

# What shall we do with the preattentive processing stage: Use it or lose it?

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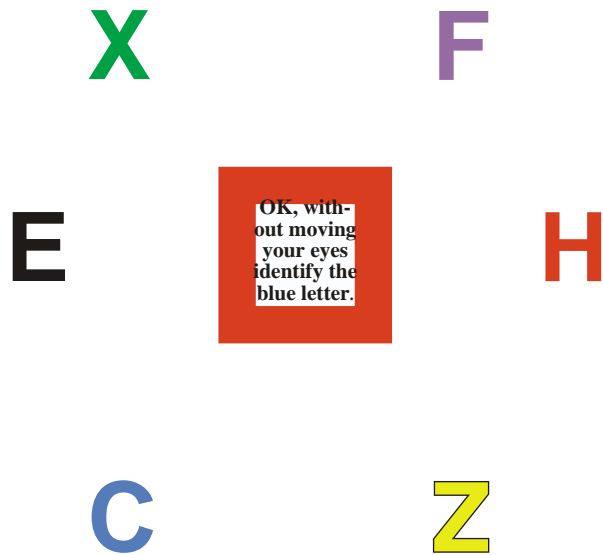
*Todd S Horowitz (Harvard Medical School & Brigham and Women's Hospital)*

**ABSTRACT:** Since Neisser (1967) and Treisman & Gelade (1980) many models of selective visual attention have included a preattentive stage of processing. Some researchers have suggested that the term “preattentive” has outlived its usefulness. While there are uses of “preattentive” that should be avoided, we argue against abandoning the concept altogether. If there is selective visual attention and if there is processing of visual stimuli prior to selection, then there is preattentive processing. We hold that a goal of this processing is to abstract a preattentive representation from the stimulus that can be used to guide attention. In that representation, features are coarsely coded in parallel. It is a mistake to think of this representation as self-sufficient “preattentive vision” whose output can directly control behavior. While some forms of perceptual grouping and segregation may be accomplished preattentively, it does not seem to be possible to go directly to a motor response without engaging attention-demanding processes. In particular, while there may be some preattentive conjoining of features, the accurate explicit binding that appears to be required for object recognition entails selective attention to specific objects. Building on the Reverse Hierarchy Theory of Hochstein & Ahissar and on re-entrant ideas of DiLollo, we suggest that features are initially encoded through a feed-forward pathway from V1 to higher visual areas in both ventral and dorsal pathways. Preattentive guidance of focused attention can then be modeled as re-entry from anatomically high-level loci onto earlier loci. Parietal areas appear to guide spatial selection and prestriate areas may guide feature-based selection. In this framework, no part of the brain is exclusively “preattentive”. The same anatomical areas may participate in the feed-forward production of a preattentive representation and then in the more detailed, selective processing modulated by attention through subsequent reentry. **Acknowledgment:** Grant support from NEI, NIMH, AFOSR

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# Define "preattentive"

Look at the red box



Premise 1: You could direct attention to the designated object.

Premise 2: It is logically possible that you had not directed attention to that object previously.

Conclusion: Any visual processing of that item prior to the act of selection can be called "preattentive".

(OK, we could call it "preselective processing" but "preattentive" is the term in

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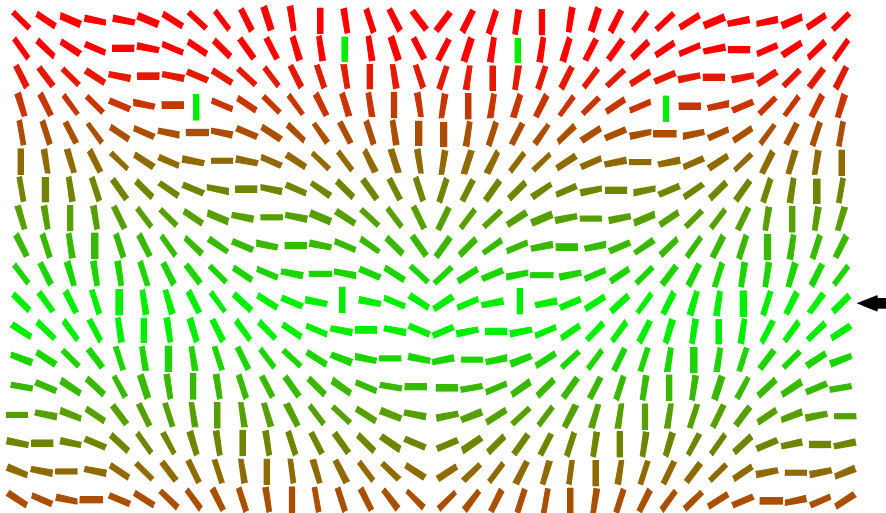
# Two Aspects of Preattentive Processing

## Preattentive *Vision*

Definition: Properties available for report about items that have not been selected

### Example: Pop-out, bottom-up salience

Items that differ from their neighbors “pop-out” and may group together.



Notice the green verticals that do not pop-out (follow arrows). ↑

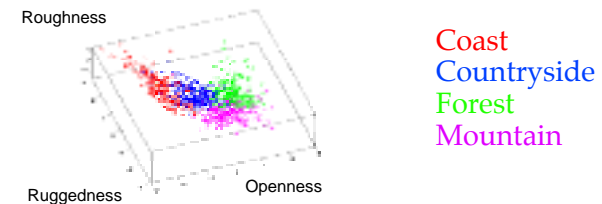
Some relevant sources  
 Nothdurft H-C. 1993. The role of features in preattentive vision: Comparison of orientation, motion and color cues. *Vision Research* 33: 1937-58  
 Nothdurft HC. 2000. Saliency from feature contrast: variations with texture density. *Vision Res* 40: 3181-200  
 Wolfe JM, Chun MM, Friedman-Hill SR. 1995. Making use of texton gradients: Visual search and perceptual grouping exploit the same parallel processes in different ways. In *Early vision and beyond.*, ed. T Pappathomas, C Chubb, A Gorea, E Kowler, pp. 189-98. Cambridge, MA: MIT Press

### Possibly: Limited Semantic Information

Make Fourier-style filters for attributes like “openness”.



Plot scenes in the resulting space and semantic categories cluster (Oliva & Torralba, '01)



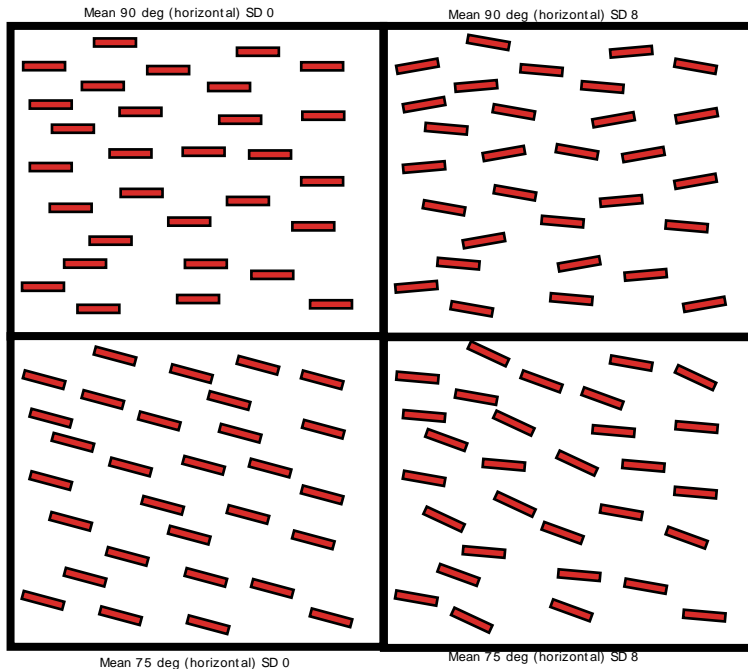
It may be possible to get a semantic label for a single unattended item (e.g. “animal”) or for the category of a scene (e.g. “beach”).

Some relevant sources  
 Oliva A, Torralba A. 2001. Modeling the shape of the scene: A holistic representation of the spatial envelope. *International Journal of Computer Vision* 42: 145-75  
 See also:  
 Li FF, VanRullen R, Koch C, Perona P. 2002. Rapid natural scene categorization in the near absence of attention. *Proc Natl Acad Sci U S A* 99: 9596-601  
 VanRullen R, Reddy L, Koch C. 2002. Visual search and dual-tasks reveal two distinct attentional resources. submitted

# Two Aspects of Preattentive Processing

## Preattentive *Vision*

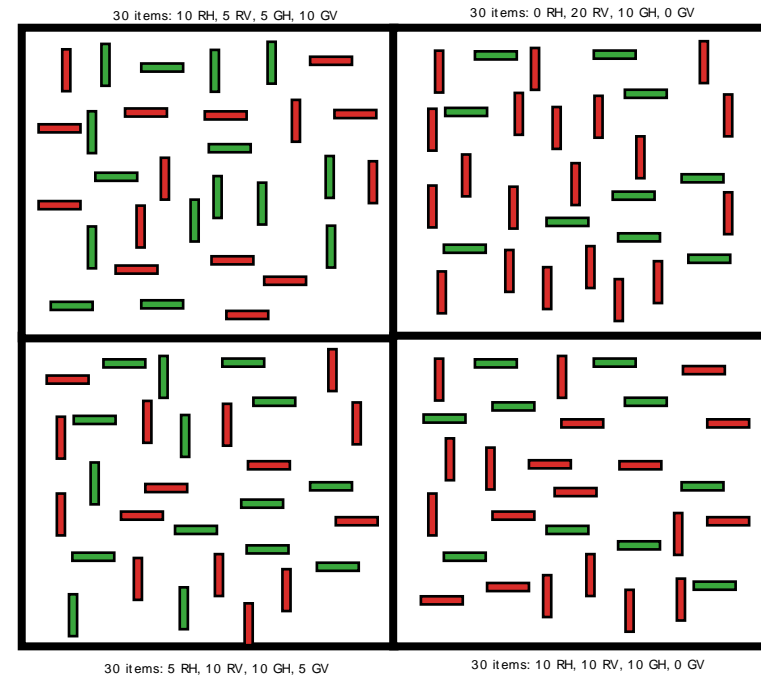
Example: Image Statistics:  
Look at the center and assess the mean  
and variability of the textures



Without scrutinizing elements, you are good at determining that rows have similar means and columns have similar variability.

Some relevant sources:  
Ariely D. 2001. Seeing Sets: Representation by statistical properties. *Psychological Science* 12: 157-62  
Chong SC, Treisman A. 2003. Representation of statistical properties. *Vision Res* 43: 393-404  
Chubb C, Landy MS. 1994. Orthogonal distribution analysis: A new approach to the study of texture perception. In *Computational Models of Visual Processing*, ed. MS Landy, JA Movshon, pp. 291-301. Cambridge, MA: MIT Press  
Wolfe JM. 1992. "Effortless" texture segmentation and "parallel" visual search are *not* the same thing. *Vision Research* 32: 757-63

Counter-example:  
Conjunctive Statistics:  
Try the same thing here



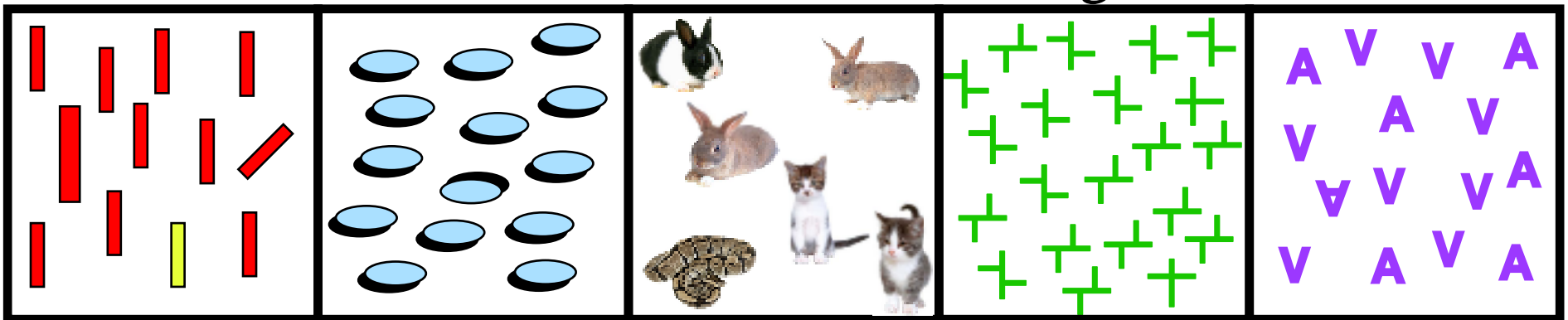
Without scrutinizing elements, you may not notice that the proportions of the four types of elements are very different in the upper and lower left-hand panels. You might not notice that the upper-right contains only two stimulus types. You can notice that the right panels are 'redder' than the left and the the top-right is more vertical than the bottom-right. Features statistics are available. Conjunctive statistics may not be.

# Two Aspects of Preattentive Processing

## Preattentive *Guidance*

Definition: Properties that can be used to guide the subsequent deployment of attention.

A limited set of feature dimensions can guide attention:



Color? Size?  
Orient? sure

Treisman A. 1985. Preattentive processing in vision. *Computer vision, graphics, and image processing*. 31: 156-77

3-D Layout?  
yes

Enns JT, Rensink RA. 1990. Sensitivity to three-dimensional orientation in visual search. *Psychological Science* 1: 323-6  
Sun J, Perona P. 1996. Preattentive perception of elementary three dimensional shapes. *Vision Research* 36: 2515-29

Danger?  
Snakes?

Öhman A, Lundqvist F, Esteves F. 2001. Emotion Drives Attention: Detecting the Snake in the Grass. *Journal of Experimental Psychology: General* 130: 3  
*I predict this will not replicate with proper control for low level features (JW)*

Intersection?  
no

Julesz B, Krose B. 1988. Features and spatial filters. *Nature* 333: 302-3  
Wolfe JM, DiMase JS. 2003. Do intersections serve as basic features in visual search? *Perception in press*

Novelty?  
doubtful

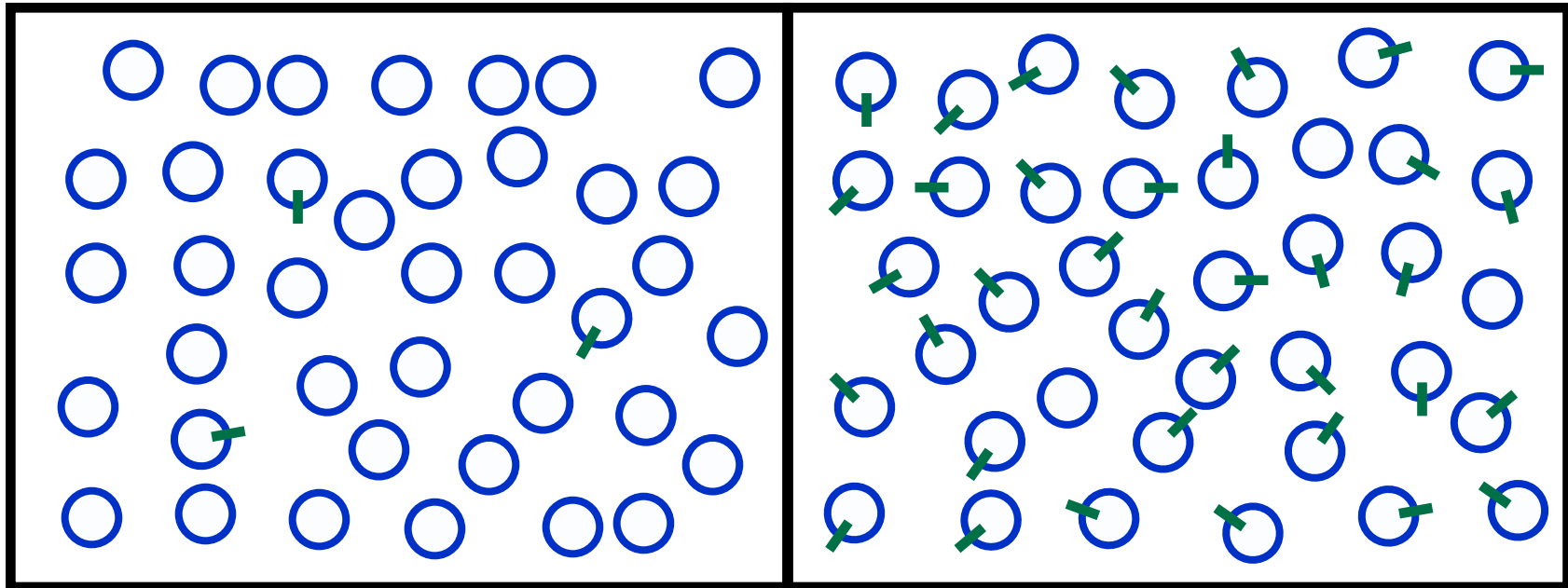
Wolfe JM. 2001. Asymmetries in visual search: An Introduction. *Perception and Psychophysics* 63: 381-9  
But see: Wang Q, Cavanagh P, Green M. 1994. Familiarity and pop-out in visual search. *Perception and Psychophysics* 56: 495-500

# Two Aspects of Preattentive Processing

## Preattentive *Guidance*

Definition: Properties that can be used to guide the subsequent deployment of attention.

Presence of a feature is better than absence



FIND  *Three of them*

FIND  *Three of them*

Treisman A, Gormican S. 1988. Feature analysis in early vision: Evidence from search asymmetries. *Psych. Review* 95: 15-48

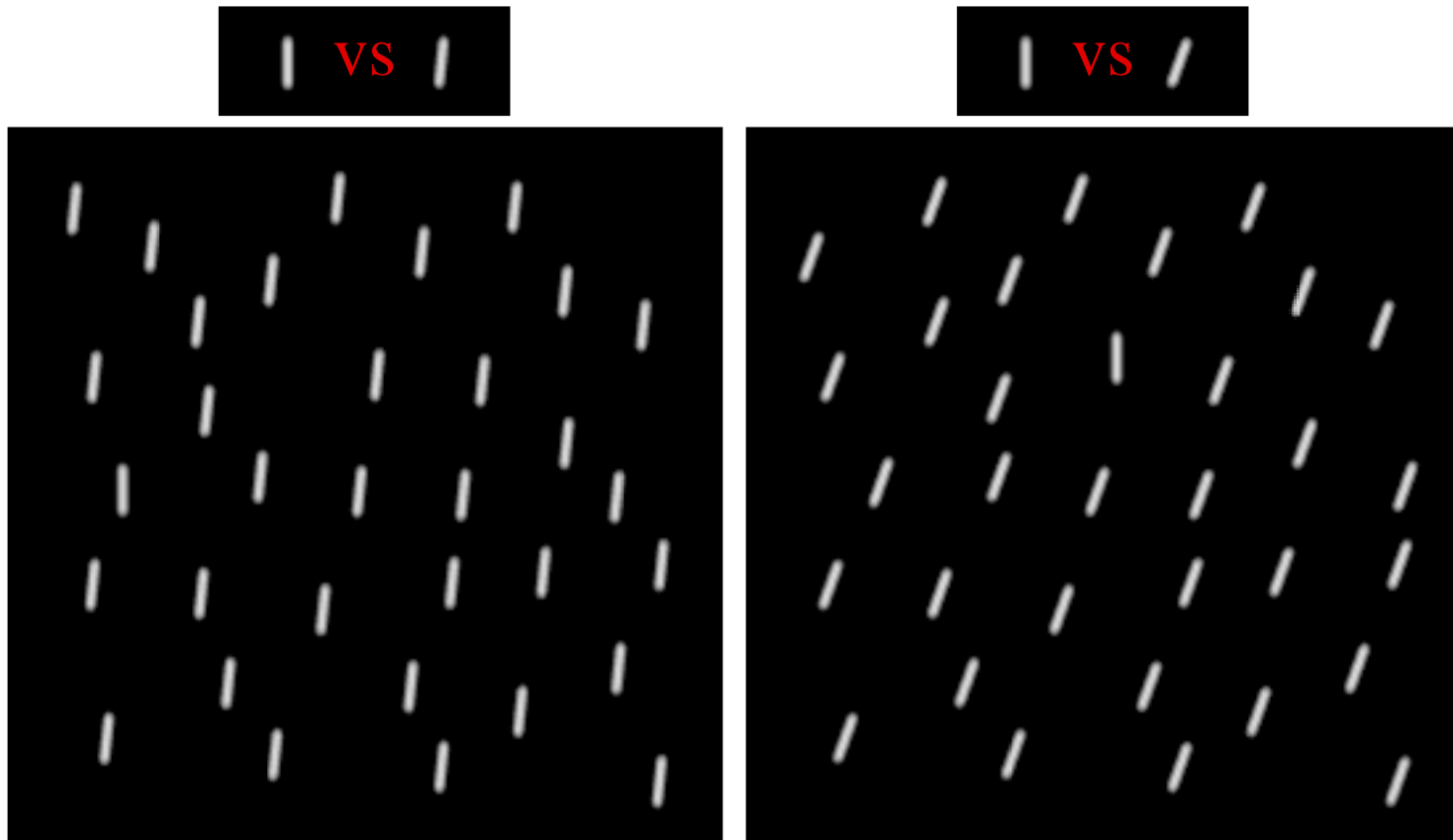
Treisman A, Souther J. 1985. Search asymmetry: A diagnostic for preattentive processing of separable features. *J. Exp. Psychol. - General* 114: 285-310

Rosenholtz R. 2001. Search asymmetries? What search asymmetries? *Perception and Psychophysics* 63: 476-89

# Two Aspects of Preattentive Processing

## Preattentive *Guidance*

Preattentive guidance is coarse  
Find the Vertical line



Even though it is easy to tell the difference between a vertical (0 deg) item and a 6 deg item, preattentive guidance requires a larger difference.

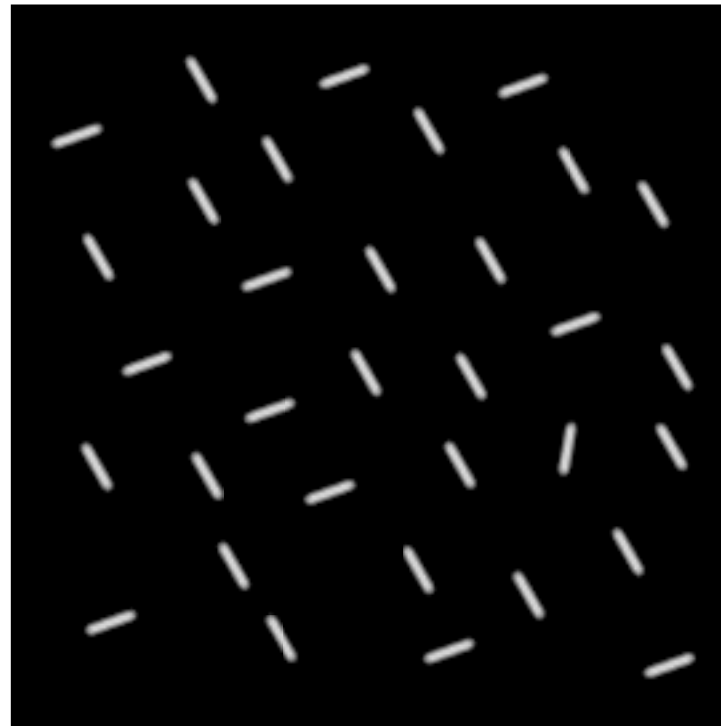
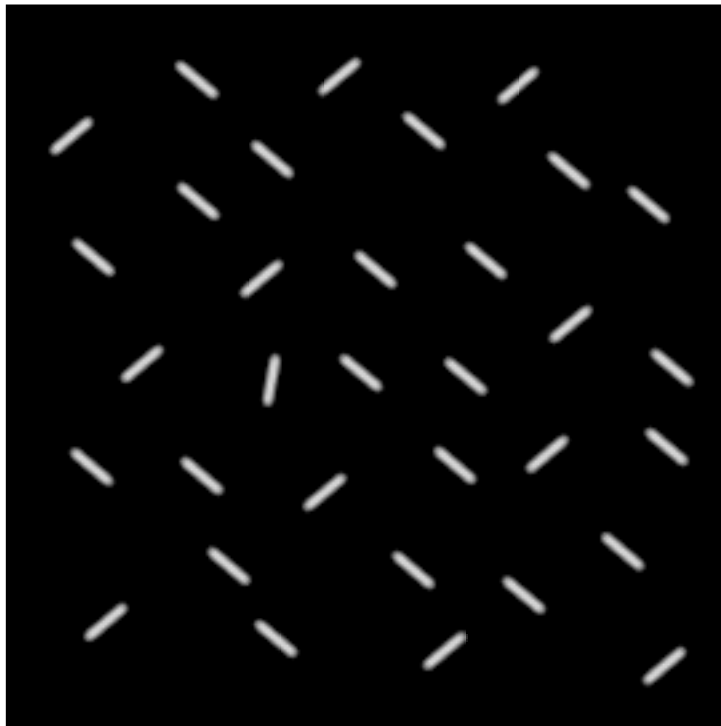
e.g. Foster DH, Westland S. 1995. Orientation contrast vs orientation in line-target detection. *Vision Research* 35: 733-8  
Baldassi S, Verghese P. 2002. Comparing integration rules in visual search. *Journal of Vision* 2: 559-70

# Two Aspects of Preattentive Processing

## Preattentive *Guidance*

Preattentive guidance is categorical

T:10, D+/-50 Find the 10 deg target T:10, D+70/-30



Uniquely steep - easier

Merely steepest - harder

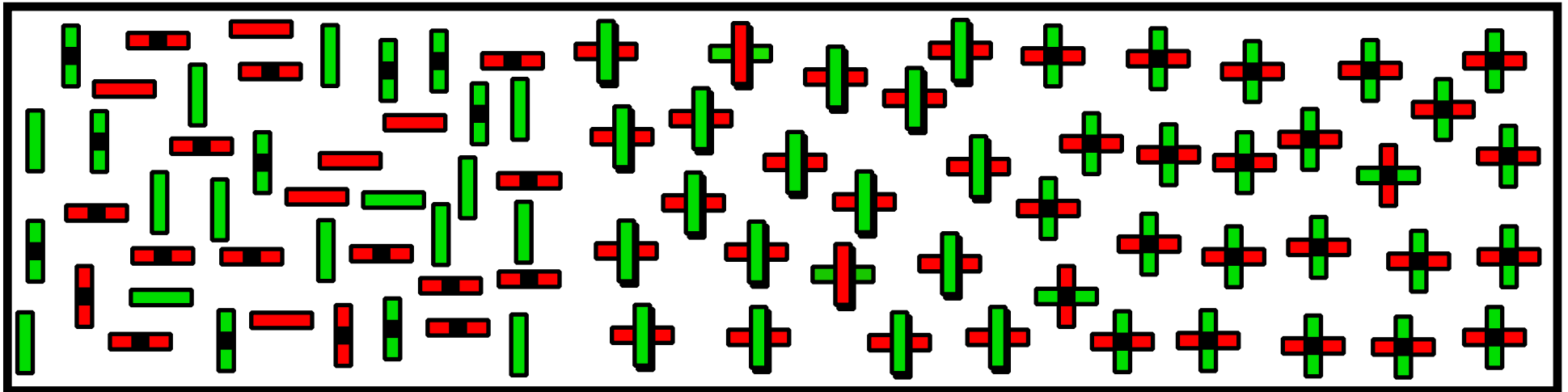
Wolfe JM, Friedman-Hill SR, Stewart MI, O'Connell KM. 1992. The role of categorization in visual search for orientation. *J. Exp. Psychol: Human Perception and Performance* 18: 34-49

# Two Aspects of Preattentive Processing

## Preattentive *Guidance*

Preattentive guidance is guidance to **OBJECTS**

Find Red Vertical rectangles



Easy when there are Red Vertical objects. Attention can be guided to red and vertical

Remains easy even if discrete objects overlap.

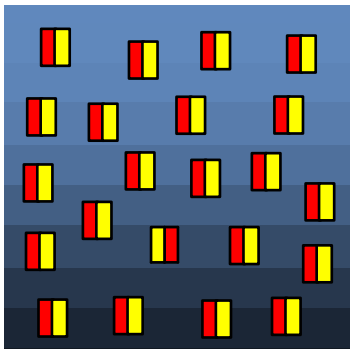
But hard if all items are objects that are red and green and vertical and horizontal

# Two Aspects of Preattentive Processing

## Preattentive *Guidance*

Preattentive guidance is guidance to objects with some **STRUCTURE**

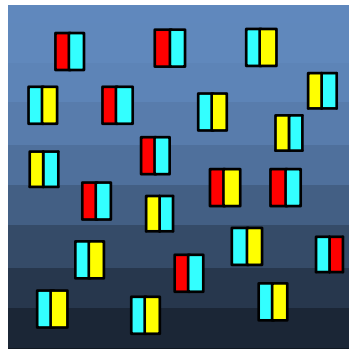
Find  yellow left of red



**Not Spatial position**

Logan G. 1995. Linguistic and conceptual control of visual spatial attention. *Cognitive Psychology* 28: 103-74


Find  yellow AND red

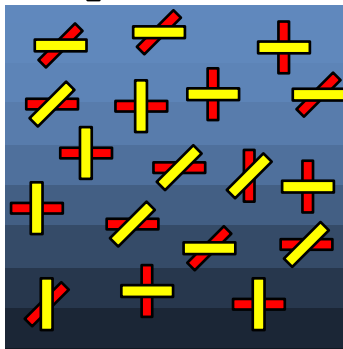


**Not part x part relations in color or orient**

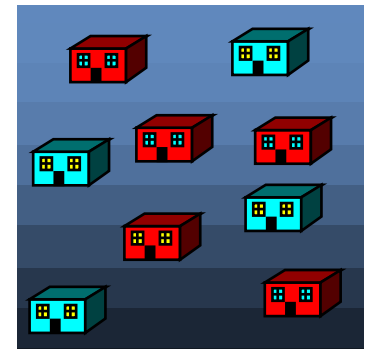
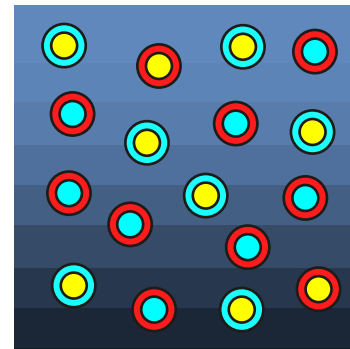
Wolfe JM, Yu KP, Stewart MI, Shorter AD, Friedman-Hill SR, Cave KR. 1990. Limitations on the parallel guidance of visual search: Color X color and orientation X orientation conjunctions. *J. Exp. Psychol: Human Perception and Performance* 16: 879-92

Carrasco M, Ponte D, Rechea C, Sampedro MJ. 1998. "Transient structures": The effects of practice and distractor grouping on a within-dimension conjunction search. *Perception and Psychophysics* 60: 1243-58

Find  vertical AND oblique



Find the red object/house with the yellow part/window.



**But part-whole relations in color are OK**

Bilsky AA, Wolfe JM. 1995. Part-whole information is useful in size X size but not in orientation X orientation conjunction searches. *Perception and Psychophysics* 57: 749-60

Wolfe JM, Friedman-Hill SR, Bilsky AB. 1994. Parallel processing of part/whole information in visual search tasks. *Perception and Psychophysics* 55: 537-50

Xu Y. 2002. Feature integration across parts in visual search. *Perception* 31: 1335-47

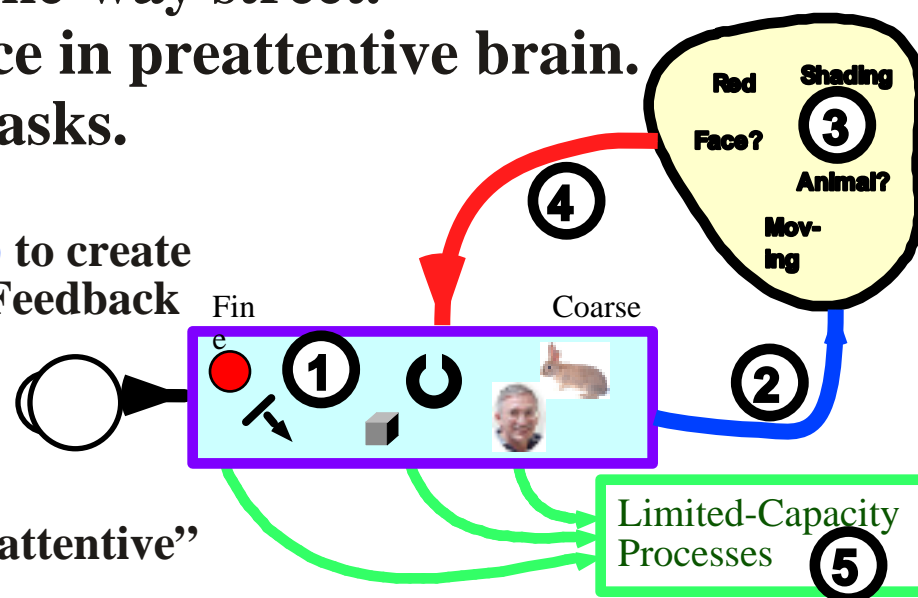
# What is the fuss about?

## Things we no longer believe (if we ever did)

- A. Preattentive --> Attentive is a one-way street.
- B. Preattentive processes take place in preattentive brain.
- C. There are preattentive search tasks.

**No, no, & no.**

Early vision processes (1) feed-forward (2) to create a coarse, preattentive representation (3). Feedback (re-entry) to earlier stages (4) selects a subset of the input for processing by limited capacity mechanisms (5).



It follows that a piece of brain can be “preattentive” and then, following re-entry, “attentive”.

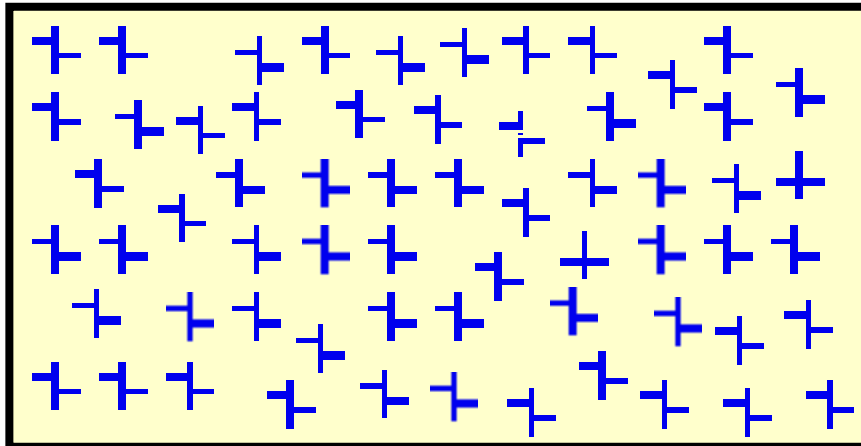
Efficient search occurs when preattentive processes can guide attention efficiently, not when preattentive processes hit the response key.

# What is the fuss about?

## Things we do not believe (but others might)

- A. Search can be explained by stimulus similarity alone.
- B. Search can be explained by signal detection theory alone.
- C. Preattentive is just another word for “coarse”.

Find  (easy) &  (hard) among 



Duncan J, Humphreys GW. 1989. Visual search and stimulus similarity. *Psychological Review* 96: 433-58  
Nakayama K, Joseph JS. 1998. Attention, pattern recognition and popout in visual search. In *The Attentive Brain*, ed. R Parasuraman, pp. 279-98. Cambridge: MIT Press  
Eckstein MP, Thomas JP, Palmer J, Shimozaki SS. 2000. A signal detection model predicts the effects of set size on visual search accuracy for feature, conjunction, triple conjunction, and disjunction displays. *Percept Psychophys* 62: 425-51

**No, no, & no.**

Maybe  is more similar to  than , but fleshing this out is likely to require a role for specific dimensions of “similarity”.

Some items differ by a detectable “signal” only after they are attended (e.g.  vs )

Is  vs  really “coarser” than  vs ?

**We conclude that successful theories of vision, attention, and search will require a role for preattentive processes.**