Perceptual Organization: Not a Monolithic Entity But a Multiplicity of Processes

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Perceptual organization

The visual processes structuring the bits and pieces of visual information into coherent units

Gestalt Psychology

- Organization is achieved by innate grouping and segregation principles

❖Grouping

- ❖Classical: proximity, good continuation, similarity, common fate, closure (Wertheimer, 1923/1955)
- ❖New: common region (Palmer, 1992); connectendess (Palmer & Rock, 1994)

❖Figure-ground segregation

- ❖Classical: relative size, contrast, convexity, symmetry (Rubin,1915/1958)
- ❖New: familiarity (Peterson and Gibson, 1994), lower region (Vecera et al., 2002), spatial frequency (Klymenko and Weisstein, 1986), base width (Hulleman and Humphreys, 2004), and extremal edges (Palmer and Ghose, 2008)

Traditional view:

- A unitary phenomenon
- Operates at a single, early, preattentive stage
- In a bottom-up fashion
- Provides the substrate on which higher-level perceptual processes operate

(e.g., Julesz, 1981; Marr, 1982; Neisser, 1967; Treisman, 1982, 1988).

PO is a multiplicity of processes

- Time course
- Developmental trajectory
- Multifaceted relation with visual attention
- Influenced by experience and familiarity
- Operate at many levels

(e.g., Behrmann & Kimchi, 2003a,b; Ben Av & Sagi, 1995; Kimchi, 1998, 2000, 2003, 2009, 2011; Kimchi & Razpurker-Apfeld, 2004; Kimchi et al., 2005; Kovacs, 2000; Kurylo, 1997; Hadad & Kimchi, 2006, 2008; Palmer et al., 2003; Razpurker-Apfeld & Kimchi, 2007; Quinn & Bhatt, 2006; Quinn et al., 2002)

- Behavioral methods
  - adults
  - children
  - neurological patients
- Different but complimentary perspectives:
  - Microgenetic analysis of perceptual organization
  - Ontogenesis of perceptual organization
  - The relation between perceptual organization and visual attention

Microgenesis of Perceptual Organization

Analysis of the time course of the development of the percept in adult observers - what processing occurs when during the stream of visual processing.

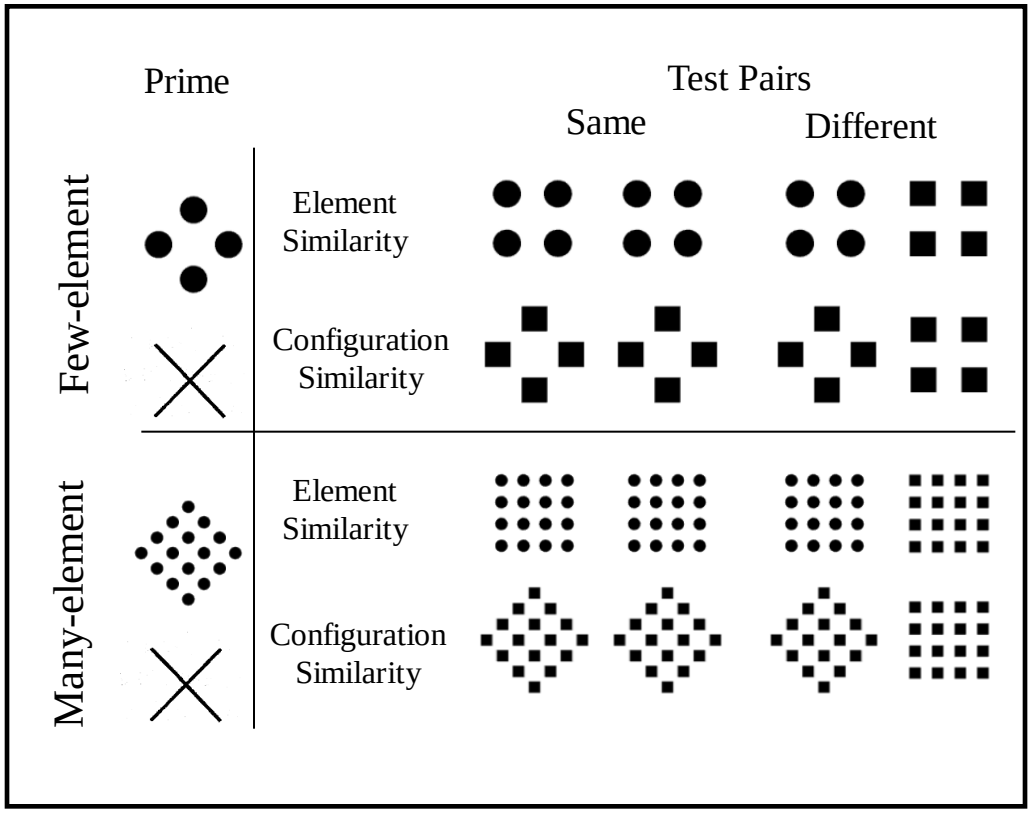
Primed matching (Beller, 1971):

- A prime is followed by a pair test of figures to be matched for identity.
- Responses to “same” pairs are faster for pairs similar to the prime than to pairs dissimilar to the prime.
- If we vary the duration of the prime and construct test figures that are similar to different aspects of the prime, it enables us to probe changes in the representation over time.

Microgenetic Studies of Grouping and Individuation of Multiple Elements

- Prime-test similarity: Element, Configuration, Neutral (Control).
- Prime duration: 40, 90, 130, 390, or 690 ms.
- Comparing responses to test pairs at different prime durations reveals which structures are available in earlier and later representations.

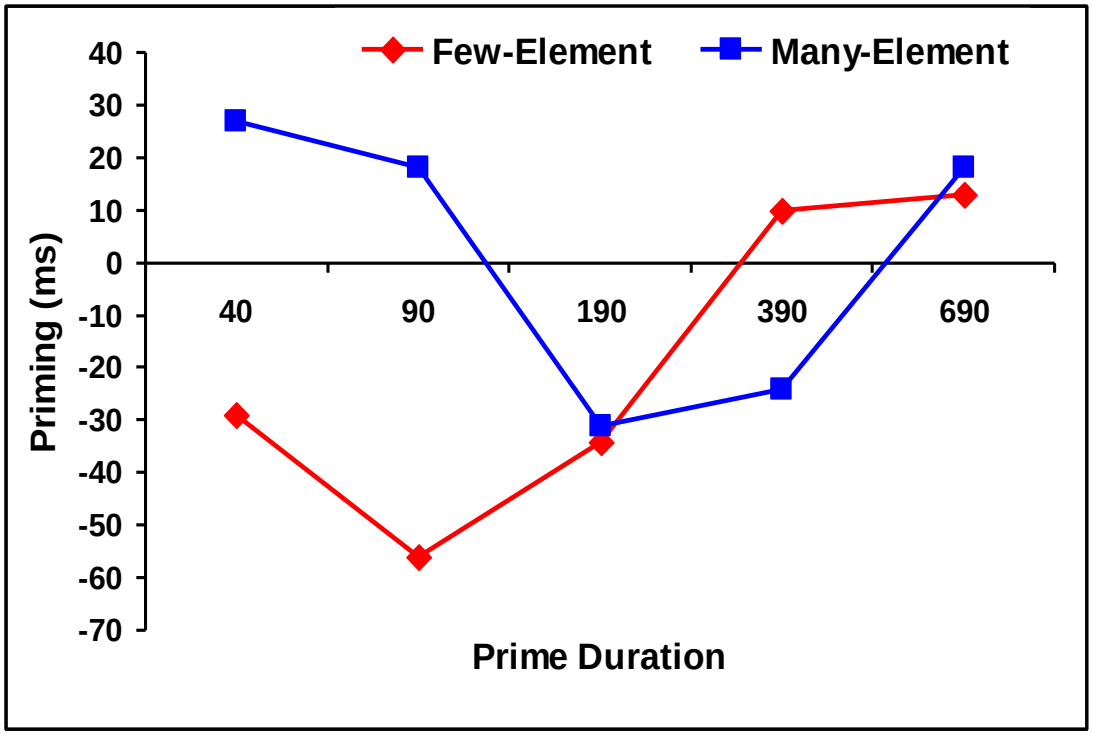
Primed Matching



(Kimchi, 1998)

Priming = [RT(ES/Prime)-RT(CS/Prime)] –
[RT(ES/Control)-RT(CS/Control]

Priming > 0 ⟶ Priming of Configuration
Priming < 0 ⟶ Priming of Elements



Many-Element:

- Configuration is primed at brief exposures.
- Elements are primed at longer exposures

Few-Element:

- Elements are primed at brief exposures.
- Configuration is primed at longer exposures.

Adapted from Kimchi, 1998

Time course (primed matching, visual search):

- **Organization of hierarchical stimuli** (Kimchi, 1998, Kimchi et al., 2005; Behrmann & Kimchi, 2003)

  - grouping many relatively small elements into a global configuration is early and rapid
  - grouping a few relatively large elements consumes time

  Desirable characteristics for a system whose one of its goals is object recognition: many small elements – texture of a single object; few large elements: separate object or distinctive parts

- **Grouping by different cues: proximity, closure, collinearity, familiarity** (Hadad & Kimchi, 2008; Kimchi, 2000; Kimchi & Hadad, 2002)

  - Gestalt principles hold only when everything else is equal, i.e., when they are the only rule that applies and no other grouping factors are present

  - Perceptual organization is natural scenes is clearly determined by the simultaneous operation of several grouping principles

  - The integration of multiple grouping factors

- Grouping by different cues: proximity, closure, collinearity, familiarity (Hadad & Kimchi, 2008; Kimchi, 2000; Kimchi & Hadad, 2002)

  - Spatial proximity is critical for rapid grouping of shape by closure

  - Collinearity facilitates rapid grouping when the closure-inducing fragments are spatially distant

  - Familiarity can override the effect of low spatial proximity even in the absence of collinearity.

- **Grouping by lightness similarity** (Razpurker-Apfeld & Kimchi, 2007)

  - Grouping elements by lightness similarity into columns/rows is faster than grouping into a shape.

  - Even when guided by the same principle, groupings can vary in their time course

  - Time course of grouping depends not only on the Gestalt principle that guides the grouping but also on the processes involved in the grouping.

Ontogenesis of Perceptual Organization

- Functional onset

✓ Rate of development

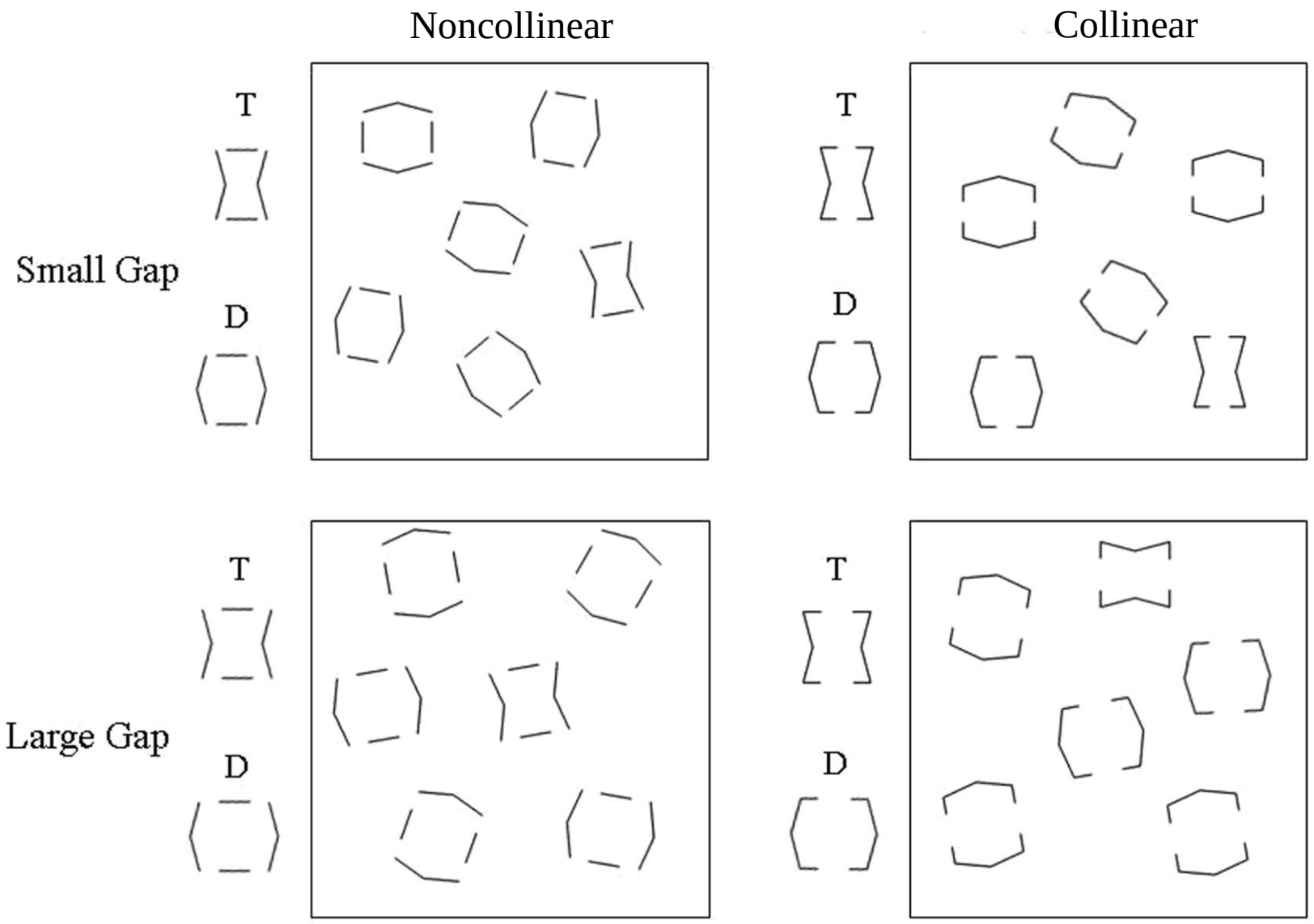
✓ The age at which ultimate functioning is attained

Age-related changes in

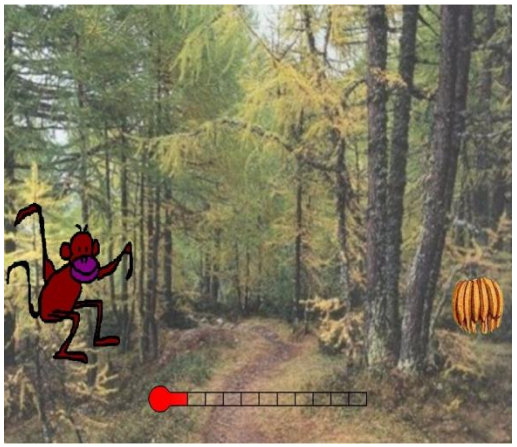
- Grouping of multiple elements into a global shape
- Grouping of shape by perceptual closure, proximity and collinearity.

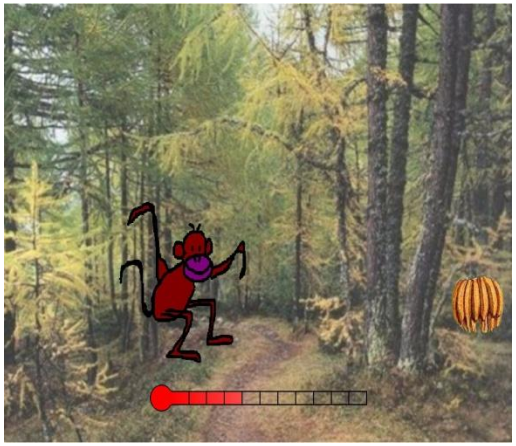
Tasks

- Visual Search
- Speeded classification
- Primed matching

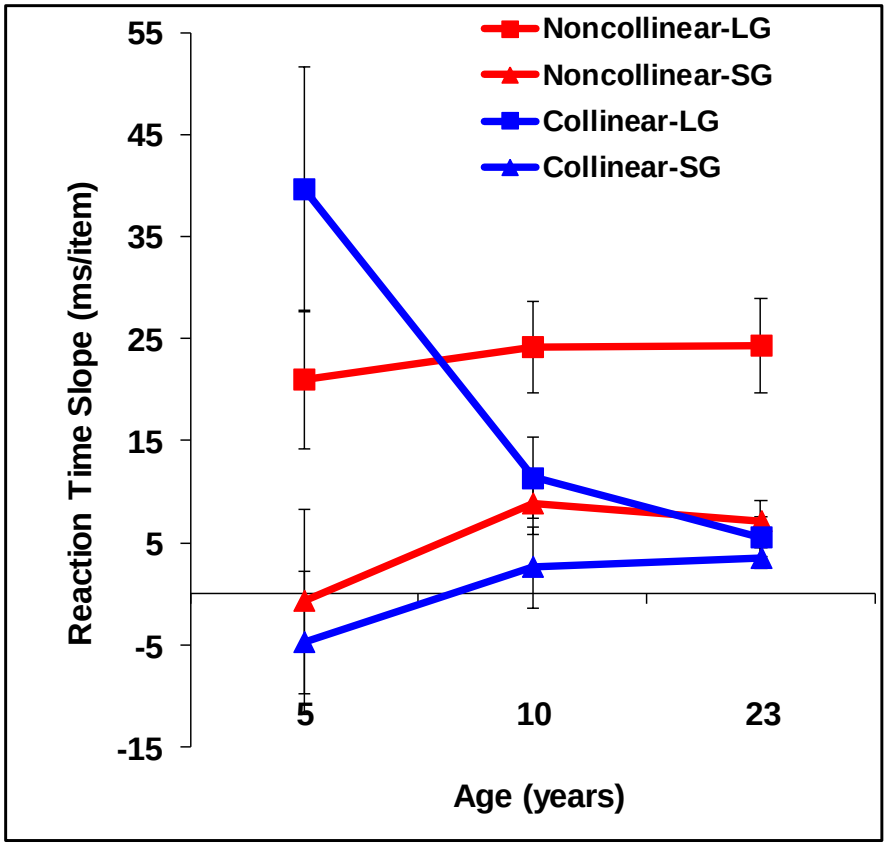

Noncollinear
Collinear
Small Gap
Large Gap
T
D
T
D
T
D
T
D

To increase children's motivation, in each session we used vivid pictures to present a story about a character on a mission (e.g., a monkey trying to reach bananas) and told the children that their own progress in the task would help the character reach its goal.





RT Slopes
(Target-present trials)

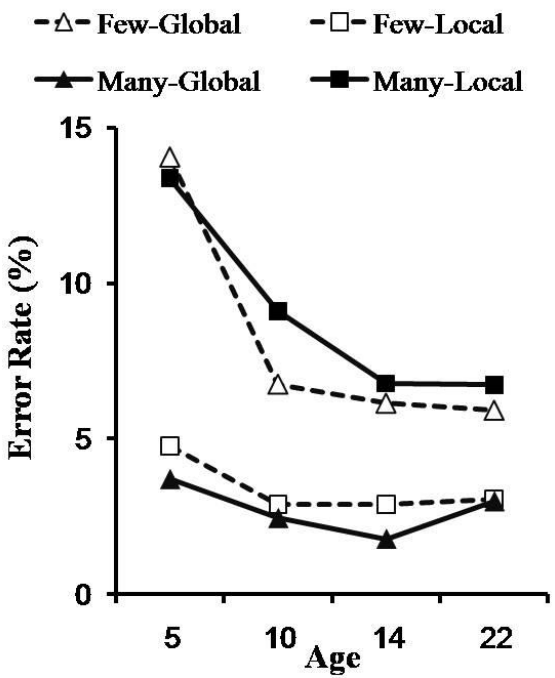


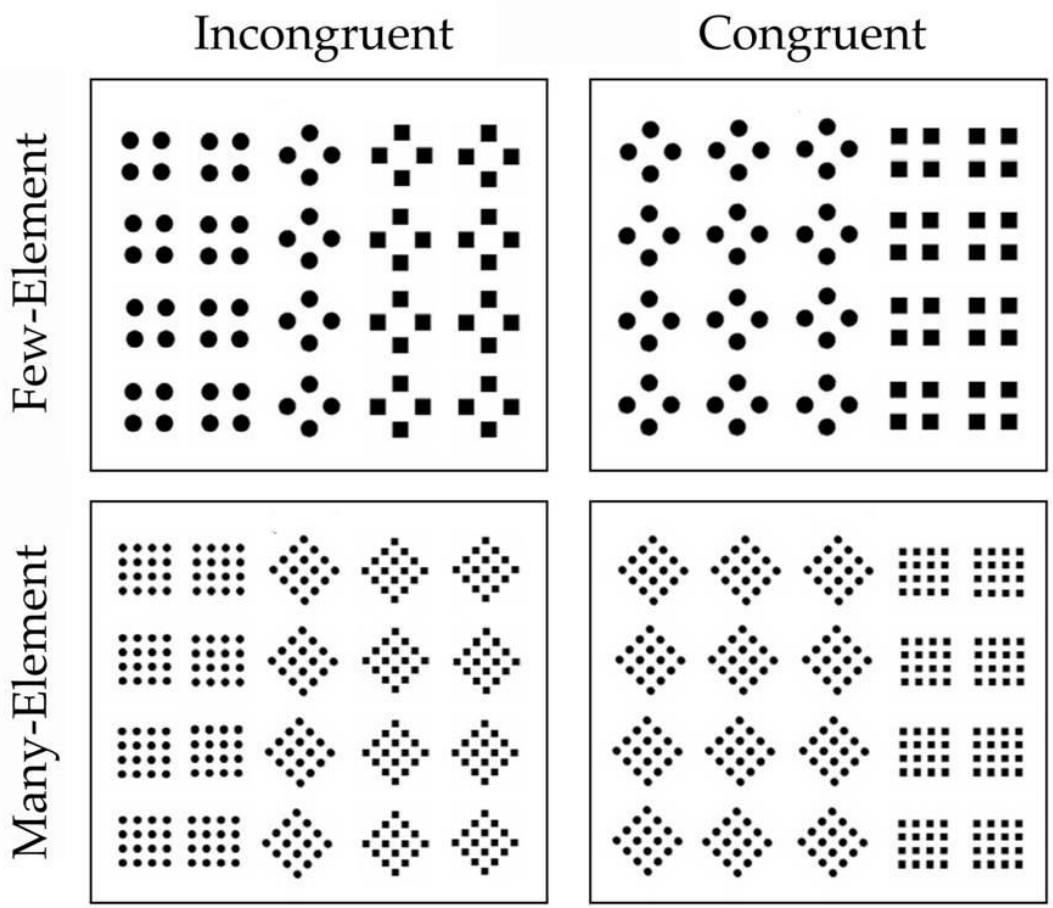
- **Noncollinear**:

  Efficient search for small gap, inefficient search for large gap for all age groups.

- **Collinear:** Efficient search for small gap for all age groups. Significant improvement from age 5 to 10 for large gap.

Hadad & Kimchi, 2006





Kimchi et al., 2005

- Some organizational processes mature relatively early:
  - Individuation of a few large elements (Kimchi et al., 2005)
  - Grouping spatially close fragments into a shape (in visual search; Hadad & Kimchi, 2006)
- Other organizational processes develop with age and reach adult-like levels only in late childhood
  - Grouping multiple elements into a global shape (Kimchi et al., 2005, Scherf et al., 2009)
  - Grouping spatially distant fragments by collinearity into a shape (Hadad & Kimchi, 2006)

- Even processes that appear to emerge early in life may have a long developmental course:
  - ❖ Infant are sensitive to the global configuration of hierarchical stimuli (e.g., Ghim & Eimas, 1988)
  - ❖ The ability to group multiple elements into a global shape continues to develop, and adult-like performance is not observed before the age of 10.
  - ❖ Infant are sensitive to good continuation (e.g., Quinn & Bhatt, 2005)
  - ❖ The ability to group fragments by collinearity matures between ages 5 and 10.

The developmental changes in perceptual organization abilities

- May depend on maturation of the visual system
- May be acquired through learning and experience
- May be a function of developmental improvements in other processes, such as flexibility of attention

- Our findings of the longer developmental trajectory coincides with what is known about the structural and functional development of the ventral visual pathway (Bachevalier, Hagger, & Mishkin, 1991; Burkhalter, 1993 Gogtay et al., 2004).

Perceptual Organization and Visual Attention

- Recent research suggests a close interplay between attentional and perceptual organization processes
- Perceptual organization constrains attentional selectivity (e.g., Baylis and Driver, 1992; Duncan, 1984; Egly et al., 1994; Kramer and Jacobson, 1991; Lavie and Driver, 1996; Moore et al., 1998).
- Attention constrains perceptual organization (Freeman et al., 2001; Freeman et al., 2004 Vecera, Flevaris, & Filapek, 2004).

- **Can perceptual organization take place without attention?**

- **Can perceptual organization affect the automatic deployment of attention?**

Can perceptual organization take place without attention?

Traditional view:

"the theories all agree that perceptual grouping occurs automatically and in parallel, without attention" (Treisman, 1982)

Logical considerations: Prima facie, if attention is to select candidate objects, organization of the visual scene into these objects must occur prior to selection.

- Empirical findings: mixed

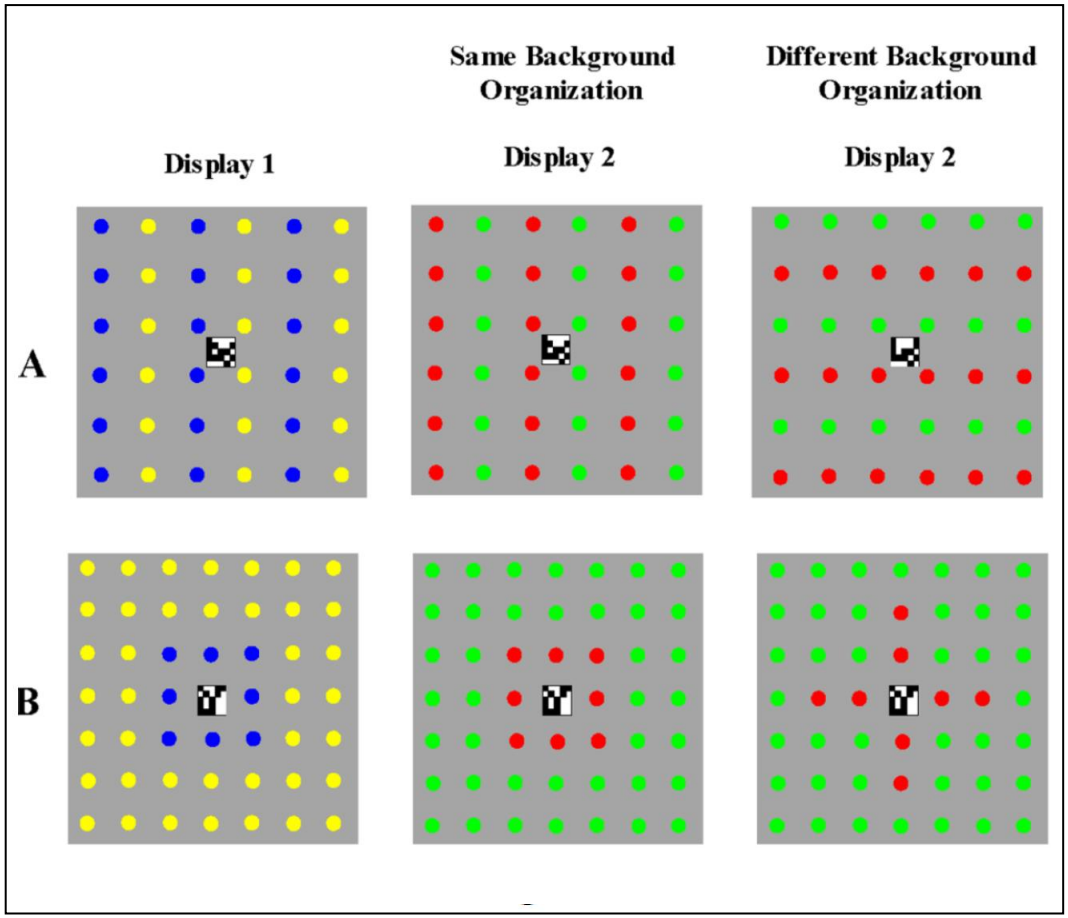
  (e.g., Ben-Av et al., 1992, Braun & Sagi, 1990; 1991; Driver et al., 2001; Julesz, 1981; Kimchi, 1998; Mack et al., 1992, Moore & Egeth, 1997; Rock et al., 1992; Treisman, 1982; Trick & Enns, 1997).

  - ❖Attention condition: inattention vs. divided attention or “spread” attention
  - ❖Measures: self-report vs. on-line measures
  - ❖Tapping different organizational processes

- **Conditions of inattention:**
  - ❖Highly demanding visual task
  - ❖The unattended stimuli are completely irrelevant to the task at hand, so that participants have no reason whatsoever to attend to them
- **Measures:**
  - ❖On-line measures
  - ❖Self-report

Grouping Under Inattention

- **Trial**: Two successive displays, each comprising a central matrix target and background elements.
- **Task**: Judge whether the successive targets are same or different. When different, only a single pixel changed.
- **Background organization:** stays the same or changes, independently of the targets. Colors of background elements always changed.
- **Measure:** influence of the background organization on the target same-different judgments.



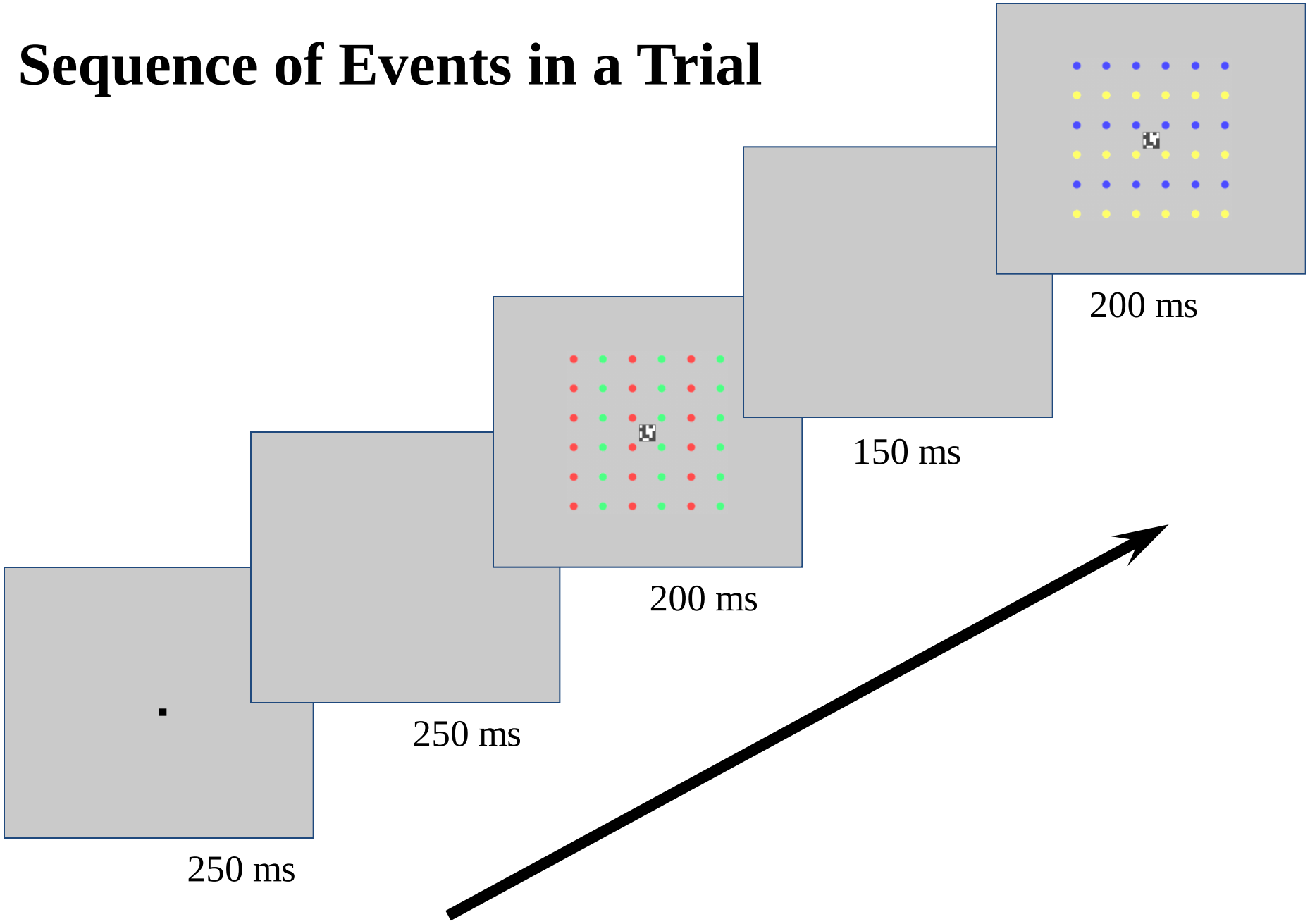
Kimchi & Razpurker-Apfeld, 2004

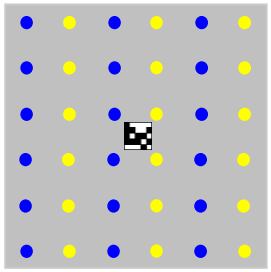
If organization of the background elements occurs without attention then "congruency effects" should be obtained:

- Target-same judgments would be faster and/or more accurate when the background organization stays the same than when it changes.

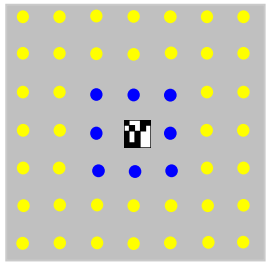
- Target-different judgments would be faster and/or more accurate when the background organization changes than when it stays the same.

Sequence of Events in a Trial

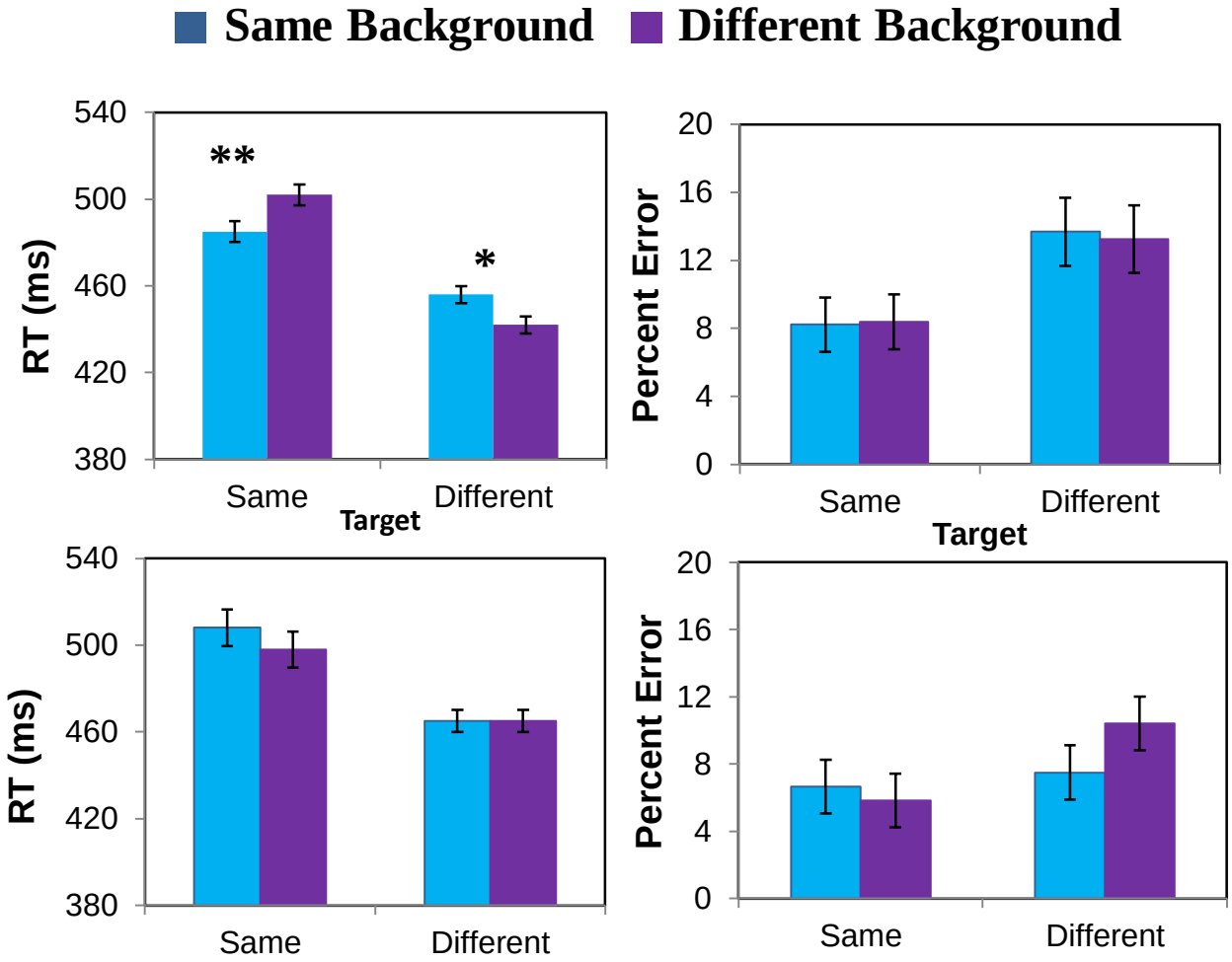




Columns/Rows by color similarity



Square/Cross by color similarity



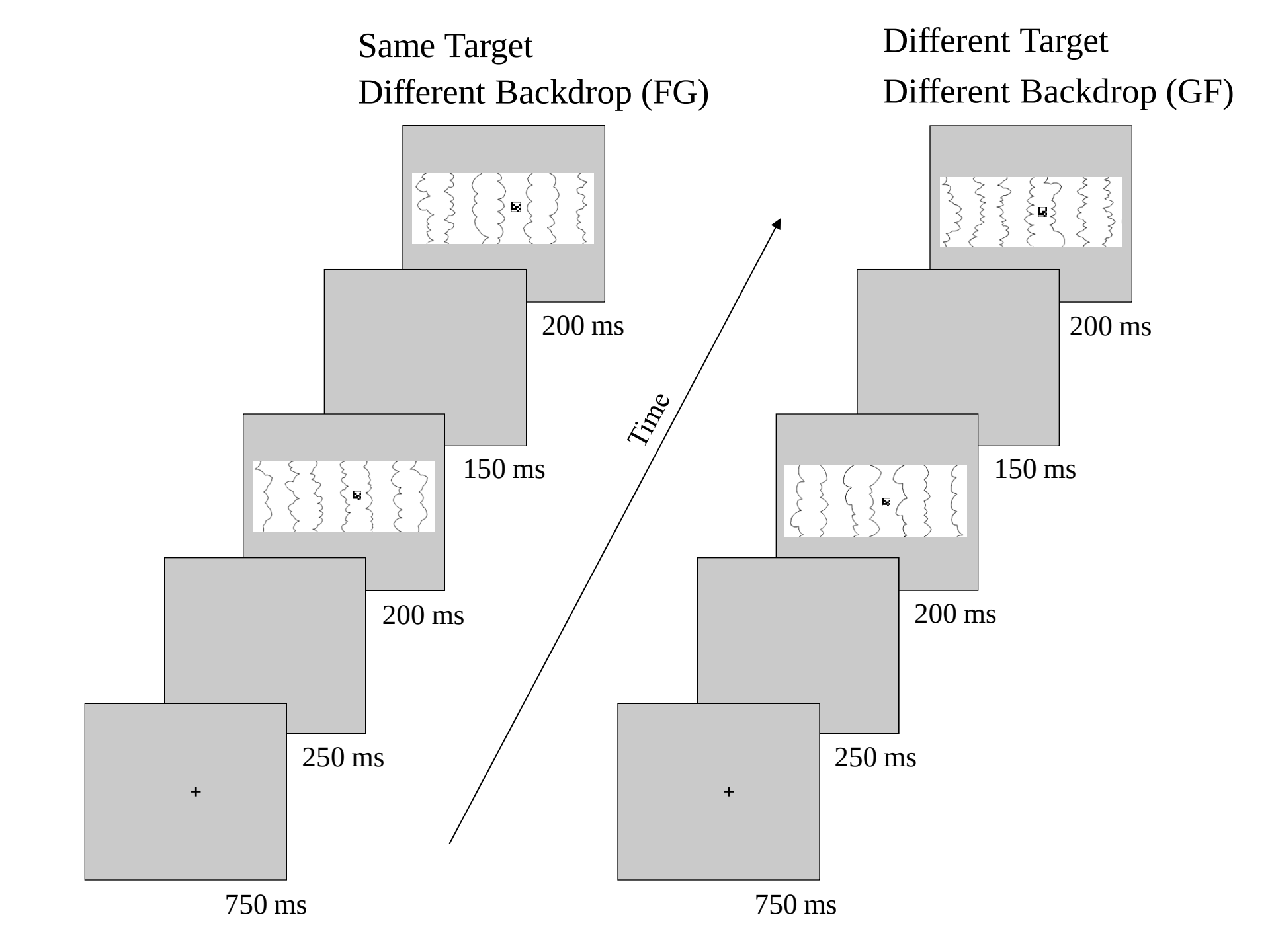
- **Grouping by color similarity of columns/rows:** congruency effects on the matrix-change judgments, even though participants reported no awareness of the background grouping (Kimchi & Razpurker-Apfeld, 2004)

  - Accomplished without attention

  - Further support: testing individuals with hemispatial neglect (Shomstein, Kimchi, et al., 2010).

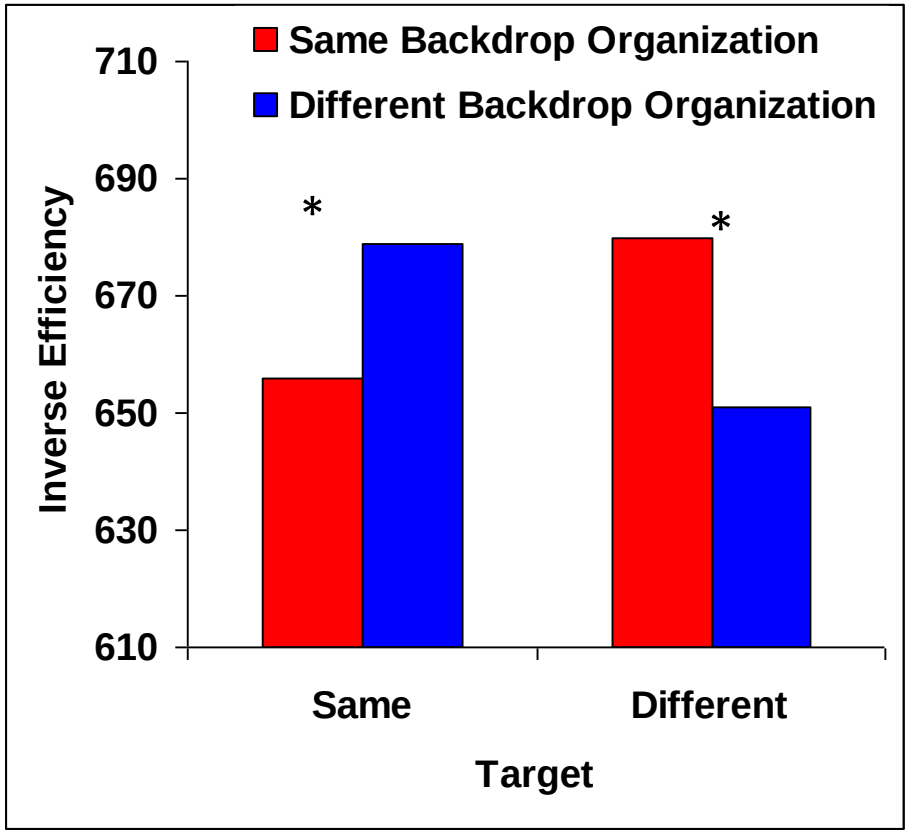
- **Grouping by color similarity of shape:** No congruency effects (Kimchi & Razpurker-Apfeld, 2004).

  - Cannot be accomplished without attention


Same Target
Different Backdrop (FG)
Different Target
Different Backdrop (GF)
200 ms
150 ms
200 ms
250 ms
750 ms
Time
200 ms
150 ms
200 ms
250 ms
750 ms

On-line performance on the matrix task

Inverse Efficiency (IE) = correct RT/p(correct)



- Figure-ground segmentation can occur without focal attention.
- Does not imply that figure-ground segmentation must always precede the deployment of focal attention:
  - ❖ Convexity is a powerful cue; when less potent figural cues are involved, segmentation may require the scrutiny of focal attention.
  - ❖ In natural scenes, adjacent regions are likely to have multiple competing cues. Figure-ground assignment in this case requires the resolution of cross-edge competition, which may demand attention.

Can perceptual organization take place without attention?

- Not all organizational processes are created equal. Some forms of grouping and figure-ground segmentation can occur under inattention. Others appear to require focused attention.
- Regardless of attentional demands, the products of organization are not available to awareness without attention.

- **An ongoing project:**
  - Different organization cues (e.g., Ruth Peled; Joshua Kotler)
  - Competition between organization cue (e.g., Einat Rashal)

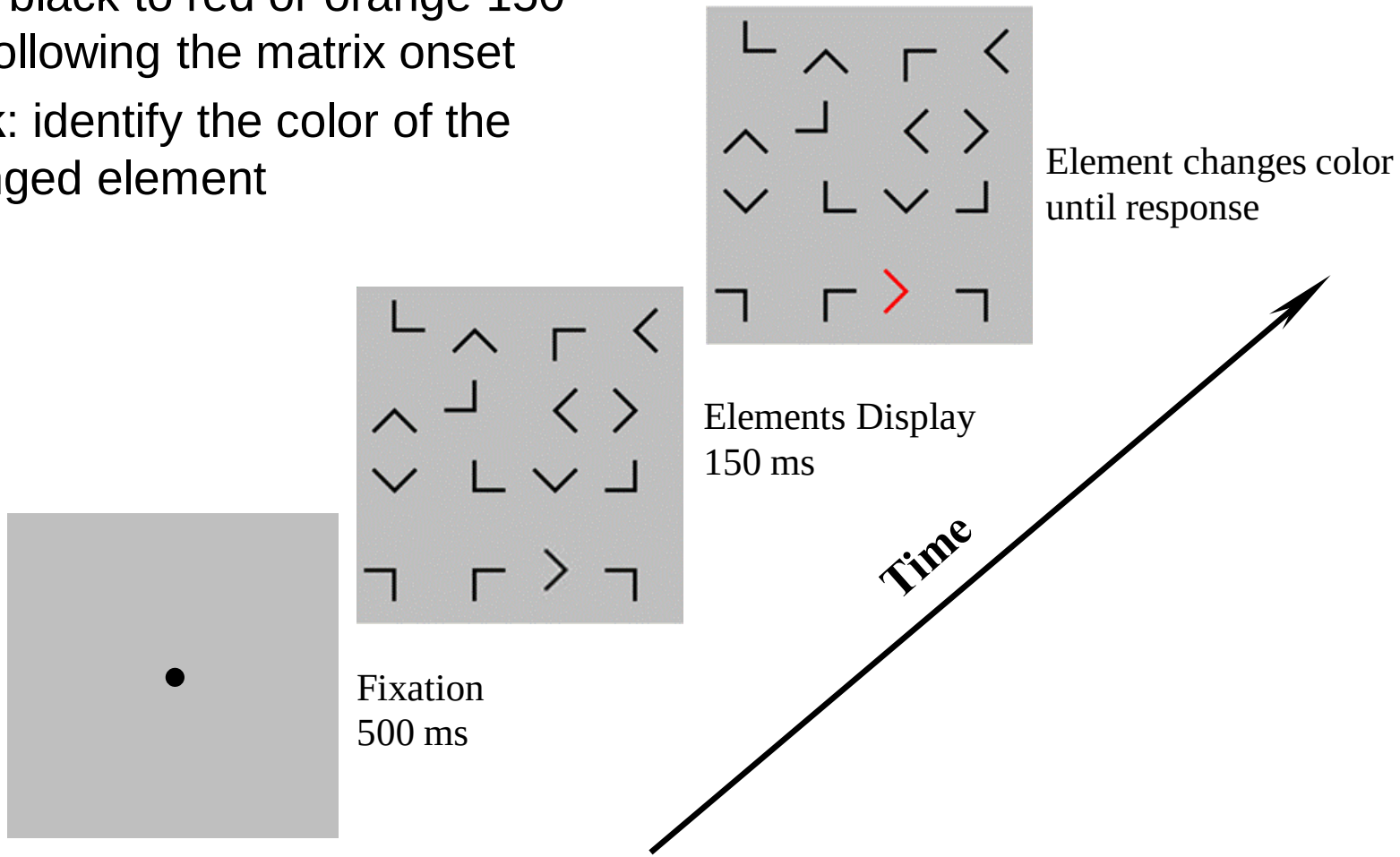
Can perceptual organization affect the automatic deployment of attention?

- The Gestalt organization factors and perhaps other non-accidental properties are likely to arise from environmental regularities, probabilistically implying objects in the environment.

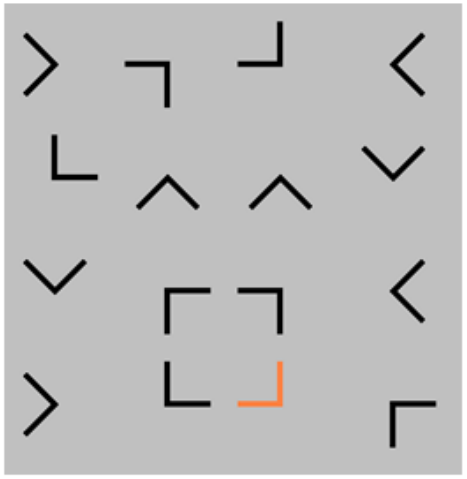
- Favoring a perceptual unit that conforms to Gestalt factors is a desirable characteristic for a system whose one of its goals is object identification and recognition.

When some elements in the visual scene are organized by Gestalt factors into a coherent perceptual unit (an "object"), is visual attention automatically deployed to the "object"?

- A matrix of 16 black L elements in various orientations
- One of the Ls changes its color from black to red or orange 150 ms following the matrix onset
- **Task**: identify the color of the changed element

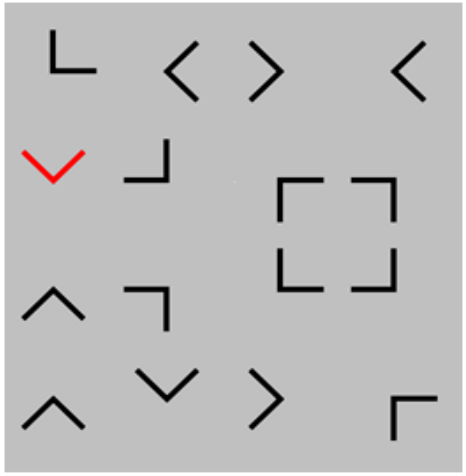


Inside Object



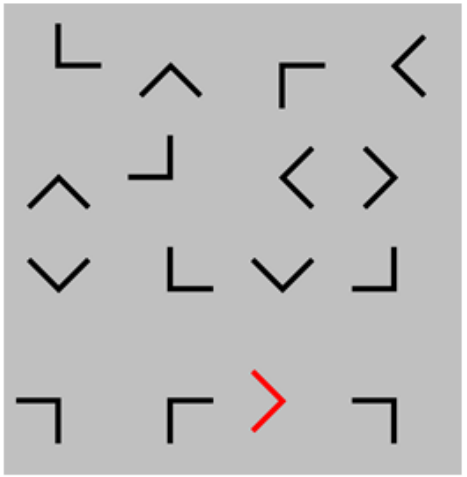
16.6% of all trials

Outside Object



34.4% of all trials

No Object



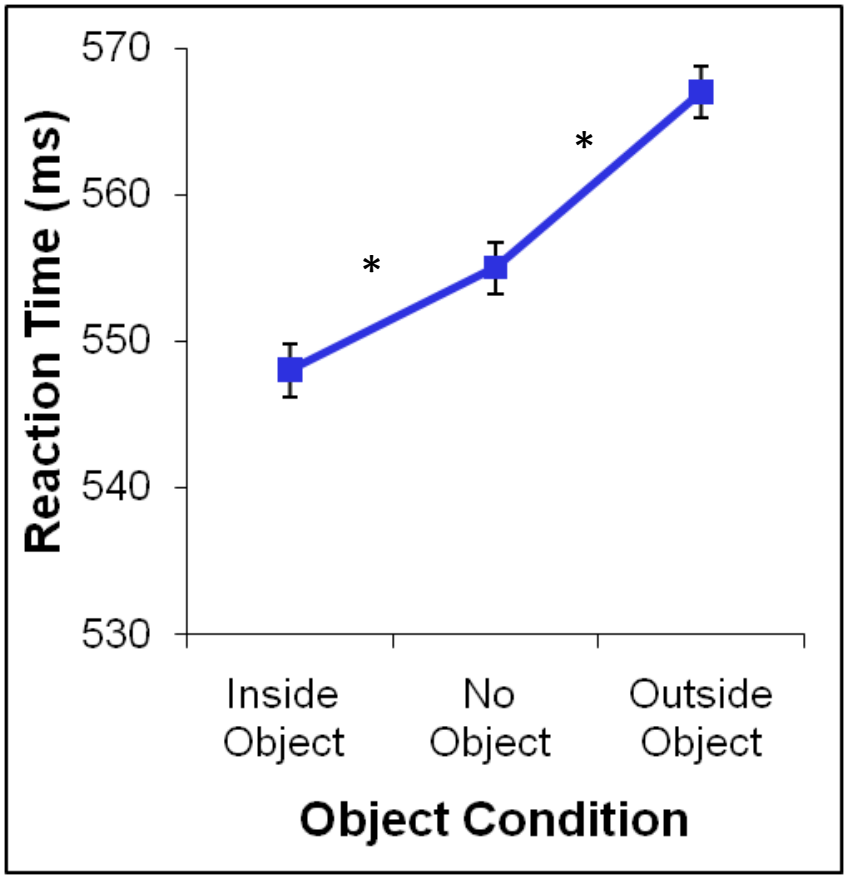
50% of all trials

The object is irrelevant to the task at hand and is not predictive of the target

If attention is automatically drawn to the object, then target's color identification would be:

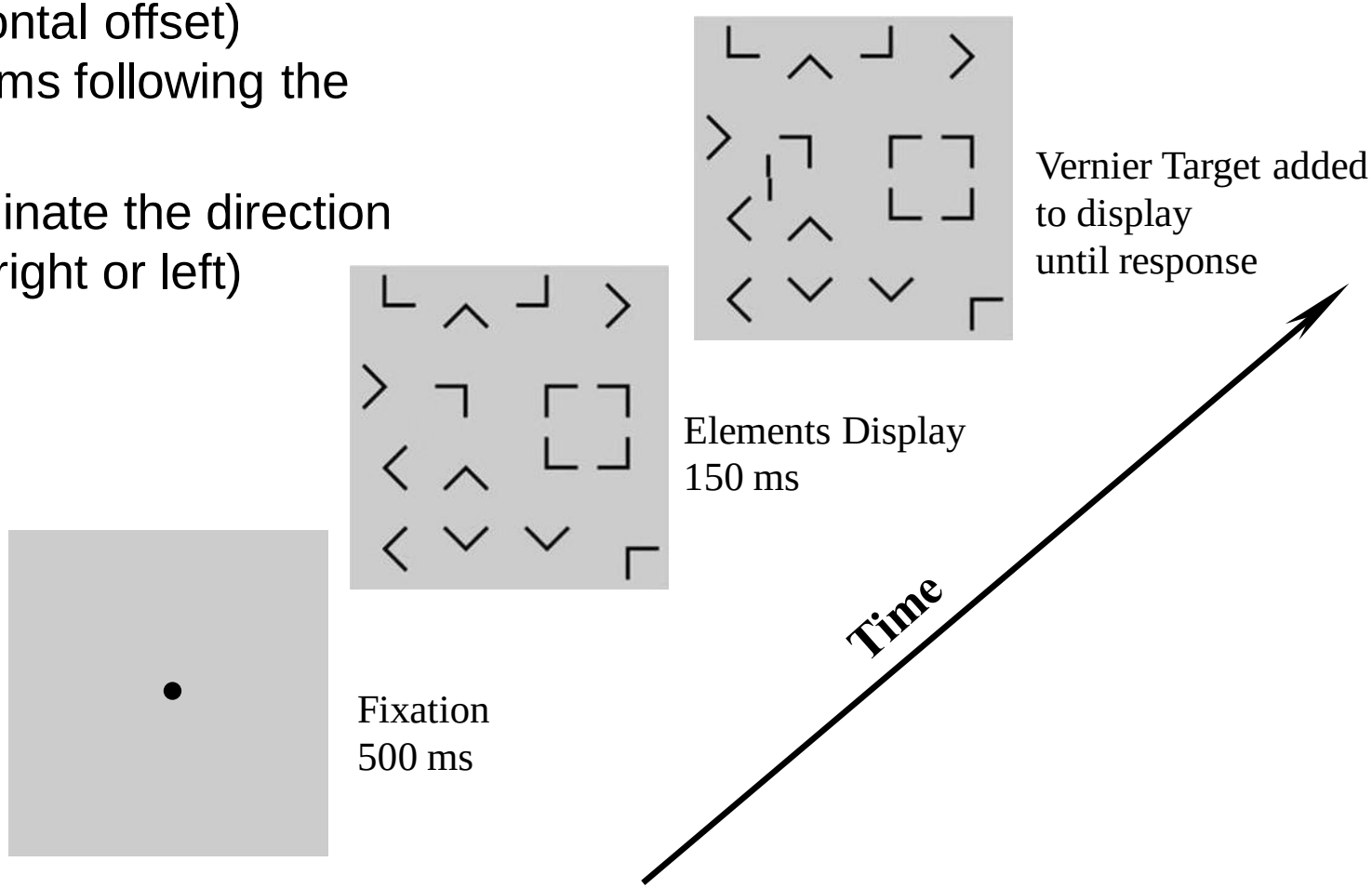
- Faster in the Object-inside trials than in the No-object trials (a **benefit**), because attention is allocated in advance to the object.

- Slower in the Object-outside trials than in the No-object trials (a **cost**), because attention has to be redirected from the object to the target.


570
560
550
540
530
Reaction Time (ms)
*
*
Inside Object
No Object
Outside Object
Object Condition

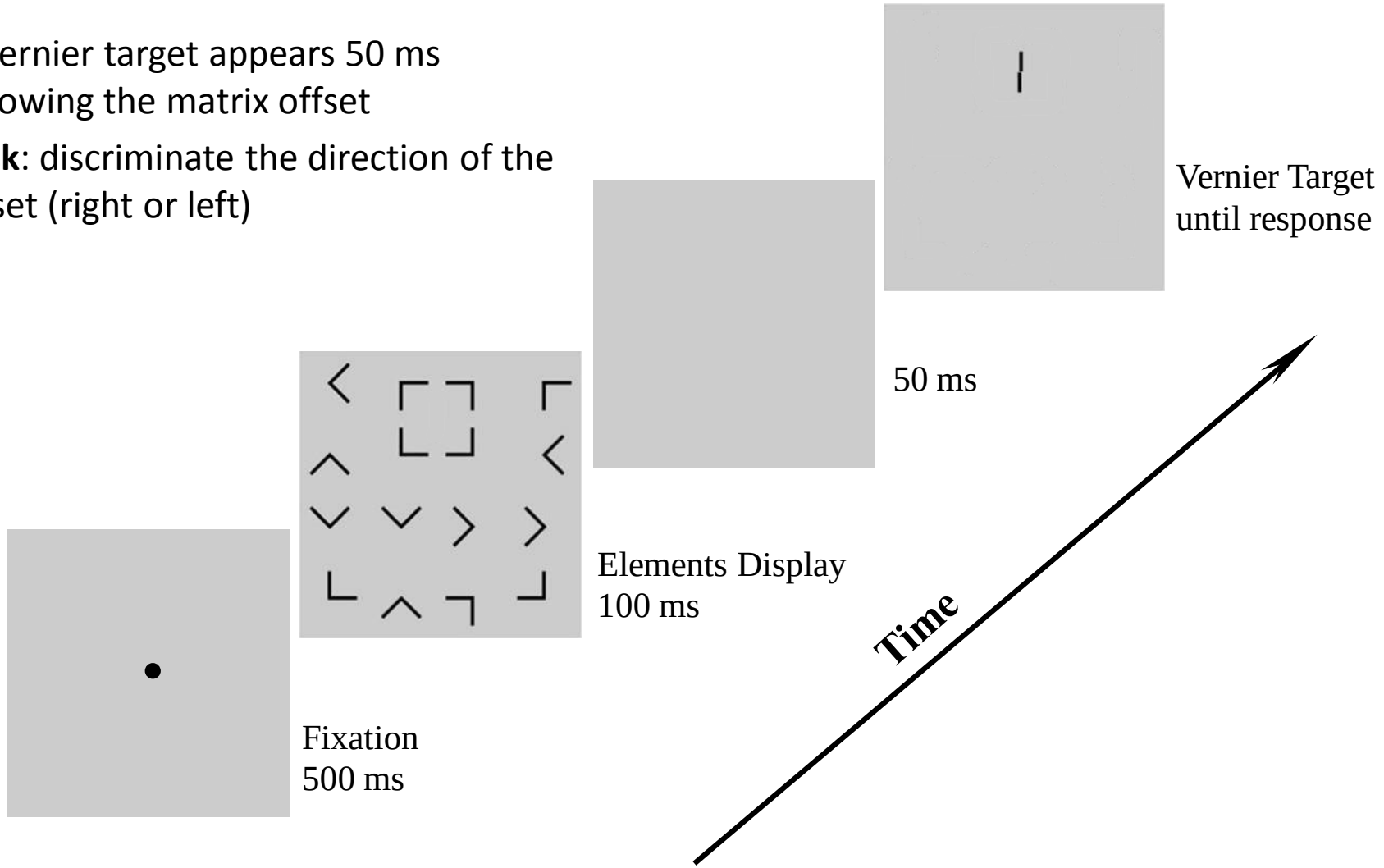
Target is not part of the object

- A matrix of 16 black L elements in various orientations
- A Vernier target (two vertical lines, one above the other, with a small horizontal offset) appears 150 ms following the matrix onset
- **Task**: discriminate the direction of the offset (right or left)



Target appears after matrix offset

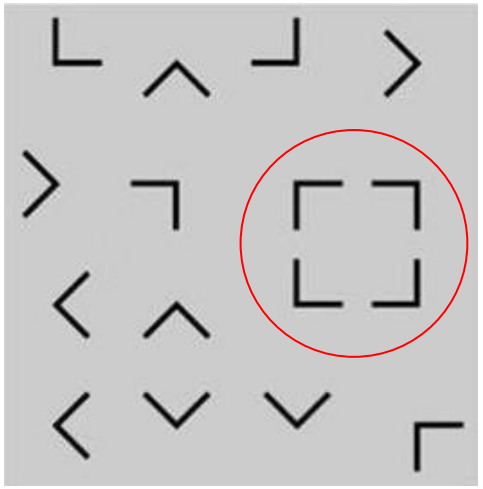
- A matrix of 16 black L elements in various orientations appears for 100 ms
- A Vernier target appears 50 ms following the matrix offset
- **Task**: discriminate the direction of the offset (right or left)



- Perceptual “object” captures attention automatically
- Fast like exogenous cues, but no IOR
- The automatic attraction of attention by an “object” is mediated, at least partially, by spatial factors

Kimchi, Yeshurun, & Cohen-Savransky, 2007;
Yeshurun, Kimchi, et al., 2009

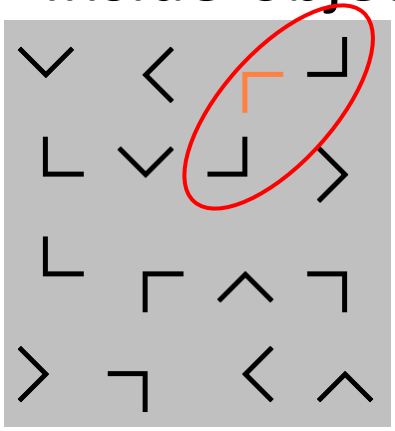
- Which organization factors suffice for an "object" to capture attention?

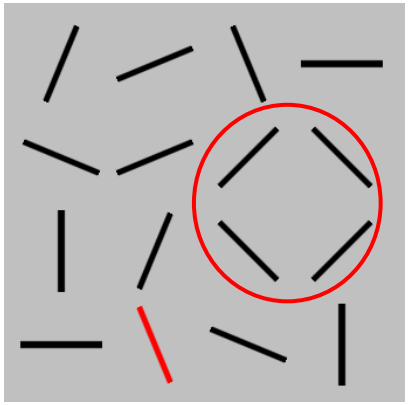


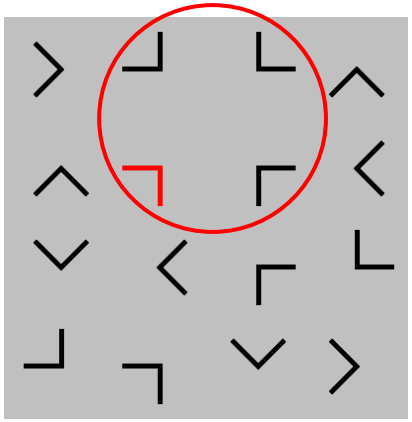
- collinearity
- closure
- symmetry

➢ This may provide insights into the nature of "objecthood"

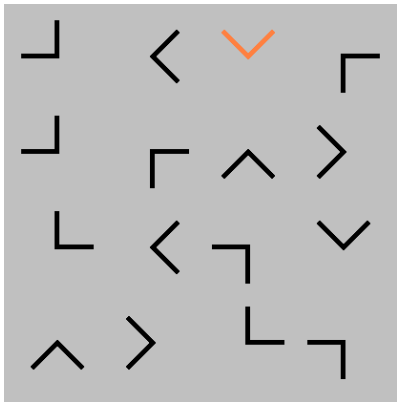
Inside-object

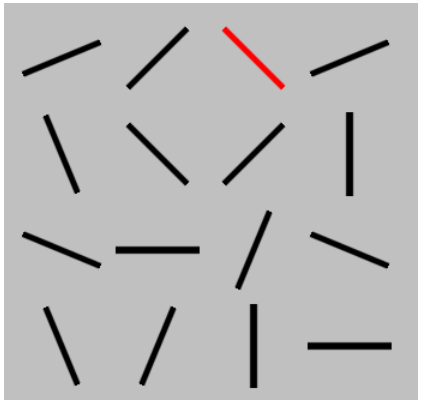


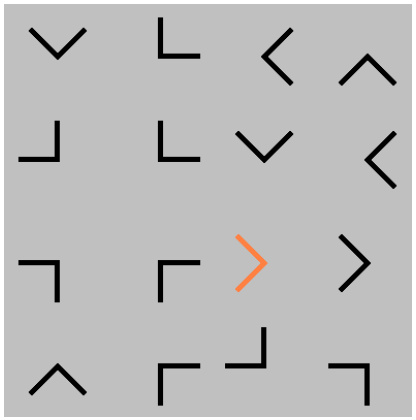




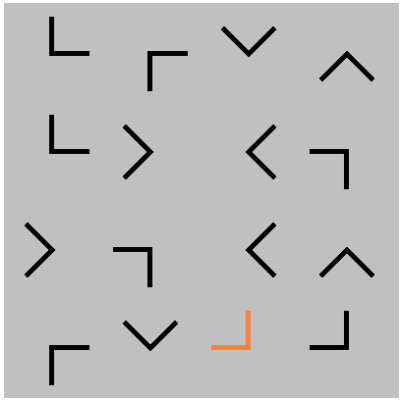
Outside-object

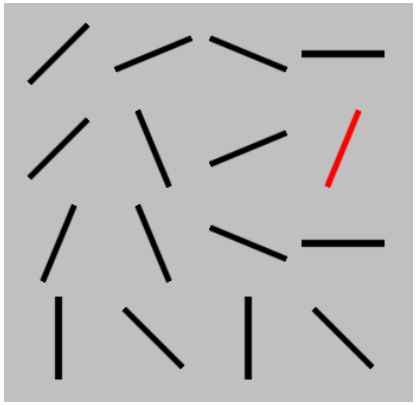


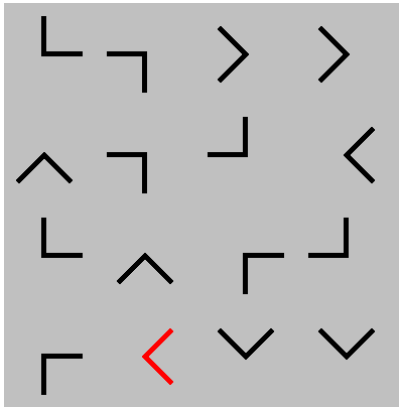




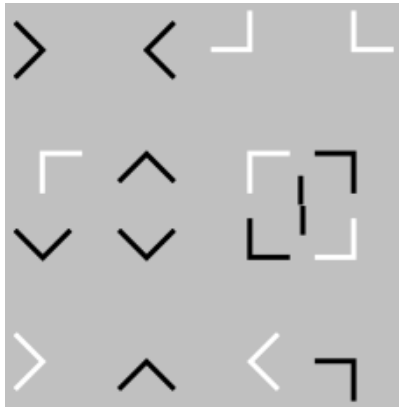
No-object





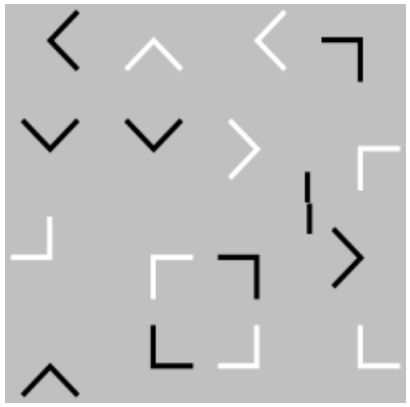


Inside-object



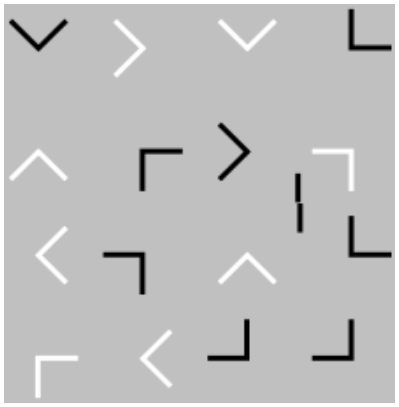
12.5%

Outside-object



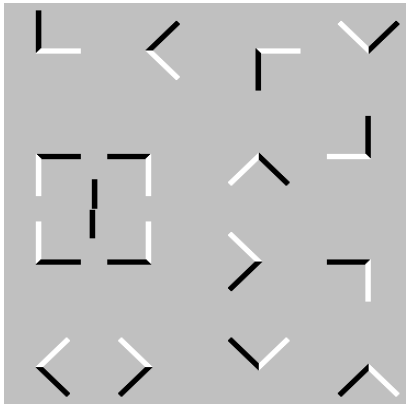
37.5%

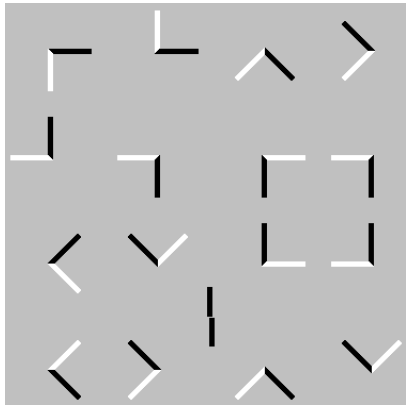
No-object

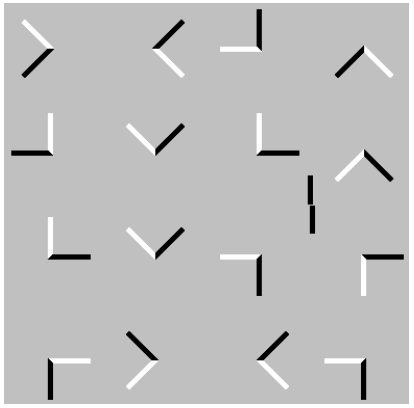


50%

Strong







Weak

- Attentional capture by perceptual “object”
  - ➢Based on collinearity and closure, but not symmetry
  - ➢Affected by the strength of organization

(Kimchi et al., in preparation)

- A single account for a variety of ‘object advantage’ effects
- Insights into the nature of ‘objecthood’

PO is a not a monolithic entity but a confluence of multiple processes

- ✓ Time course
- ✓ Developmental trajectory
- ✓ Multifaceted relation with visual attention
- ✓ Influenced by experience and familiarity

- Marlene Behrmann
- Tomer Carmel
- Aliza Cohen-Savransky
- Batsheva Hadad
- Steve Palmer
- Mary Peterson
- Yossi Pirkner
- Irene Razpurker-Apfeld
- Suzy Scherf
- Guy Sha’ashua
- Sarah Shomstein
- Branka Spehar
- Yaffa Yeshurun

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- BSF

Thank You