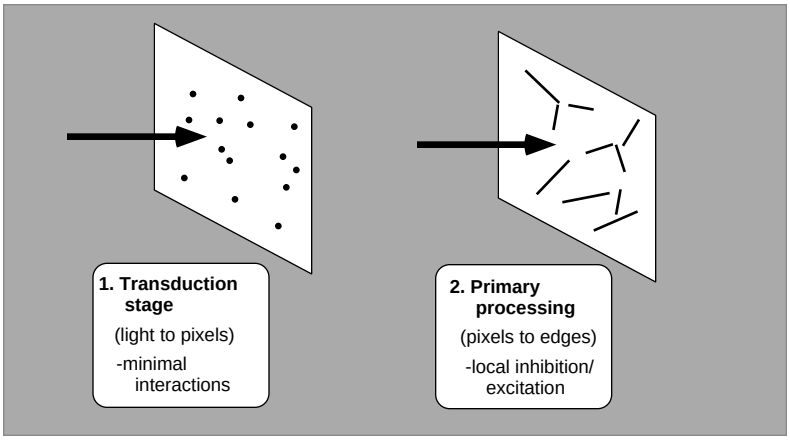
CPSC 532E — Lecture 2

Preattentive Vision II

- Guidance of visual search by attentional selection
- Complex preattentive properties that make detection easier
- Complex preattentive properties that make detection harder

Preattentive (Rapid) Vision

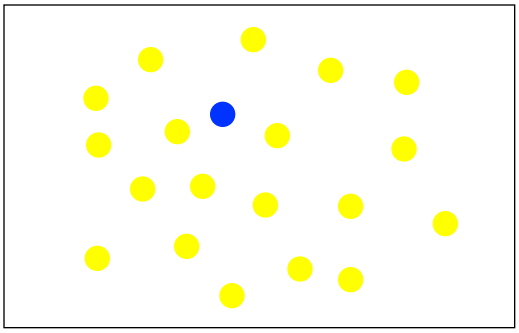
Initial stages of visual processing



"Visual primitives" formed rapidly and in parallel

Implication for the perception of displays:

- a unique feature automatically draws attention

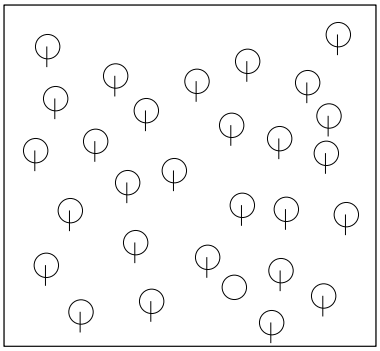


Easy to see when many other items around

Important note

The presence of an item containing a unique feature is easy to see

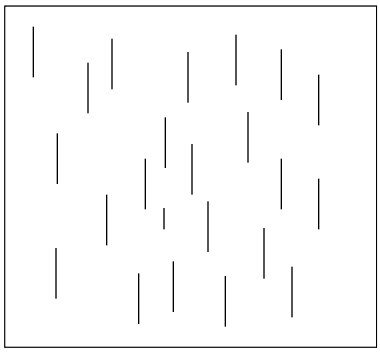
The absence of an item containing a unique feature is difficult…



Search asymmetry

For quantities (e.g. length, area, intensity)

An item containing a unique larger value is easier to see than an item containing a unique smaller value



Search asymmetry

In both cases, search speed is determined by the signal-to-noise ratio:

Feature presence: 1 (target has it) vs 0 (others don't) SNR = ∞

Feature absence: n-1 (target doesn't have it) vs n (others do) SNR = 1 - 1/n

In both cases, search speed is determined by the signal-to-noise ratio:

High-value target: 1 (target has a lot) vs n x .5 (others don't) — SNR = 1 + 1/n

Low-value target : .5 (target doesn't have much) vs n (others do) — SNR = 1 - 1/(2n)

Interpretation (Treisman & Gormican, 1988):

Rapid search:

- Visual primitives calculated in absence of attention
  (-> "pre-attentive features")
- Unique preattentive feature draws attention

Slow search:

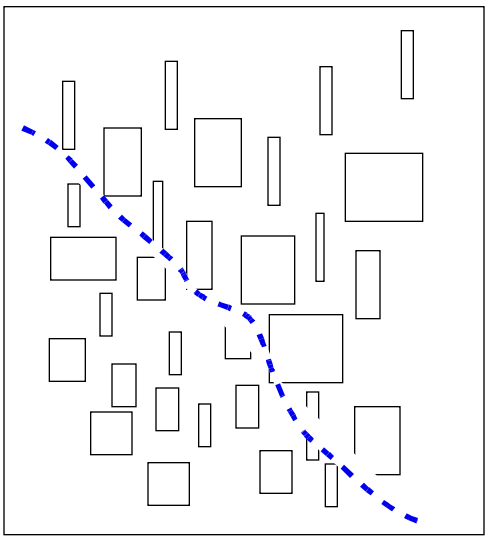
- Combination (conjunction) of pre-attentive features requires a **spotlight of attention**
- this "welds" together these visual primitives at a rate of c. 30 ms/item

(-> spatial relationships cannot be seen rapidly)

What about combinations of features generally?

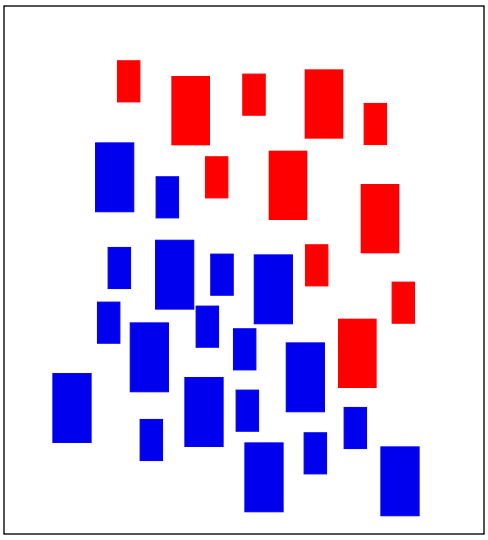
Integral features:

- operate as a unified complex
- cannot pay attention to each separately
  - if there is a variation in one, it affects the perception of the other
- e.g., width & height of a rectangle



Separable features:

- operate as separate channels
- can pay attention to each separately
  - if there is a variation in one, it does not affect the perception of the other
- e.g., color & size of a rectangle

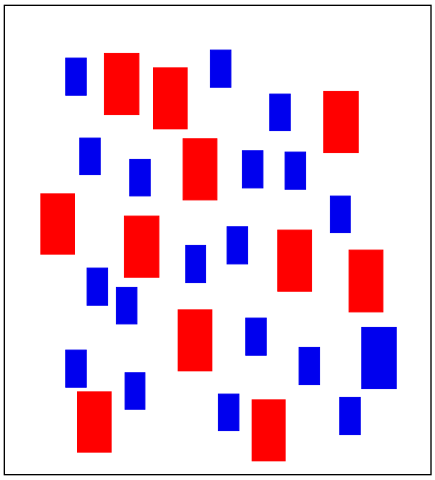


Note: when this happens, user in not doing anything except selecting particular input channels

(Such selection is not possible for integral pairs)

What if the task requires a combination of features?

(e.g. selection of a large blue object)



Results:

a) if conjunction involves a **spatial arrangement** (eg. T vs L), then search is **difficult** (≥ 30 ms/item)

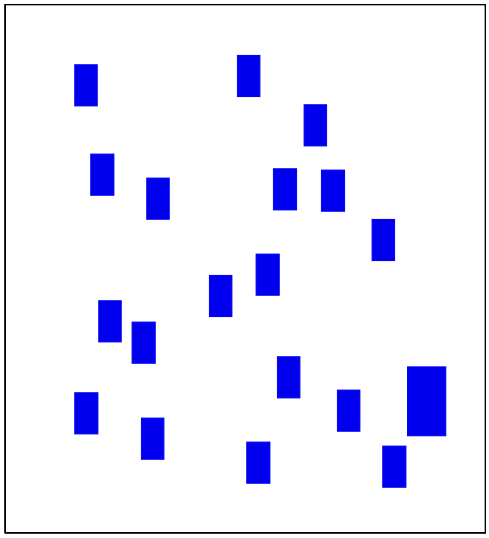
b) if conjunction involves a **conjunction of different features** (eg. large blue item), then search can be **fast** (≤ 10 ms/item) **if the user knows what they're looking for**

Explanation:

- this is **not** a form of selecting from available channels, since **both** features are needed.

- suggestion (Wolfe): Guided search
  - user **suppresses** features that are not needed
    (this suppression also suppresses the associated items)
  - then searches through the rest

Viewer suppresses red features (and all associated items)



Large blue item then pops out

What is Processed Preattentively?

Conventional View

Complex properties (e.g., 3D orientation) are not calculated preattentively:

- require information from arbitrarily far away;
- processing itself can be time-consuming

Belief: To achieve its great speed, early vision sacrifices the **complexity** of the properties it determines.

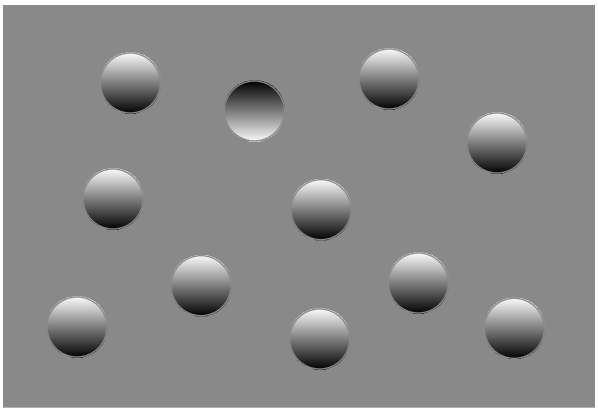
However…

Scene-based properties

1. Convexity (Kleffner & Ramachandran, 1992)

Image-based (2D) properties are the same in both target and distractor

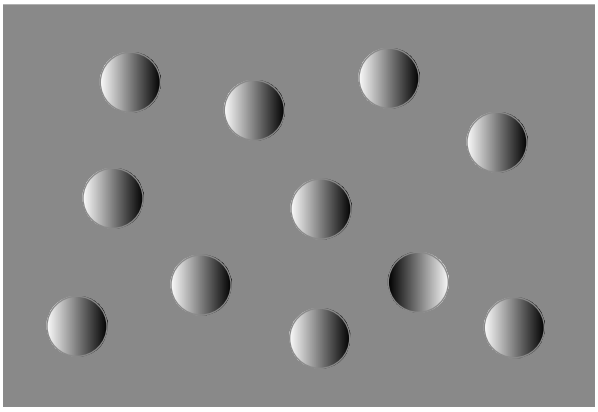
If these are the only properties computed at early levels, search should be slow



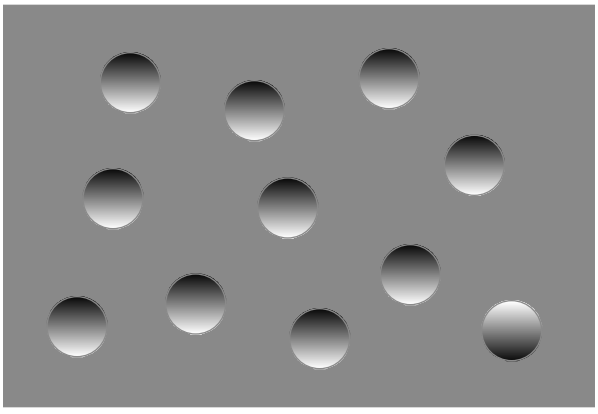
Search is fast -> unique preattentive feature

Feature: surface convexity (scene-based property) recovered rapidly at early levels

Note: This doesn't work for most orientations



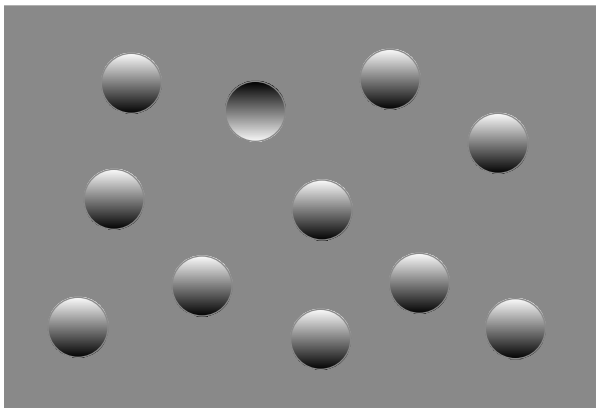
Search is slow for left/right differences…



Search is slow for items with white tops…

Explanation: Recovery of lighting requires assumption of **lighting from above**

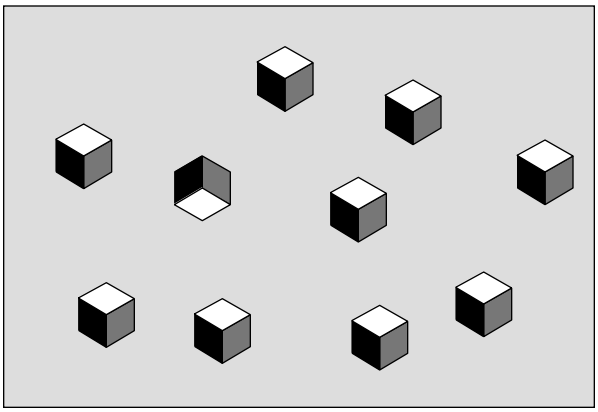
- **concave item** then pops out

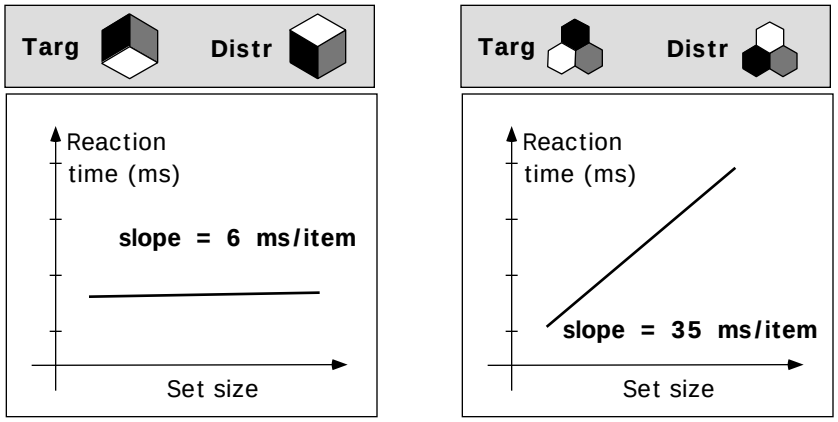


2. 3D Orientation (Enns & Rensink 1990, 1991)

Image-based (2D) properties are the same in both target and distractor

If these are the only properties computed at early levels, search should be slow



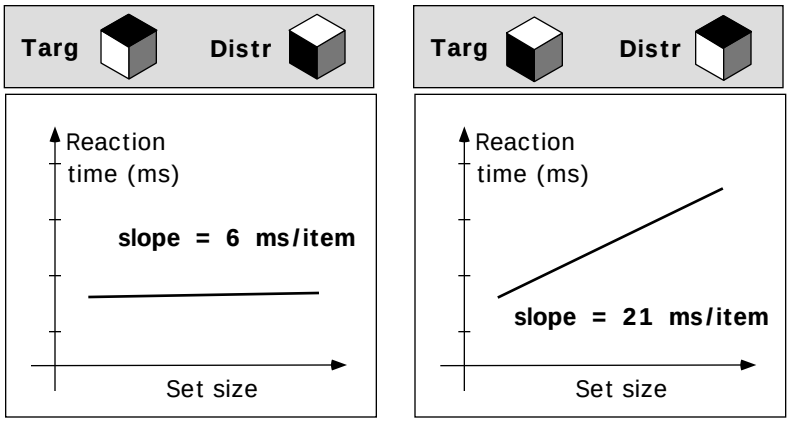


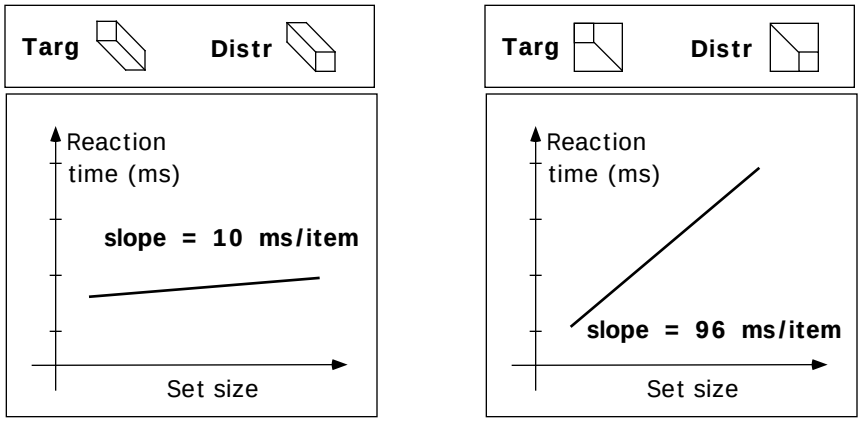
Rapid search for cubes!

Slow search for others

Three-dimensional orientation can be recovered rapidly

Note: Search is again slower for items with white tops



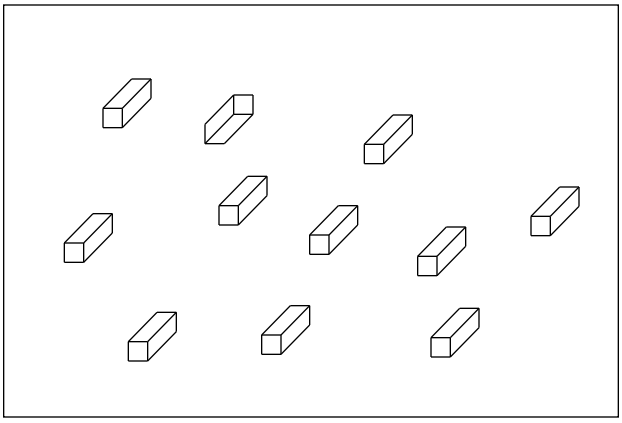


Rapid search for 3D
- even in line drawings

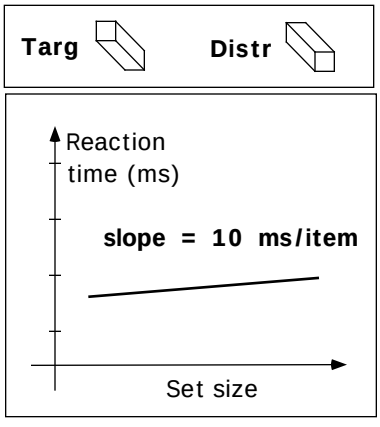
Slow search for others
- not just line patterns

Rapid interpretation of line drawings!

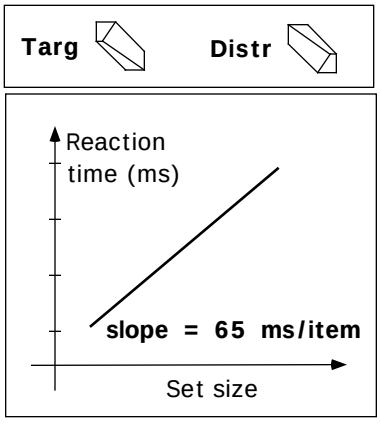
Note: Rapid search only when target is **angled upwards**
(rising up from ground plane?)



What assumptions might be used?



Rapid when corners 90°



Slow when corners ≠ 90°

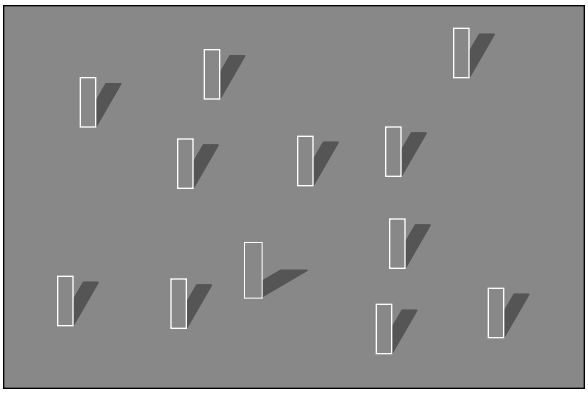
Assumption of rectangularity used for line drawings

3. Identification of Shadows (Rensink & Cavanagh, 1993)

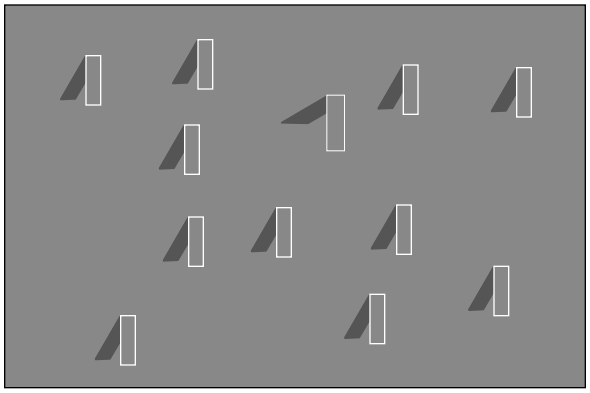
Target and distractor have shadows with different orientations…

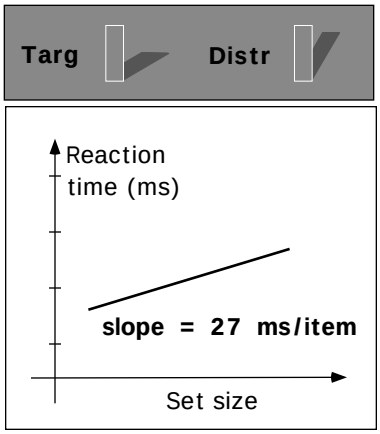
If 2D (or 3D) orientation is accessible, **search should always be rapid,** no matter what.

First try it right side up…

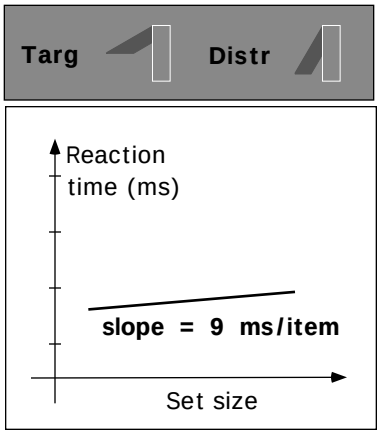


And then upside down…



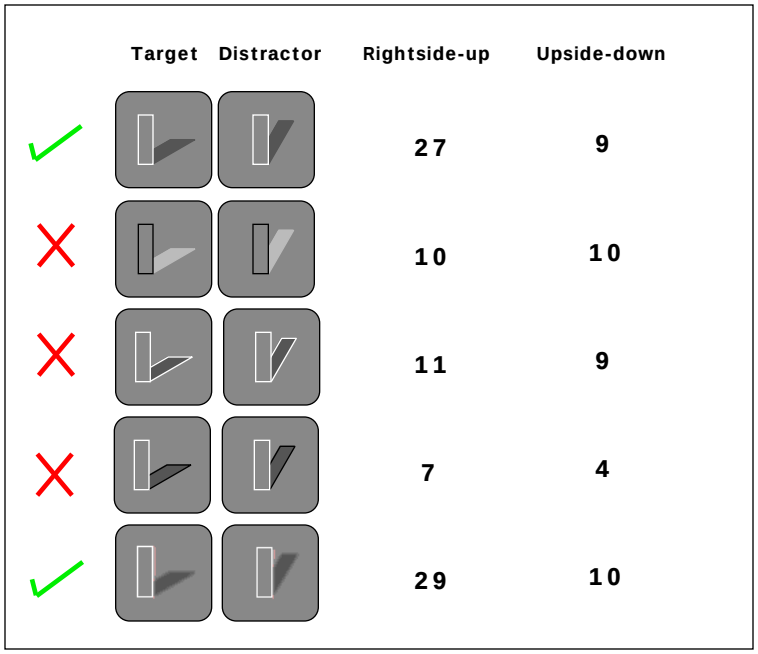


For right-side up,



For upside-down,

Why? Search for shadows is difficult
- 2D orientation available only for upside down



Shadows are identified at early levels, rapidly and in parallel

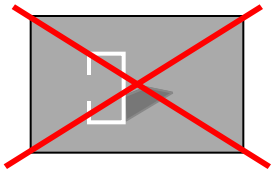
- Difficult to access (suppression?)
- Conservative assumptions for interpretation:
  - 1: lighting direction must be from above
  - 2: shadow must be dark
  - 3: shadow cannot have distinctive edge

Other constraints on shadow interpretations

4: shadow cannot have a texture
- region must be uniform

5: shadow can be colored (blue, red, etc.)
- lightness must be darker than background

6: shadow caster must be seen as a surface element
- can't be seen as a line element (wire)

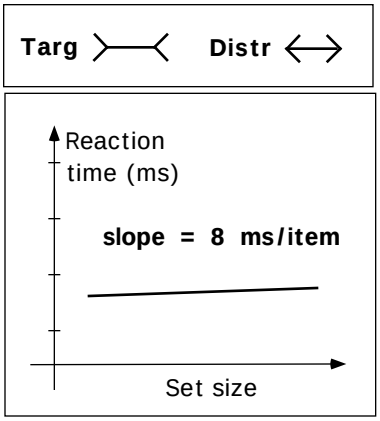


Structural Rules

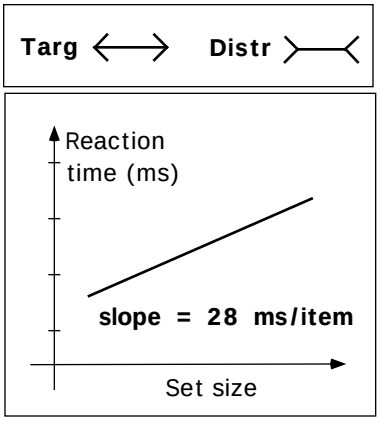
1. Grouping (Rensink & Enns, 1995)

Target and distractor have same (2D) pieces.

If these are the only properties computed at early levels, situation much like (L vs T)

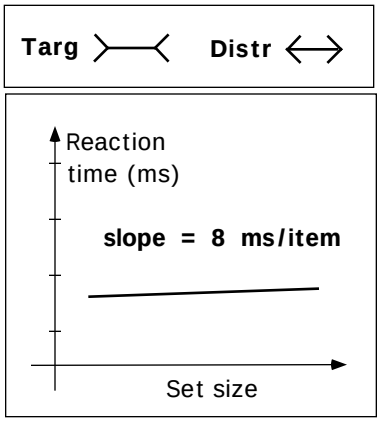


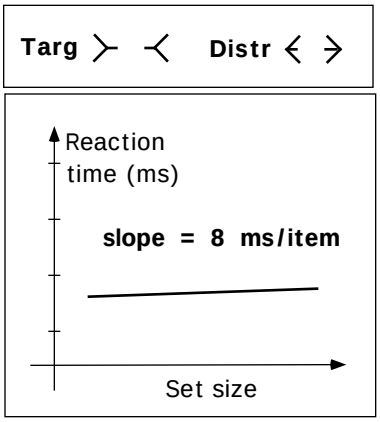
Search is rapid - based on length of **group**



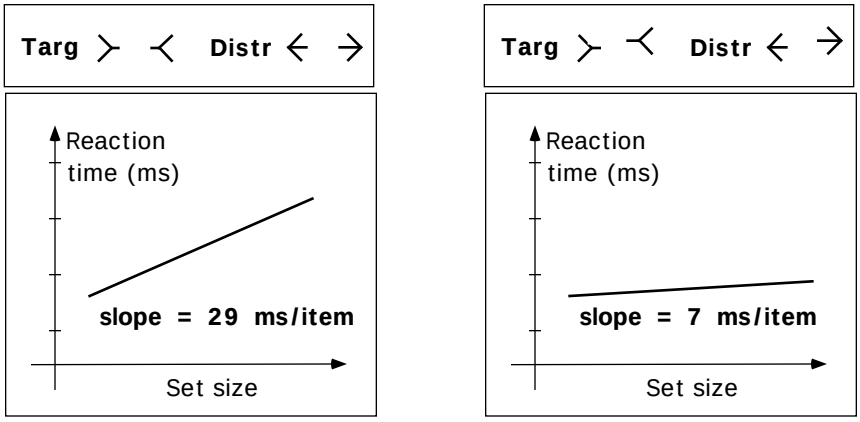
Search is slow - based on length of **individual pieces**

-search is based only on outputs of grouping process





Grouping can operate over gaps…



As long as the parts line up.

-> Preattentive structures must have precise spatial alignment. **Just can't access it**.

Note: In all cases, search is based on length of group, not length of individual pieces

This occurs even when search would be faster if based on length of pieces

-> Pre-emption:

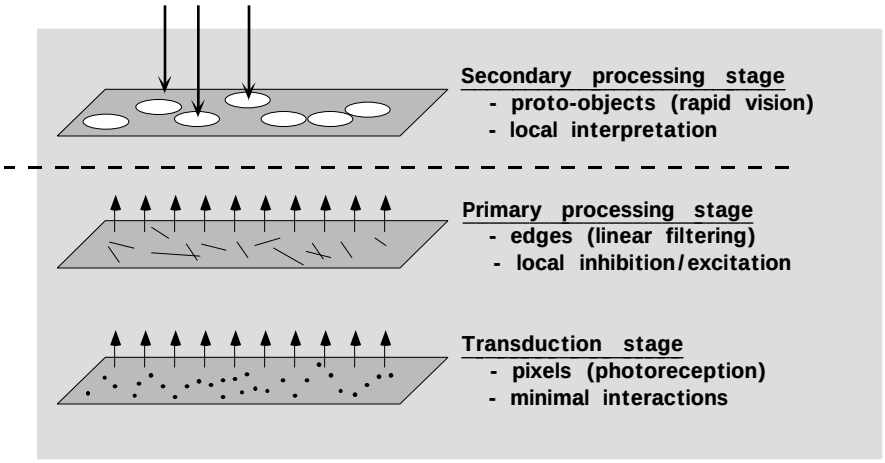
Attention can't directly access individual pieces

Can only access structures formed at early levels

-> Proto-objects (Rensink & Enns, 1998):
- "quick and dirty" estimates of scene properties (e.g., surface slant, true surface color)
- limited extent in space

-> can be rapidly computed

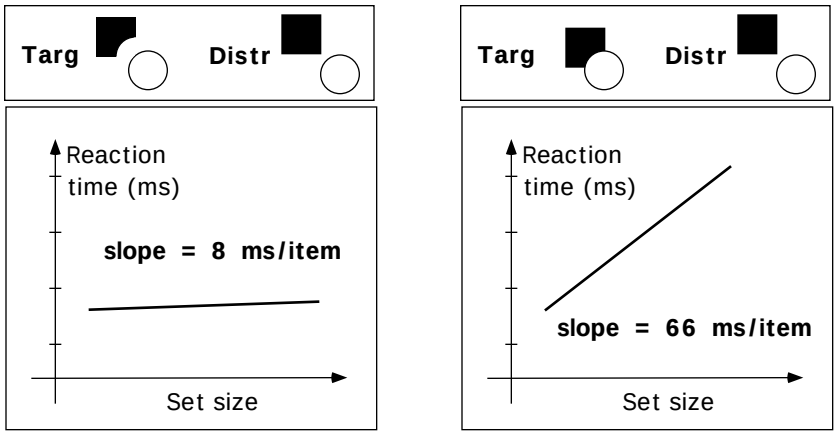
Only structures above primary line
are "visible" to focused attention



2. Completion of Occlusions (Rensink & Enns, 1998)

Target and distractor have different pieces.

If these are the relevant properties at early levels,
search should always be rapid,
no matter how they are arranged.



- based on distinctive parts

- cannot access visible pieces

-**search is based on completed surface only**

- pre-emption again occurs

Summary - Preattentive Vision

- complex properties (e.g., 3D orientation) can be determined rapidly and in parallel
- these are calculated via simple rules that work most of the time (e.g., lighting from above)

Old view: To achieve its great speed, early vision sacrifices the **complexity** of the properties it determines.

New view: To achieve its great speed, early vision sacrifices the **reliability** of the properties it determines.

Summary - Implications for Display Design

Information Visualization

→ Displays need not be limited to simple 2D properties (e.g., color and orientation) to convey information. More complex properties can also be used.

- will only work under the appropriate conditions
- likely to be as effective as “old” dimensions

→ “Primitive” properties won’t always work as expected.

- will be unavailable to rapid vision if pre-empted by proto-objects