
Data Visualisation

CMP020L013A

Week 5: Visual Perception

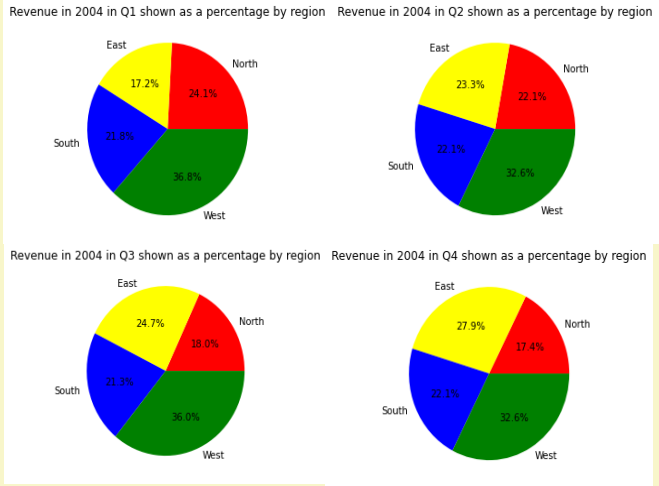
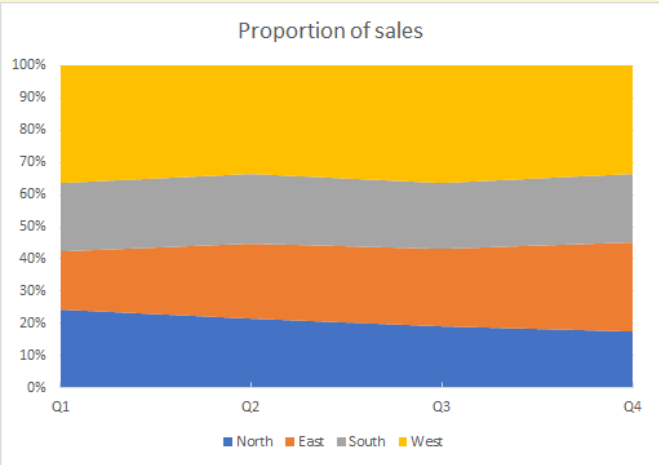
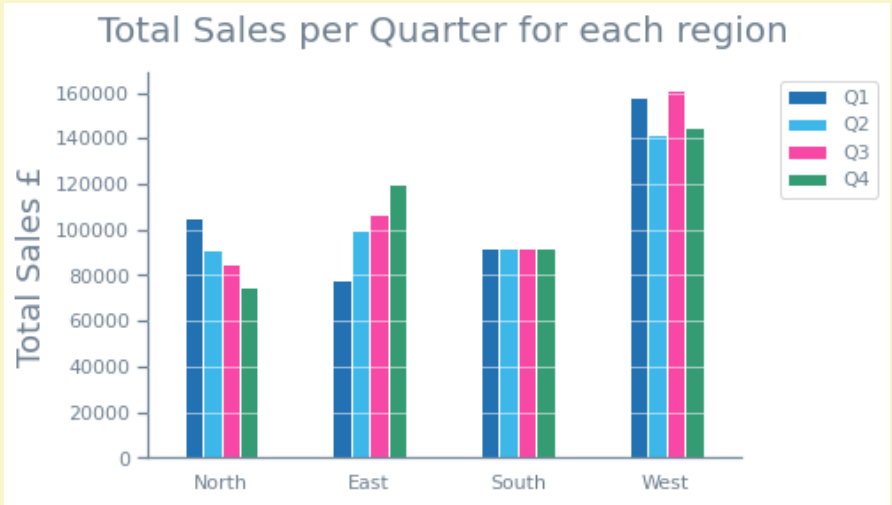
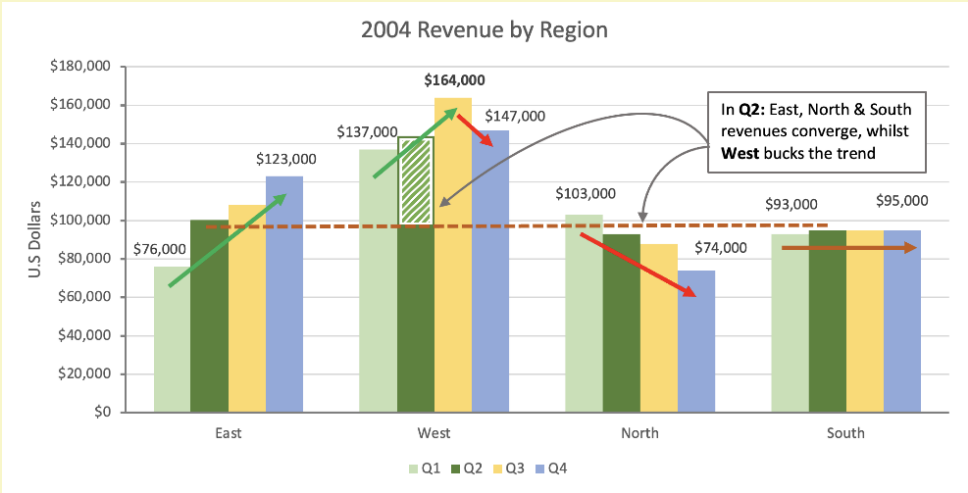
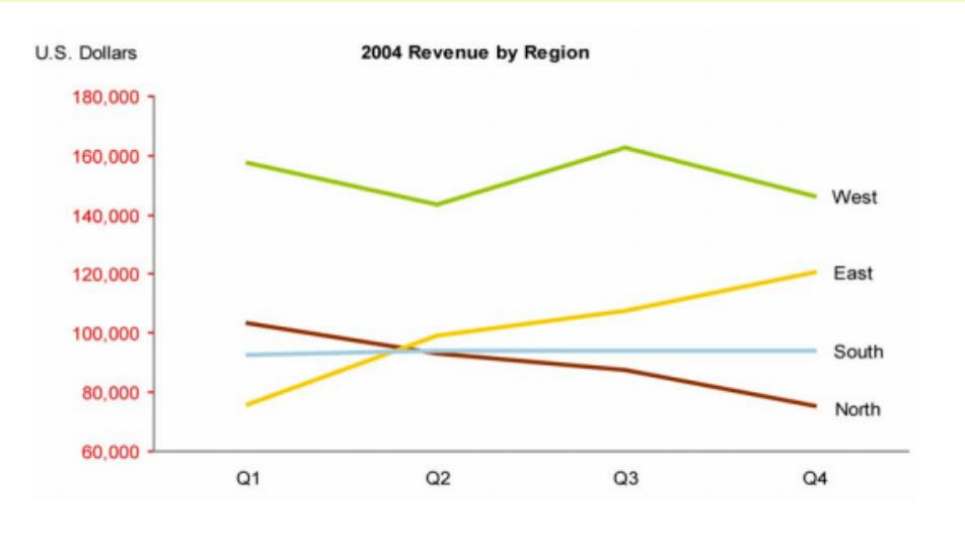
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Topics

- ▶ Sensory vs arbitrary symbols
- ▶ Three-stage information processing model
- ▶ Visual Perception



Visual Perception in Data Visualisation

- ▶ 1. The collection and storage of data
- ▶ 2. Pre-processing, transformation, data reduction
- ▶ 3. Mapping selected data to visual representation
- ▶ 4. Processed by human perceptual and cognitive system

Understand visual perception to improve visual communication

Semiotics of Graphics

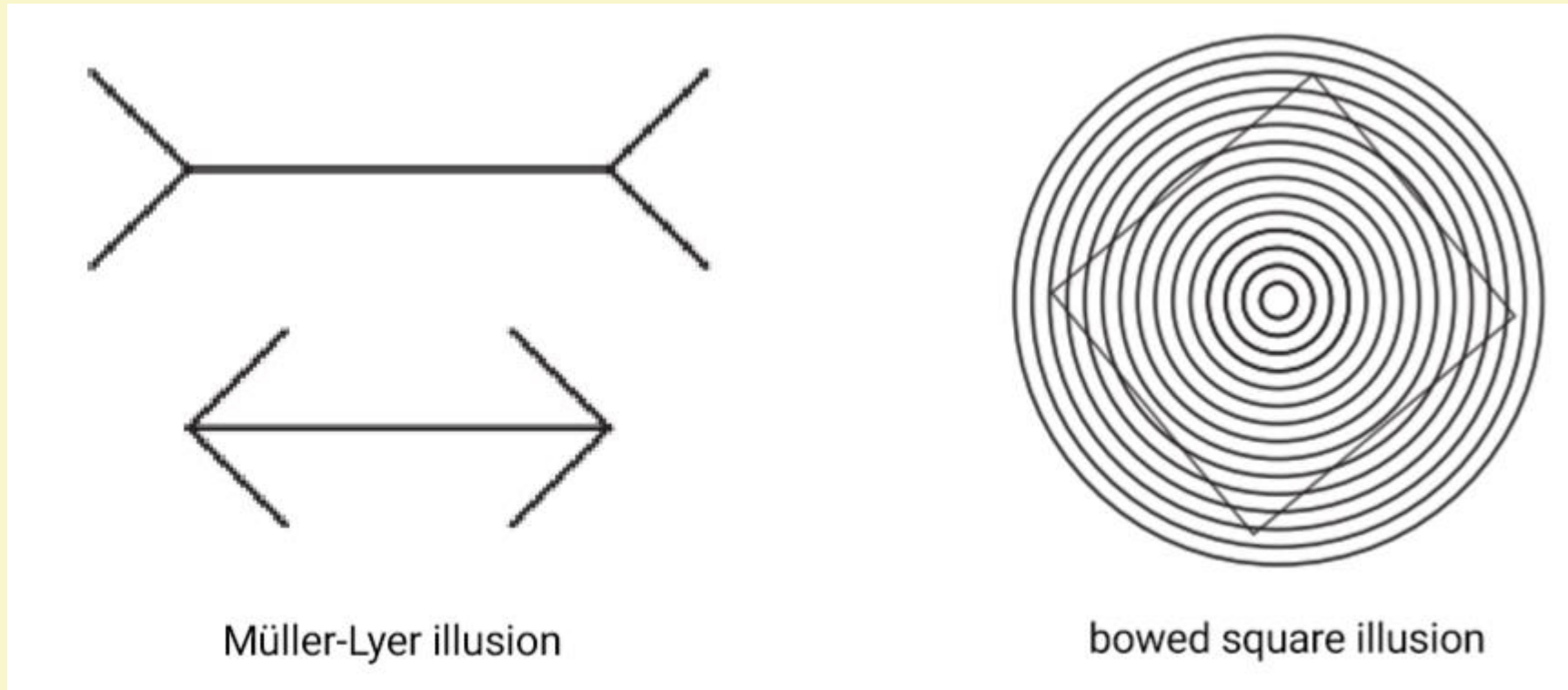
- ▶ Study of visual **symbols** and how they convey meaning
- ▶ Classical view (Saussure)
 - ▶ all symbols are arbitrary
 - ▶ must be learnt
 - ▶ no system of representation can be better than any other
- ▶ Scientific view
 - ▶ the visual system has particular properties(product of evolution)
 - ▶ Different forms of representation are more closely aligned with our perception mechanisms
 - ▶ There are some grounds for determining better/worse forms of visual communication

Sensory vs Arbitrary Symbols

- ▶ Sensory
 - ▶ aspects of visualisations that derive their expressive power from their ability to use **the perceptual processing power of the brain without learning**
- ▶ Arbitrary
 - ▶ aspects of representation that **must be learned**, because the representations have **no perceptual basis**

Sensory Symbols

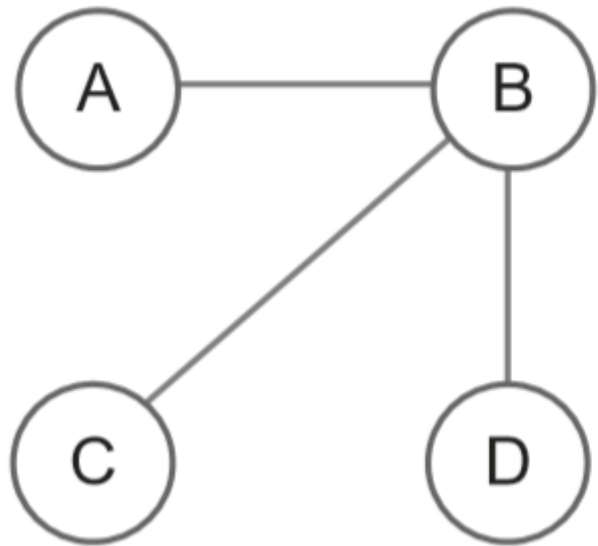
- ▶ Well matched to the first stages of neural processing
- ▶ Tend to best able across individuals, cultures, and time



Arbitrary symbols

- ▶ Derive power from culture
- ▶ Dependent on individual culture knowledge



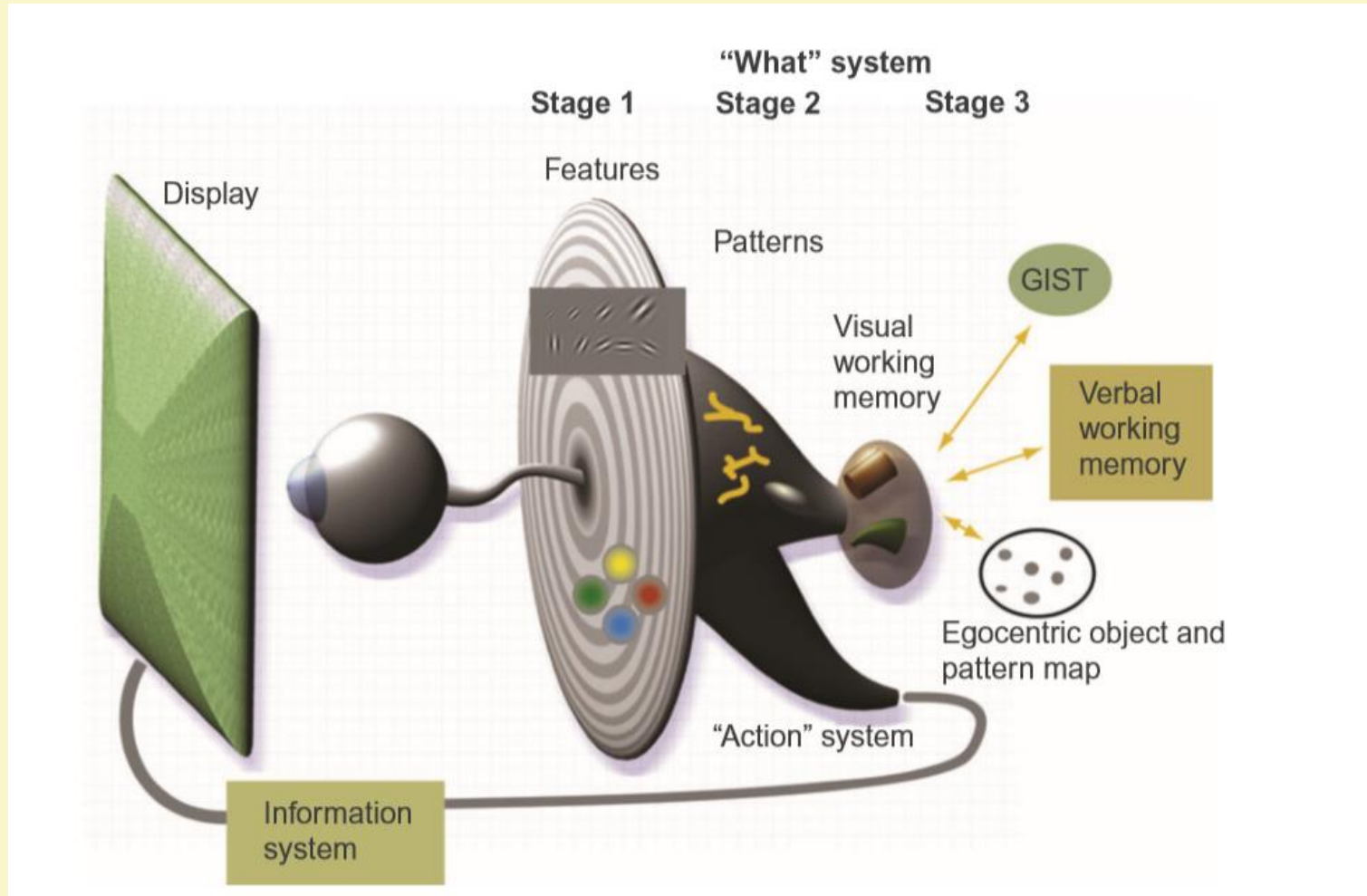


Relationships
Arbitrary or sensory symbols?

Vision

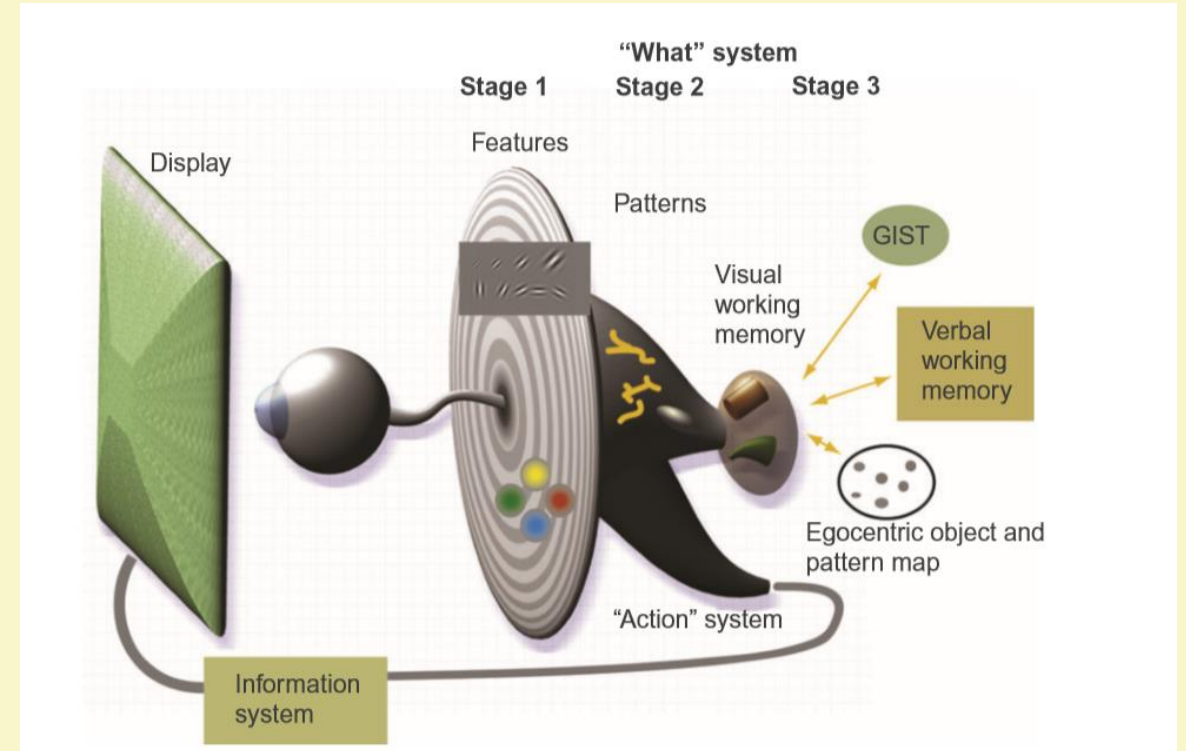
- ▶ Our primary sense
- ▶ 70% of our sense receptors are in the eye
- ▶ large areas of the brain devoted to visual processing
- ▶ it's complex!
- ▶ e.g. synaesthesia

Three-stage Information Processing Model



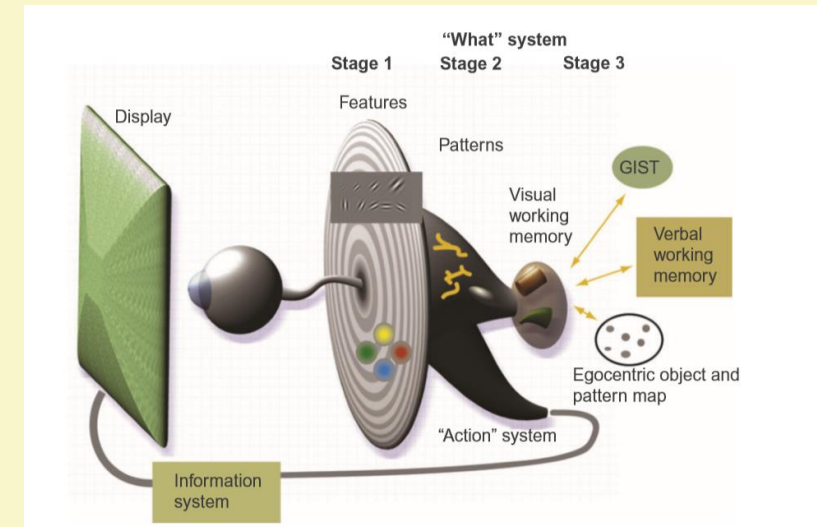
Stage1: Low-level Feature Extraction

- ▶ Parallel processing
- ▶ Specialised neurons
 - ▶ Edge detection and orientation
 - ▶ Colour
 - ▶ texture
 - ▶ Movement
- ▶ pre-conscious
- ▶ bottom-up
- ▶ data-driven



Stage2: Pre-attentive Processing and Pattern Perception

- ▶ Visual field is divided into regions and simple patterns
 - ▶ Continuous contours
 - ▶ Regions of the same colour
 - ▶ Regions of the same texture
 - ▶ Both bottom-up and top-down
- ▶ Between one and three patterns can be held for **one or two seconds** by top-down attentional processes
- ▶ Fork in pattern processing pathway
 - ▶ 1. Object perception (linguistic brain areas)
 - ▶ 2. control of actions(motor control)

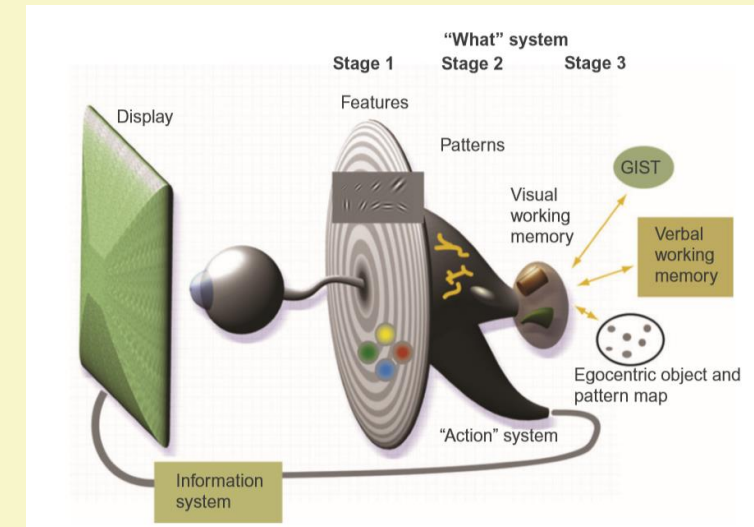


Stage2: Pre-attentive Processing and Pattern Perception

- ▶ Stage two of processing of visual features, subconscious accumulation of sensory information; then, the brain filters and processes what is important.
- ▶ Information that has the highest salience (a stimulus that stands out the most) or relevance to what a person is thinking about is selected for further and more complete analysis by conscious (attentive) processing
- ▶ < 200 ms
- ▶ features: orientation, size, curvature, colour(hue), intensity, flicker, motion, 2D position, stereoscopic depth, convex and concave shape

Stage3: Visual Working Memory

- ▶ Highest level of perception
- ▶ Very few objects held in working memory by demands of active attention objects constructed from available patterns and information stored in long-term memory
- ▶ Query driven
 - ▶ Search for patterns that satisfy attentional goals
 - ▶ e.g. looking for a place on a map



Expectations and Usefulness

- ▶ Visual information processing is highly dynamic
- ▶ Information flow is multi-directional
 - ▶ Up from sensory input
 - ▶ Down from conscious processes
- ▶ low-level information is modulated by
 - ▶ 1. expectations
 - ▶ 2. its usefulness in any given situation
 - ▶ Information content

Sensory Perception is Relative

- ▶ Luminance \neq perceived brightness
- ▶ Signals from the eyes to the brain transmit nothing about the amount of light falling on the retina
- ▶ They signal **the relative amount of light**
 - ▶ how a patch of light differs from a neighbouring patch
 - ▶ how a patch of light has changed in the past instant
- ▶ *Visualization is not good for representing precise absolute numerical values, but rather for displaying patterns of differences or changes over time, to which the eye and brain are extremely sensitive"*

(Ware, p.70)

Preattentive Processing (Stage 2) and Ease of Search

45929078059772098775972655665110049836645
27107462144654207079014738109743897010971
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25747072354745666142018774072849875310665

(a)

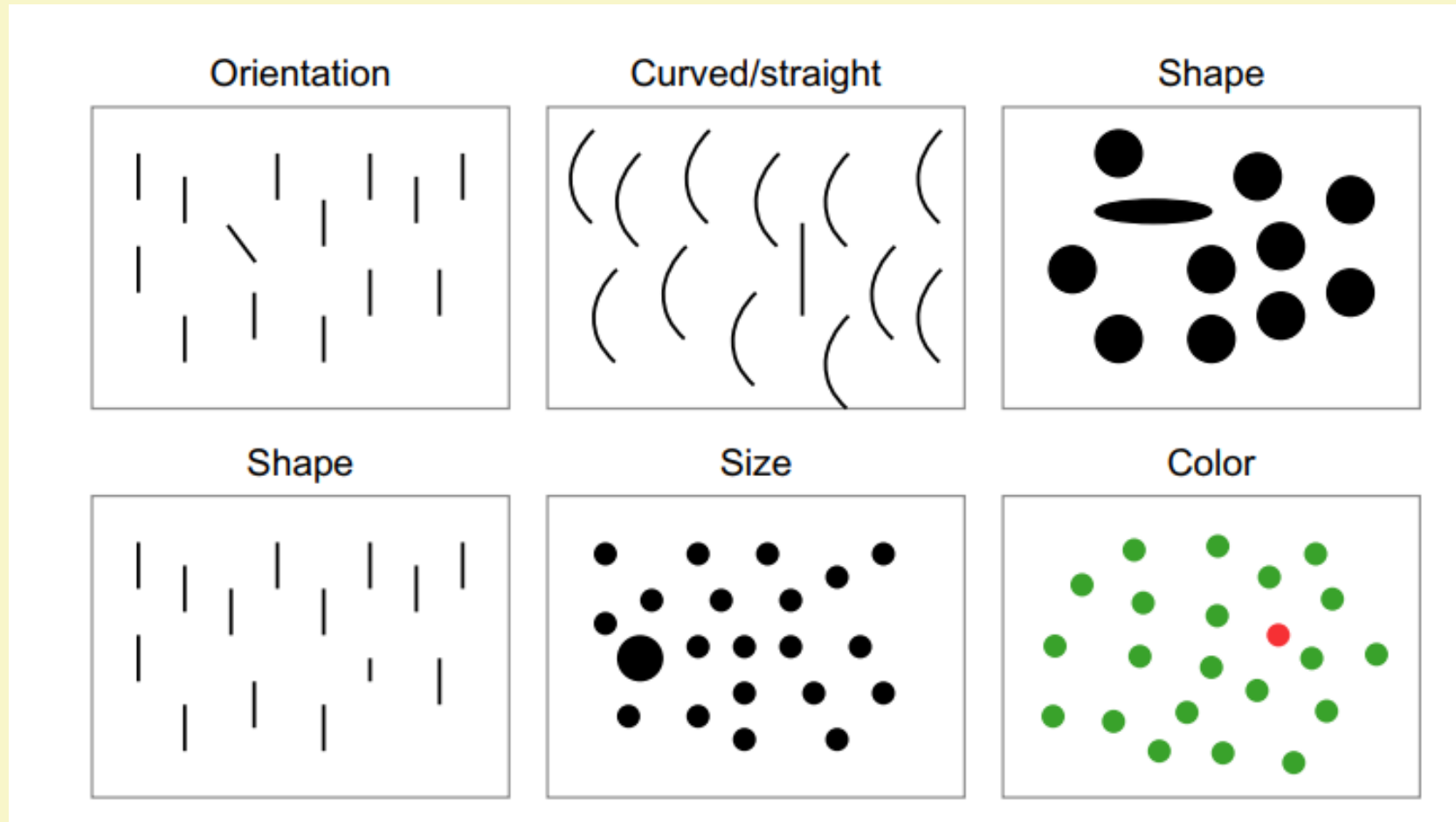
459290780597720987759726556651100498**3**6645
271074621446542070790147**3**8109743897010971
4**3**907097**3**49266847858715819048630901889074
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(b)

Preattentive Processing (Stage 2) and Ease of Search

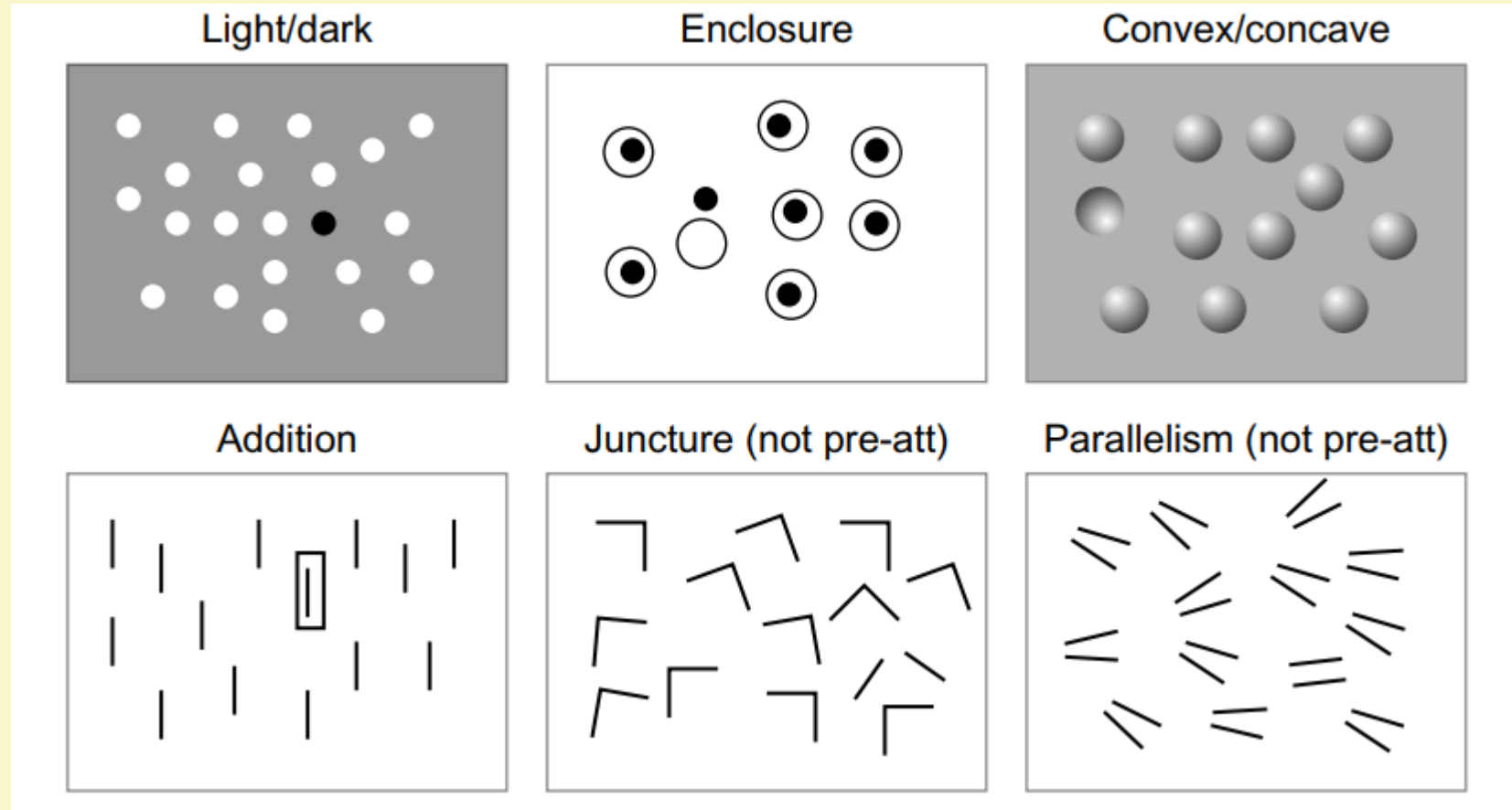
- ▶ This is because colour is **pre-attentively** processed.
- ▶ Certain simple shapes or colours seem to pop out from their surroundings.
- ▶ The theoretical mechanism underlying popout (salience) was called pre-attentive processing because early researchers thought that it must occur before conscious attention
- ▶ A more modern view is that attention is integral.
- ▶ Dv Vis App:
 - ▶ Use strong pre-attentive cues before weak ones where ease of search is critical.

Preattentive Processing (Stage 2) and Ease of Search



- The features that are pre-attentively processed can be organized into a number of categories based on form, color, motion, and spatial position.

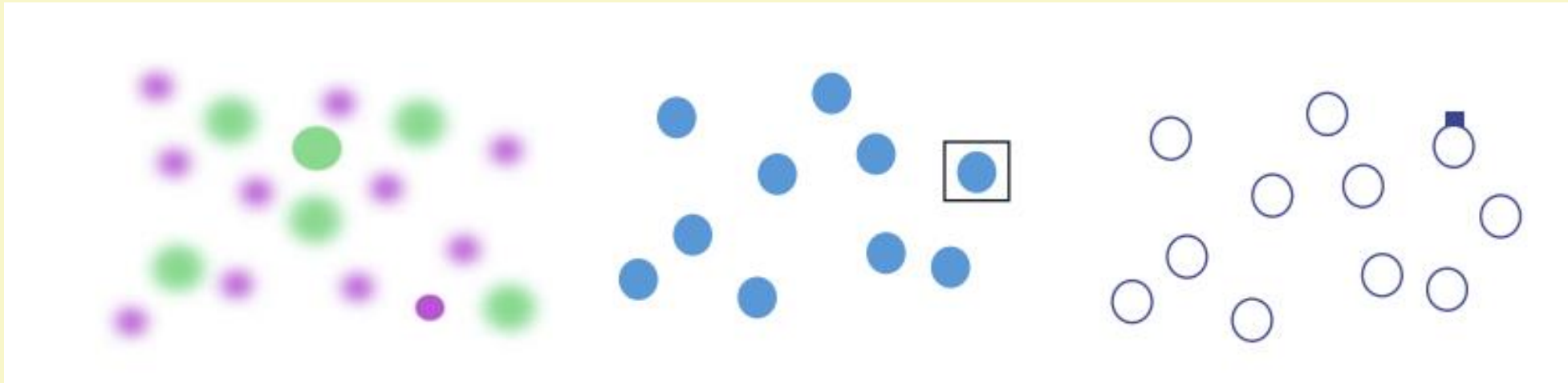
Preattentive Processing (Stage 2) and Ease of Search



- The features that are pre-attentively processed can be organized into a number of categories based on form, color, motion, and spatial position.

Highlighting and Asymmetries

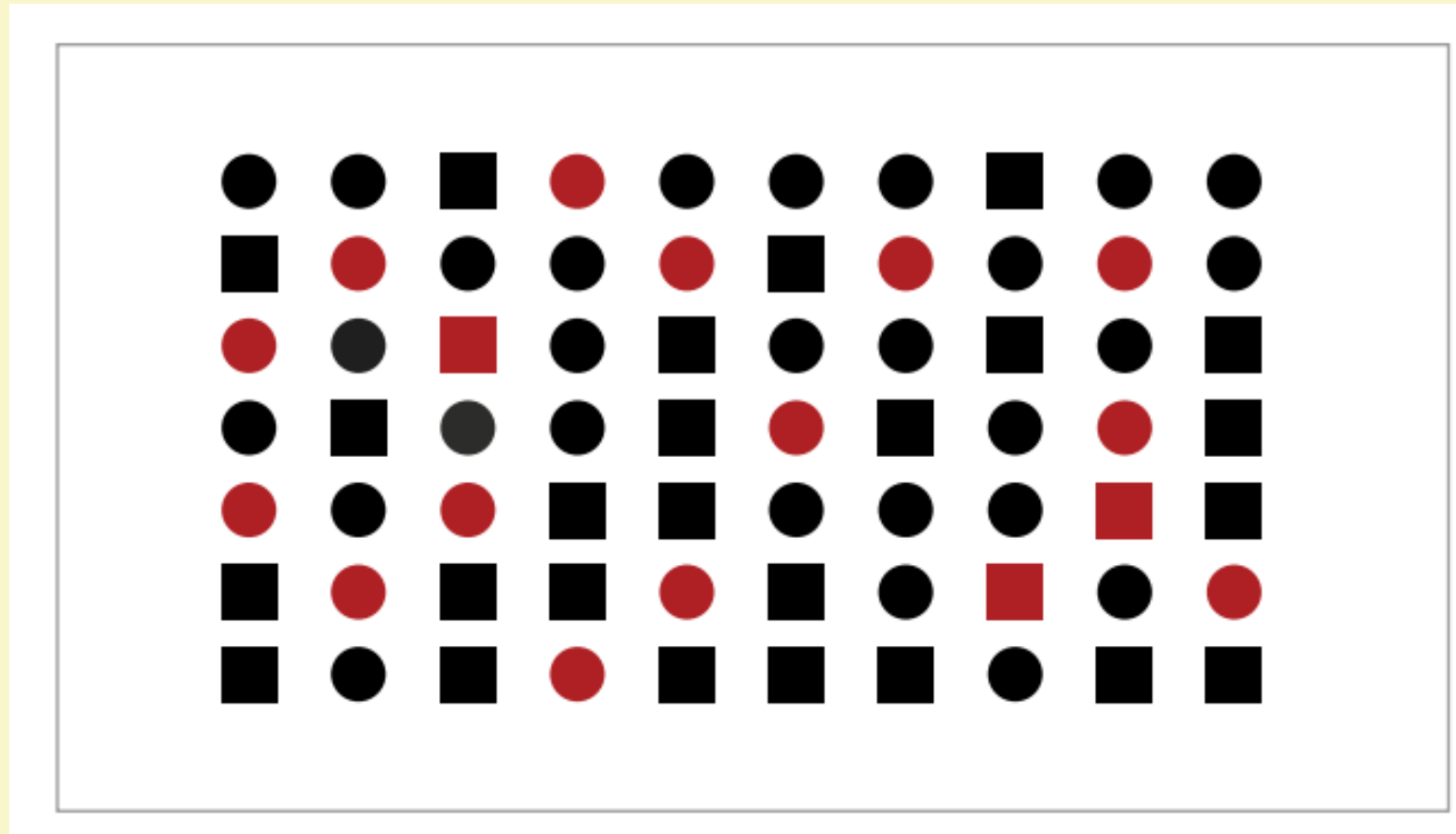
- ▶ Another issue relating to making targets distinctive comes from research that has revealed asymmetries in some pre-attentive factors; for example, adding marks to highlight a symbol is generally better than taking them away.



Highlighting and Asymmetries

- ▶ Dv Vis App:
- ▶ Use positively asymmetric preattentive cues for highlighting.
- ▶ For highlighting, use whatever feature dimension is used least in other parts of the design.
- ▶ When colour and shape channels are already fully utilised, consider using motion or blink highlighting.
- ▶ Make the motion or blinking as subtle as possible, consistent with rapid visual search.

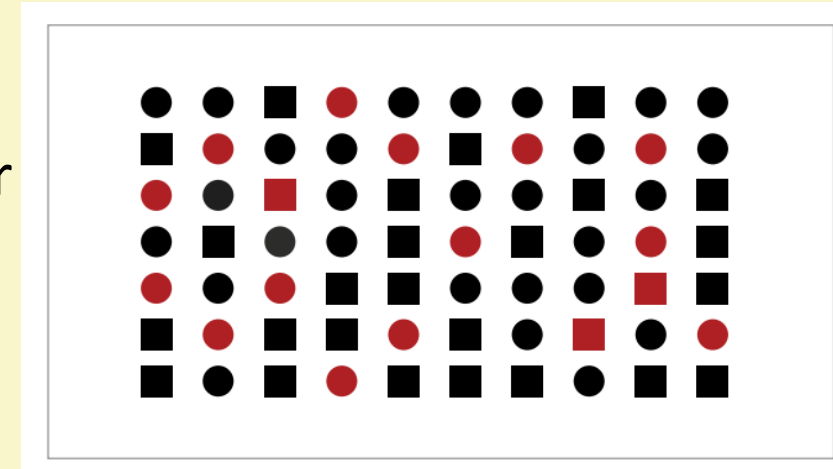
What Is Not Easily Findable: Conjunctions of Features



Search for the red squares

What Is Not Easily Findable: Conjunctions of Features

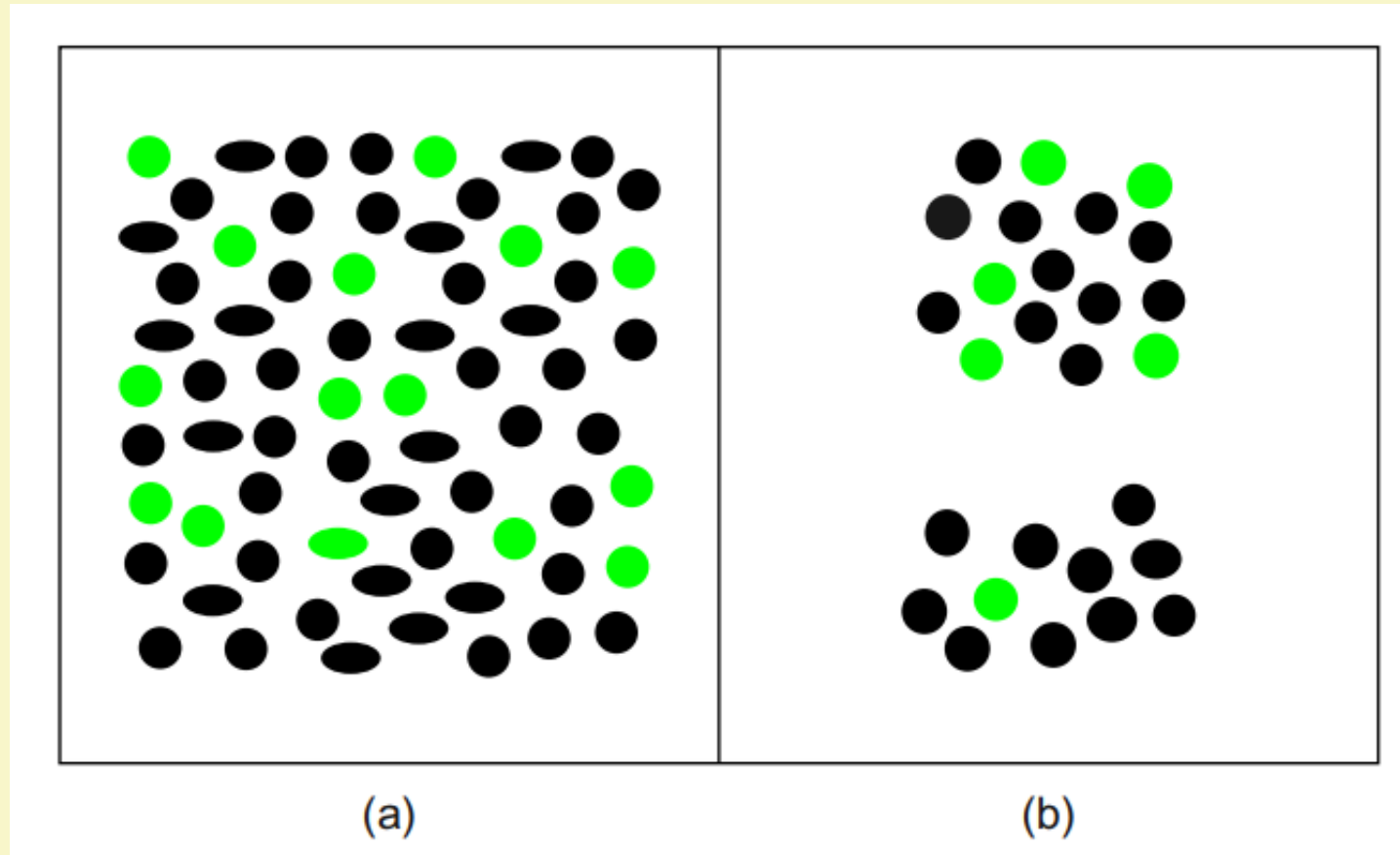
- ▶ What happens if we search for a **red square**, not just something that is red or something that is square?
- ▶ This kind of search is slow if the surrounding objects are squares (but not red ones) and other red shapes.
- ▶ We are forced to do a *serial search* of either *the red shapes* or *the square objects*.
- ▶ This is called a conjunction search, because it involves searching for the specific conjunction of redness and shape attributes.
- ▶ if symbols are to be preattentively distinct, avoid coding that uses conjunctions of basic graphical properties.



Highlighting Two Data Dimensions: Conjunctions That Can Be Seen

- ▶ Research suggest that preattentive search can be guided by the identification of spatial clusters.
- ▶ This led to the discovery that the conjunction of space and color can be searched preattentively.
- ▶ These exceptions are all related to space perception.
- ▶ Searches can be preattentive when there is a conjunction of spatially coded information (position on the XY plane, stereoscopic depth, shape from shading, or motion) and a second attribute, such as colour or shape.

Highlighting Two Data Dimensions: Conjunctions That Can Be Seen



- ▶ (a) we cannot conjunctively search for green ellipses
- ▶ (b) we can rapidly search the conjunction of lower cluster and green target.

Highlighting Two Data Dimensions: Conjunctions That Can Be Seen

► Dv Vis App:

- When it is important to highlight two distinct attributes of a set of entities, consider coding one using motion or spatial grouping and the other using a property such as colour or shape.

