

CSC2524 L0101—TOPICS IN INTERACTIVE COMPUTING:
INFORMATION VISUALISATION

VISUAL PERCEPTION

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UNIVERSITY OF
TORONTO

inria
informatics mathematics

VISUAL PERCEPTION & COGNITION

KNOWING HOW WE PERCEIVE
... TO BETTER REPRESENT



The diagram illustrates the visual system's processing flow. On the left, an eye icon represents the visual field. A grey tube leads to a grid of white ovals representing feature processing. Below this, a small inset shows various features like lines and dots. A red box highlights the eye and feature processing area. Arrows lead from the feature grid to a central yellow box containing a pattern of a dog's head. Below this, a red box highlights the pattern building area. Arrows lead from the pattern box to a final green box containing an object of a dog and its associated words: 'DOG', 'loyal', 'friendly', 'pet', 'furry'. Below this, a red box highlights the object recognition area. At the bottom, a large blue arrow points right, labeled 'Bottom-up information drives pattern building'. A large red arrow points left, labeled 'Top-down attentional processes reinforce relevant information'.

Features are processed in parallel from every part of the visual field. Millions of features are processed simultaneously.

Patterns are built out of features depending on attentional demands. Attentional tuning reinforces those most relevant.

Objects most relevant to the task at hand are held in Visual Working Memory. Only between one and three are held at any instant. Objects have both non-visual and visual attributes.

Bottom-up information drives pattern building

Top-down attentional processes reinforce relevant information

[Source: Ware et al.]

VISION: PERCEPTUAL CONSTRAINTS

Temporal perception

- reaction time: 200ms to initiate a conscious observation
- stimuli $< 100\text{ms}$ apart are not perceived

Visual acuity

- Lines can be detected from $0.5''$
- Distance between two lines from $30''$ to $1'$

Implications for Information Visualisation

- Animations should have cycles $> 1/10^6$ seconds
- Large datasets: guarantee that the data displayed remains above limits

arcminute (") = 1/60 of one degree. arcsecond (") : 1/60 of one arcminute

The diagram illustrates the visual system's processing flow. On the left, a grey sphere represents the eye, with a green cone of light entering. An orange arc above it indicates the visual field. Below the eye is a grey rectangle containing several small, blurry images of objects, representing the initial visual input. A grey tube connects the eye to a large, dense grid of white ovals, representing the retina or a layer of feature detectors. From this grid, multiple blue arrows point towards a central yellow square containing a red, irregular shape with a yellow diagonal line, representing a pattern. Below this grid is a text box explaining that features are processed in parallel from every part of the visual field. From the yellow square, multiple blue arrows point towards a green circle on the right. Inside the green circle is a small image of a dog, with the words 'DOG', 'loyal', 'friendly', 'pet', and 'furry' arranged around it. Below the dog image is a blue stick figure, representing a person. A text box to the right of the green circle explains that objects most relevant to the task are held in Visual Working Memory. At the bottom, a large blue arrow points from left to right, labeled 'Bottom-up information drives pattern building'. A large red arrow points from right to left, labeled 'Top-down attentional processes reinforce relevant information'.

Features are processed in parallel from every part of the visual field. Millions of features are processed simultaneously.

Patterns are built out of features depending on attentional demands. Attentional tuning reinforces those most relevant.

Objects most relevant to the task at hand are held in Visual Working Memory. Only between one and three are held at any instant. Objects have both non-visual and visual attributes.

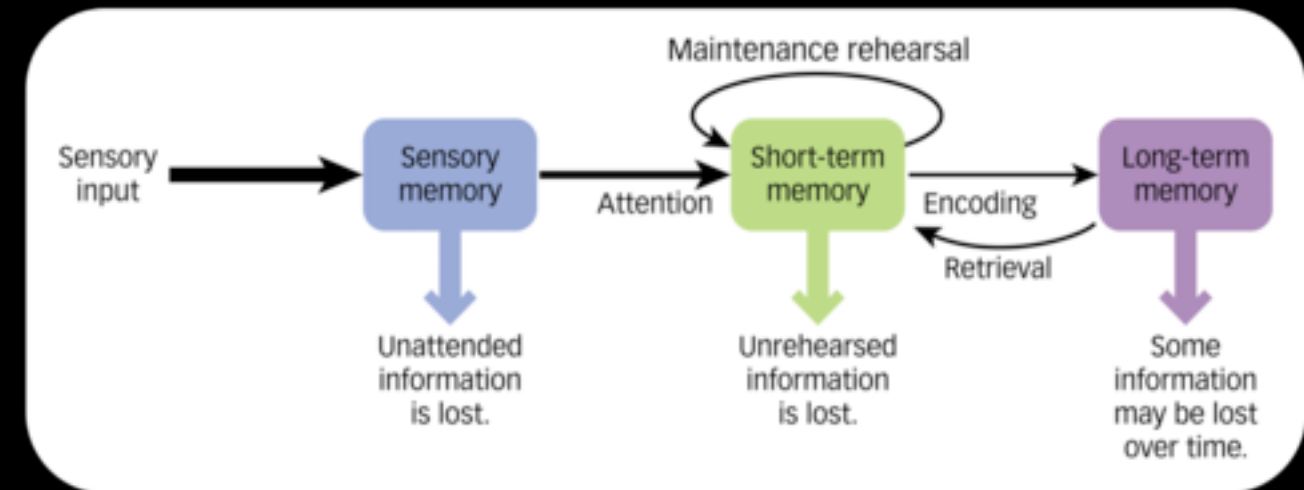
Bottom-up information drives pattern building

Top-down attentional processes reinforce relevant information

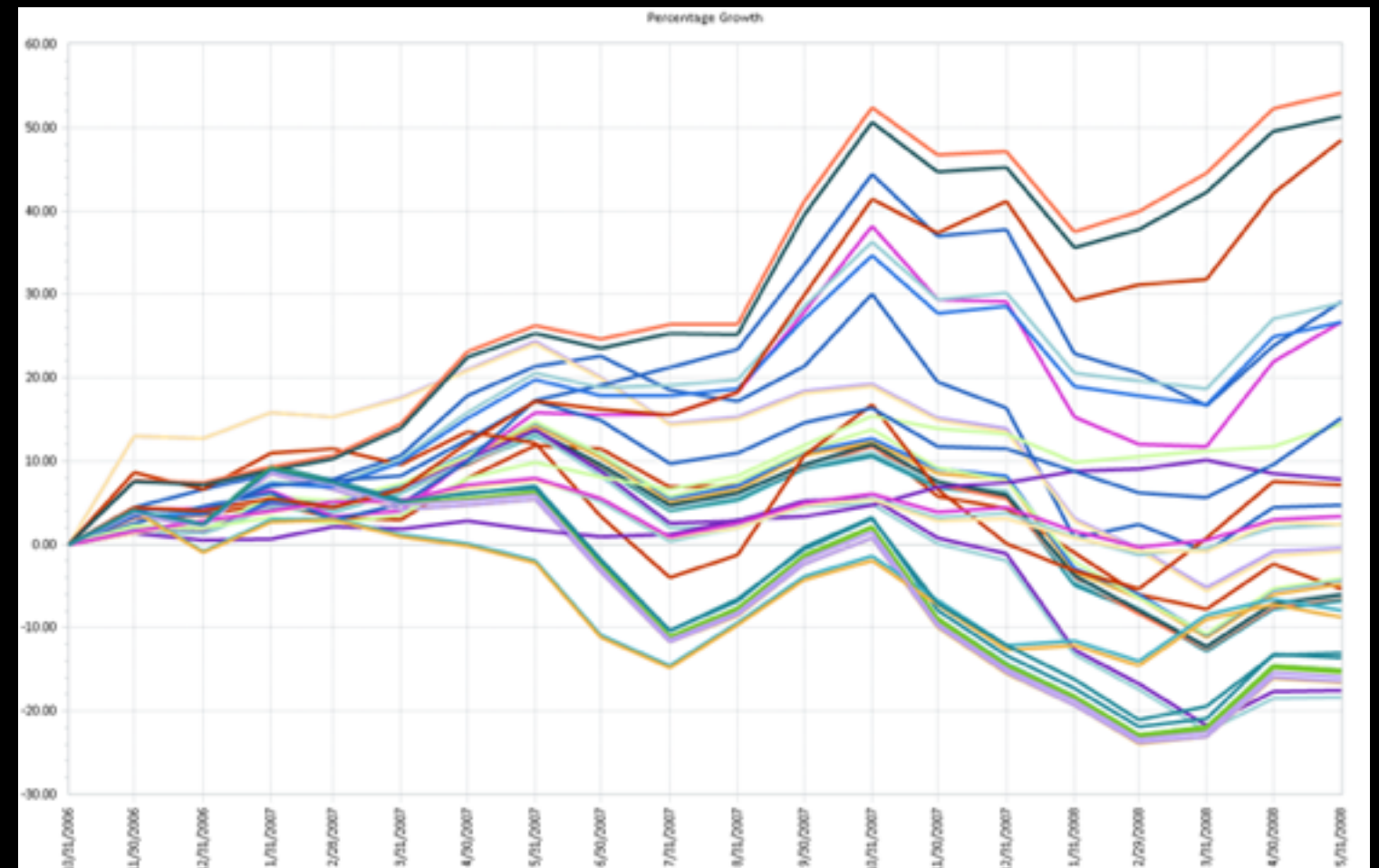
[Source: Ware et al.]

Problems with cognitive load

- **short-term memory** = working memory
- **memory span** is limited : [Miller 1956]
7 ± 2 independent memorable items
- Critical for visualization of large datasets

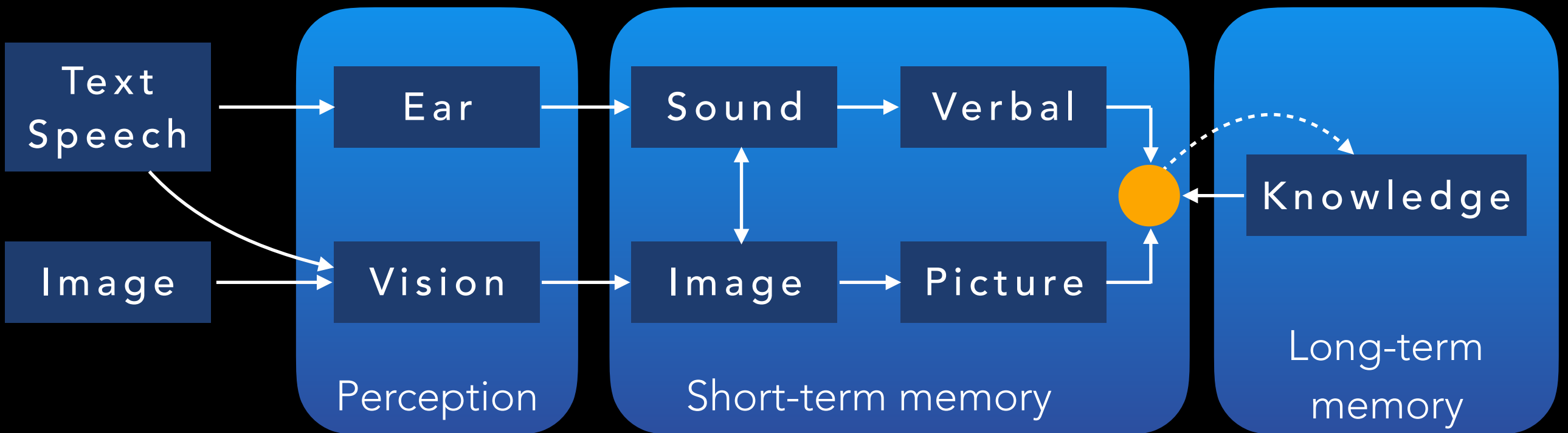


- Group, aggregate in **chunks** (analogy: phone numbers)
- Never require to compare more than 3 independent elements at a time



Cognitive load : workarounds

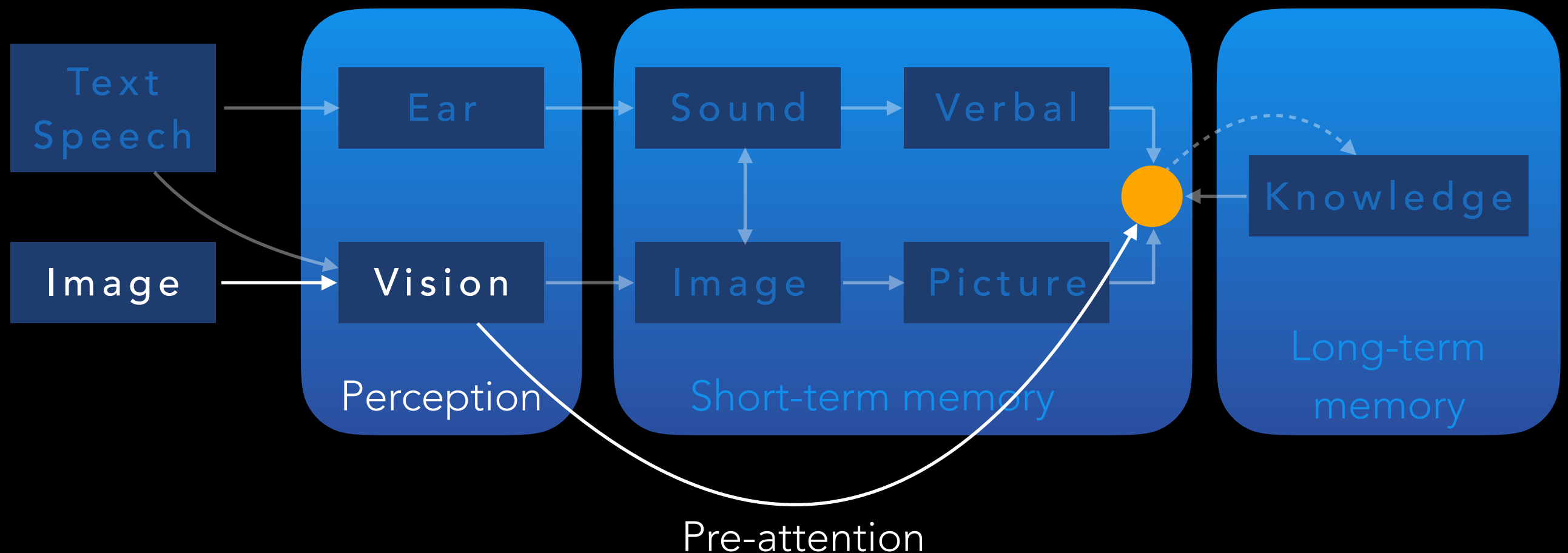
- sketch pad, phonological loop, episodic buffer) [Baddeley A., Wilson B.A., 2002]



- **Pre-attentive perception**

[Treisman & Gormican, 1988]

-



[Treisman & Gormican, 1988]

Implications for Information Visualisation

- No cognitive load
- Direct processing : what must be perceived immediately

Perception

Short-term memory

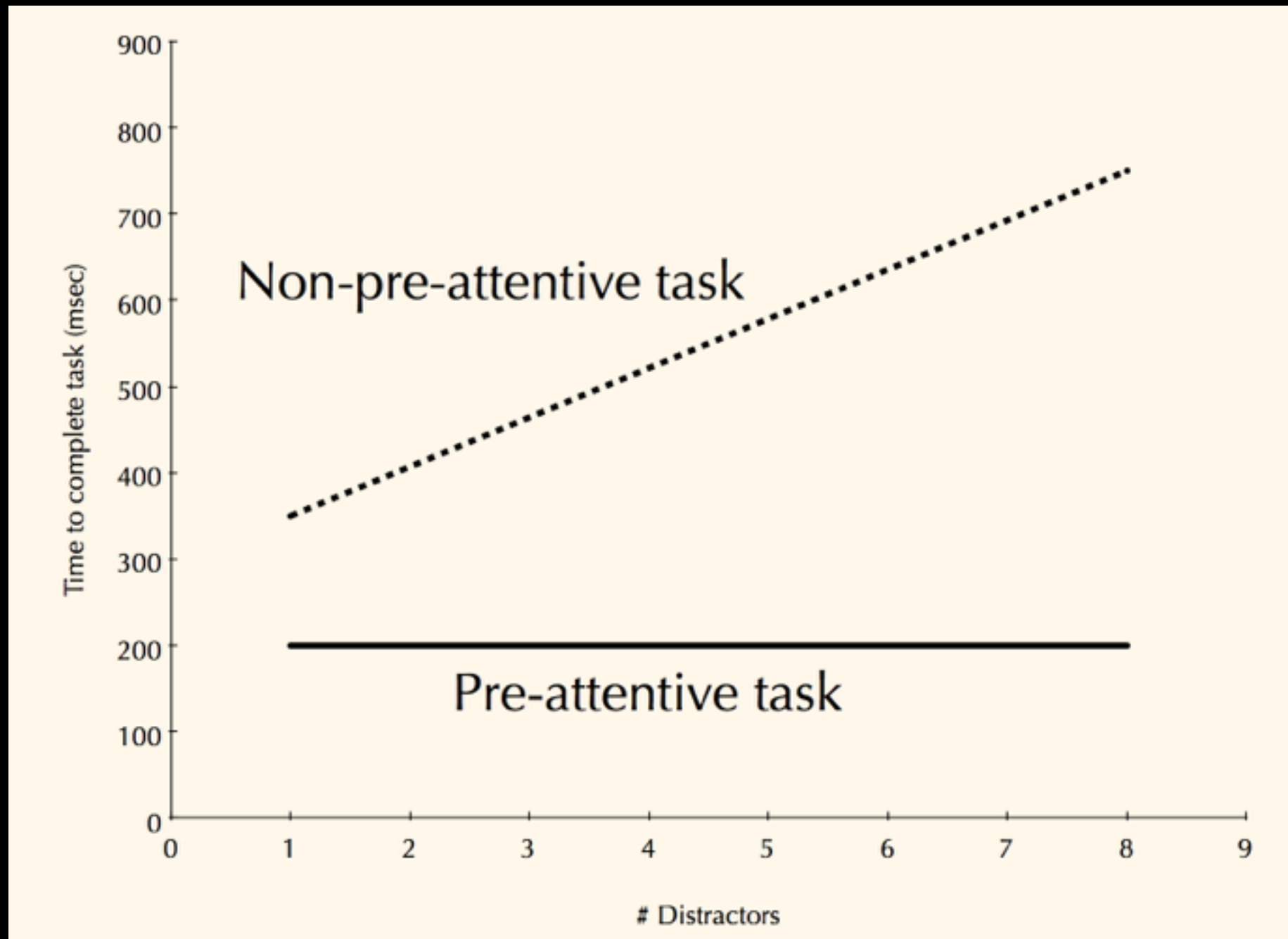
Long-term memory

A scatter plot on a white background. It contains 40 blue circular dots and 1 red circular dot. The dots are scattered across the plot area, with the red dot located near the center.

A collection of 30 red squares and 1 red circle, all of uniform size, scattered across a white background. The shapes are arranged in a seemingly random pattern, with the circle positioned slightly to the right of the center.

PRE-ATTENTIVE PERCEPTION

Takes the same amount of time, regardless of the number of distractors



[Slide inspired by J. Wirz & S. Bedrid course material]

Find the 3's

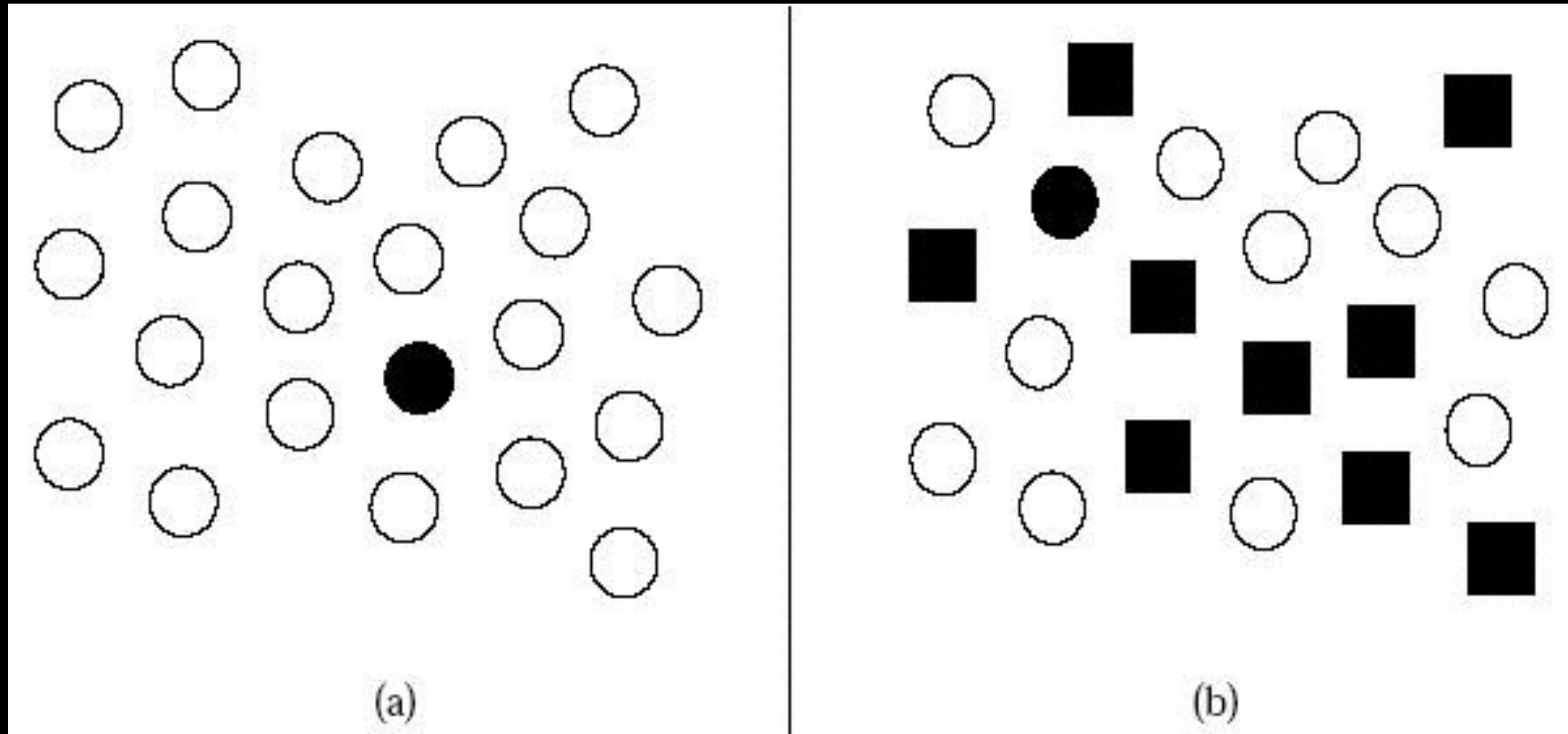
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285960799918712845268101495969124567781
874241649645757659608149596912456701285
960799164964575127879918712845298496912
223591649645759588198250963576596080596

Find the 3's

142416496**3**57598475921765968474891728482
285958819829450968504850695847612124044
074674898985171495969124567659608020860
608**3**6541649645759064**3**980479248576960781
285960799918712845268101495969124567781
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22**3**59164964575958819825096**3**576596080596

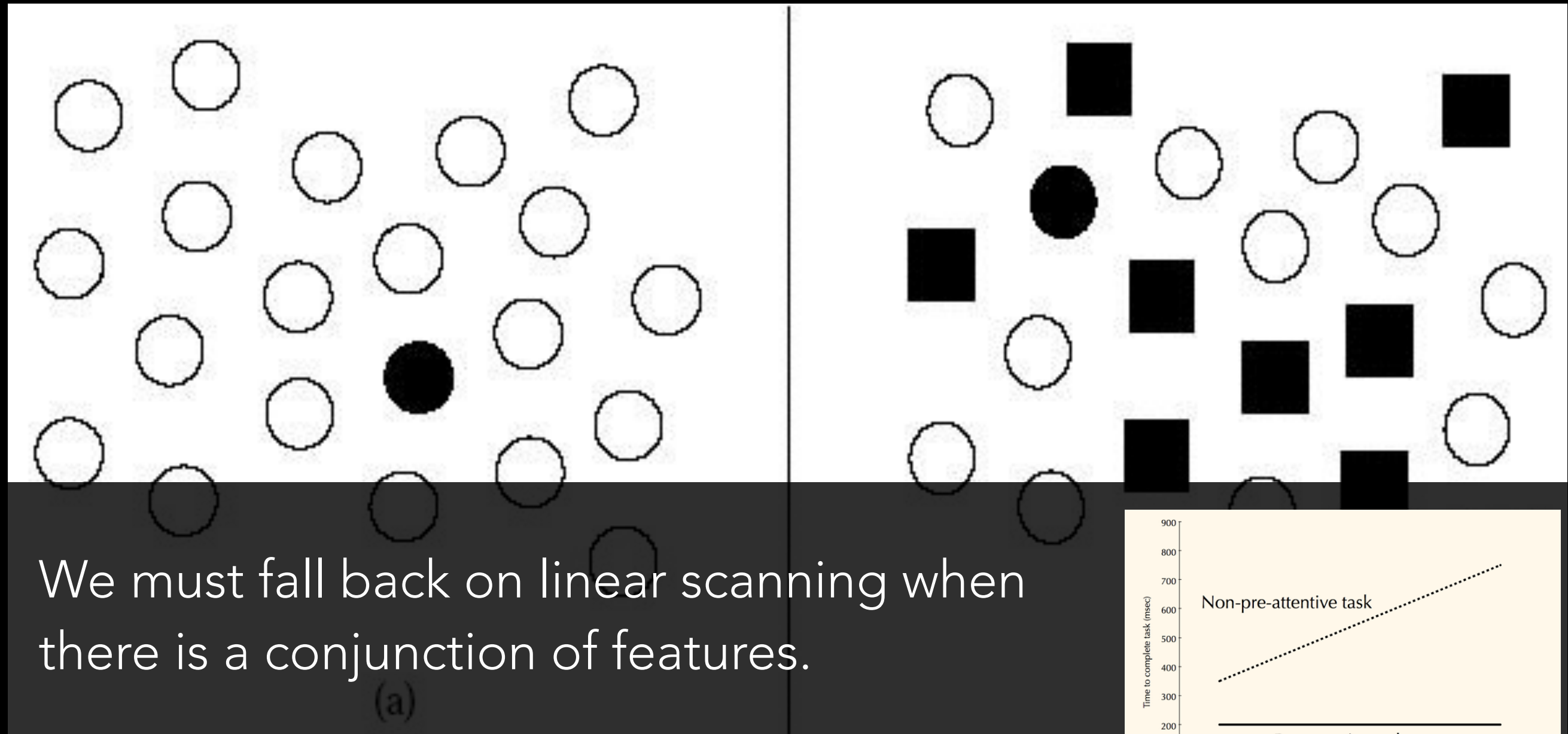
PRE-ATTENTIVE PERCEPTION

Only works when the distractors differ from one feature:

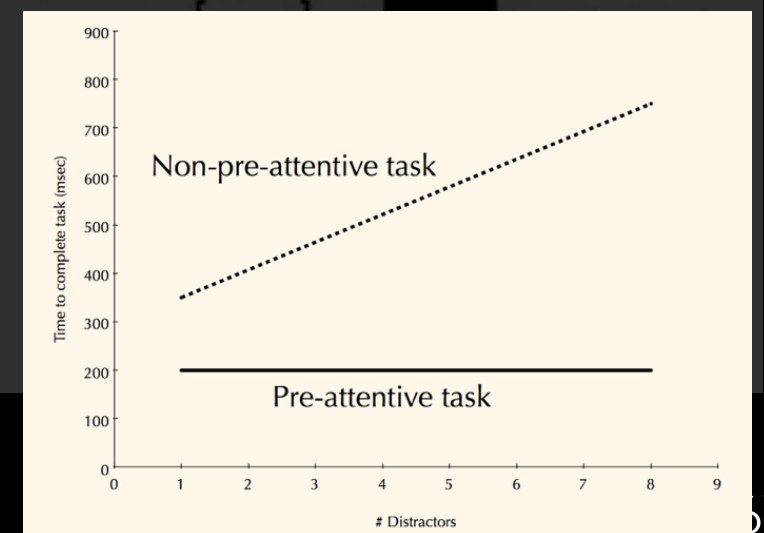


PRE-ATTENTIVE PERCEPTION

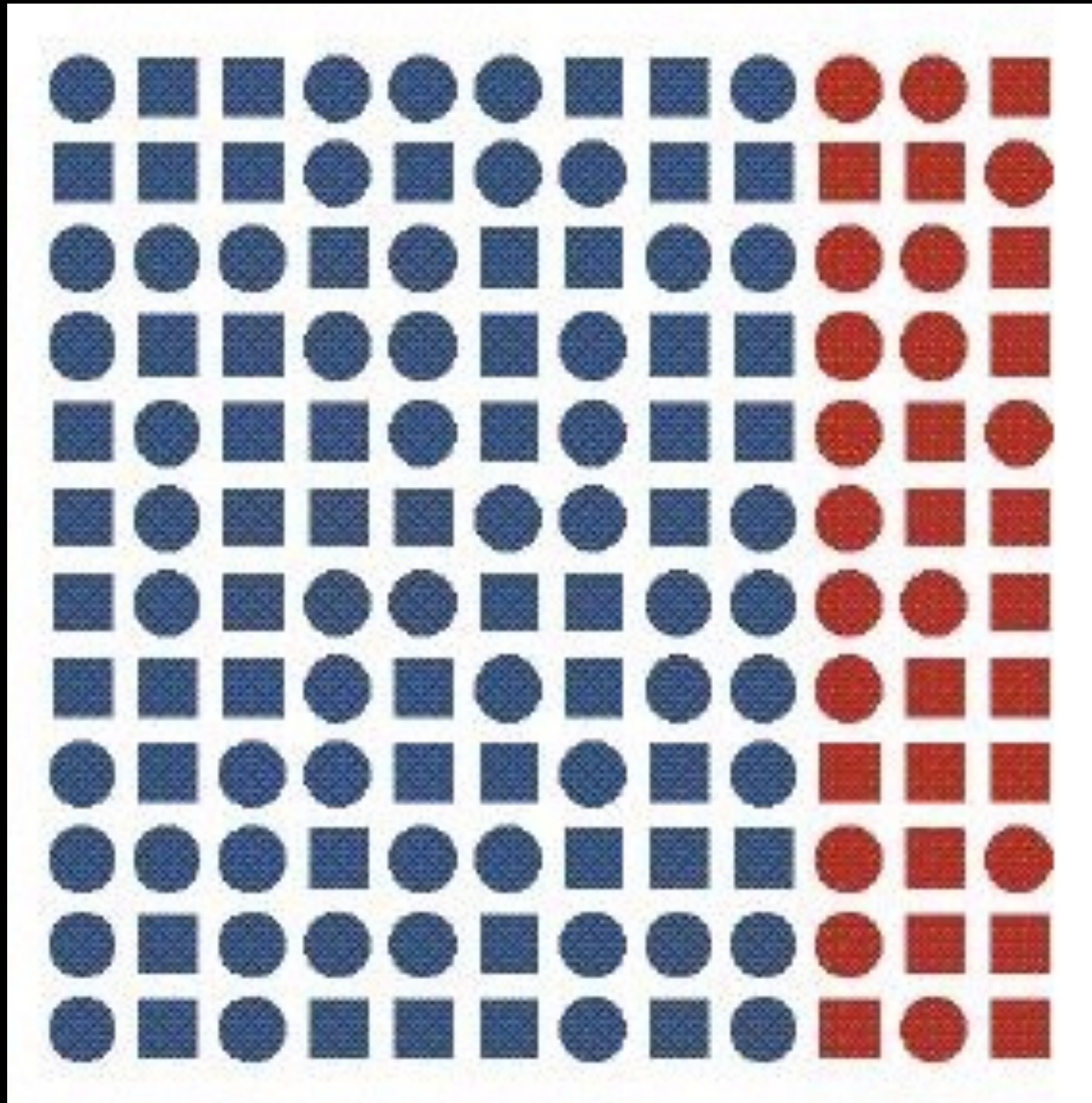
Only works when the distractors differ from one feature:



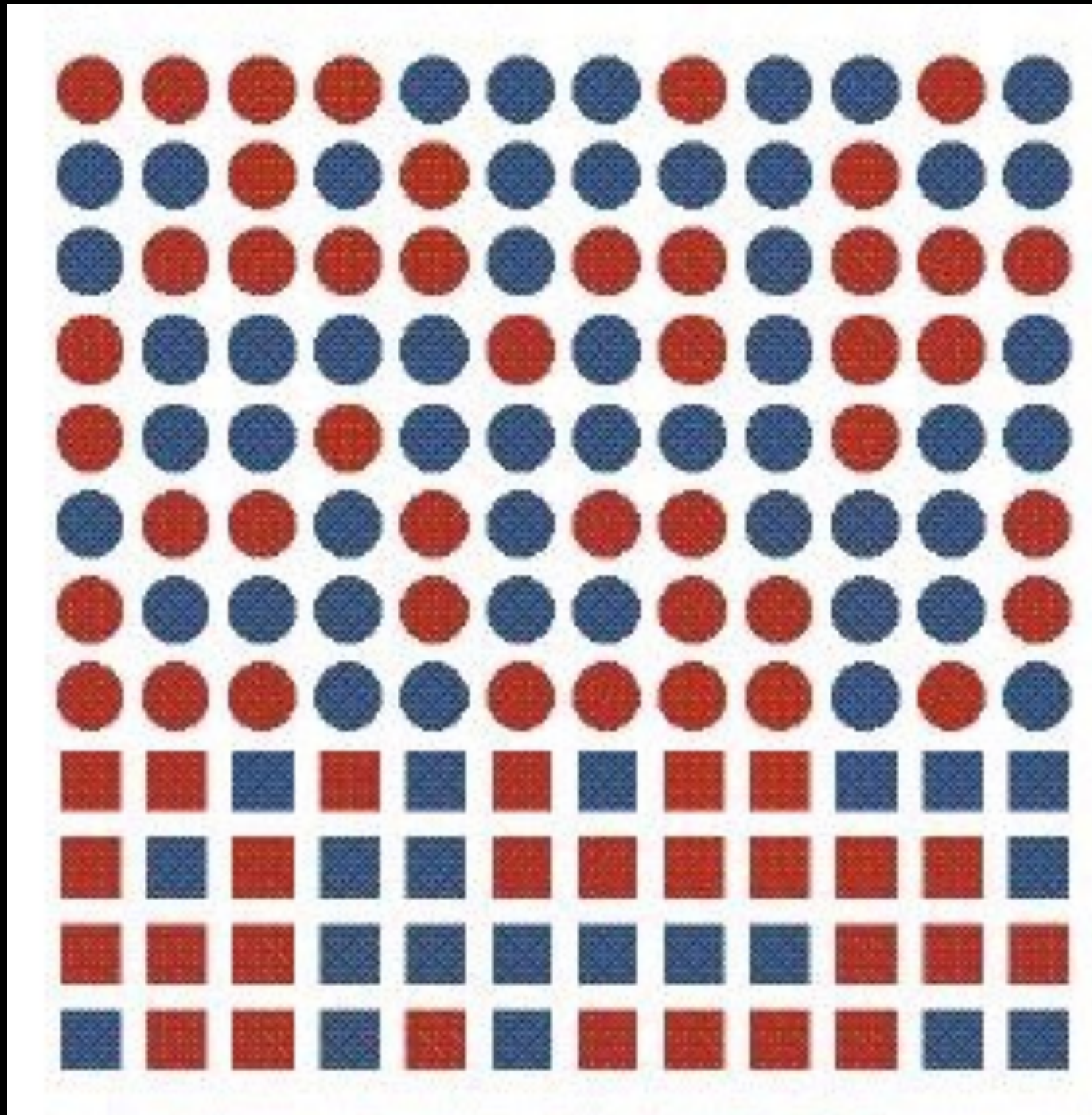
We must fall back on linear scanning when there is a conjunction of features.



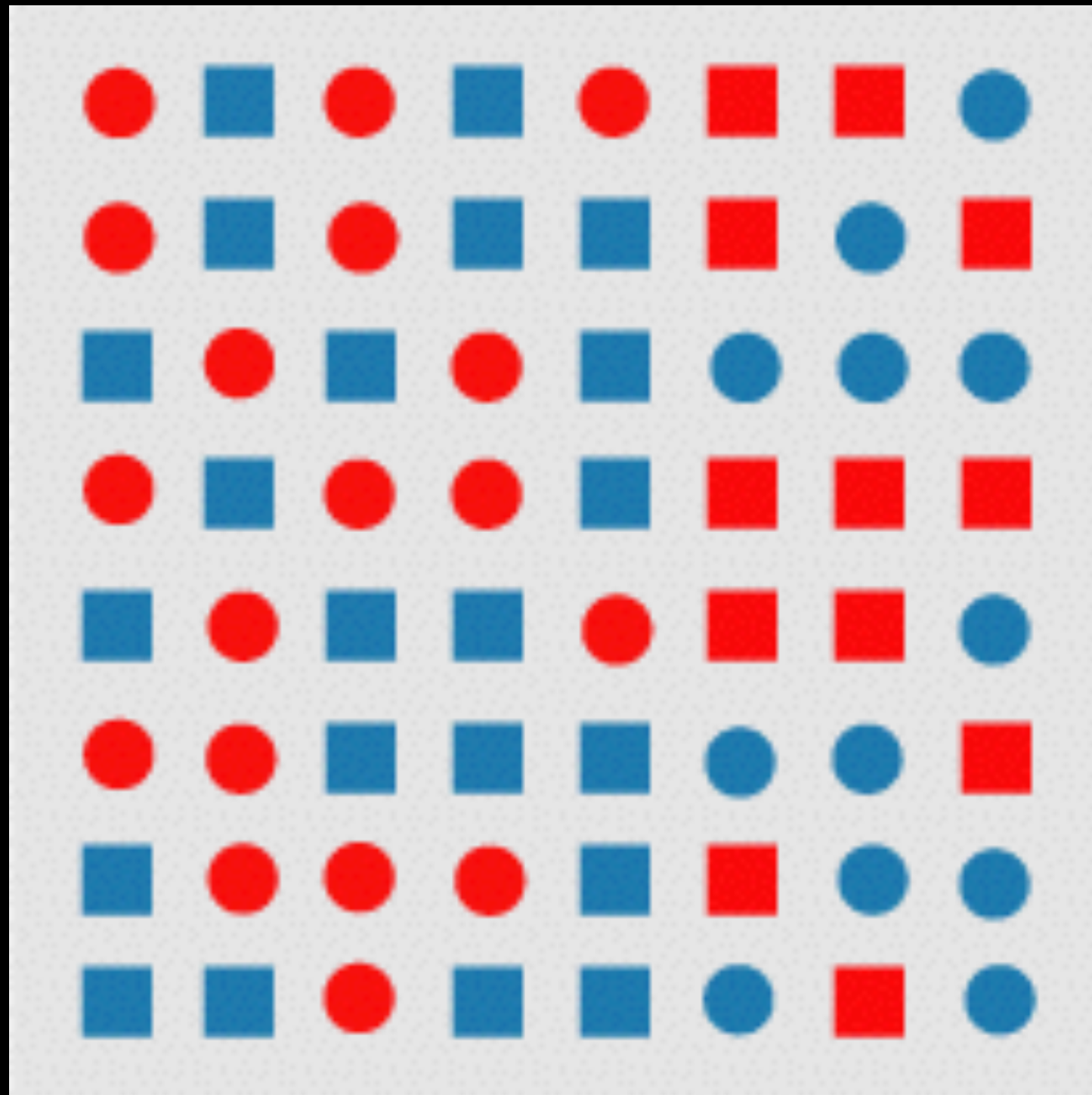
Is there a boundary?



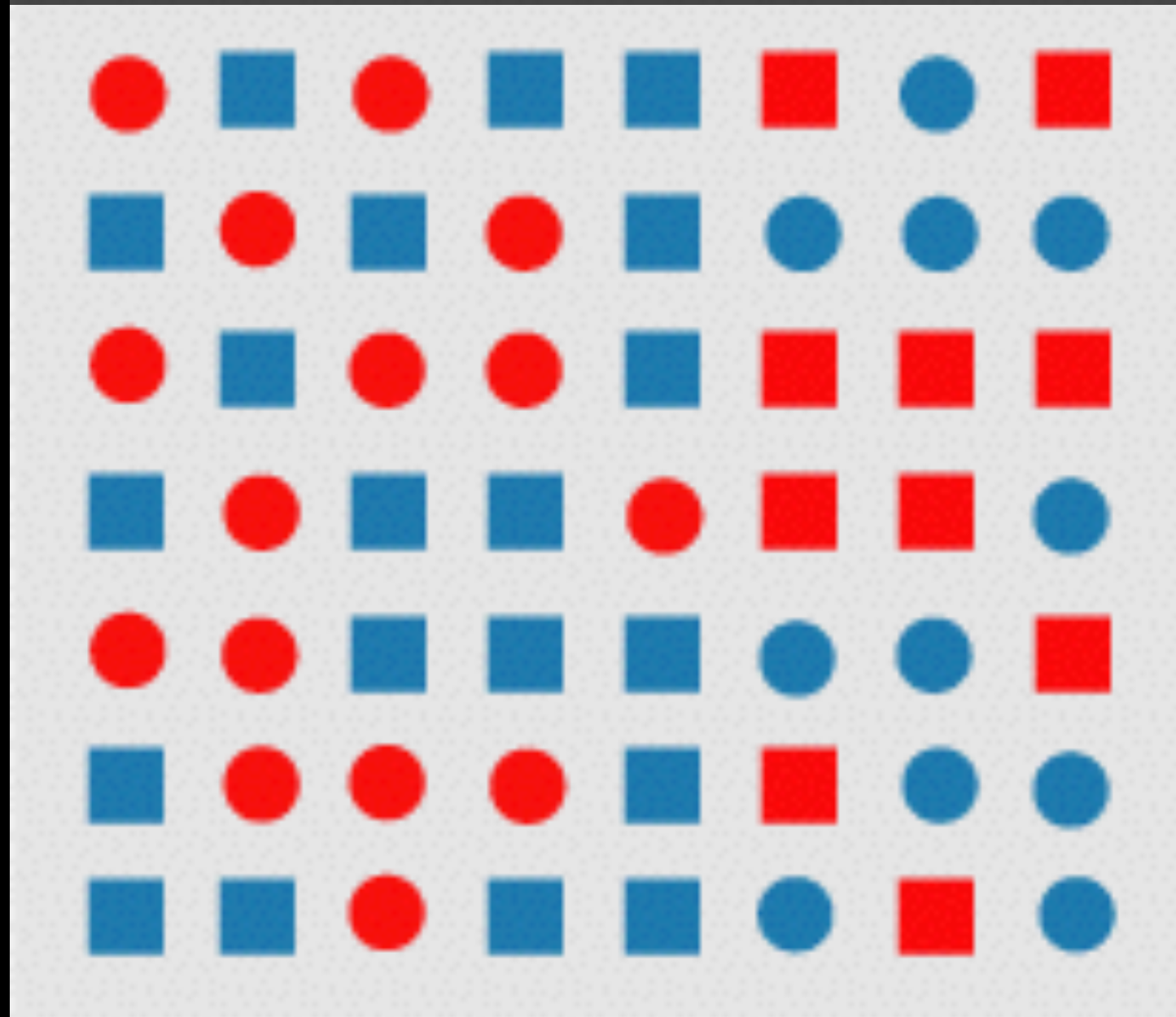
Is there a boundary?



Is there a boundary? (hint: YES!)



a boundary defined by a conjunction of features (here red circles and blue squares on the left, blue circles and red squares on the right) cannot be preattentively perceived



(SOME) PRE-ATTENTIVE VISUAL FEATURES

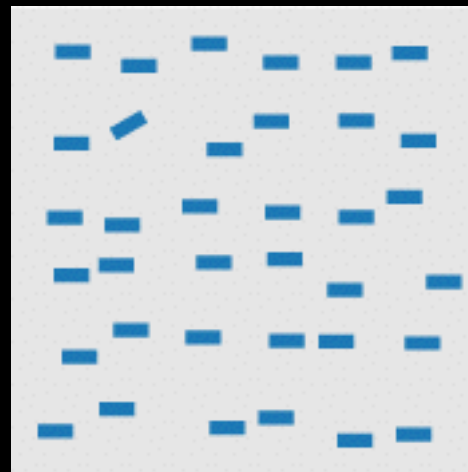
orientation

[Julész & Bergen 83]

[Sagi & Julész 85]

[Wolfe et al. 92]

[Weigle et al. 2000]

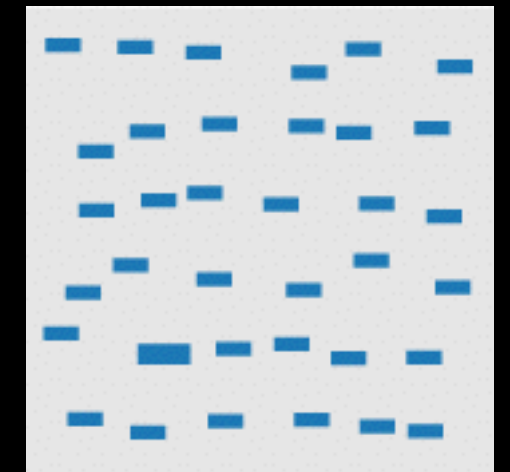


size

[Treisman & Gelade 80]

[Healey & Enns 98]

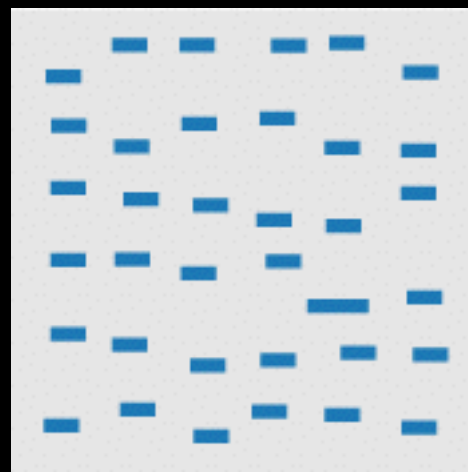
[Healey & Enns 99]



length, width

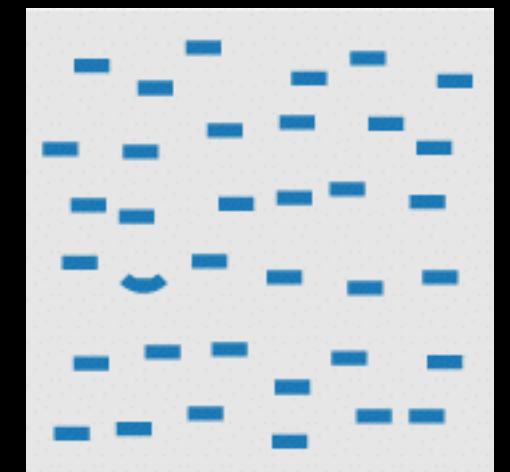
[Sagi & Julész 85]

[Treisman & Gormican 88]



curvature

[Treisman & Gormican 88]



closure

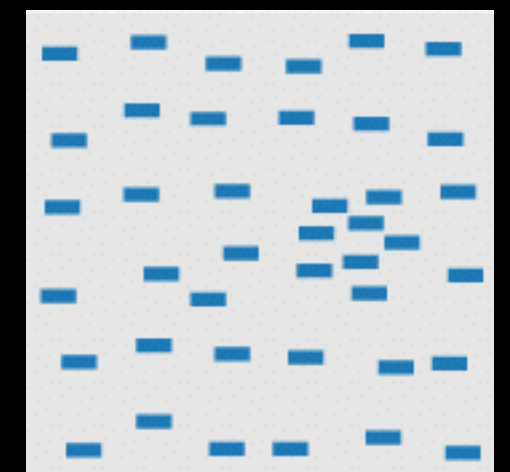
[Julész & Bergen 83]



density, contrast

[Healey & Enns 98]

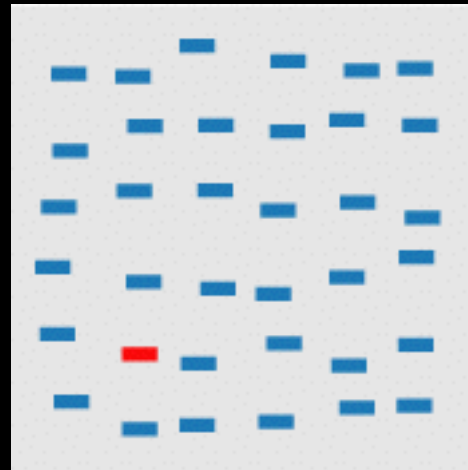
[Healey & Enns 99]



(SOME) PRE-ATTENTIVE VISUAL FEATURES

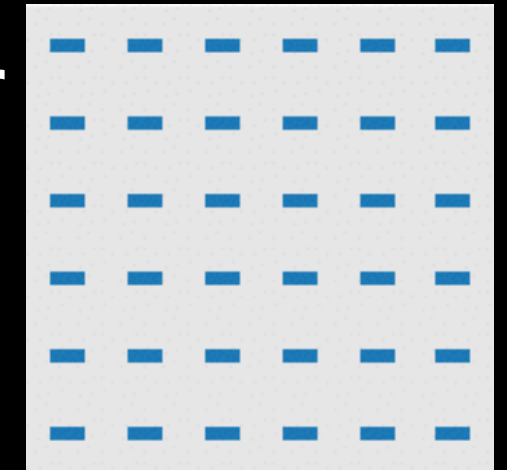
color, hue

Nagy & Sanchez 90; Nagy et al. 90; D'Zmura 91; Kawai et al. 95; Bauer et al. 96; Healey 96; Bauer et al. 98; Healey & Enns 99



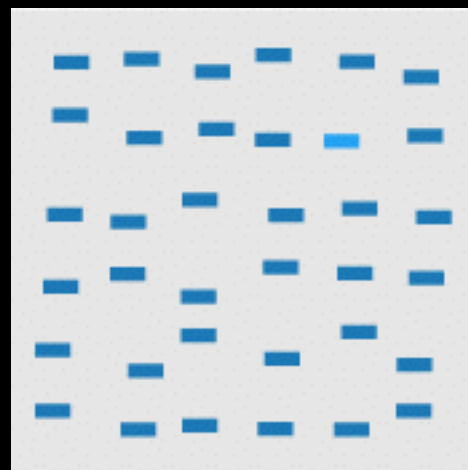
flicker

[Gebb et al. 55; Mowbray & Gebhard 55; Brown 65; [Julész 71] [Huber & Healey 2005]



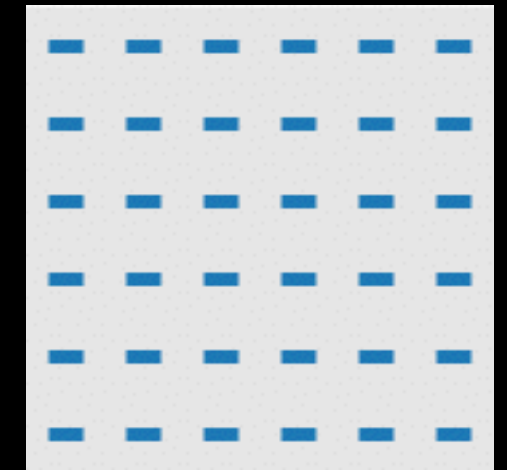
intensity

[Beck et al. 83] [Treisman & Gormican 88] [Wolfe & Franzel 88]



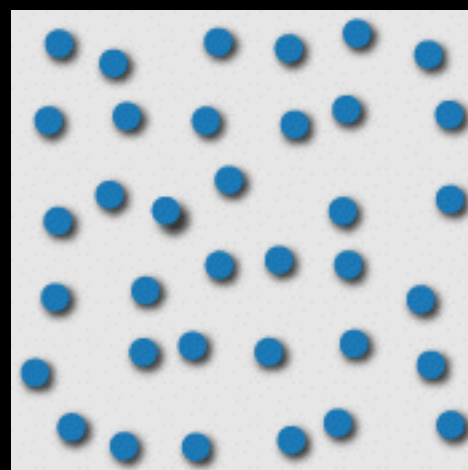
direction of motion

[Nakayama & Silverman 86; Driver & McLeod 92; Huber & Healey 2005]



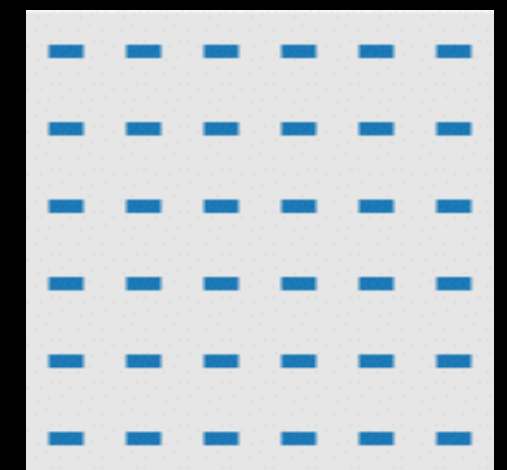
3D depth cues

[Enns 90b; Nakayama & Silverman 86]

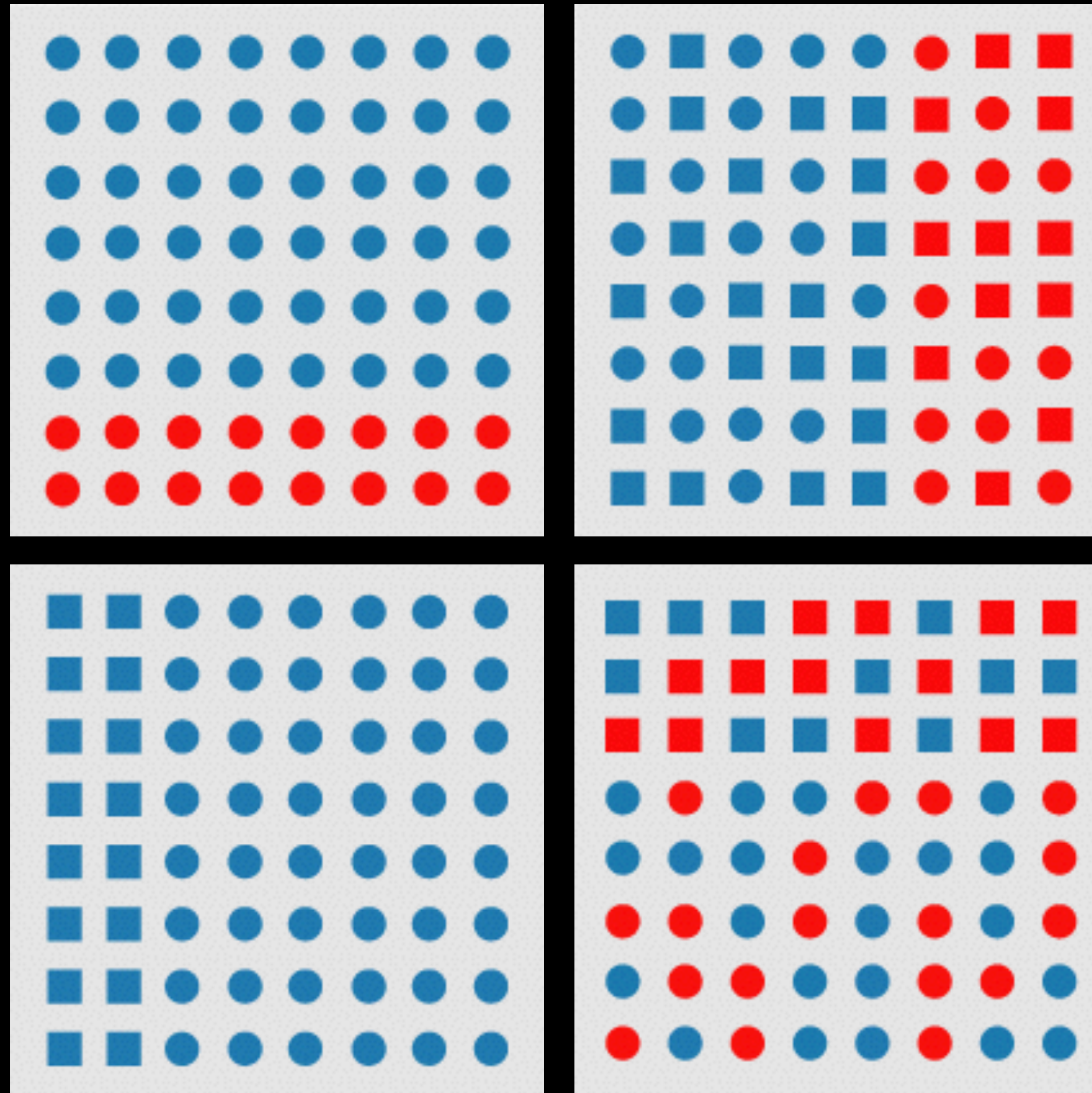


velocity of motion

[Tynan & Sekuler 82; Nakayama & Silverman 86; Driver & McLeod 92; Hohnsbein & Mateeff 98; Huber & Healey 2005]



Note that these various features are not created equal!



We seem to have a strong bias towards color perception over shape perception, etc...

What does all of this mean?

1. Certain tasks that depend on pre-attentive features can sometimes be done “for free” by our brains:

Target detection

Region tracking

Boundary detection

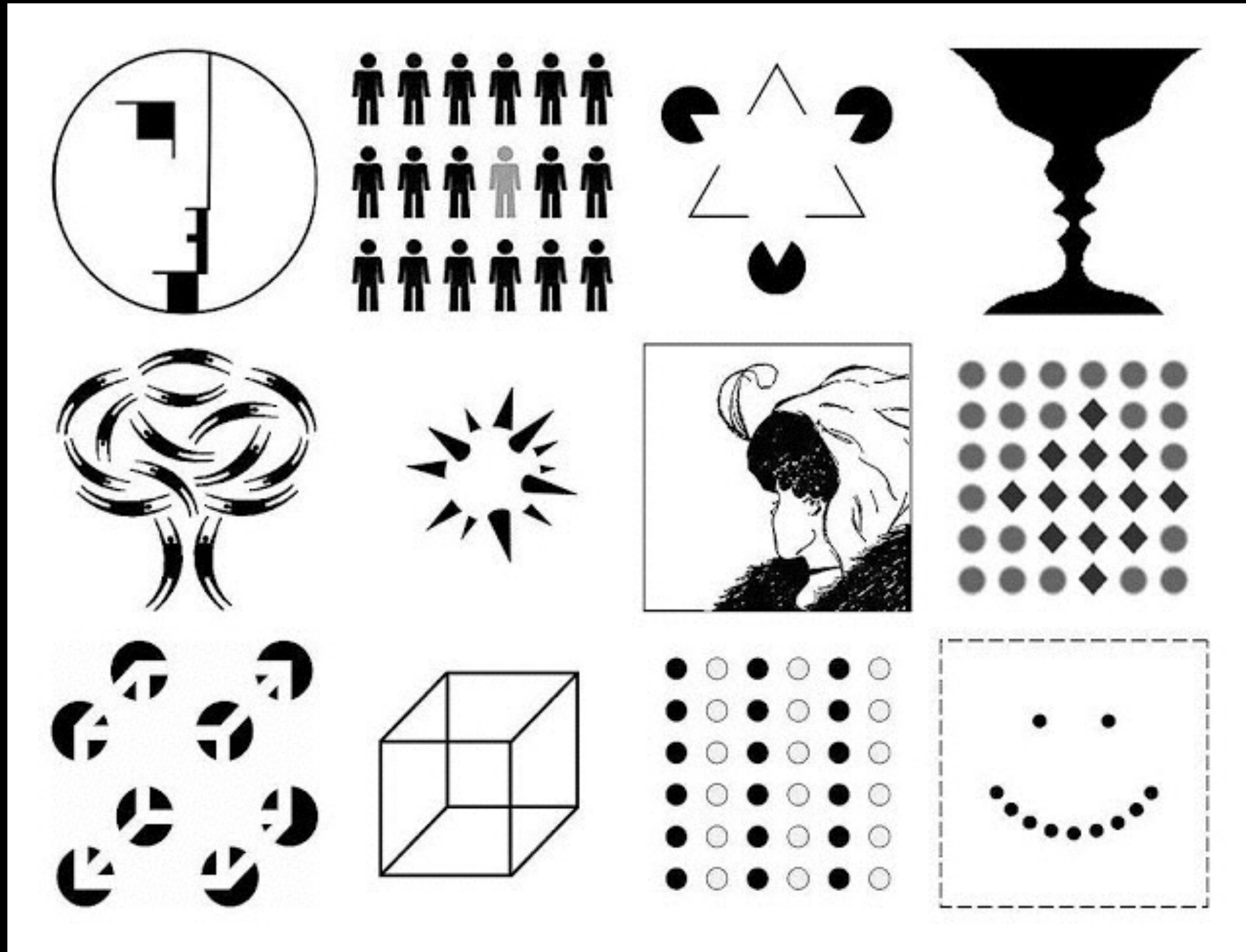
Counting (estimation)

2. The more of our story we can tell using pre-attentive features, the faster and better our viewer will “get it”.

3. We can easily mess up our viewer's ability to interpret our visualisation by "triggering" pre-attentive perception inappropriately!

Many of the things that make a bad visualisation "bad" can be traced back to problems relative to pre-attentive processing.

ANOTHER PERSPECTIVE: GESTALT PSYCHOLOGY



DEFINITION

The Gestalt psychology is a **theory of perception** that is often summed up by:

“The whole is other than the sum of the parts”
— Kurt Koffka (1922)

THE BASIC IDEA:

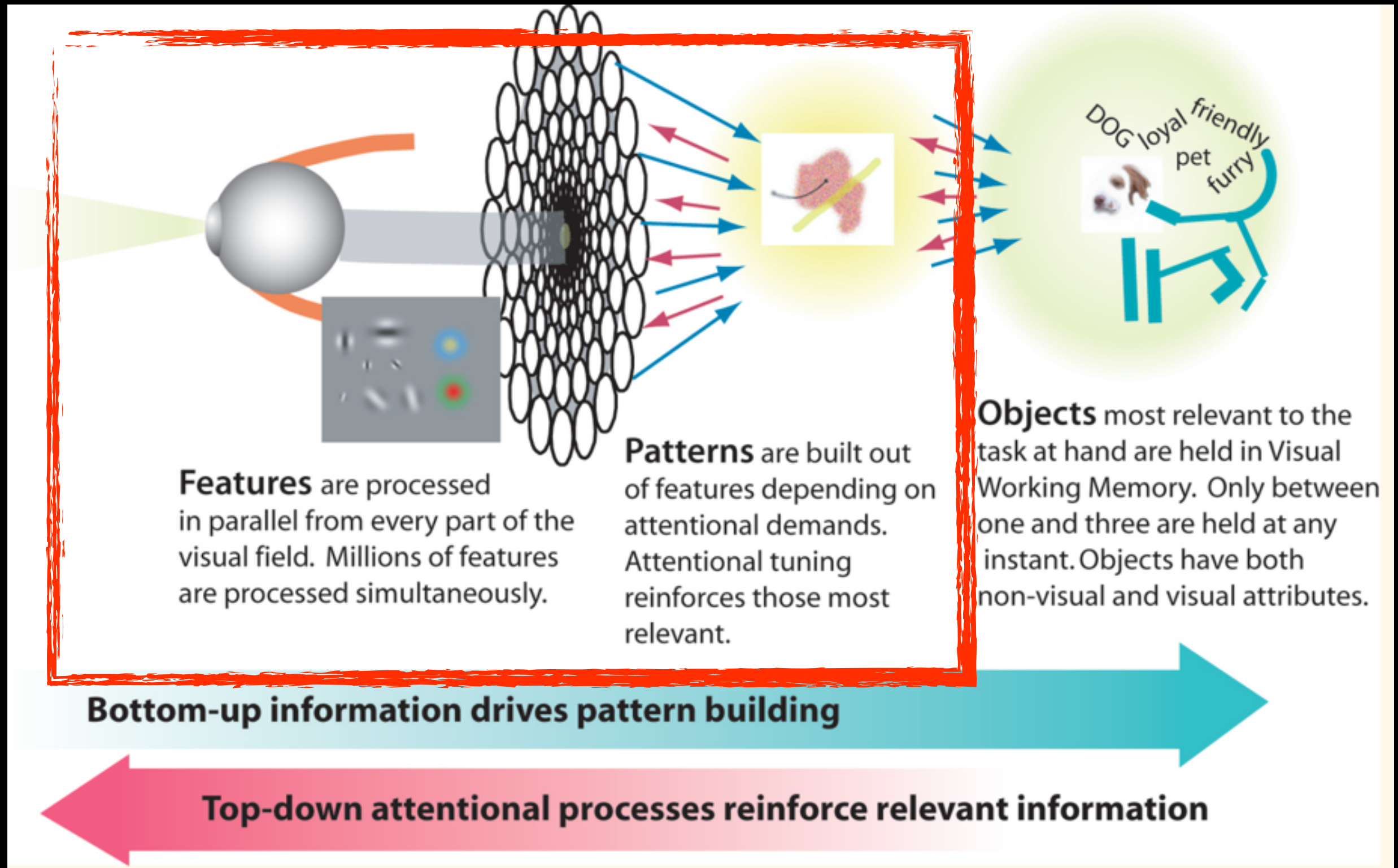
Our brains operate less on individual points, lines, etc...

... but rather on **higher-level constructs** ...

... which is what our perceptual systems are
optimised for.



DIFFERENT FROM



The Gestalt psychology notably describes the **perception of forms** by the visual system.

It relies on four **principles**:

- Emergence
- Reification
- Multistability
- Invariance

It also describes our visual perceptions by a set of **laws**.

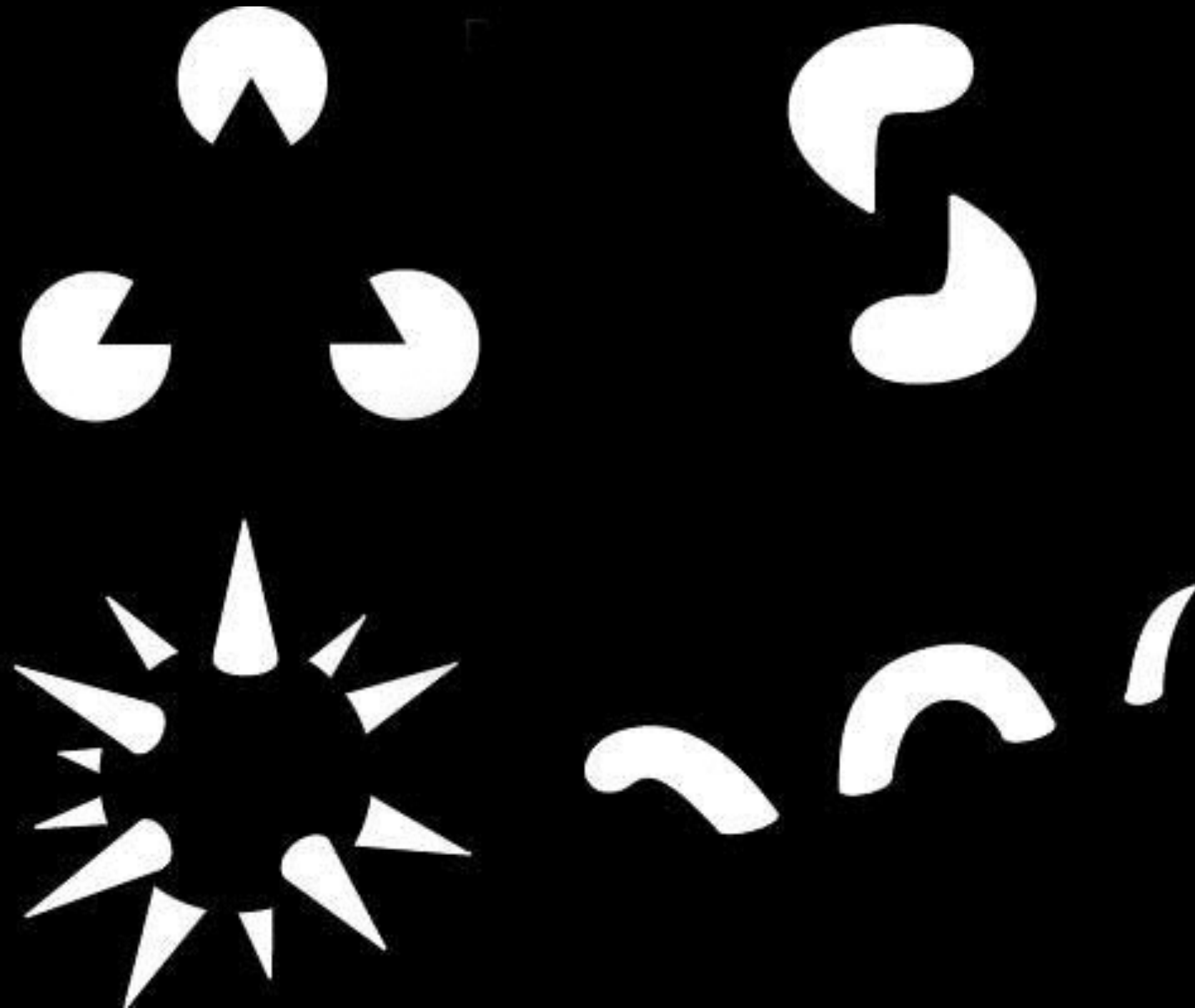
EMERGENCE

The **global perception** can **not** be explained by
the **sum of its parts**.

EMERGENCE



REIFICATION



REIFICATION

The **perception** contains **more spatial information than the stimulus** on which it is based: **part of the perception is generated.**

MULTISTABILITY

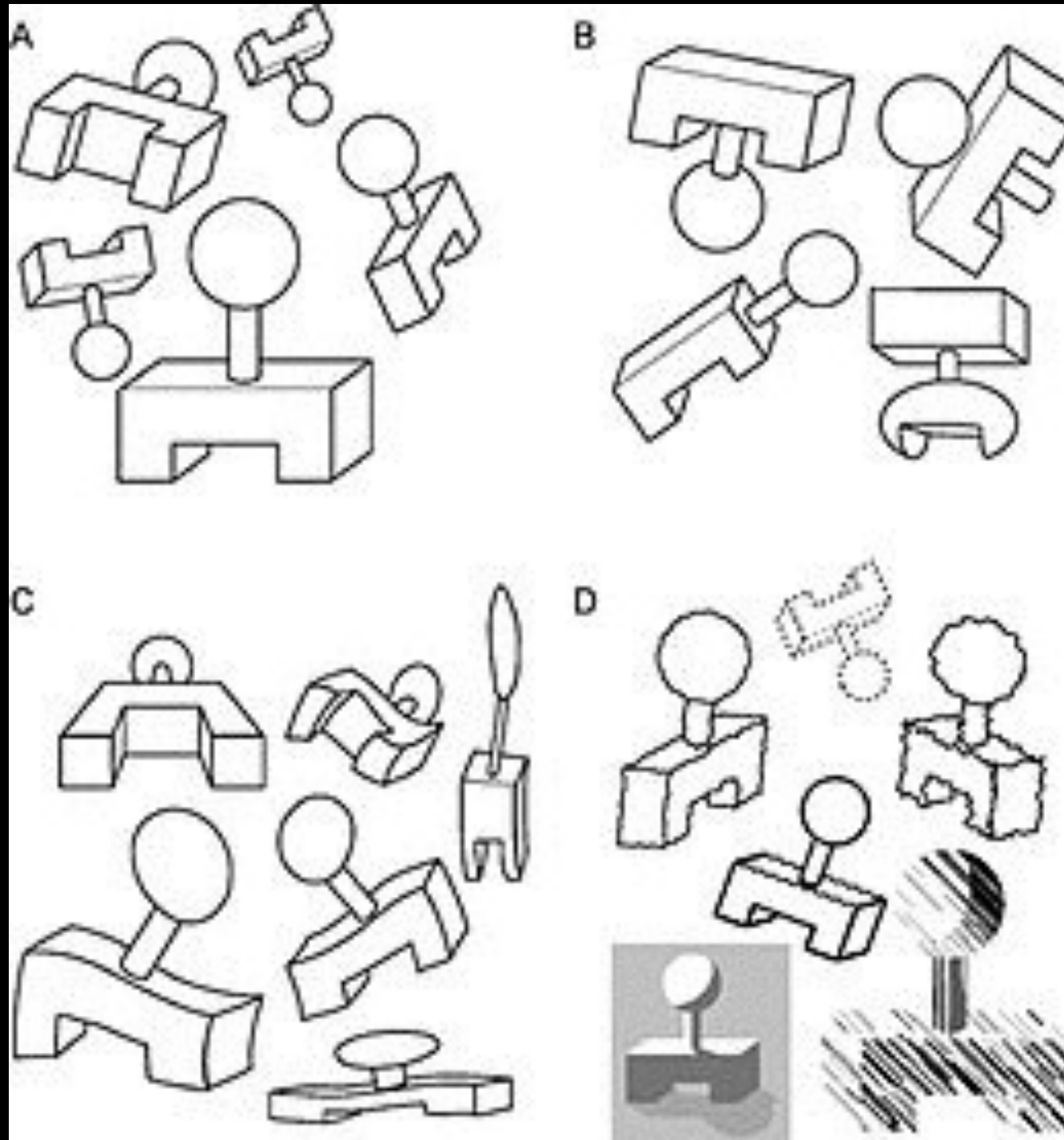


"My wife and my mother-in-law." (1915)

MULTISTABILITY

Ambiguous stimuli can generate **different perceptions** but they **can not coexist** simultaneously.

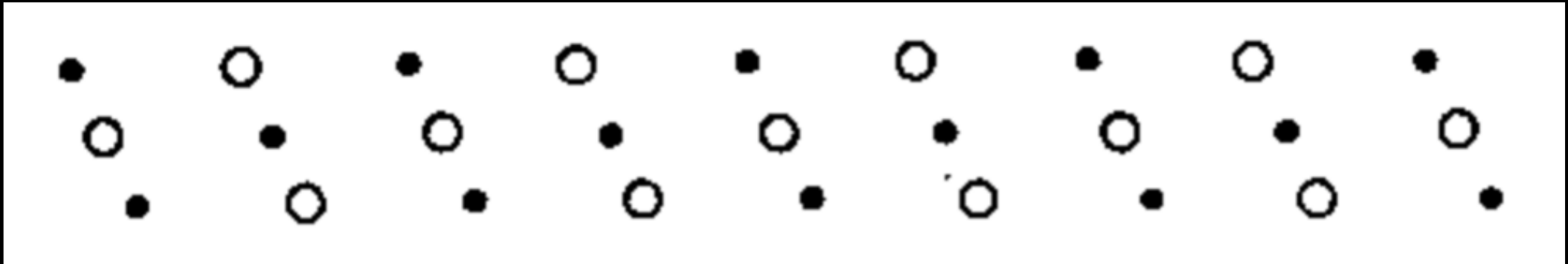
INVARIANCE



INVARIANCE

Objects are **recognized independently of various variations**, such as geometrical transformations, lighting, etc.

GESTALT LAWS OF GROUPING



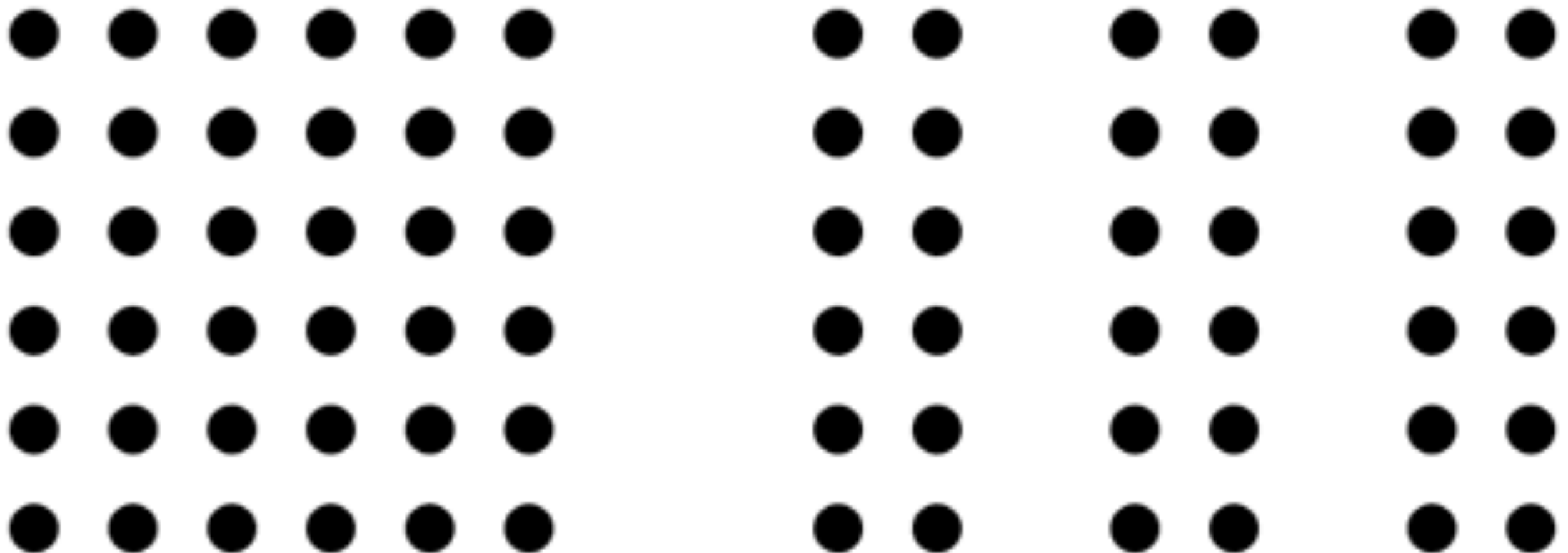
The **laws of grouping** state how **low-level perceptions** are **grouped** into higher-level objects.

Good Gestalt (Prägnanz)

We tend to order our experience in a manner that is regular, orderly, symmetric, and simple.

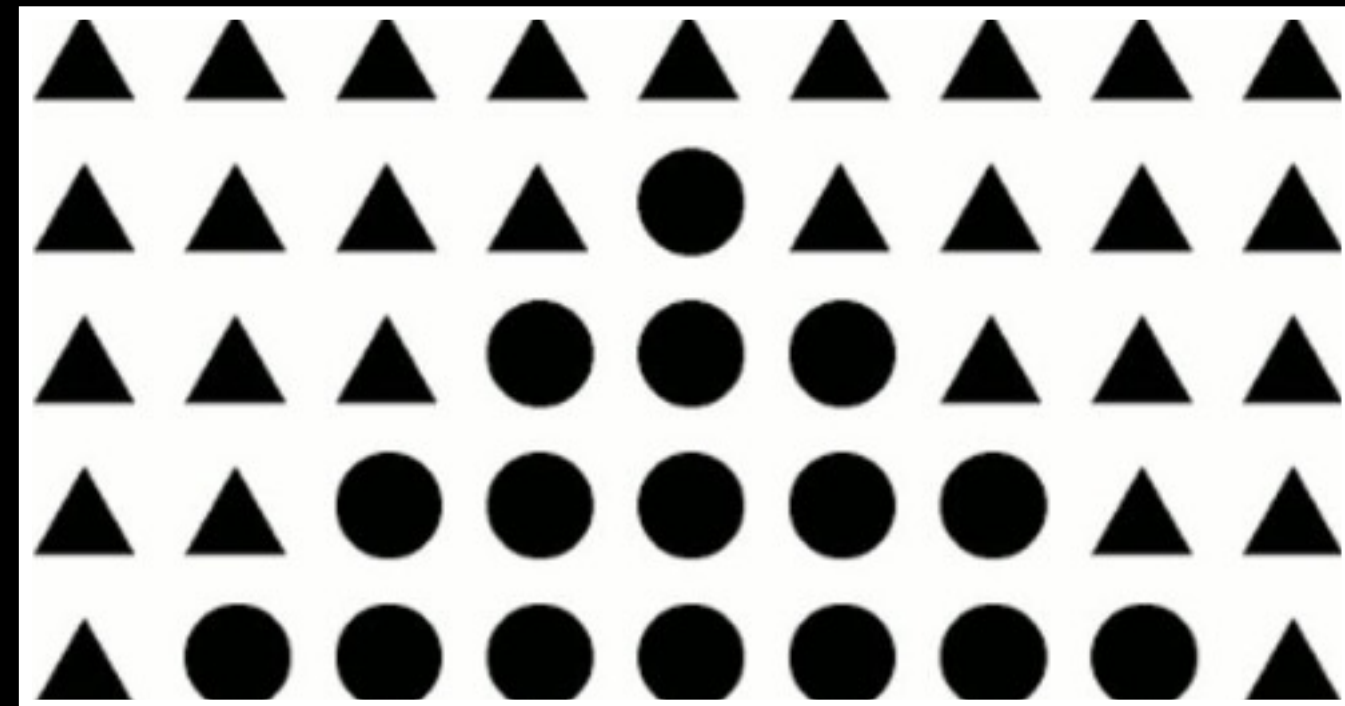
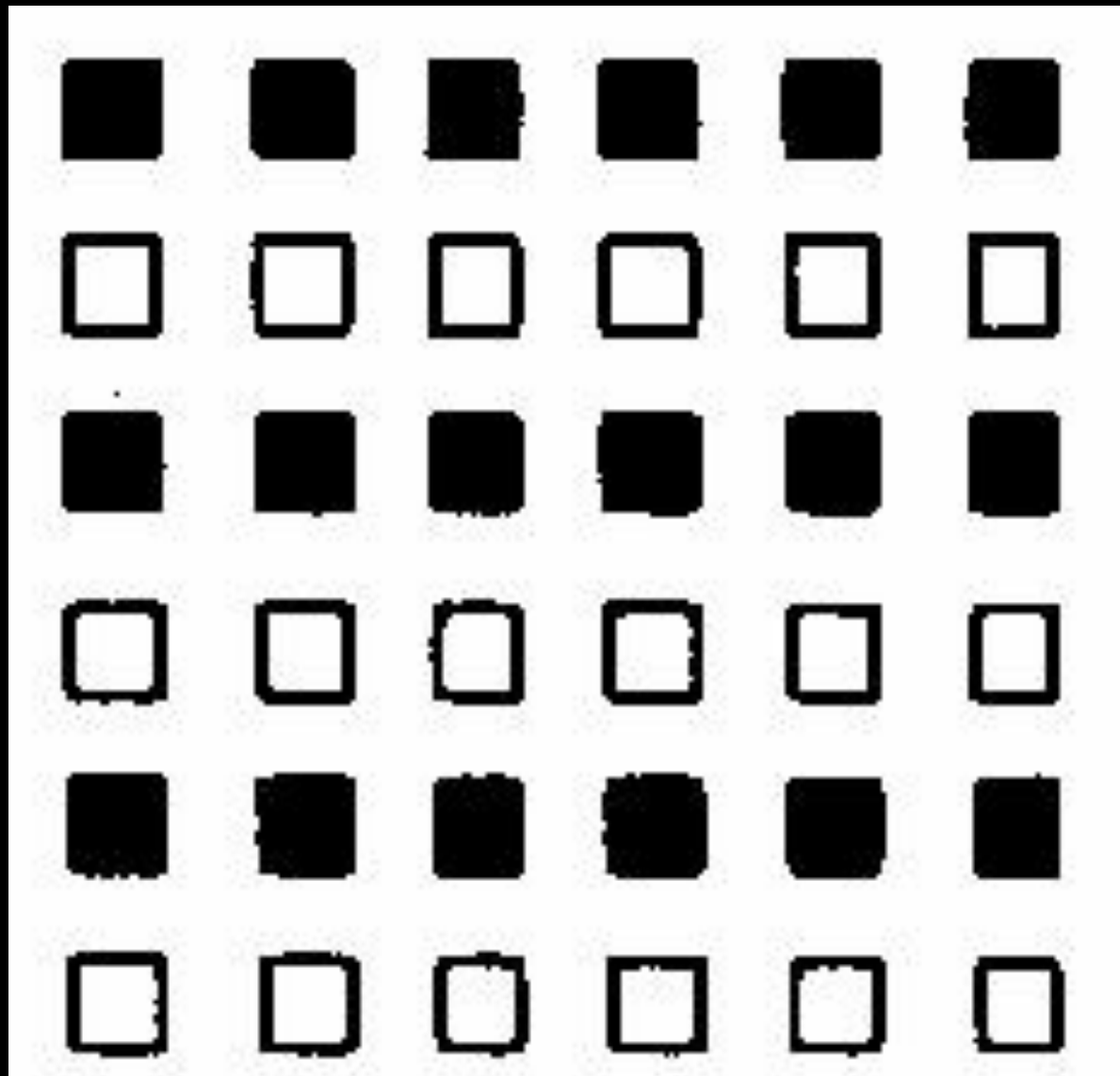
LAW OF PROXIMITY

Objects that are close tend to be perceived as a group.



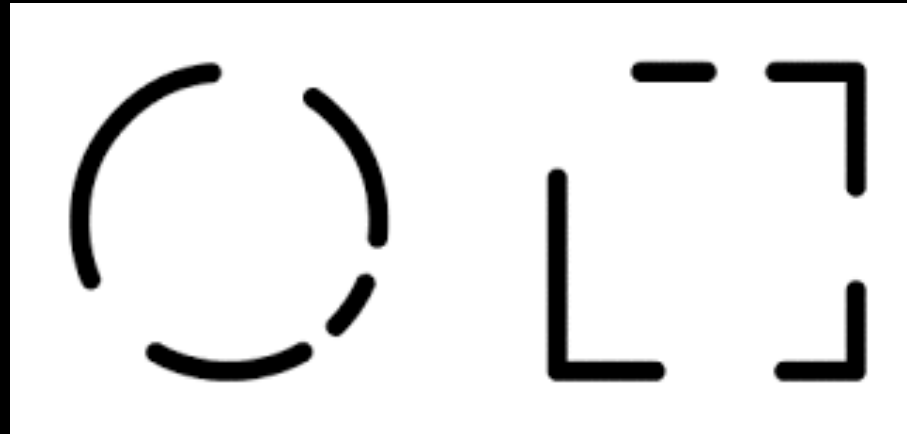
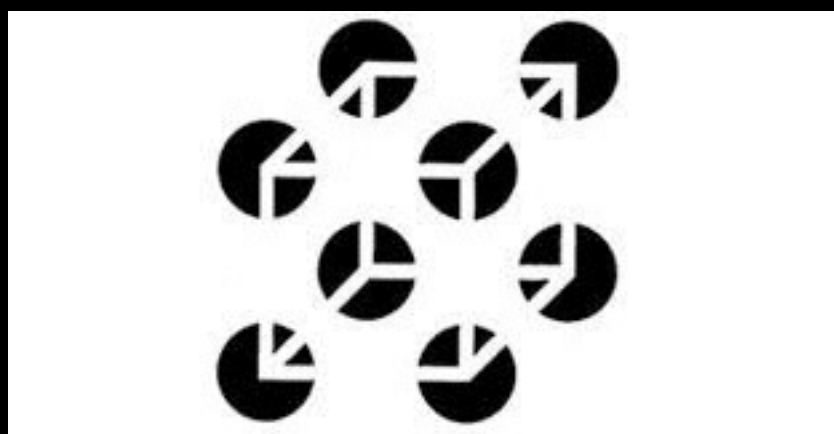
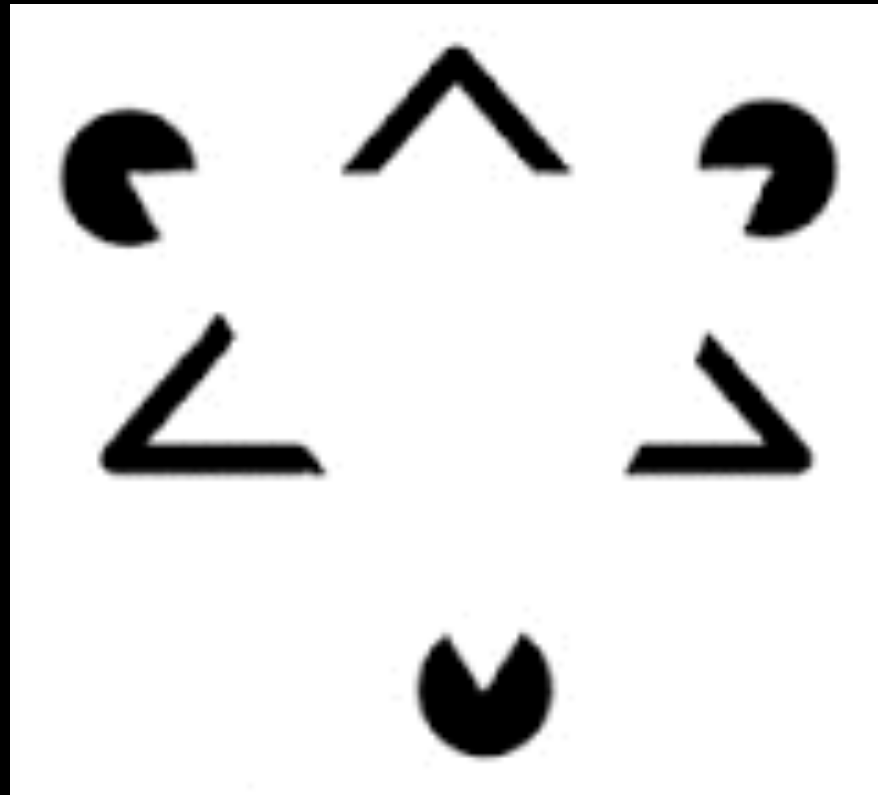
LAW OF SIMILARITY

Objects that are similar (in shape, color, shading, etc.) tend to form a group.



LAW OF CLOSURE

The perception fills gaps in stimuli.



LAW OF SYMMETRY

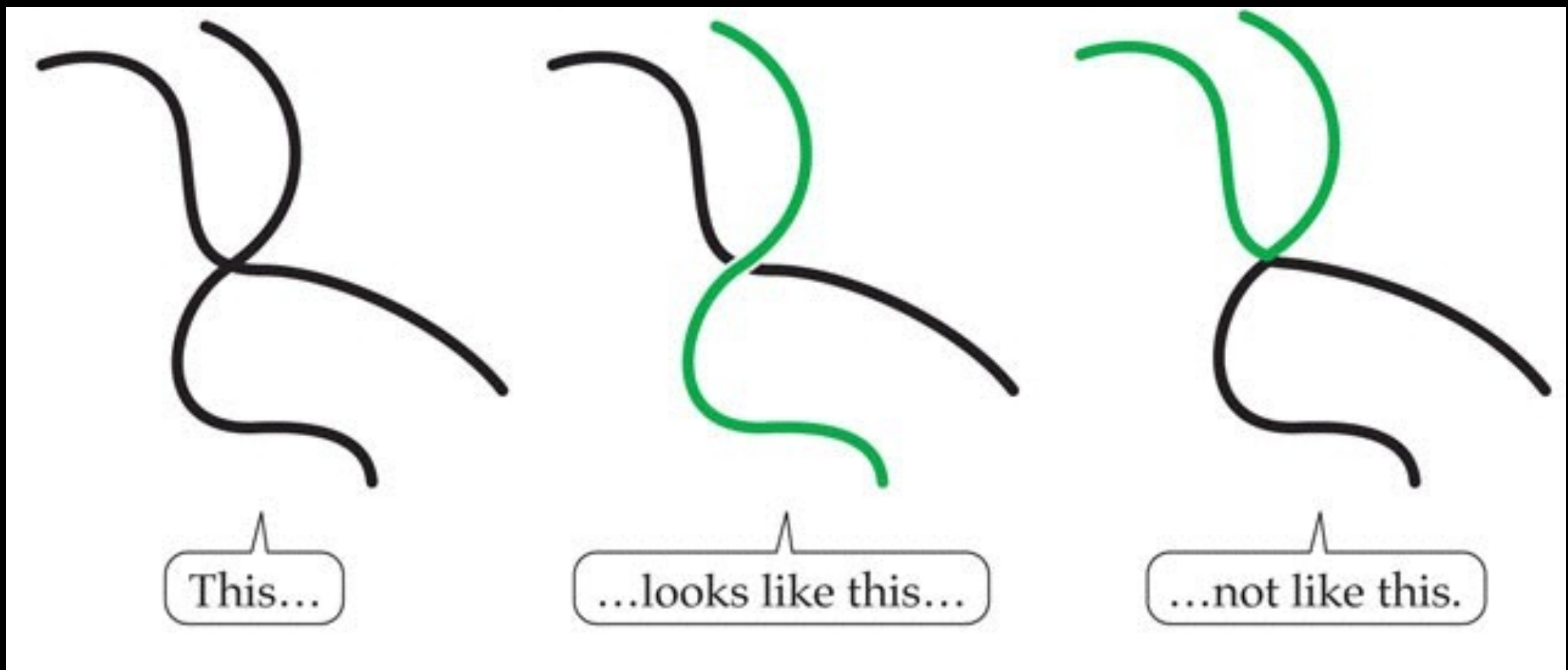
Objects with symmetric disposition tend to be perceived as forming a whole.

[] { } []

How many groups of elements are there?

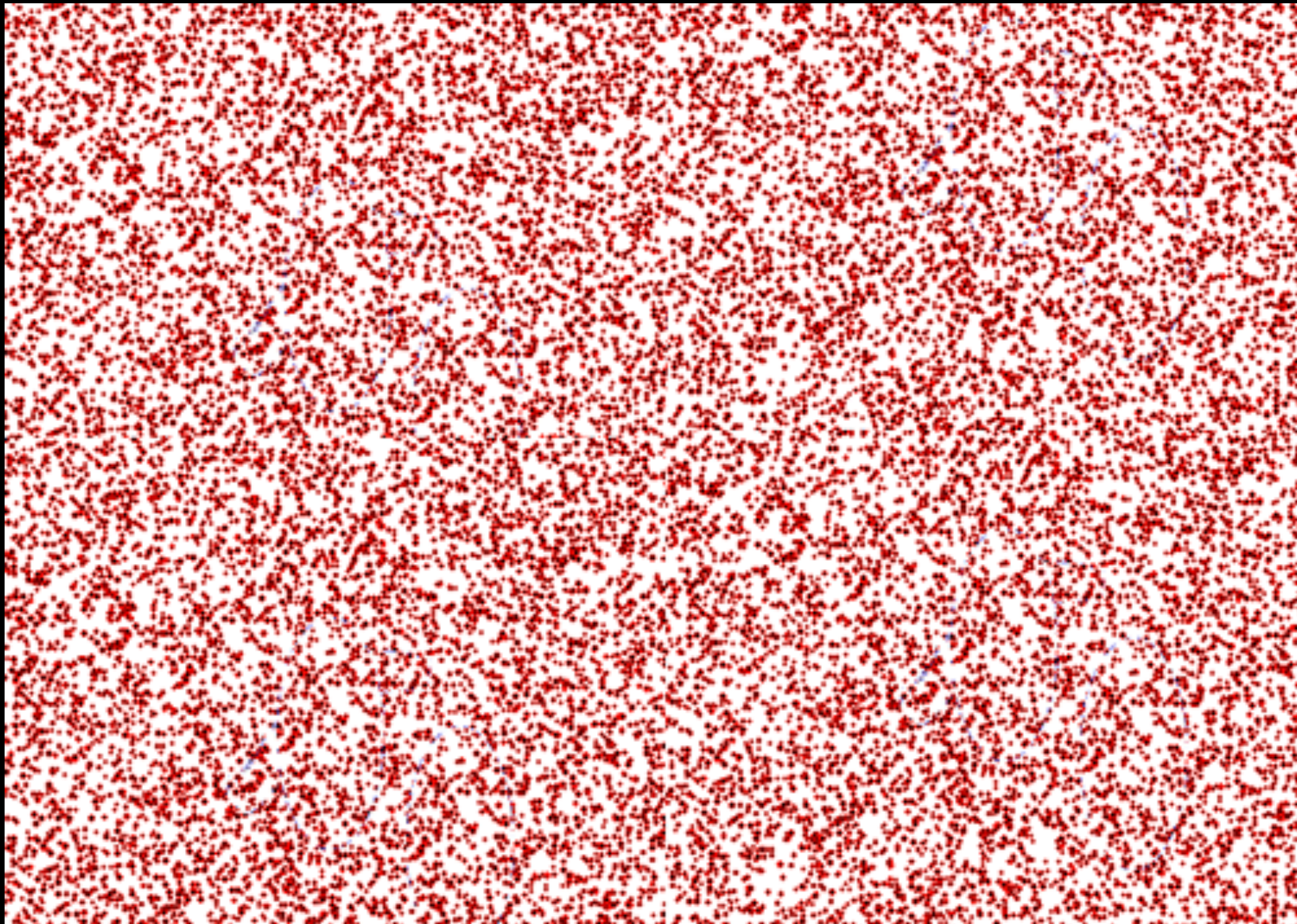
LAW OF CONTINUITY

Ambiguous stimuli are perceived preferentially with the interpretation that is the most continuous.



LAW OF COMMON FATE

Objects evolving together are perceived as a group.



LAW OF FIGURE & GROUND

Elements are perceived as either a **figure** (element of focus) or **ground** (background on which the figure sits)

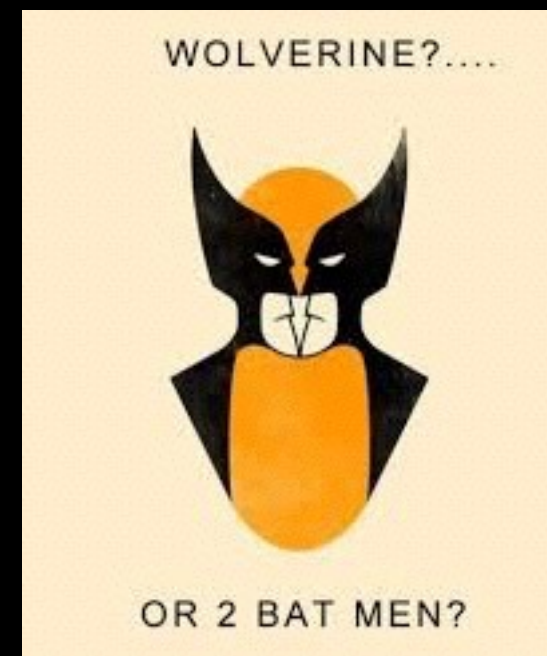
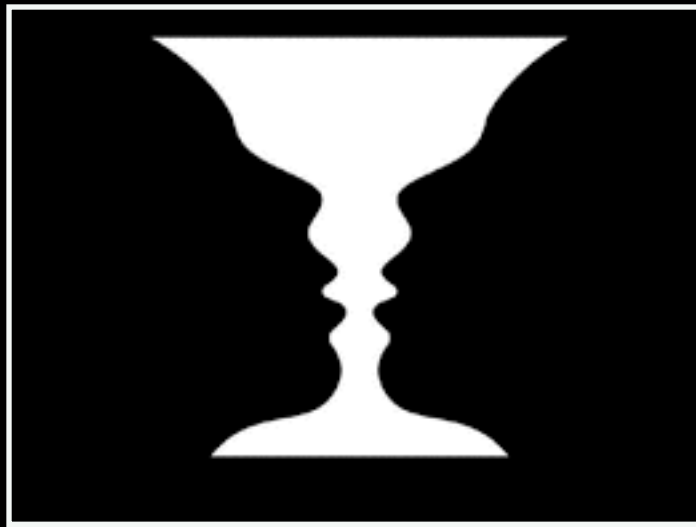


FIGURE & GROUND IN ART



FIGURE & GROUND IN ART

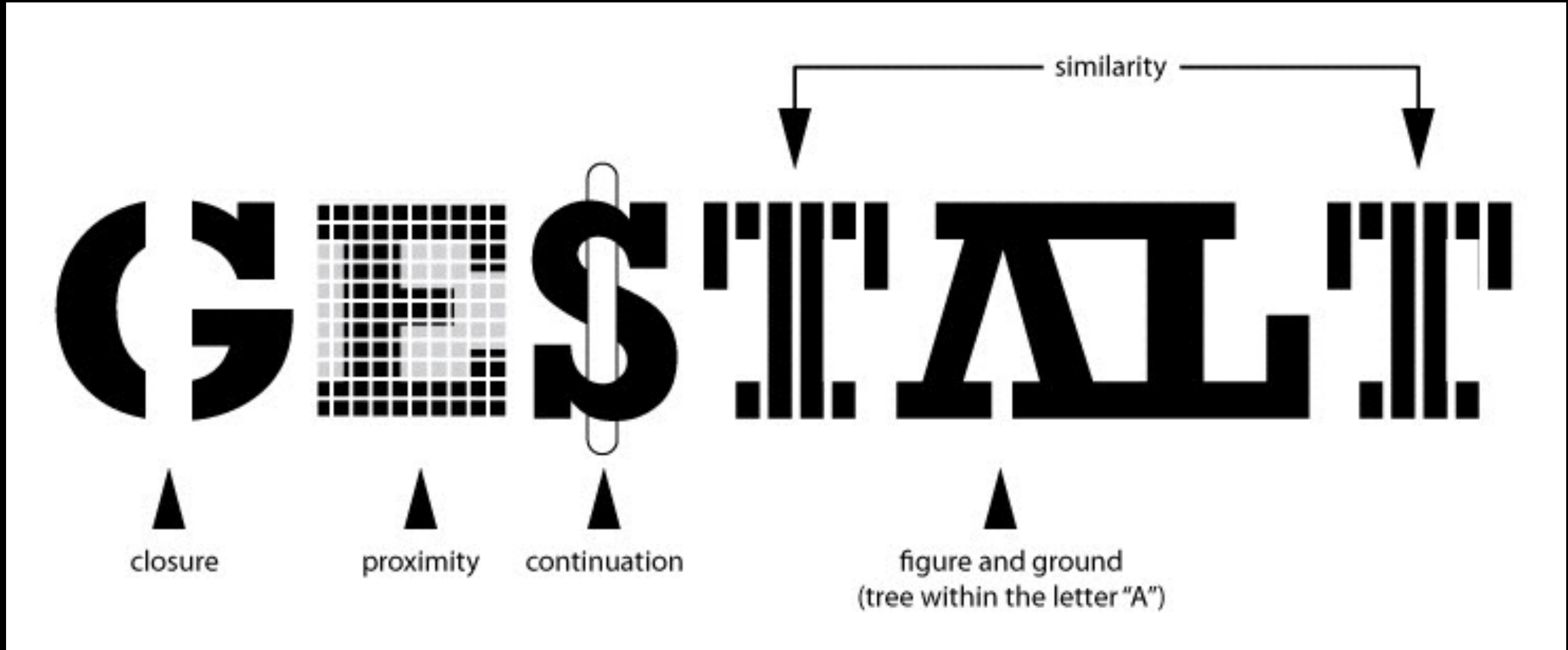


FIGURE & GROUND IN DESIGN



FIGURE & GROUND: BEFORE GESTALT

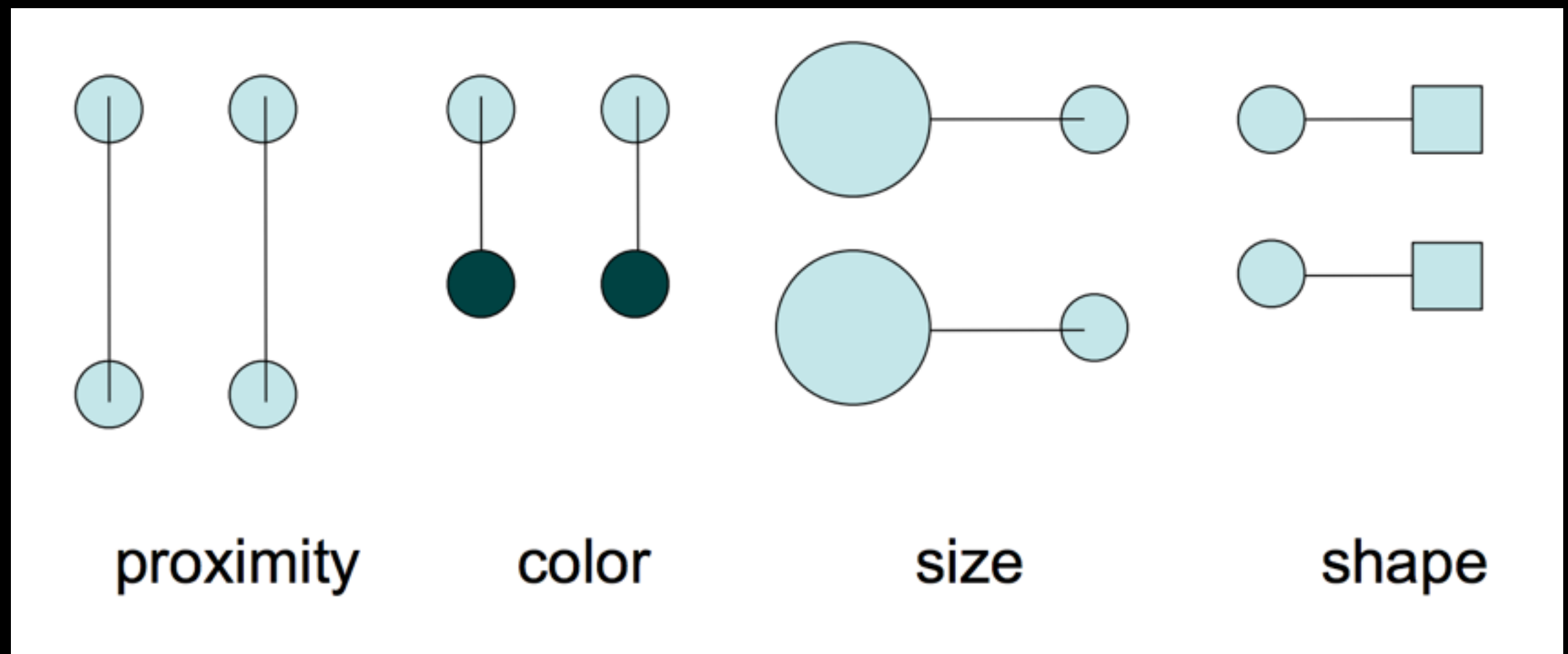




MORE LAWS!

LAW OF CONNECTEDNESS

Things that are linked are perceived as belonging to the same group.

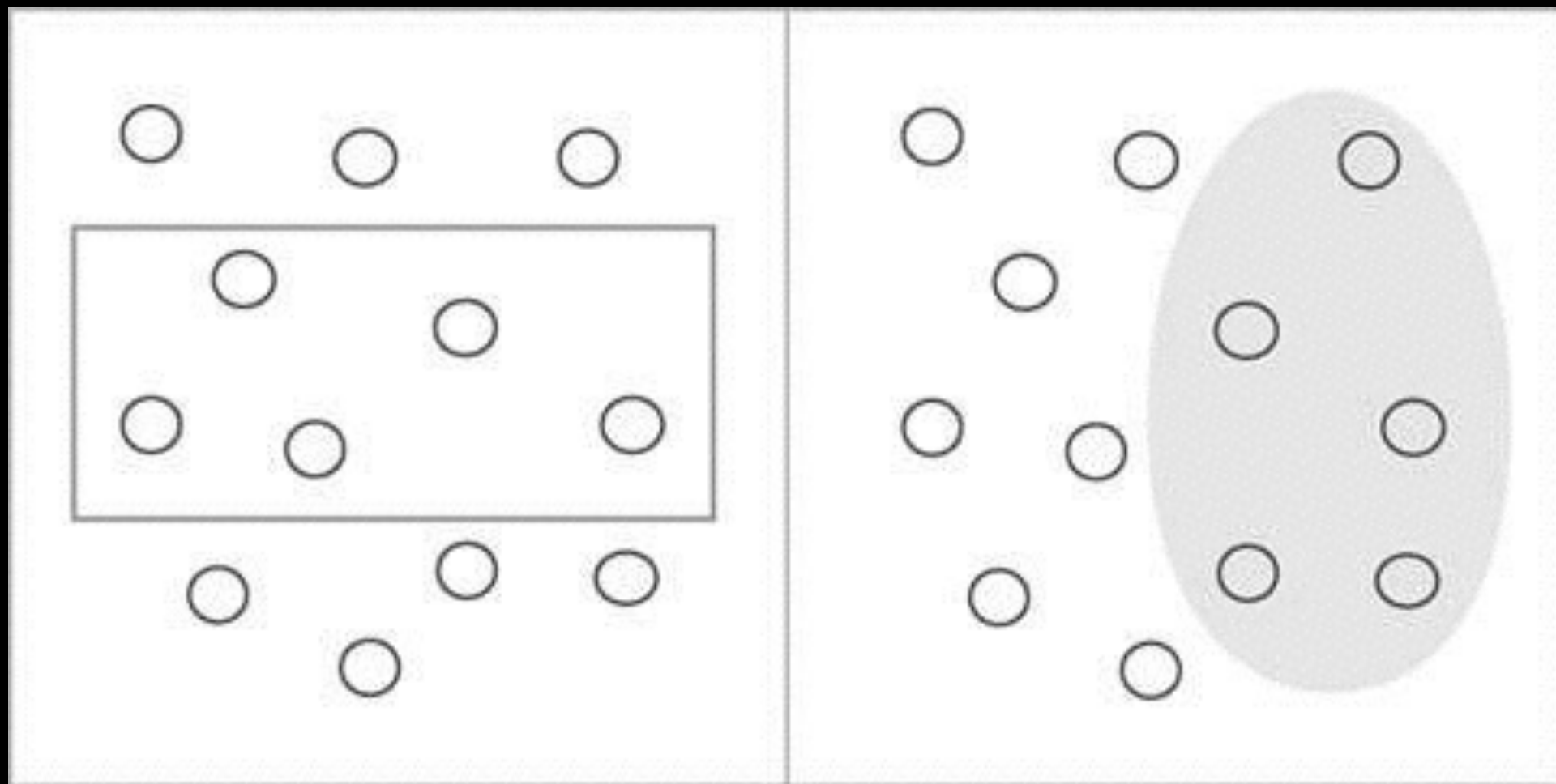


More powerful than proximity, color, size, shape...

MORE LAWS!

LAW OF ENCLOSURE

Objects that are enclosed are perceived as a group



Again, more powerful than proximity, color, size, shape...

IN SUMMARY

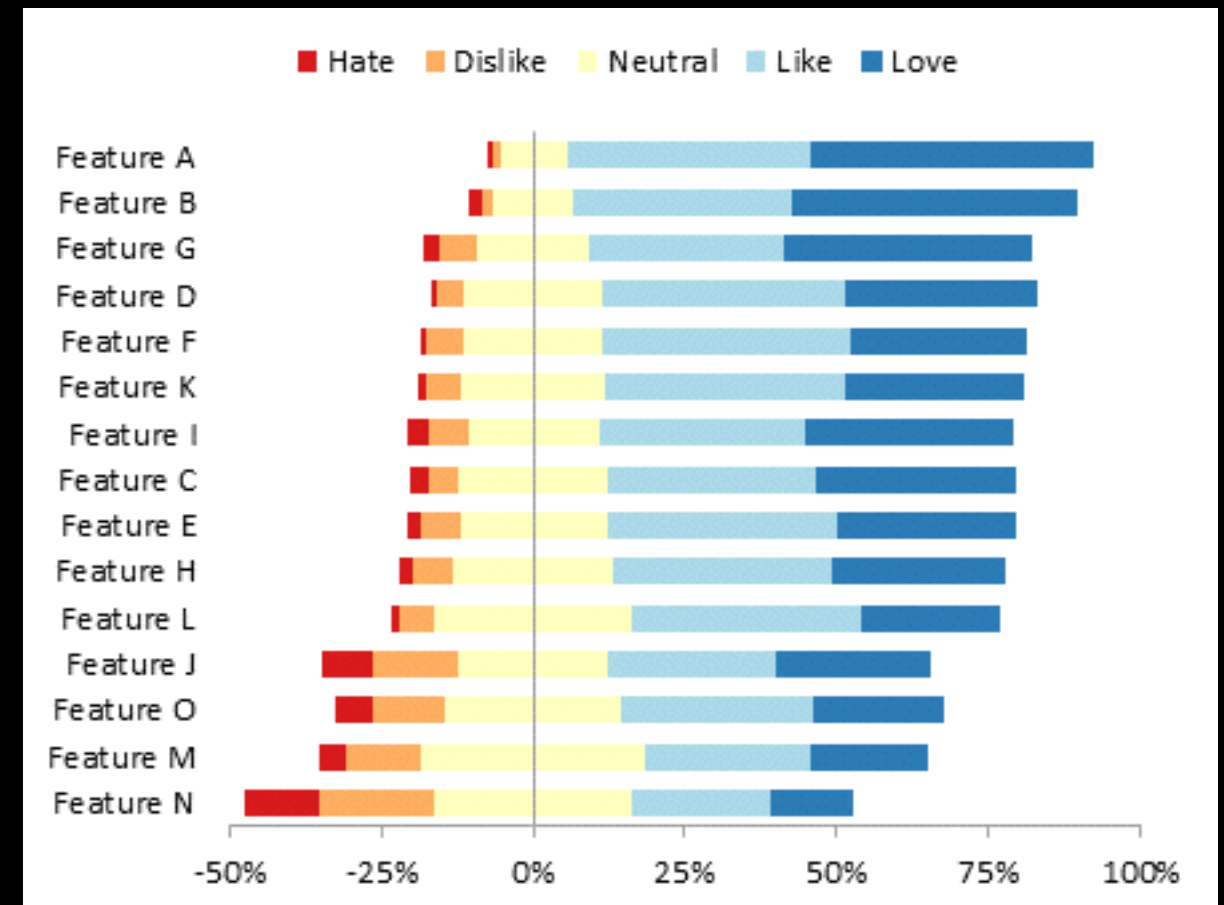
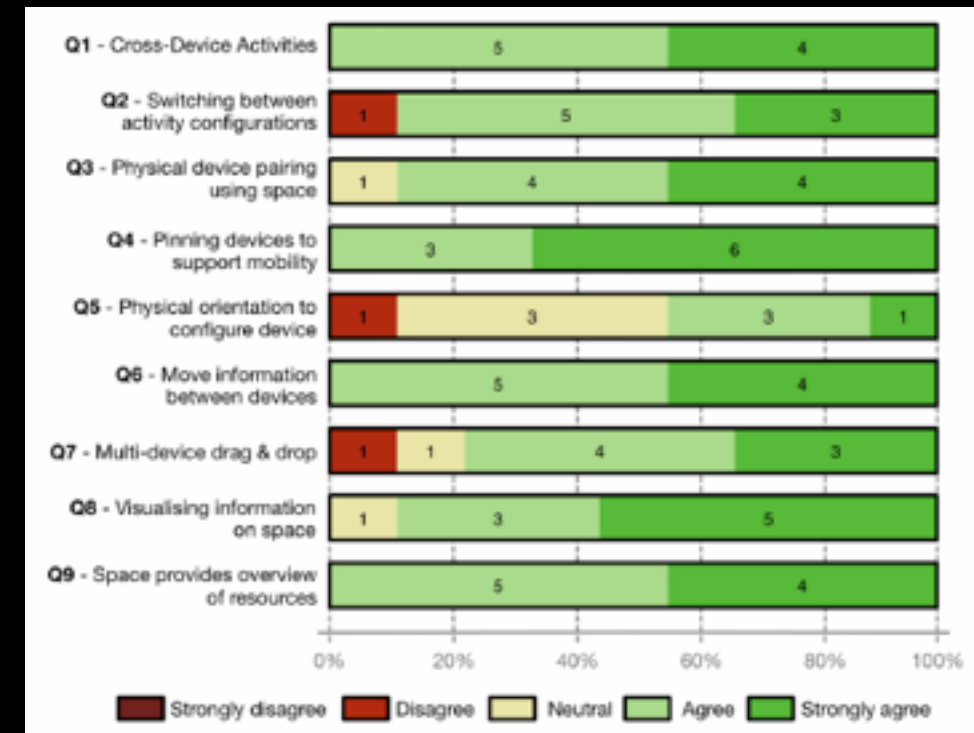
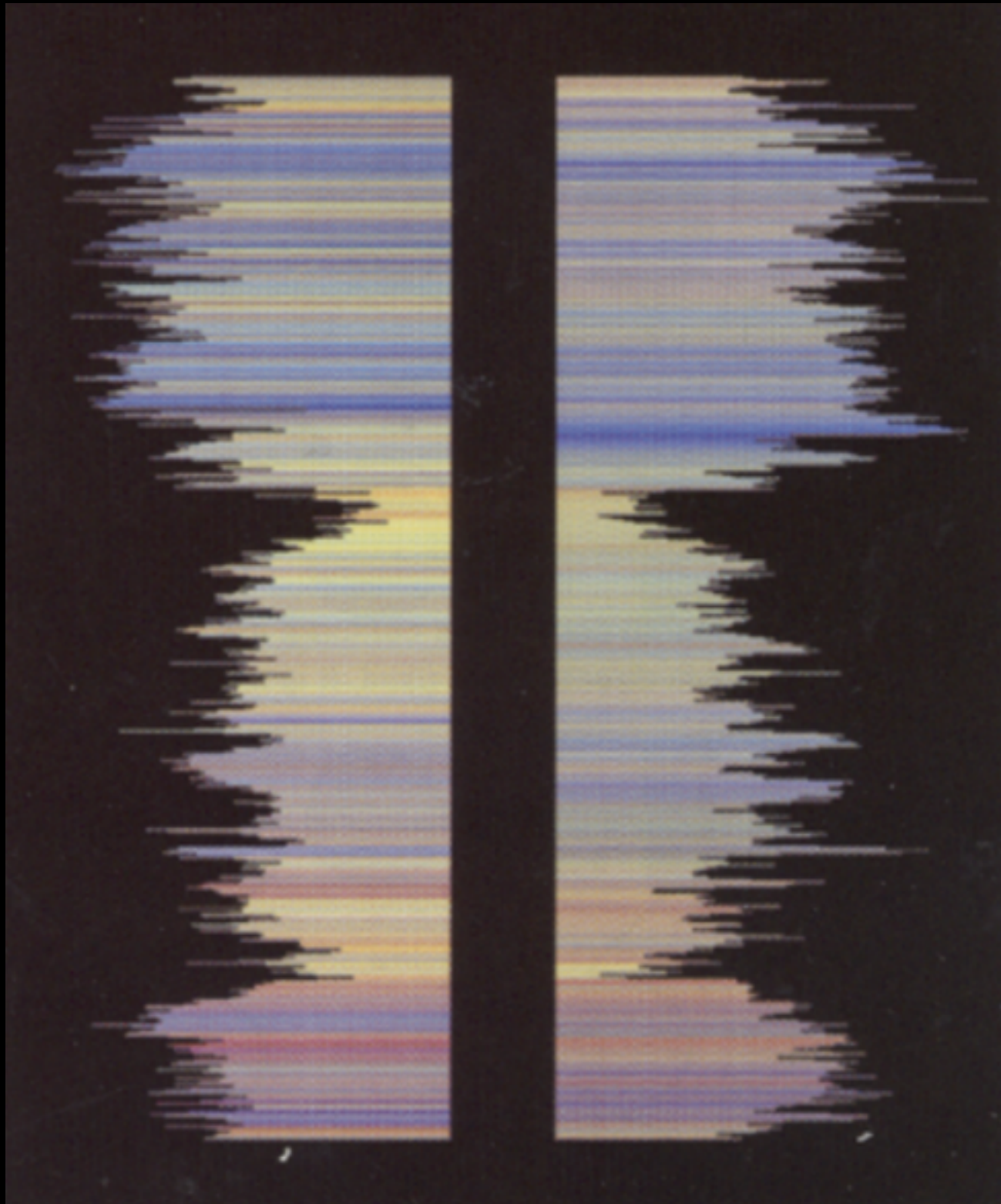
Our brains take lots of perceptual “shortcuts”...

... which can either help or harm our visualizations!

It is not enough to simply show something, we need to pay attention when and how it is shown.

A GOOD UNDERSTANDING OF PERCEPTUAL AND COGNITIVE PROCESSES IS CRITICAL!

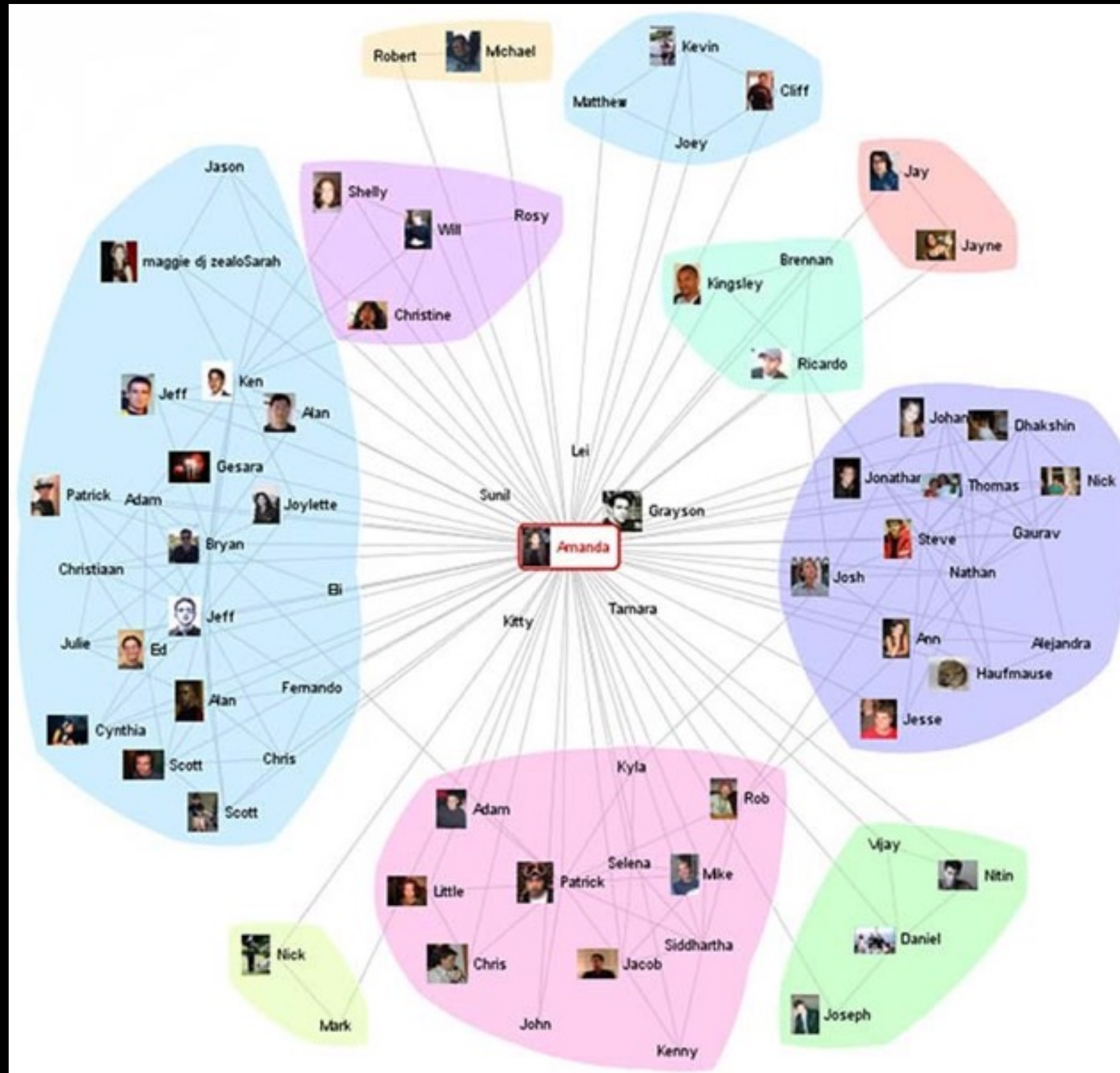
IMPLICATIONS FOR INFOVIS



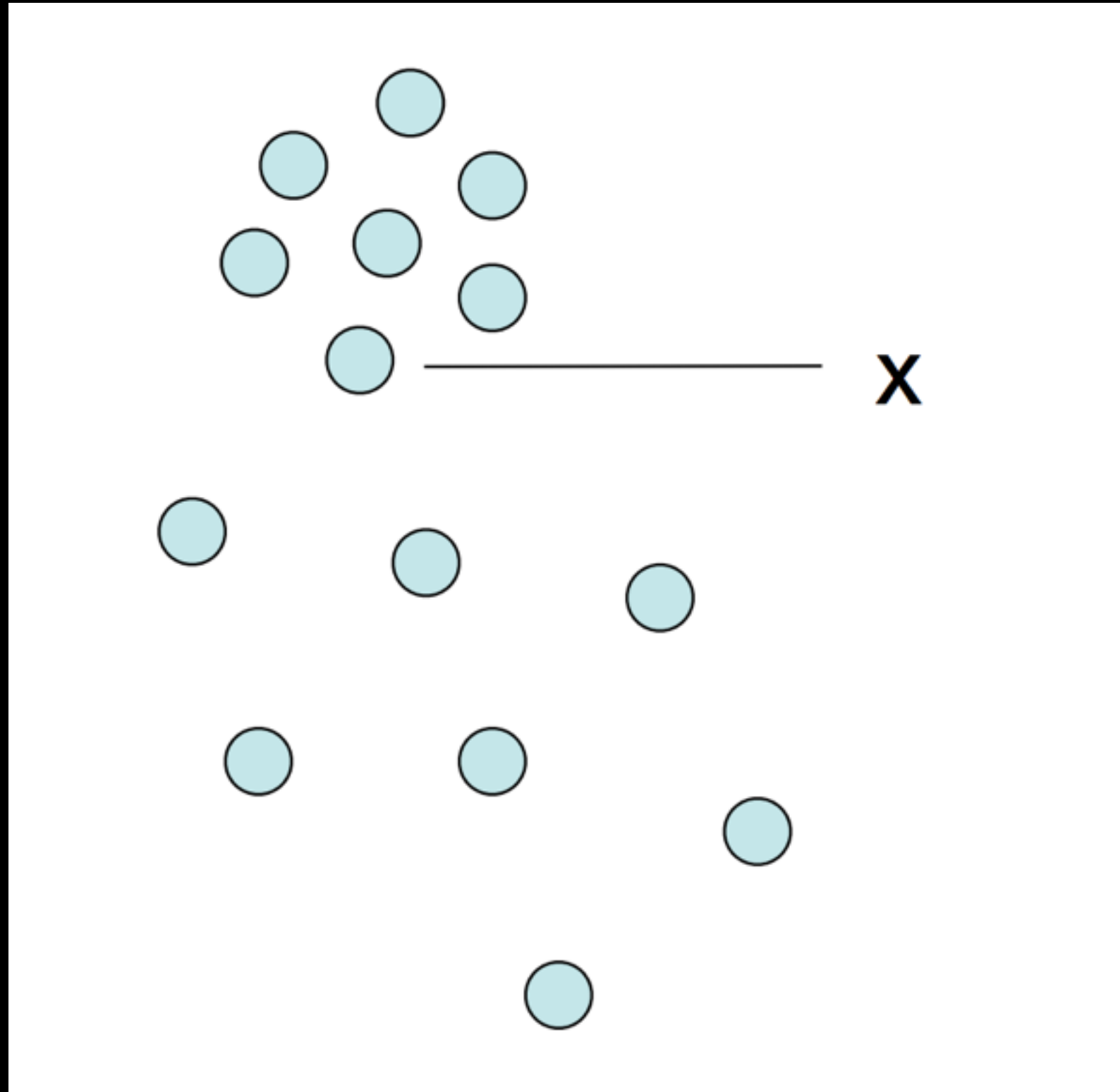
IMPLICATIONS FOR INFOVIS



IMPLICATIONS FOR INFOVIS



IMPLICATIONS FOR INFOVIS



ASSIGNMENTS

PAPER PRESENTATIONS &
PROSPECTIVE PROJECTS

PLANNING

WEEK 1	WELCOME - INTRODUCTION	
WEEK 2	VISUAL PERCEPTION, DATA MODELS / PROSPECTIVE PROJECTS	
WEEK 3	NETWORKS / MULTIDIMENSIONAL DATA	
WEEK 4	INTERACTION / ANIMATION	
WEEK 5	~HOLIDAY~	
WEEK 6	GUEST SPEAKER : CHRIS COLLINS — TEXT VISUALISATION	
WEEK 7	MID-TERM REVIEW	
WEEK 8	GUEST SPEAKER : RICHARD BRATH — VISUALIZATION IN INDUSTRY	
WEEK 9	STUDENTS PAPER PRESENTATION	
WEEK 10	GUEST SPEAKER : JUSTIN MATEJKA — VISUALIZATION AESTHETICS	
WEEK 11	GUEST SPEAKER : ISABEL MEREILLES — DESIGN	
WEEK 12	STUDENTS PAPER PRESENTATION	
WEEK 13	FINAL PRESENTATIONS + WRAP UP	

Edge compression techniques for visualization of dense directed graphs

Absolutely

It is expected that you explore and discuss

- Related work
- Analysis of domain, tasks, design goals
- Implementation
- (evaluation)

Deliverable

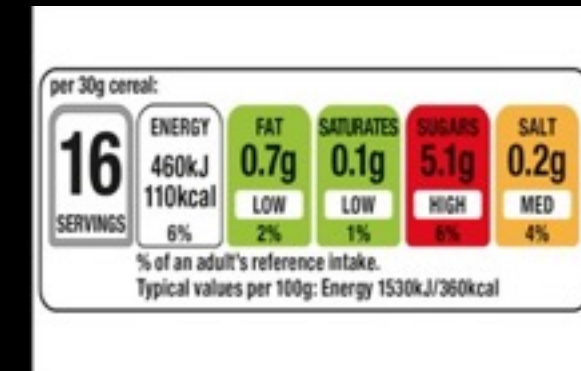
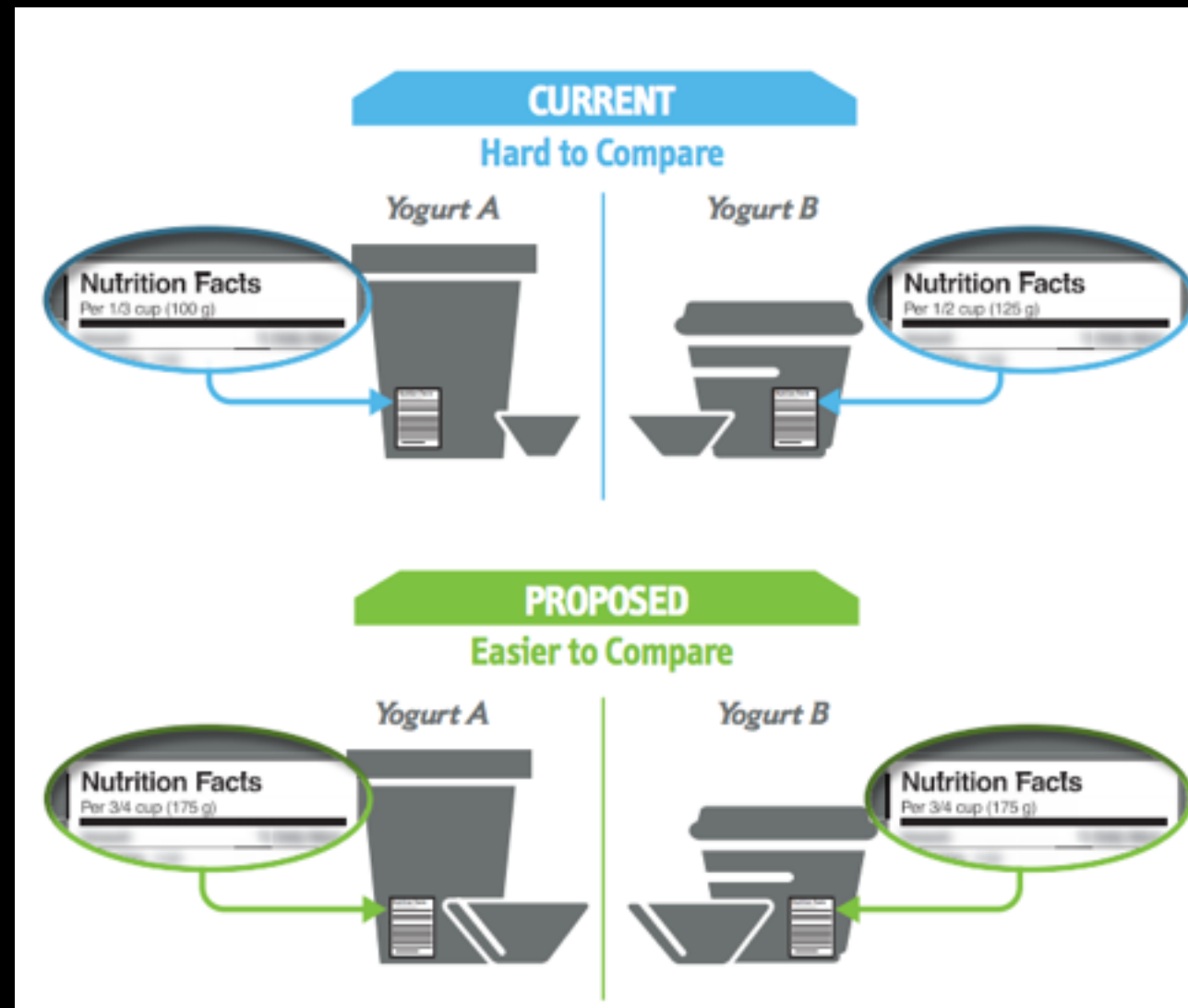
- mid-term presentation (5-10min presentation of the project)
- Stand-alone demo
- Final presentation (live demos welcome!)
- Paper (4-6 pages)

PROSPECTIVE PROJECT 1
VISUALIZING PIXEL HISTORY / LAYERS

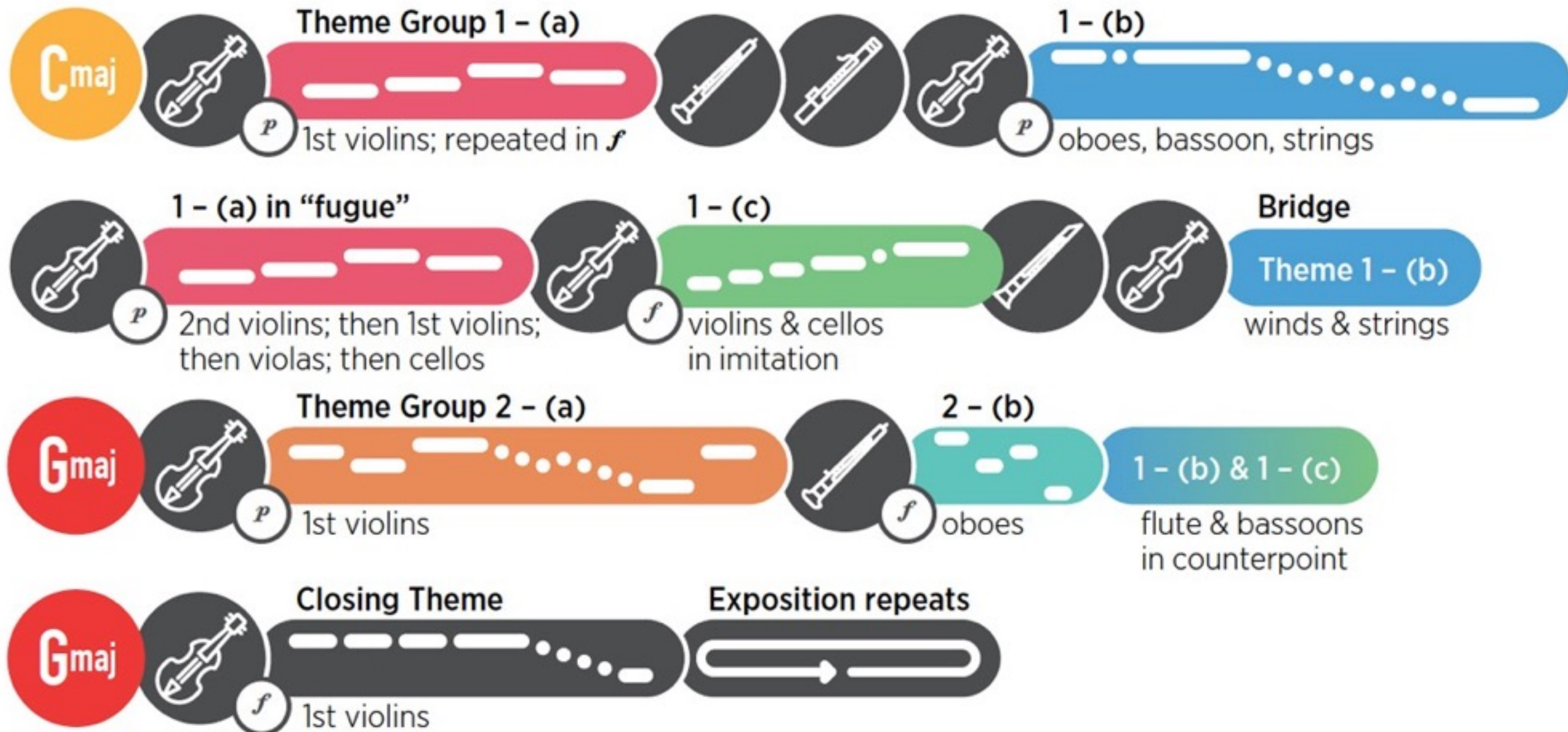


Cracker B

Nutrition Facts			
Per 4 crackers (20 g)			
Amount	% Daily Value		
Calories 85			
Fat 2 g			3 %
Saturated 0.3 g + Trans 0 g			2 %
Cholesterol 0 mg			
Sodium 90 mg			4 %
Carbohydrate 15 g			5 %
Fibre 3 g			12 %
Sugars 1 g			
Protein 2 g			
Vitamin A	0 %	Vitamin C	0 %
Calcium	2 %	Iron	7 %



Exposition: initial presentation of thematic material



PROSPECTIVE PROJECT 4
ANIMATED TRANSITIONS OF THE INTERNET

```
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<center> <br><br><br><br><br><br>
<h1><font size=10 color=#FFFFFF>Glimpse:</font></h1>

<h2>
<font face="Courier New" color=#FFFFFF> what you glimpse is |</font>
</h2>

</center>
<br><br><br><br>
<br><br><br>

<p align=right>

<font size=4 face="Helvetica" color=99CCFF> <b><i>Pierre Dragicevic</i></b>
</font><br>
<font face="Helvetica" color=6699CC> INRIA </font><br><br>

<font size=4 face="Helvetica" color=99CCFF> <b><i>Stéphanie Huot</i></b>
</font><br>
<font face="Helvetica" color=6699CC> LRI - Université Paris-Sud & CNRS, INRIA
</font><br><br>

<font size=4 face="Helvetica" color=99CCFF> <b><i>Fanny Chevalier </i></b>
</font><br>
<font face="Helvetica" color=6699CC> OCAD University </font>

</p>

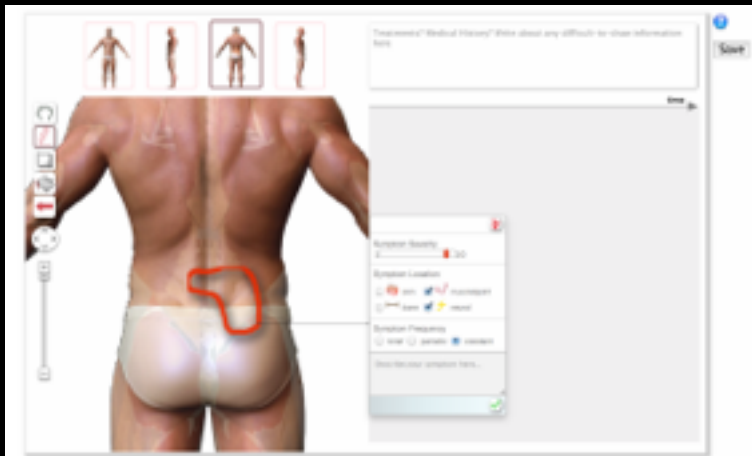
</html>
```

PROSPECTIVE PROJECT 5

(SKETCH-BASED) TOOL FOR AUTHORIZING ANIMATION



EXPRESSING AND VISUALIZING BODY PAIN



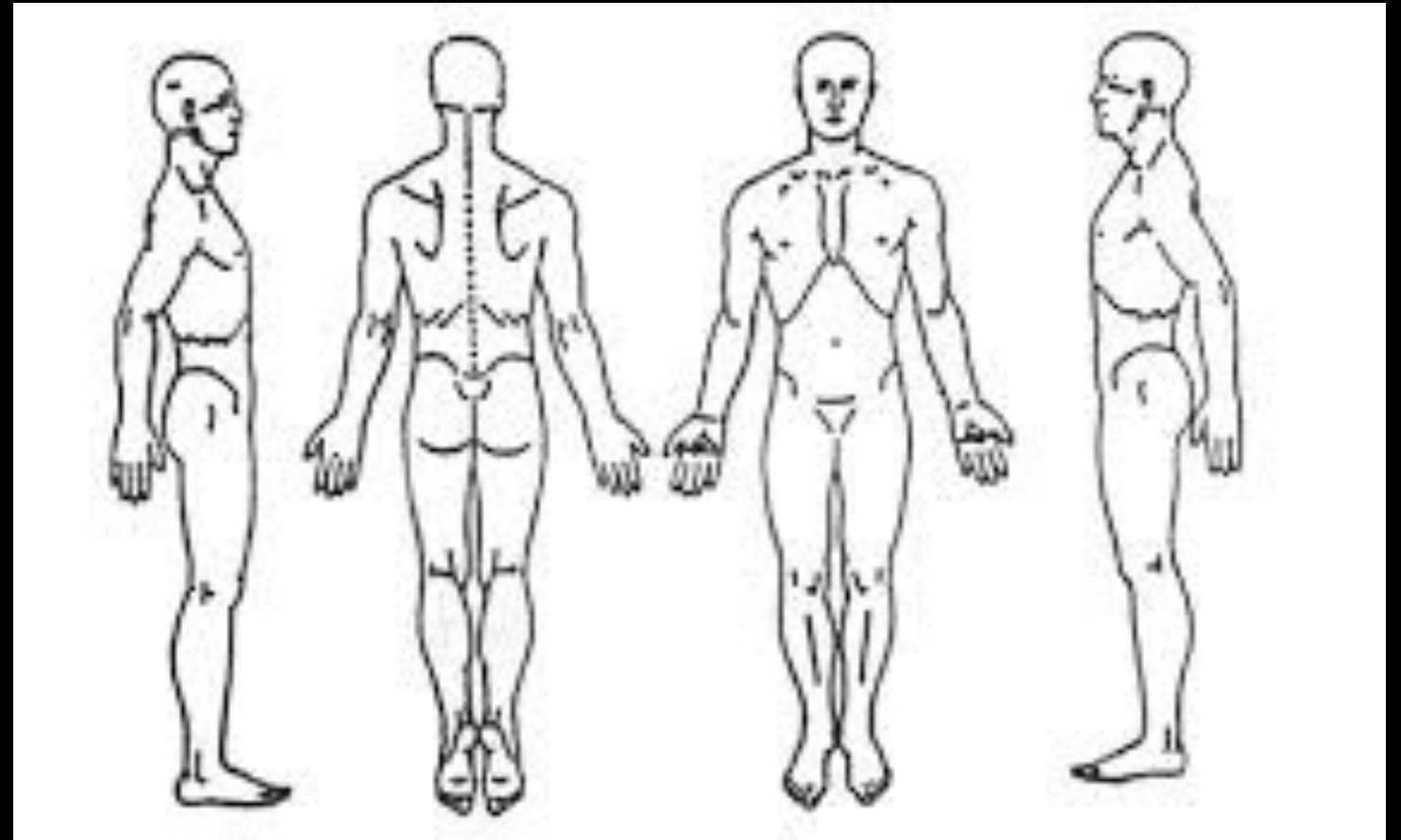
(b) Back pain drawn using pen.



(c) Grouped leg pain drawings.



(d) Changing the duration and starting time.



PROSPECTIVE PROJECT 7
VISUALIZATION LITERACY AT SCHOOL



PROSPECTIVE PROJECT X
VAST CHALLENGES



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VAST Challenge

The Visual Analytics Science and Technology (VAST) Challenge is an annual contest with the goal of advancing the field of visual analytics through competition. The VAST Challenge is designed to help researchers understand how their software would be used in a novel analytic task and determine if their data transformations, visualizations, and interactions would be beneficial for particular analytic tasks. VAST Challenge problems provide researchers with realistic tasks and data sets for evaluating their software, as well as an opportunity to advance the field by solving more complex problems.

Researchers and software providers have repeatedly used the data sets from throughout the life of the VAST Challenge as benchmarks to demonstrate and test the capabilities of their systems. The ground truth embedded in the data sets has helped researchers evaluate and strengthen the utility of their visualizations.

Challenge Archive

- [VAST Challenge 2015](#) "Mayhem at DinoFun World"
- [VAST Challenge 2014](#) "The Kronos Incident"
- [VAST Challenge 2013](#) "Three Mini-Challenges"
- [VAST Challenge 2012](#) "BANKWORLD"
- [2011 - 2013 VAST Cyber Challenges](#)
- 2011: <http://hcil2.cs.umd.edu/newvarepository/benchmarks.php#VAST2011> Epidemic Spread and Computer Networks
- 2010: <http://hcil2.cs.umd.edu/newvarepository/benchmarks.php#VAST2010> Illegal Arms and Virus Pandemic
- 2009: <http://hcil2.cs.umd.edu/newvarepository/benchmarks.php#VAST2009> Trouble at the Embassy
- 2008: <http://www.cs.umd.edu/hcil/VASTchallenge08/> "The Paraiso Movement"
- 2007: <http://www.cs.umd.edu/hcil/VASTcontest07/> "Blue Iguanodon"
- 2006: <http://www.cs.umd.edu/hcil/VASTcontest06/> "A tale of Alderwood"