Selective Attention

Inattentional blindness [demo]

Cocktail party phenomenon

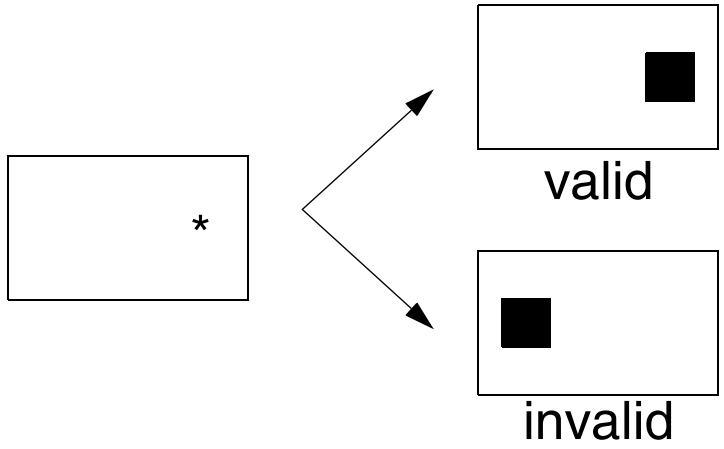
William James definition

> “Everyone knows what attention is. It is the taking possession of the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalisation, concentration, of consciousness are of its essence. It implies a withdrawal from some things in order to deal effectively with others.”

Possible Roles of Selective Attention

Enhancement of processing of selected information

e.g., Posner (1980)



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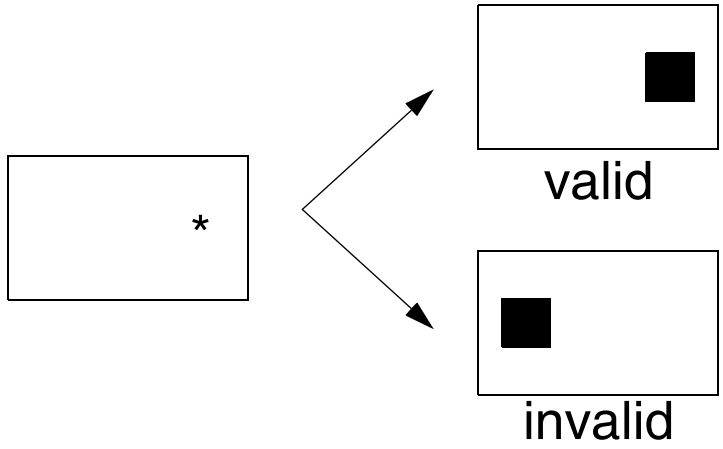
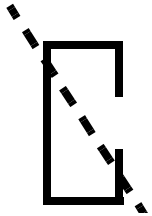


Segmentation of object from background

e.g., Duncan (1984)



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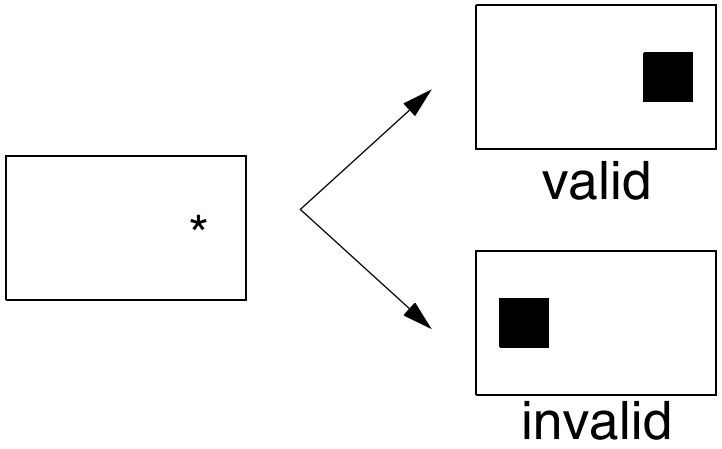

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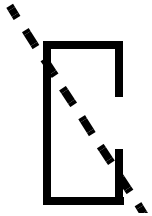


Binding

e.g., illusory conjunctions (Treisman & Schmidt, 1982)

4 X O T 5

e.g., visual search (Treisman & Gelade, 1978) [demo]

Multiple binding problems

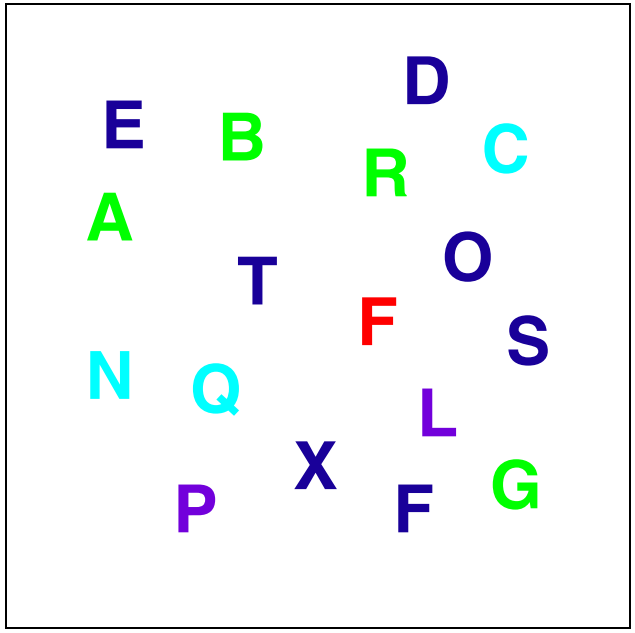
* binding features at the same location to form an object
* binding features over space to form an object
* binding features over time and space
* binding objects to form scenes

Feature Search

Find the red letter

Feature Search

Find the red letter

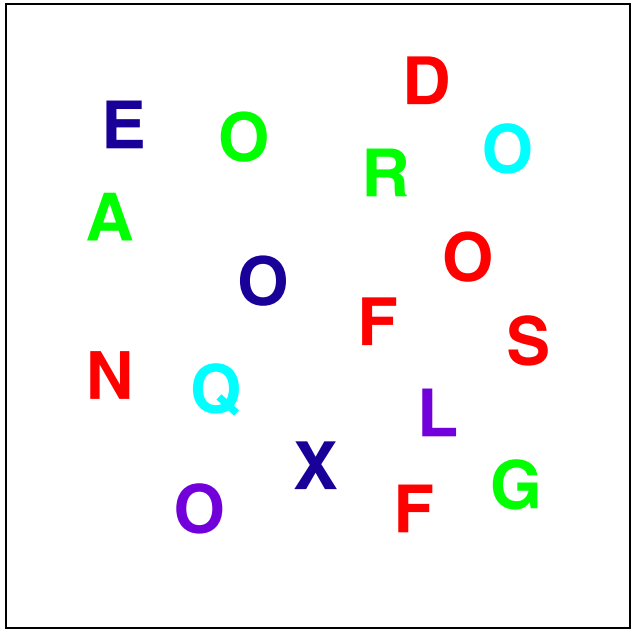


Conjunction Search

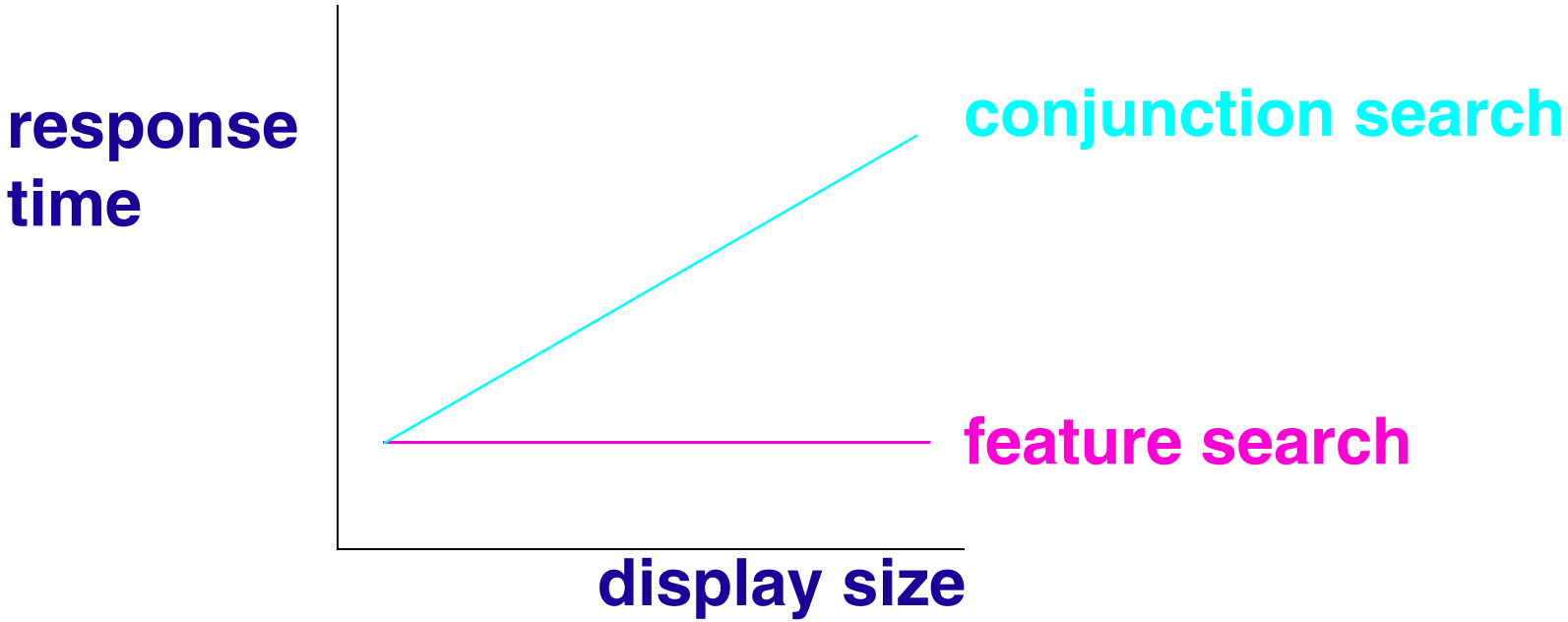
Find the red letter O

Conjunction Search

Find the red letter O



Search Latency



Early Feature Processing

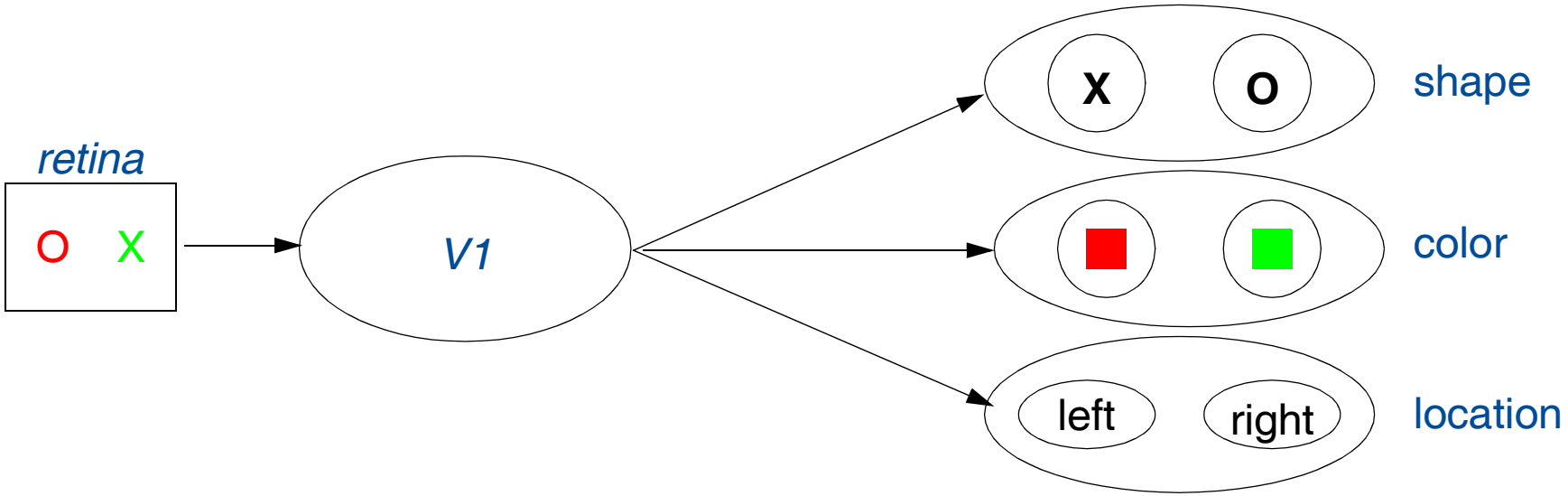
Neurons in different visual areas respond with different strengths to different feature dimensions.

e.g., V4 for color, MT and V5 for motion

evidence from monkey neurophysiology, fMRI, neuropsychology (Tong, 2003)

How are features registered independently reunited to produce our unified experience of the world?

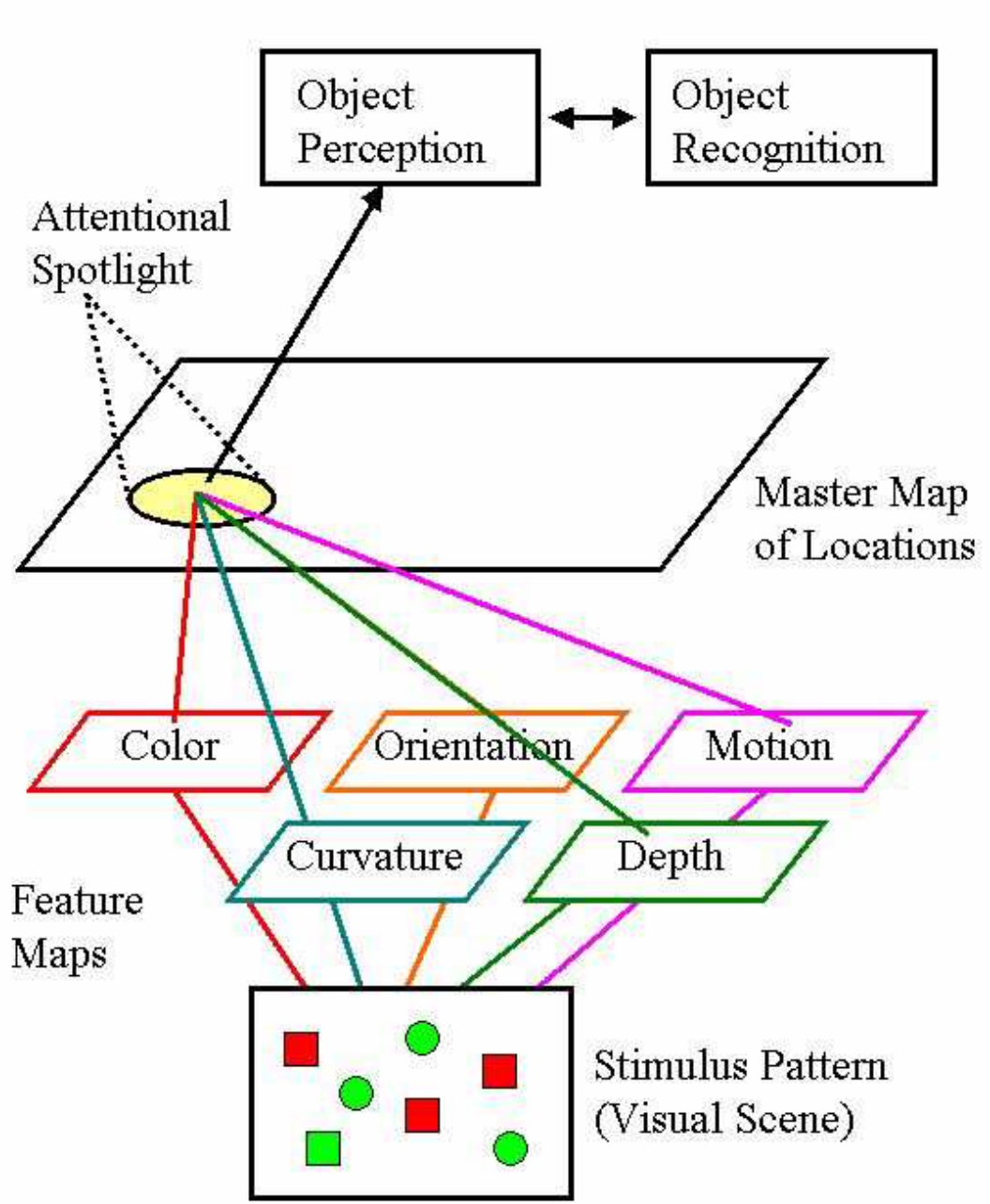
We are not aware of free floating colors or colorless shapes.



Feature Integration Theory

Late
Serial
Processing
Stage

Early
Parallel
Processing
Stage



Evidence for Role of Attention in Binding

Neglect: unilateral parietal damage

e.g., conjunction search poor in damaged hemifield; feature search ~ normal

Balint's Syndrome: bilateral parietal damage

Objects can be identified, but one at a time, and failure to bind object to location in space.

Many illusory conjunction errors (in space, not time)

e.g., patient RM: With pairs of colored letters and 10 sec viewing time and no attentional distraction, 38% illusory conjunctions

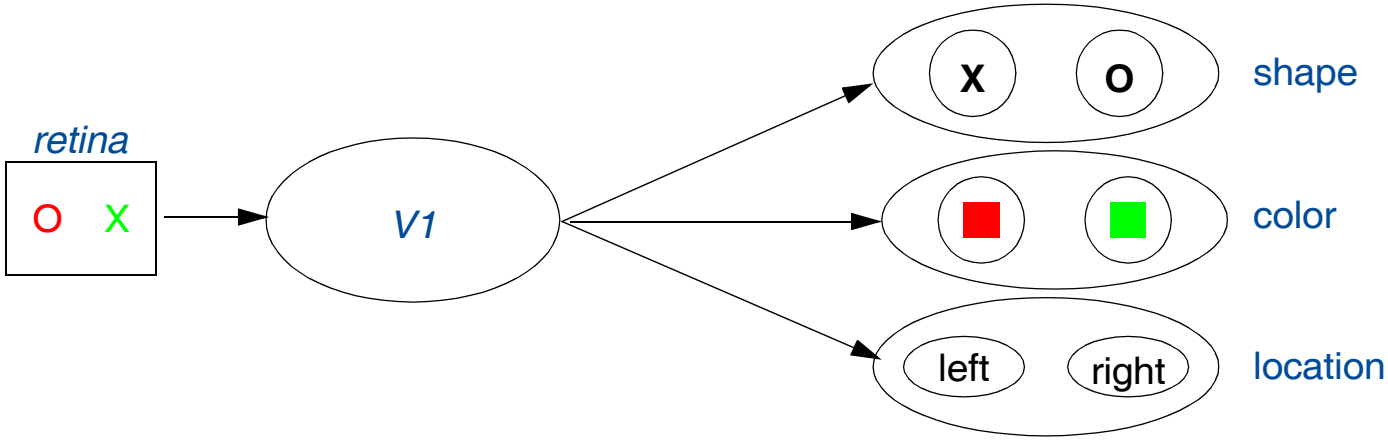
fMRI

Superior parietal cortex activation in conjunction search in a cluttered display, not in feature search.

Confound with task difficulty addressed

Parietal TMS disrupts conjunction search, not feature search

Representations of Binding



Synchrony

Timing of spikes/oscillations of individual neurons represents object tag

Allows multiple bindings to be represented simultaneously [next slide]

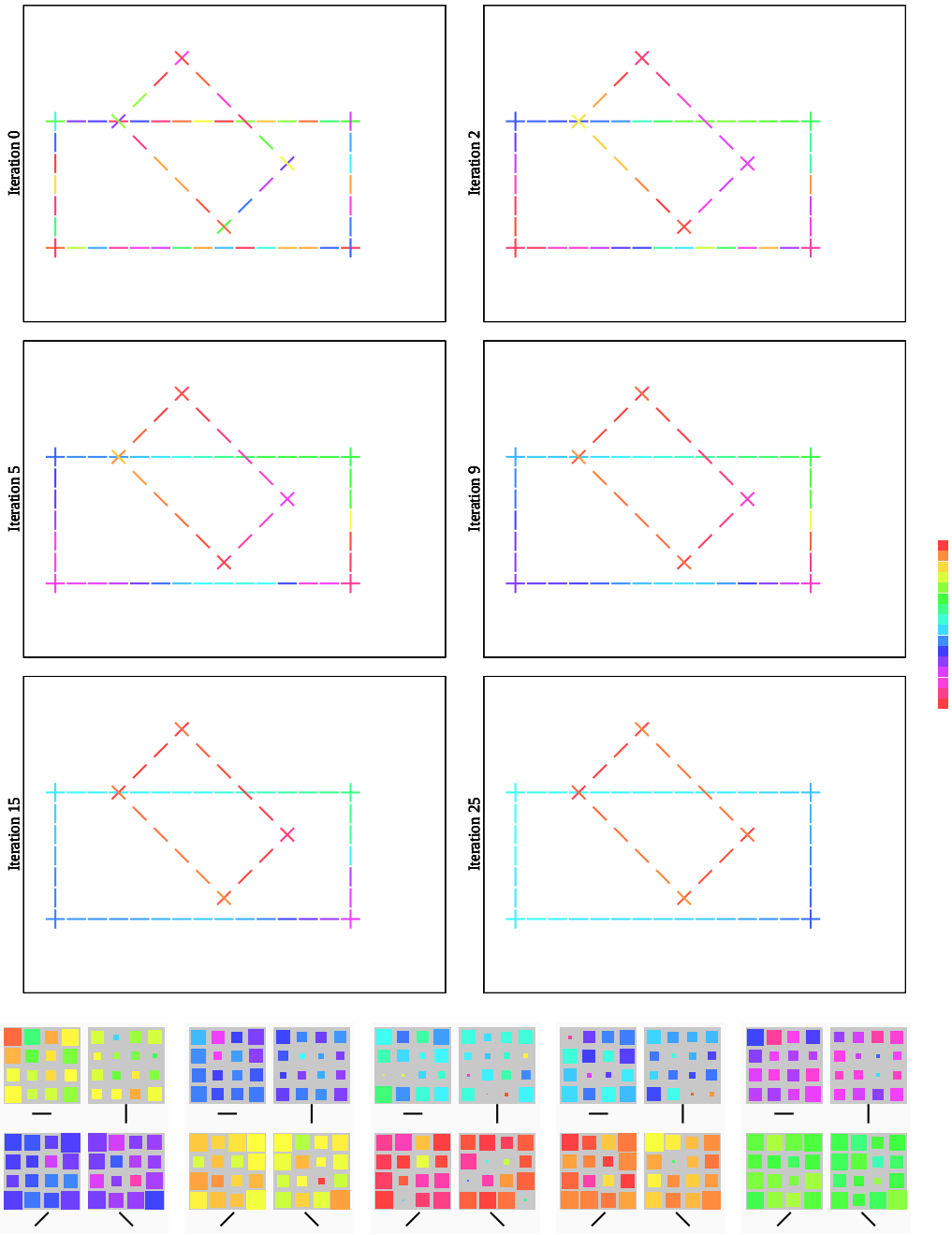
Activity

Only neurons associated with one object at a time are active

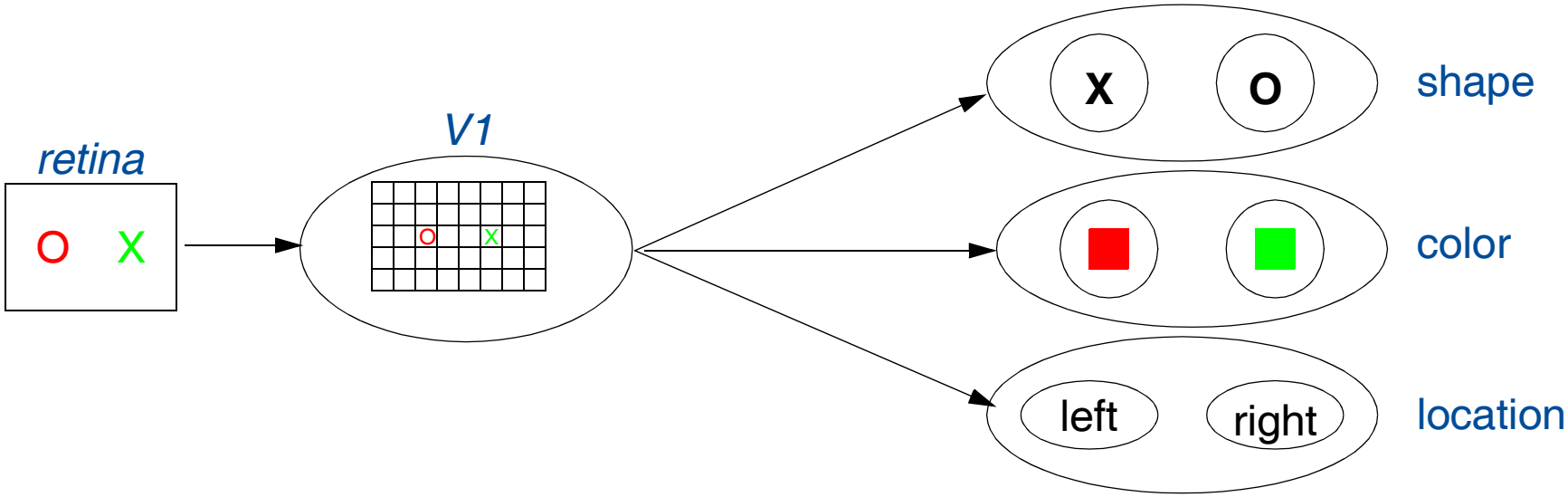
Only one binding can be represented at a time

Note role for V1 and/or higher brain centers in achieving coordination among the modular subsystems.

Synchrony Neural Network



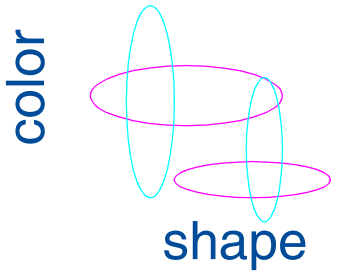
Mechanisms of Binding



Serial processing via attention applied to V1 to index all features belonging to one object

Coarse coding of representations

V4 representation includes not only color but *some* location and shape information, etc.



Top-down feedback from frontoparietal areas

Other Ideas We've Run Across Related to Binding Problem

Awareness involves achieving a consistent interpretation of the stimulus (e.g., Necker cube)

Key role of V1, possibly as a "master map"

Interactive theories of awareness

Synesthesia

Phonemic/chromatic

sounds induce perception of color

Graphemic/chromatic

letters or digits induce the perception of color

Automatic, consistent mapping throughout life

Feature binding when only one feature is present

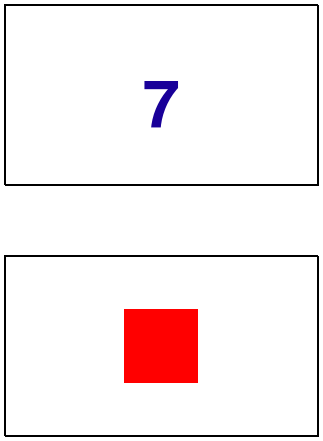
Is this a case of feature binding that does not require attention?

If so, it would go against the binding theory of attention (e.g., FIT)

Synaesthesia Depends on Awareness

Task

- Name color patch
- Patch preceded by prime: inducing letter/digits
- Letters/digits above or below threshold of awareness
- Induced color is either *consistent* or *inconsistent* with color patch



Results

- Synaesthetes slower to name inconsistent than consistent color patches with suprathreshold prime
- No effect with subthreshold prime (which is sufficient to prime a subsequent target letter)

Implication

- Awareness is necessary to obtain synaesthetic binding.

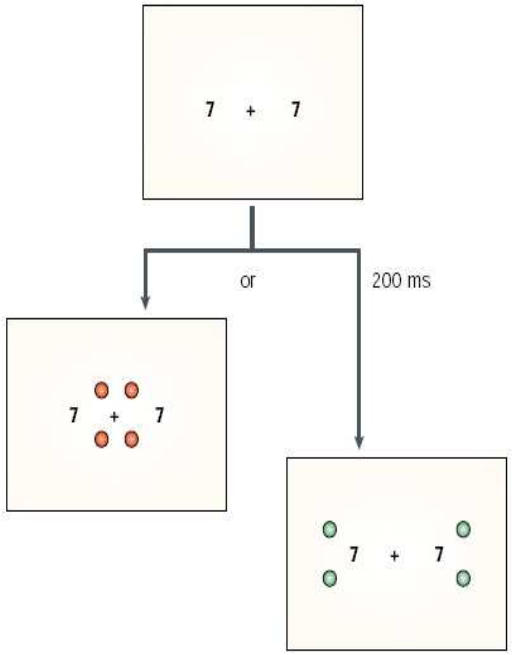
Synaesthesia Depends on Attention

Task

Name dot color

Digits irrelevant; induced color is either *consistent* or *inconsistent* with dot color

Digits either inside or outside focus of attention



Results

165 ms consistency effect with wide focus of attention

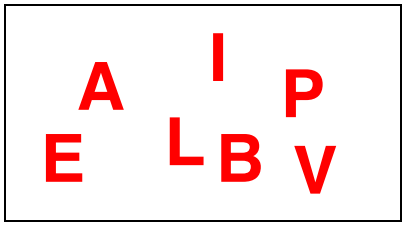
52 ms consistency effect with narrow focus of attention

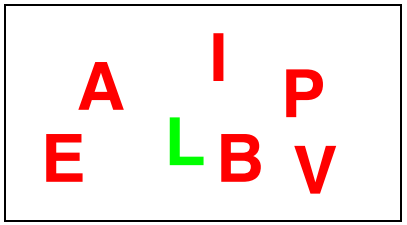
Conclusion

Synaesthetic binding depends on attention

Or Does Synaesthesia Depend on Attention?

Shape detection faster when color stands out





Some studies have found this type of "pop out" with induced synaesthetic color.

Implies that color induction occurs in parallel across display, and therefore does not require attention.

Robertson: speed up occurs only if distractors as well as target induce colors.

faster rejection of distractors

Synaesthesia Does Not Depend on Attention

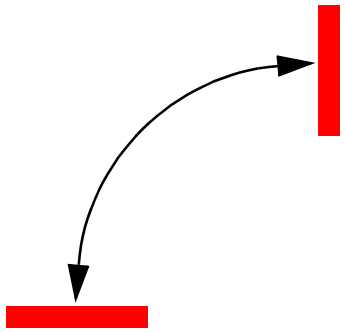
For one synaethete (but not others), detecting target with background color the same as the induced color led to poor detection.

Effect implies that shape and color induced before attention segments the display into foreground/background.

Robertson: Perhaps there are multiple forms of synaesthesia.

Apparent Motion

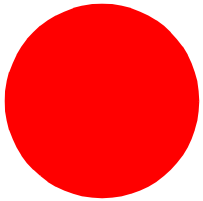
Also suggestive of binding

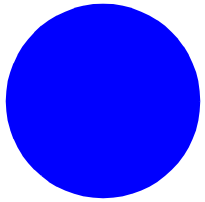


Binding of shape and motion

Color phi phenomenon

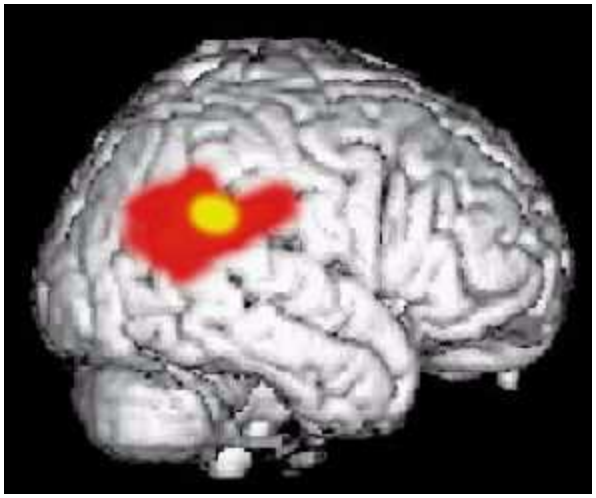
Suggestive of binding color, shape, and motion





Neglect

Typically found after lesions to right inferior parietal lobe



yellow =
supramarginal gyrus

Deficit in orienting, reaching, and responding to objects in the contralesional (left) side of space

In some patients, only when competing object on right (extinction)

No damage to primary visual cortex: patients not just blind.

Can draw patients' attention to the left

What Happens to Neglected Information?

Processing of stimuli in intact field can be influenced by presence of undetected stimulus in neglected field.

e.g., semantic priming

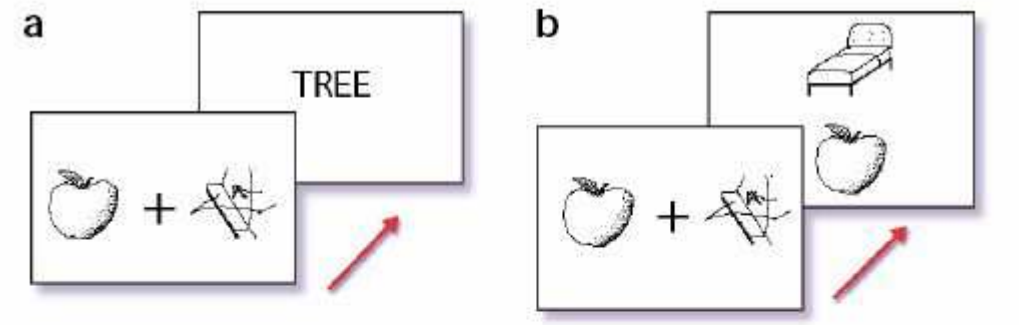
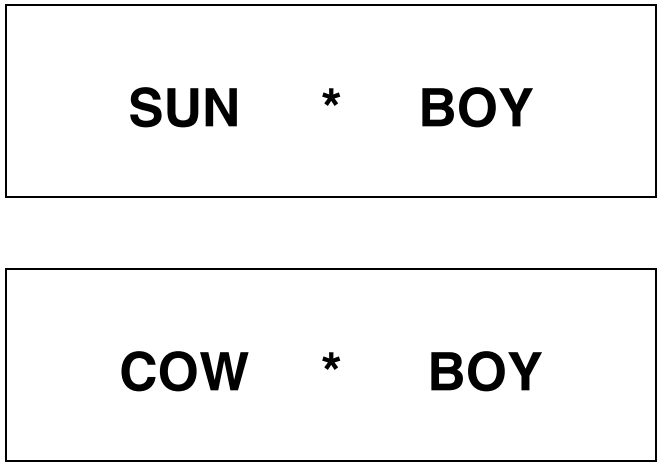


Fig. 4. Example display sequences from McGlinchey-Berroth *et al.*[30], with arrows indicating time. Each trial began with a meaningful visual object on one side of central fixation (the left in the illustration), together with a meaningless scrambled pattern on the other side, presented together for 200 msec. For the situation depicted in **(a)**, this was followed by a central letter-string, and the task was to judge rapidly if this string was a word or non-word. On some trials, the meaningful object was semantically related to the subsequent word (as for the association between the picured apple and the subsequent word 'TREE'). Such a relation speeded the word decision significantly for the neglect patients (thus revealing 'semantic priming'), regardless of whether the preceding related object had appeared on the left or right side. However, a control task **(b)** found that the neglect patients were unable to report the identity of the left object (i.e. they could not choose whether the upper or lower of two immediately-following objects matched the left object), although they could explicitly report right objects in this way. Taken together, these results suggest implicit semantic processing (i.e. activation of object identity and associations in the brain) for neglected left objects following right parietal damage.

Semantic content of information in the contralesional field can influence whether it is detected.



Even if information in neglected field does not reach awareness, it nonetheless receives significant analysis in the visual system.

Similar conclusion as Moutoussis and Zeki (binocular fusion)

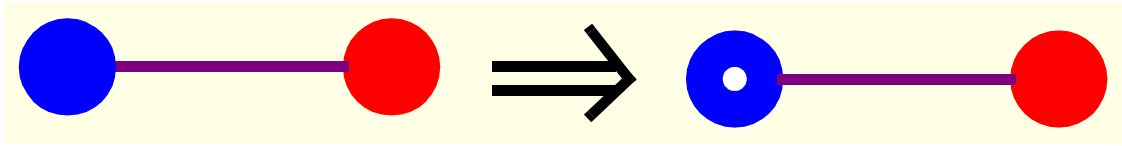
These results seem to imply that even without awareness, scenes are broken into objects, the objects are identified, and only then does attention select information to reach awareness.

Computational models can tell a different story

Barbell Studies Behrmann & Tipper (1994, 1999); Tipper & Behrmann (1996)

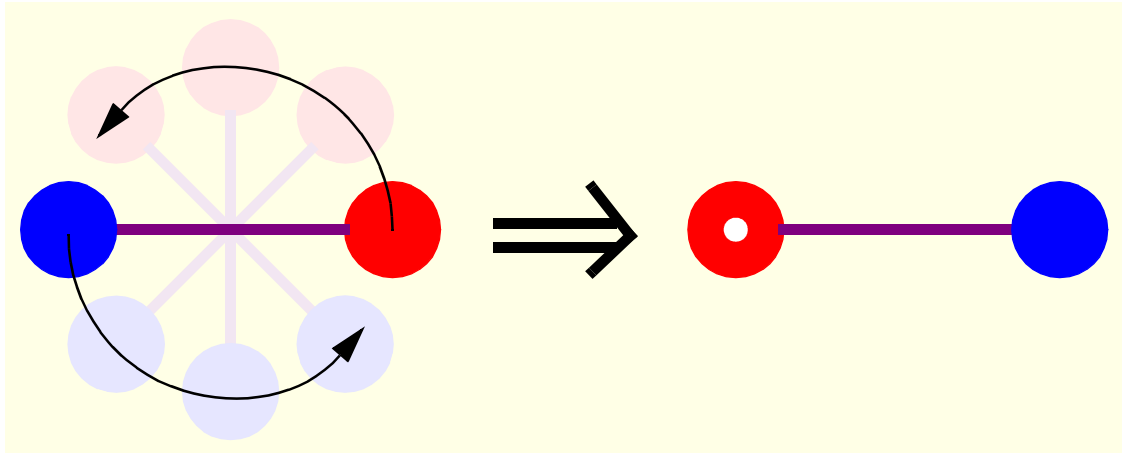
Task

static or *moving* "barbell" stimulus, followed on some trials by a target in the center of one disk



subjects report presence/absence of target

dependent variable: detection RT on target-present trials



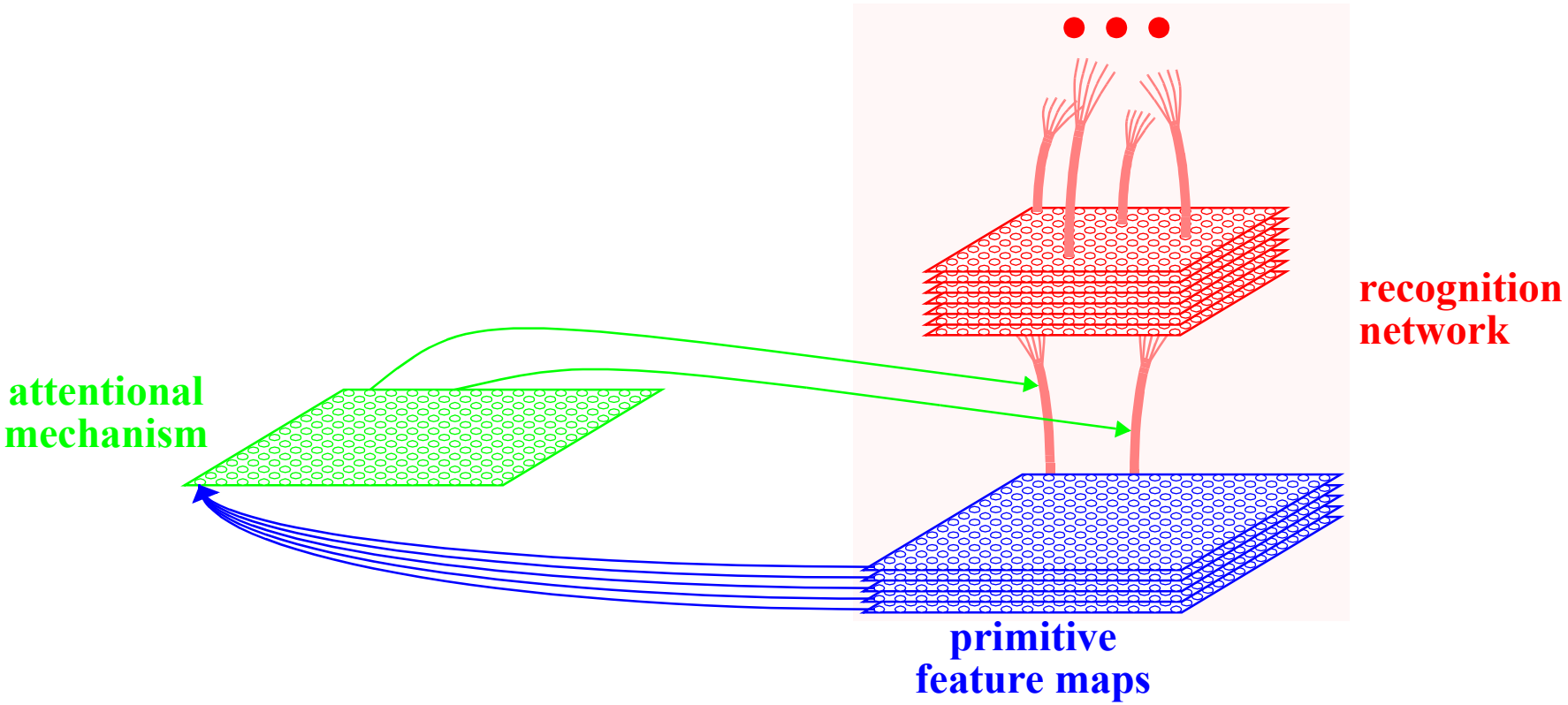
Results

Neglect reverses in moving condition: facilitation of left-sided target relative to static condition, inhibition of right-sided target

Interpretation

Consistent with hypothesis that attention operates on an object-based representation

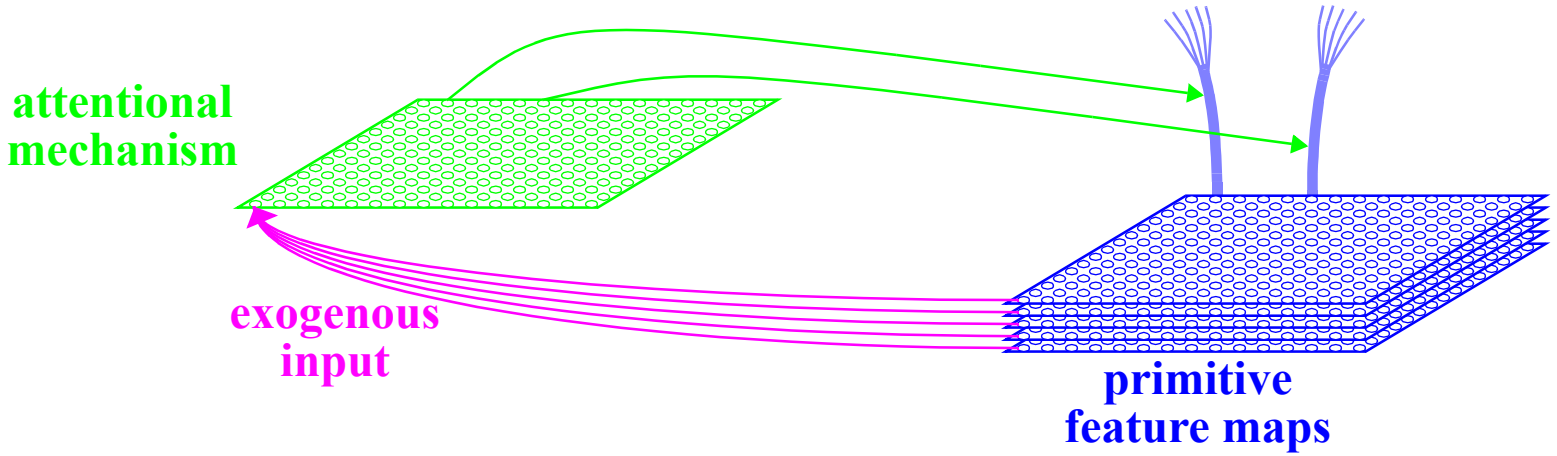
MORSEL (Mozer, 2002)



Recognition network: parallel across visual field, capacity limited

Attentional mechanism: determines where in visual field to focus processing resources

The Attentional Mechanism



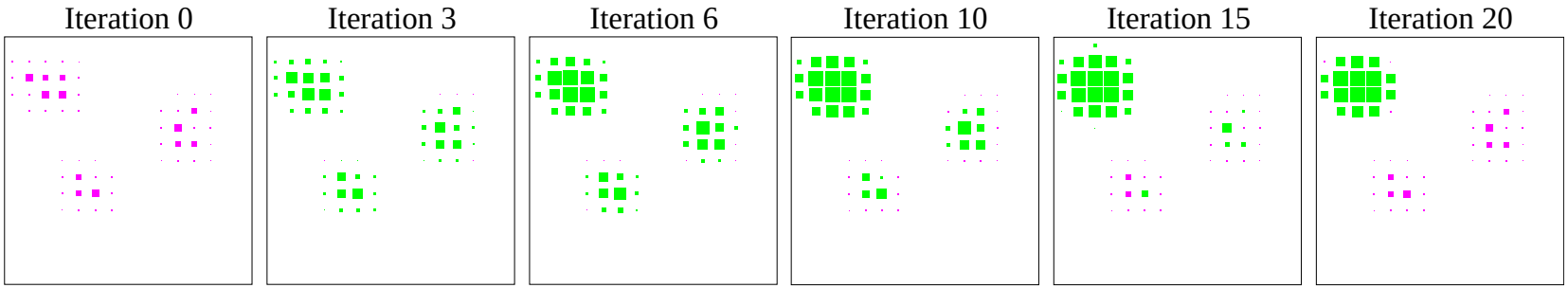
One AM unit per visual field location.

Activity of AM unit indicates salience of corresponding location, and gates activity flow through recognition system.

Competition generally results in selection of a contiguous region in which visual features are present.

Representation of space is viewer based.

Attentional Mechanism Dynamics



Operation of the AM based on three principles:

- Bias principle: Locations containing visual features should be activated.
- Cooperation principle: Locations adjacent to activated locations should also be activated.
- Competition principle: Locations whose activity grows the slowest should be suppressed.

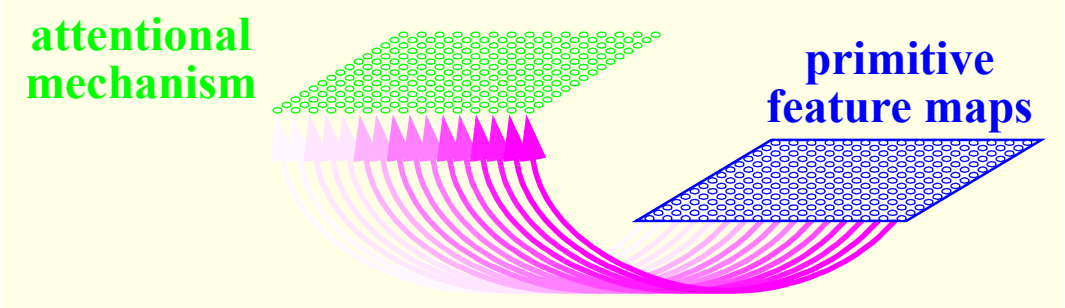
fixed parameters *free parameter*

$$a_{xy}(t) = \mathrm{f}\left(a_{xy}(t-1) + \mathrm{exo}_{xy} + \mu \sum_{\substack{i,j \in \\ \mathrm{NEIGH}_{xy}}} [a_{ij}(t) - a_{xy}(t)] - \theta[\gamma \bar{a}(t) - a_{xy}(t)] \right)$$

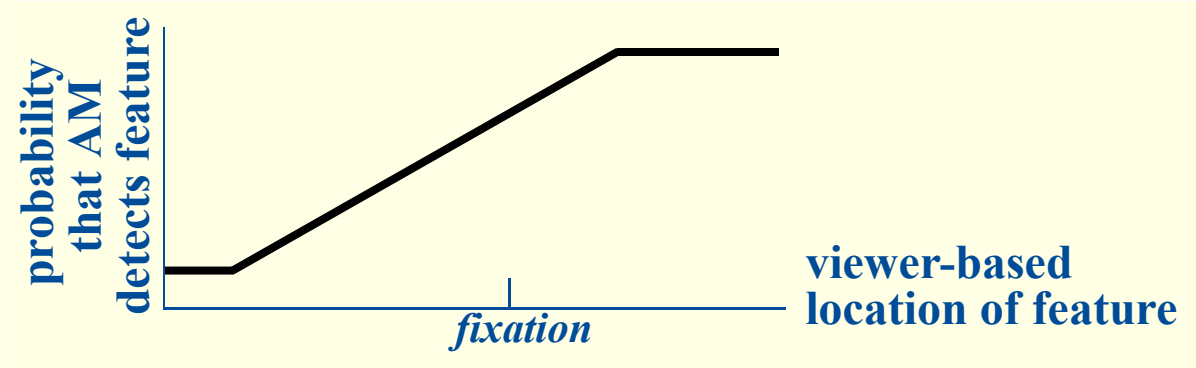
AM unit activity *linear thresh.* *exogenous input* *avg. activity of active units*

Lesioning the Attentional Mechanism

Graded lesion to the AM exogenous inputs (motivated by Kinsbourne, 1987)



Visual features are less effective in attracting attention.



Explains neglect-related deficits in reading and line bisection (Mozer & Behrmann, 1992; Mozer, Halligan, & Marshall, 1997).

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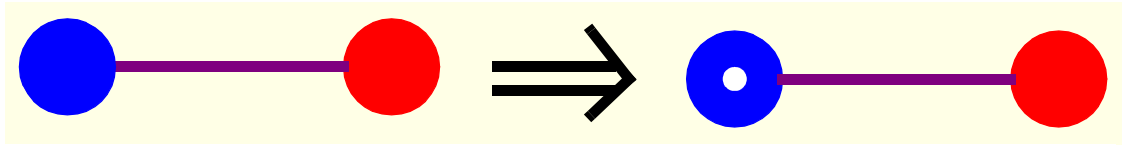

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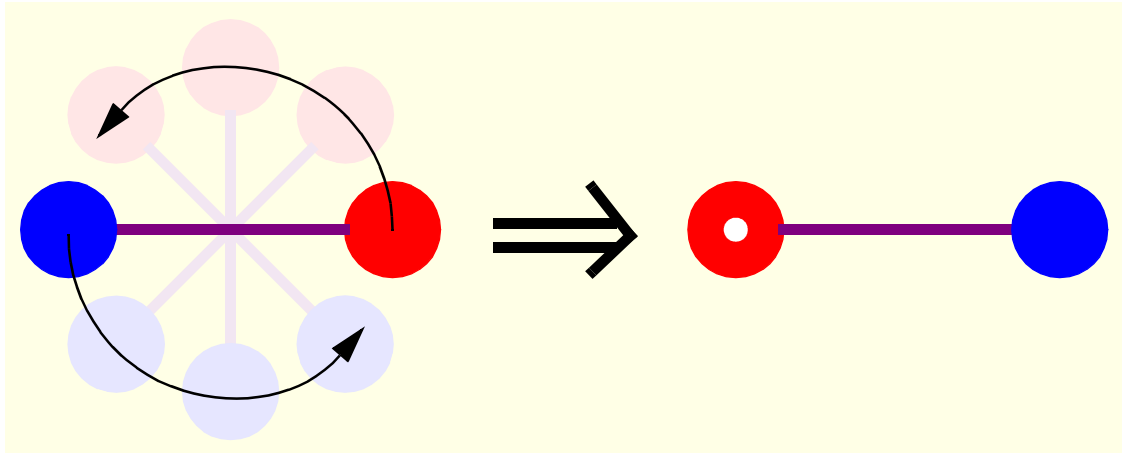

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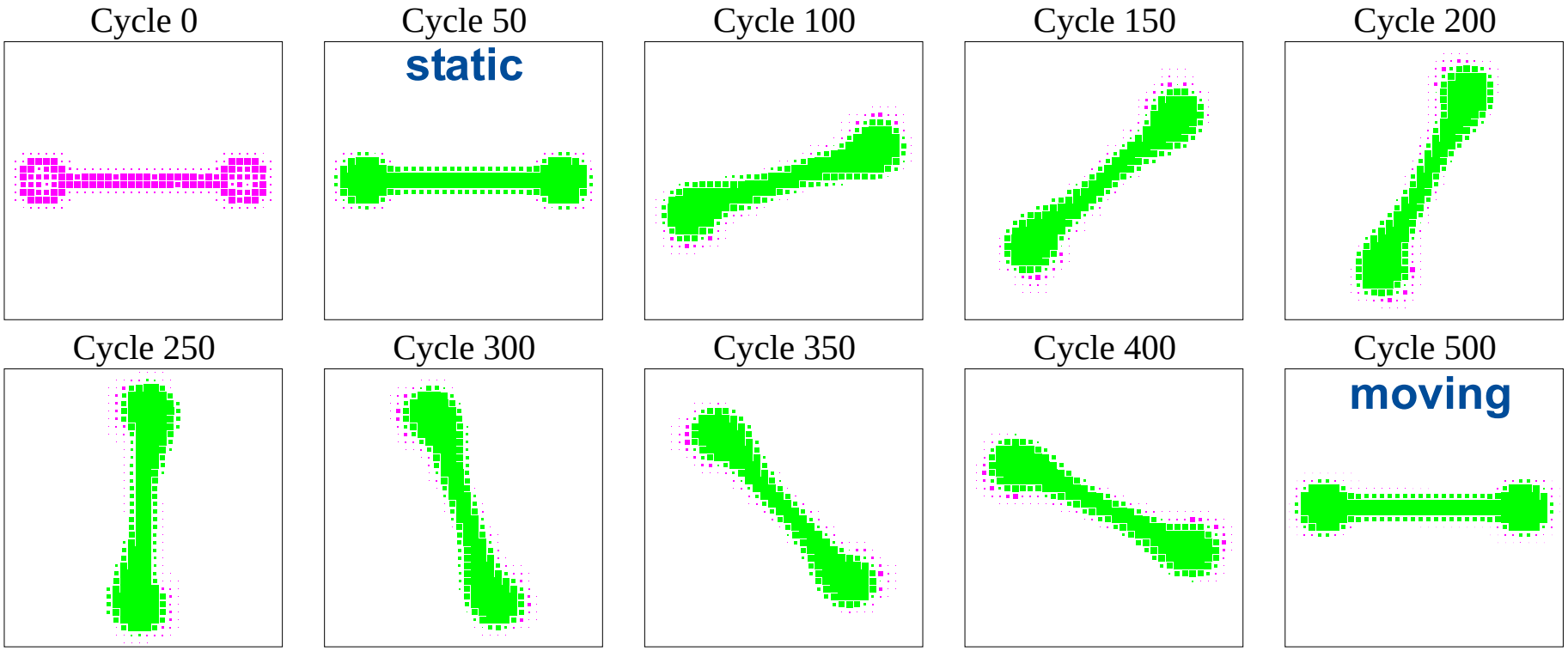
Simulation of Normal Model

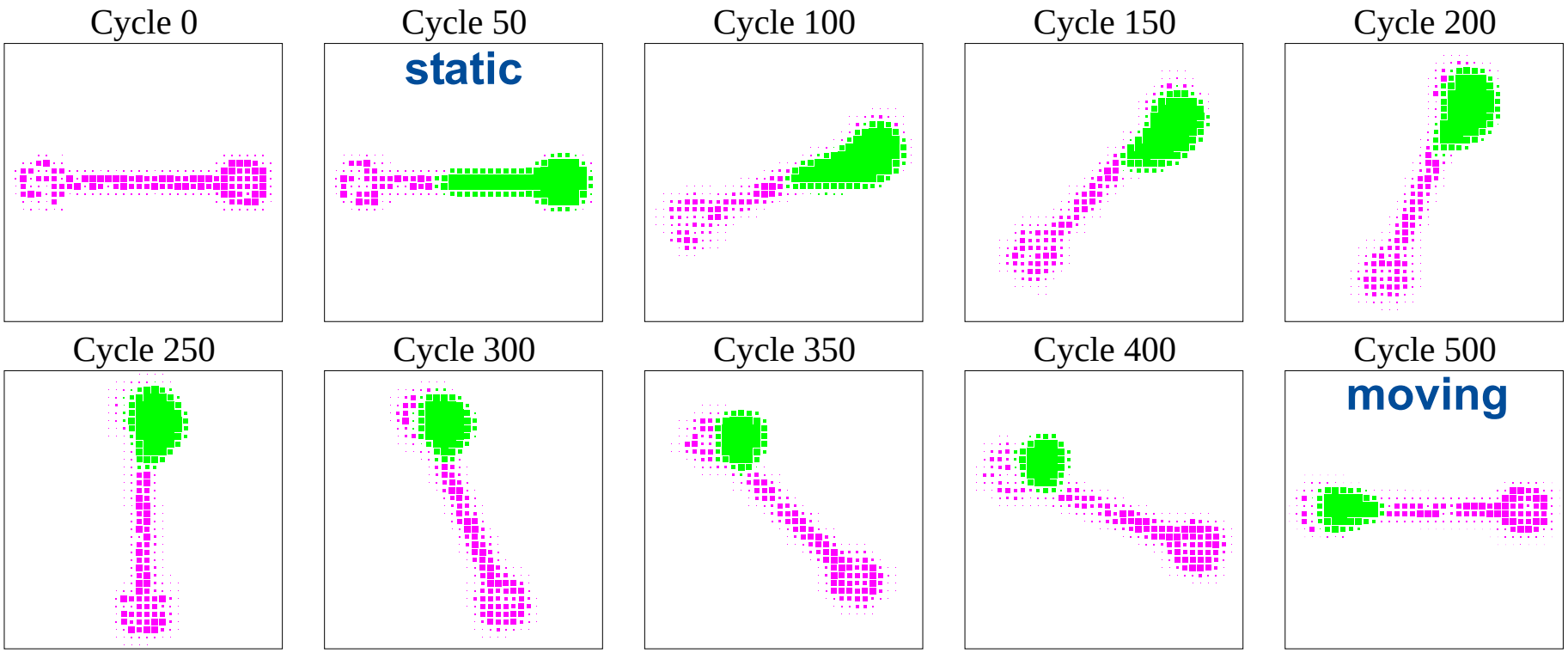


In both static and moving conditions, entire dumbell attended.

Assume RT to a target in a given disk is inversely related to attentional activity in the disk.

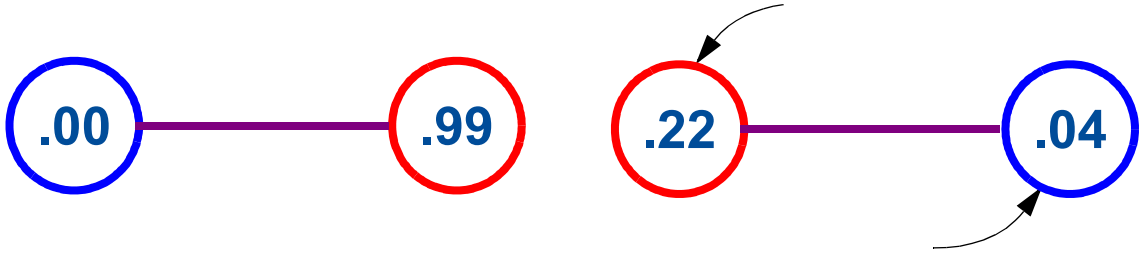
Thus, RT equal for left or right target, and moving or static.

Simulation of Lesioned Model



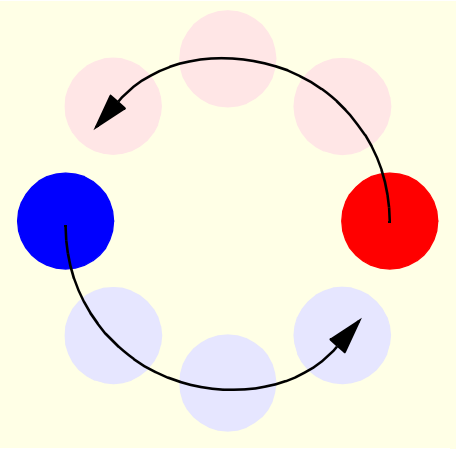
Static and moving conditions result in opposite attentional states, as would be expected from neglect in an object-based reference frame.

Mean AM unit activity shows reversal:

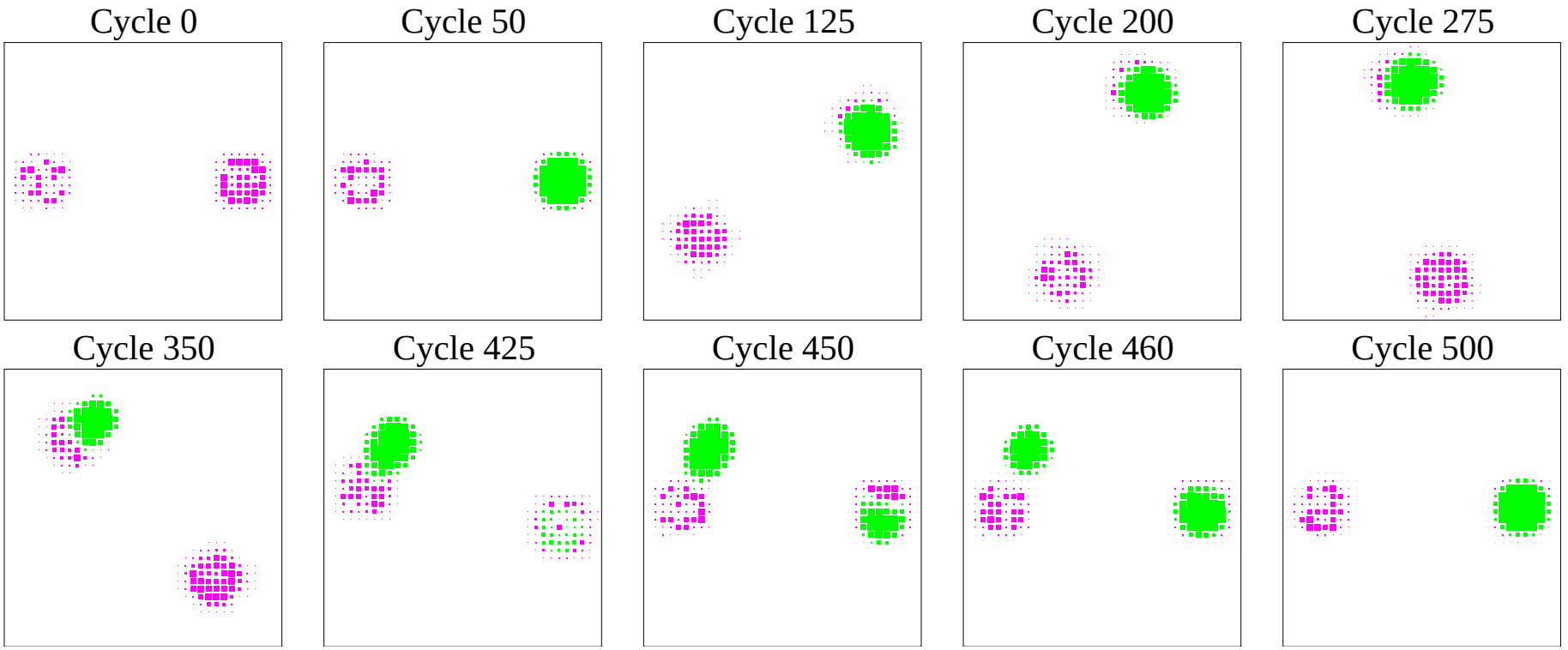


Disconnected Disks

Tipper and Behrmann (1996) found no reversal of neglect when disks are disconnected, further suggesting that objects play a crucial role in attentional allocation.



AM produces same result with no explicit object representations.

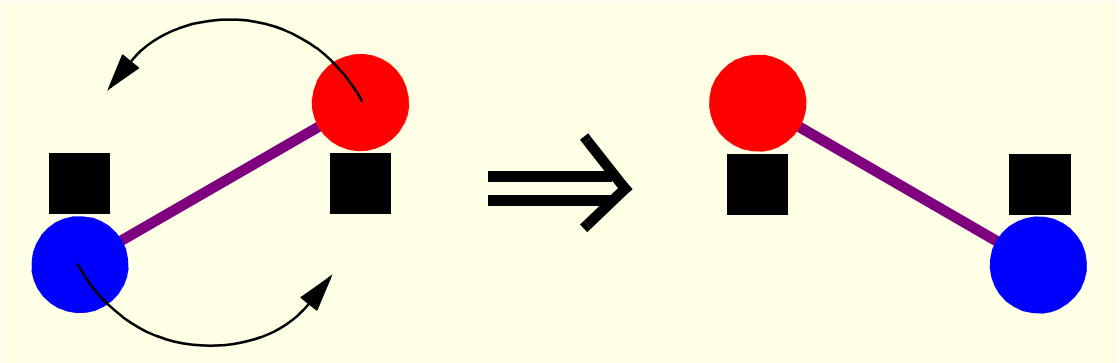


Barbell Plus Squares

Task

Barbell rotates, squares are stationary

Target may appear either on a disk or a square



Results

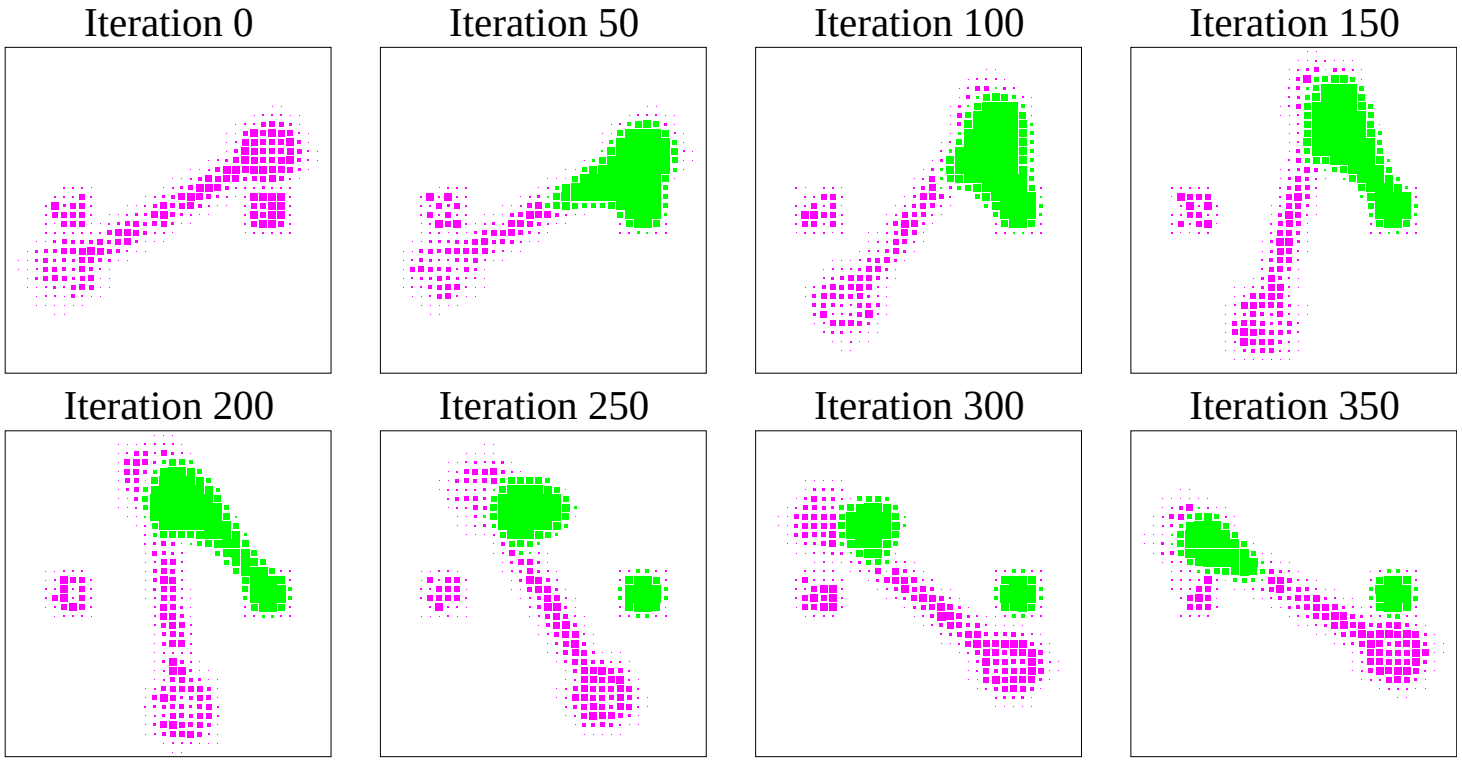
Neglect reverses for targets appearing on disks, but not for targets appearing on squares.

Interpretation

Neglect observed in both viewer- and object-based frames simultaneously.

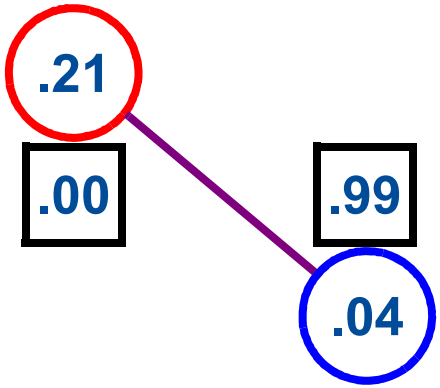
Attention can select and access information encoded with respect to multiple reference frames.

Simulation of Lesioned Model



Mean AM activity shows reversal for disks but not squares.

Similar result if spillover of AM activity from disks to squares is prevented by perceptual grouping.



Role of Modeling

Experimental studies of neglect suggested that the visual system does significant unconscious processing to analyze scene in terms of objects and their relationships.

Computational model suggests this isn't necessary.

Computational model is more consistent with neurophysiological data.

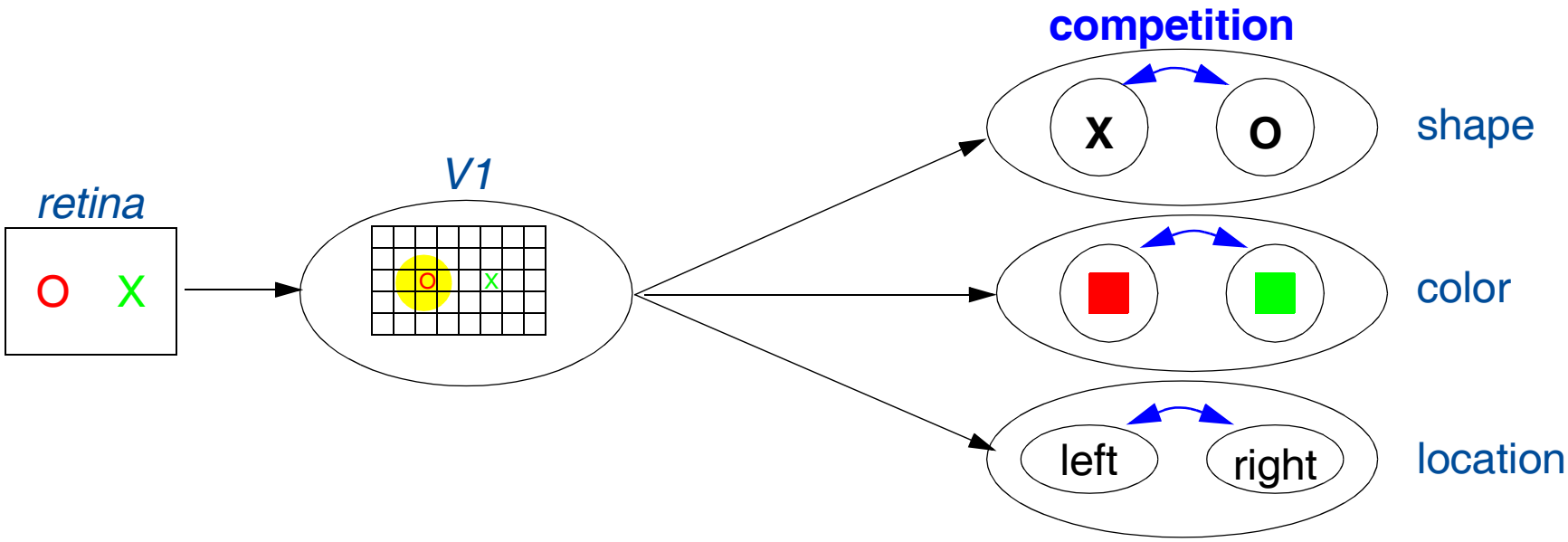
- No evidence for object-based representations in the brain.

Relationship Between Attention and Awareness

In synaesthesia and neglect, we see that attention is critical for awareness.

Two ideas concerning the relationship between attention and awareness:

1. Attention can increase activation for a stimulus to rise above threshold.



Relationship Between Attention and Awareness

In synaesthesia and neglect, we see that attention is critical for awareness.

Two ideas concerning the relationship between attention and awareness:

1. Attention can increase activation for a stimulus to rise above threshold.

2. Attention enables binding in an interactive network that consists of multiple brain regions.