hit button (t1) when change was **felt**
  - then hit button (t2) when change was **seen**



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Results

- 1/2 of observers had no feeling of change without visual experience of it
- 1/4 of observers could feel a change before seeing it
  - (t2-t1) > 1 second on 20% of trials
  - average duration = 3.7 seconds
    - increases to 8.1 seconds if color field used
- not a result of guessing:
  - accuracy on catch trials is good (82%)

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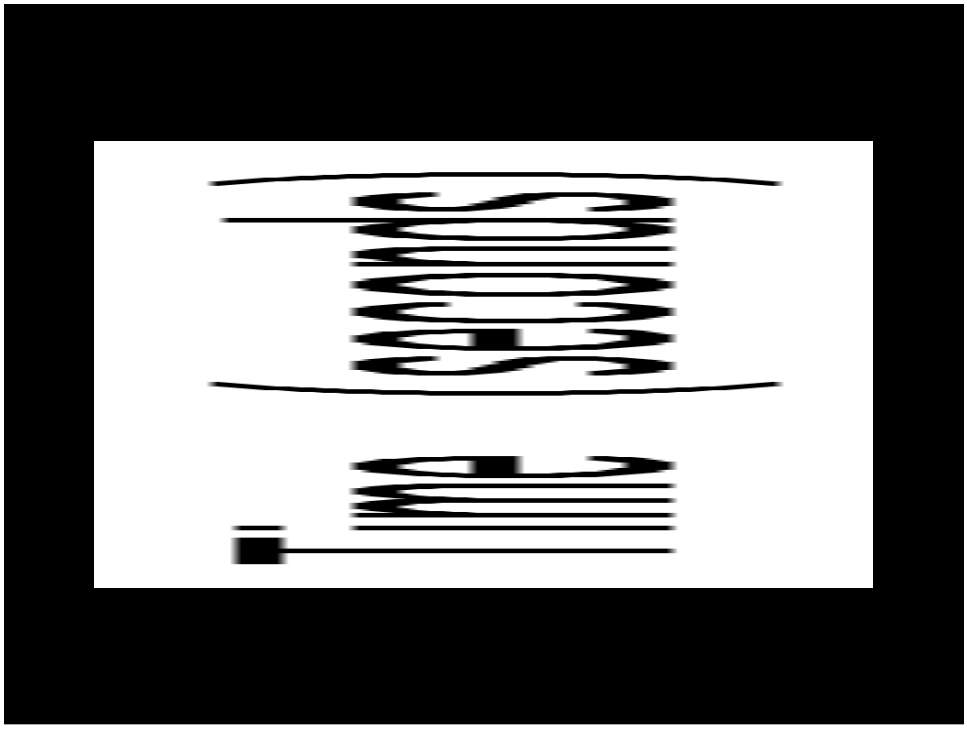

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Not a "weakened" form of seeing:

- response times for sensing are **later** than for seeing
- behavior different for different kinds of change:
  - RTs for color changes exactly the same
  - RTs for location changes are 3.5 seconds later for sensing ($p < .005$)

Mindsight: Conscious (mental) awareness without an accompanying visual experience

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Possible Explanation

- Mindsight observers have no attentional problems
  - responses generally as fast as for other observers

Mindsight due to nonattentional system (alert?)
-observers experiencing mindsight take longer to disengage from it?

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Important points (Section 4)

- There exists a limited ability to detect change by **nonattentional perceptual** systems
- Detection of change is **nonexperiential**:
  - no conscious awareness at all (cf. blindsight)
  - aware, but no visual experience (mindsight)

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Summing Up…

- **Change blindness**
  - attention needed to see change
- **Representation of scenes**
  - virtual representation (based on nonattentional systems)
- **Attentional system**
  - 4 links pooling into 1 nexus; binding problem avoided
- **Nonattentional systems**
  - implicit perception of change; mindsight

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