Visualization for Data Science
Perception 4 Design

Prof Colin Ware. Information Vis. Perception for Design CH 1
Prof. Alexander Lex
Prof. Chis Healey

Learning Outcomes

- Differentiate between sensory and arbitrary aspects of representations and describe their characteristics
- Differentiate between cognition and perception
- List the three main stages of visual information processing
- Describe the human vision system and its limitations by contrasting with cameras and by using examples
- Discuss the implications that sensory and arbitrary aspects of representations may have on visualization design
- Describe Change and Inattentional blindness

Sensory vs. Arbitrary Symbols

Sensory symbols: aspects of representation that derive their **expressive power** from their ability to use the perceptual processing power of the brain **without learning**.

Arbitrary symbols: aspects of representation that must be learned, because the representations have no perceptual basis.

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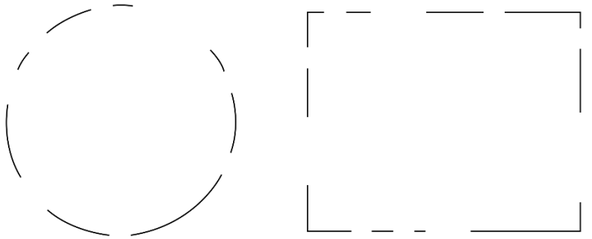
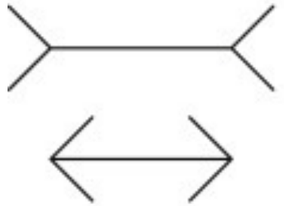
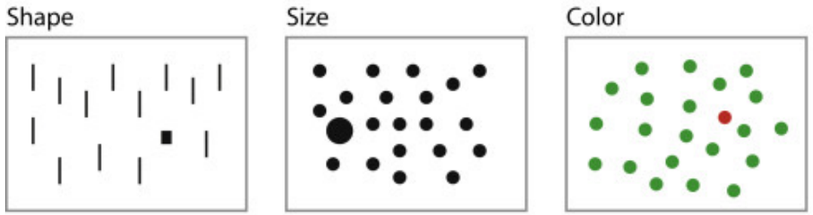
Properties of Sensory Representations

- Understanding without training
- Resistance to alternation denotation
- Sensory immediacy
- Cross-cultural validity







Design Tip: *Design by taking into account human sensory capabilities in such a way that important data elements and data patterns can be quickly perceived (more in Gestalt)*

Properties of Arbitrary Symbols

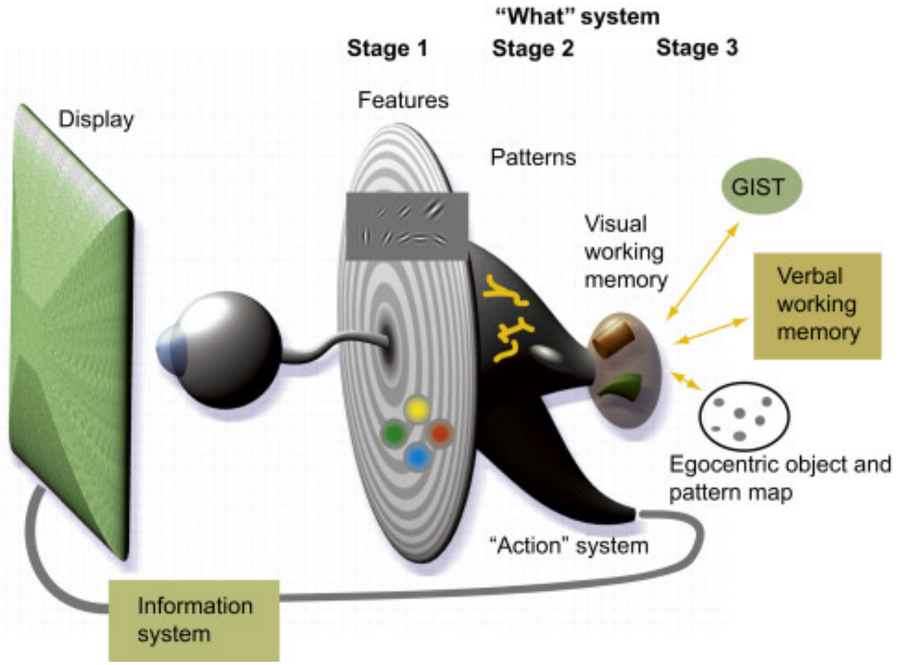
- Sometimes hard to learn
- Easy to forget
- Embedded in culture and applications

Simplified Visual Information Processing

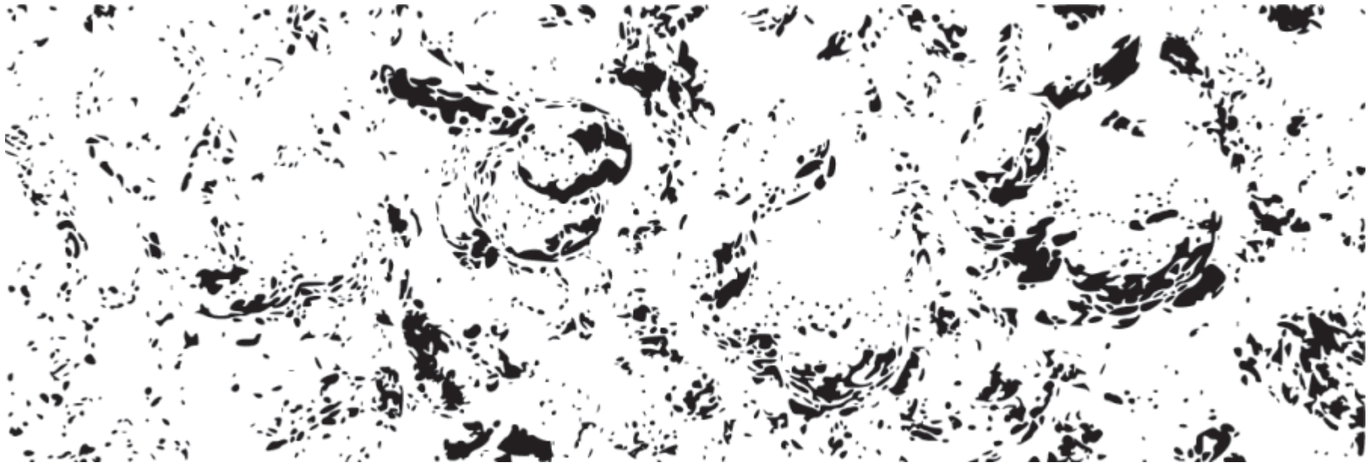
Stage 1: Feature Detection → billions of neurons extract basic features in parallel

Stage 2: Pattern Formation → active processes of perceptual organize the visual field into segments and patterns, based on color, texture, motion.

Stage 3: Visual Working Memory → information is reduced to a few objects for conscious processing by active mechanisms of **attention**



Emergence



http://graphics.stanford.edu/~niloy/research/emergence/emergence_image_siga_09.html

Emergence

Emergence refers to the unique human ability to aggregate information from seemingly meaningless pieces, and to perceive a whole that is meaningful.

This is an example of perception

Perception

from the physical stimulus to recognizing information, this includes identification and interpretation of sensory information

shaped by learning, memory, expectation

typically not conscious and reflexive

e.g. Hear someone speak

Cognition

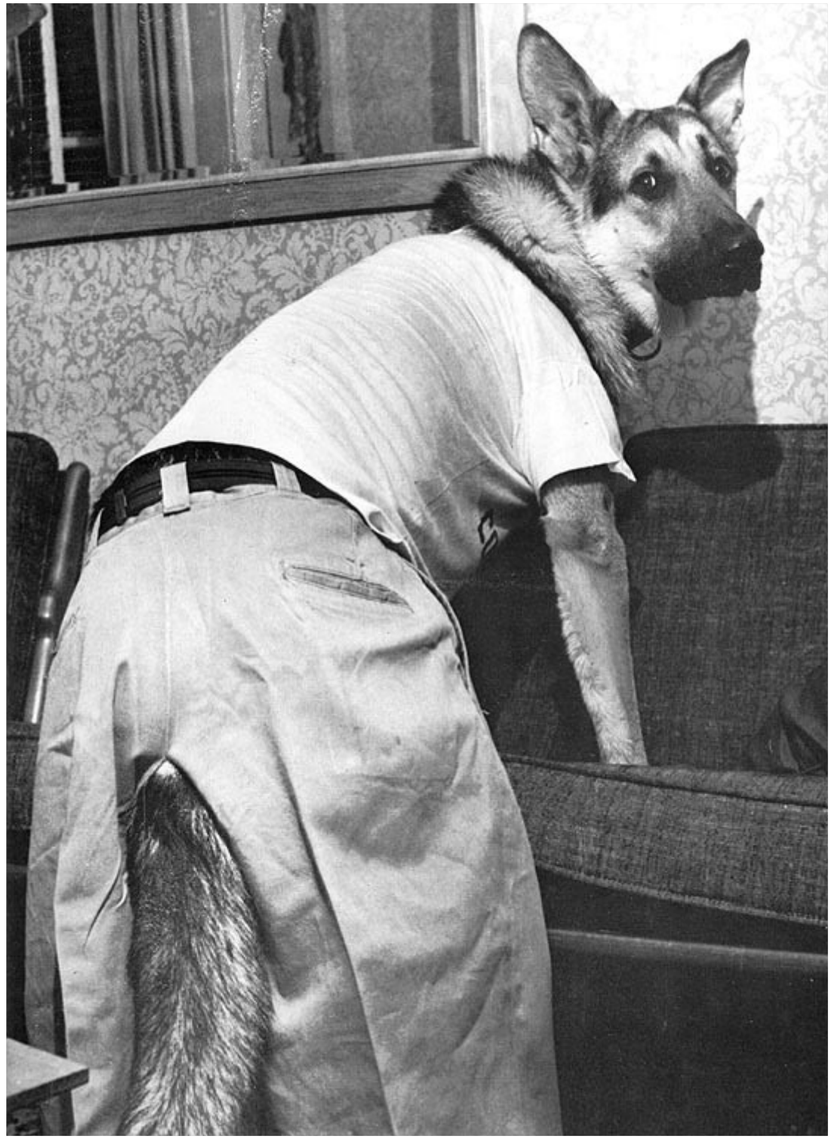
the processing of information, applying knowledge

Recognizing objects (e.g. chair), relationships between objects (water bottle on table)

Precipitated by higher-level cognitive activities: drawing conclusions, forming hypotheses, problem solving, learning,

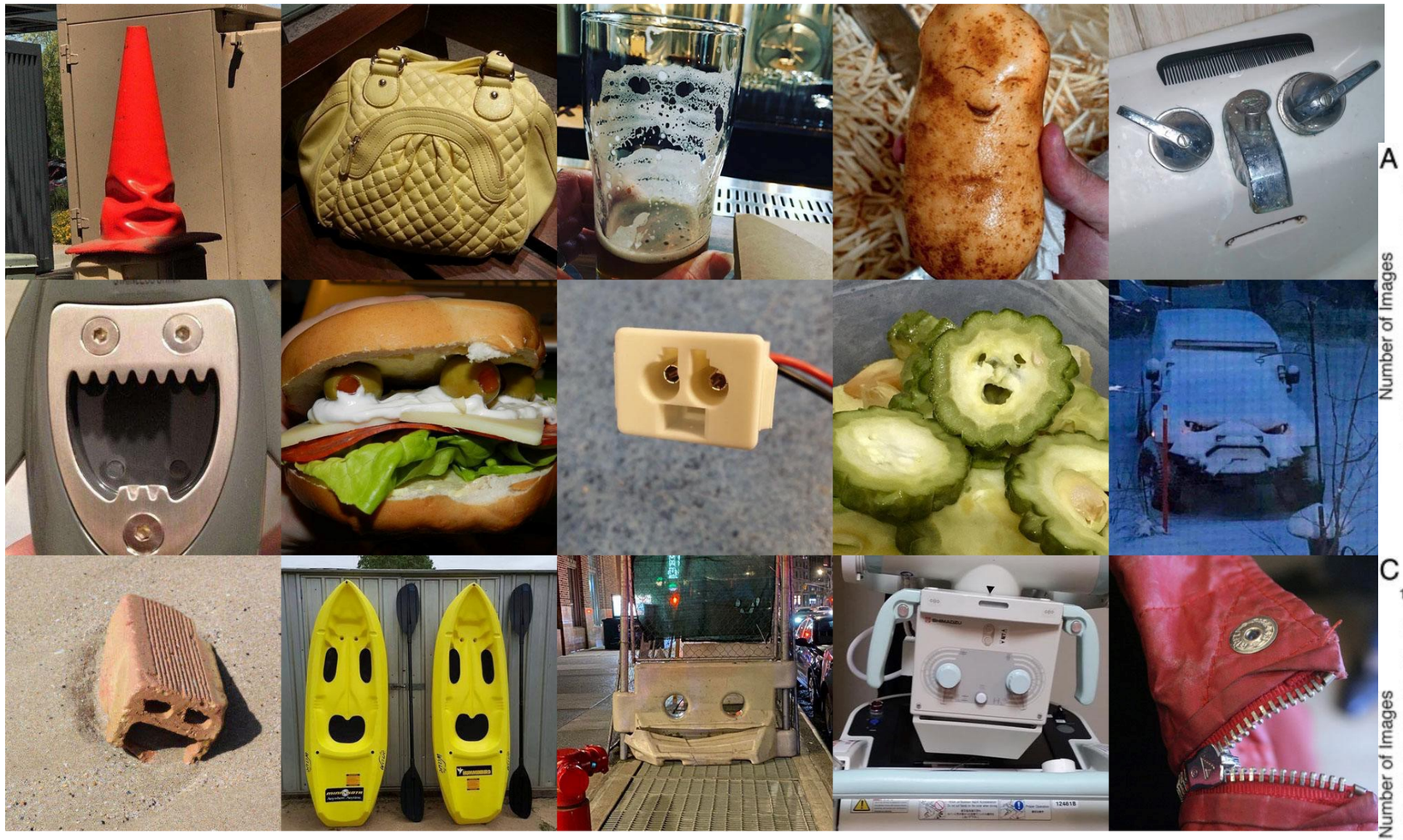
e.g., Understand the language and the words

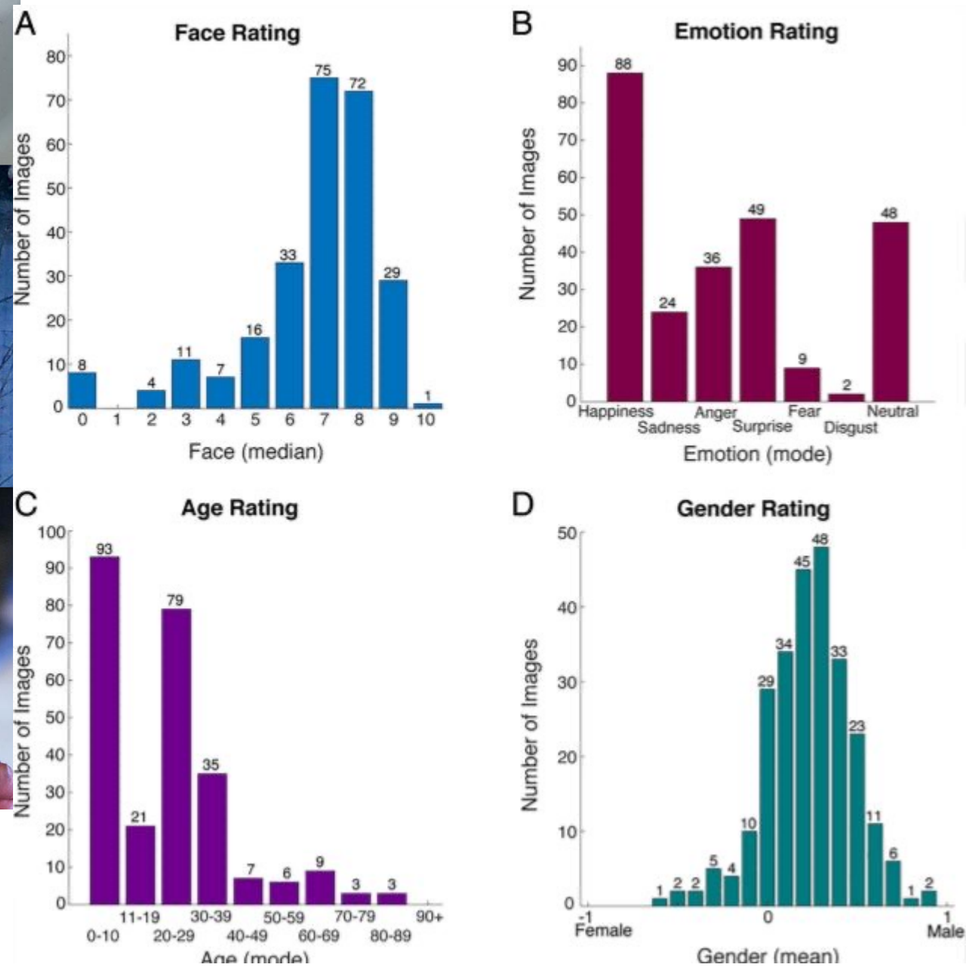
Table Exercise: Try to read the color that is shown (not read the color that is written).
Time yourself. If you make a mistake, start again.




dribbleglass.com

Pareidolia





https://www.sciencealert.com/turns-out-our-brains-perceive-the-faces-of-pareidolia-with-an-unfortunate-side-of-gender-bias

Our perception is based on priors

- We have a model of the world
- We try to fit what we see into this model.
- We get confused if something we see does not fit our priors *(resistance to expectation)*

Vision is “constructed” and dynamic

*“What you see when you see a thing depends on what the thing **is**. What you see the thing **as** depends on what you **know** about what you are seeing.”*

Zenon Pylyshyn
Canadian Cognitive Scientist and Philosopher

*“What we **perceive** is more a **property** of what we are doing and what **problems** we are trying to solve **than** what is **actually** coming in through our **eyes**”*

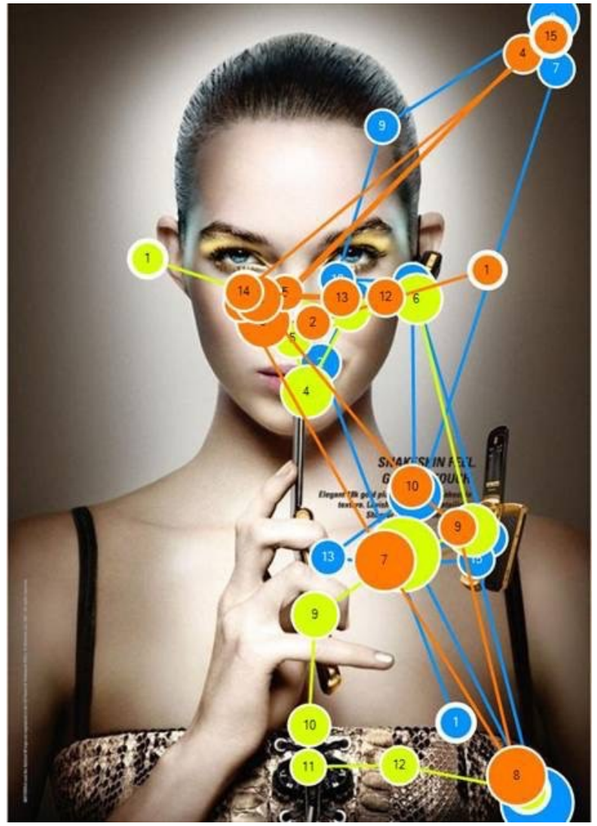
Colin Ware
Professor at University of New Hampshire
Graduate of Toronto and Waterloo

Human Visual System

Vision works as sequence of fixations and saccades

fixations: maintaining gaze on single location (200-600 ms)

saccades: moving between different locations (20-100 ms)



Vision not similar to a camera

More similar to a dynamic and
ongoing construction project

Eye Tracking: Where the focus is

https://www.youtube.com/watch?v=SG-f6ZTjwjU

https://www.youtube.com/watch?v=NNOA_S0VCVU

Ames Room

https://www.youtube.com/watch?v=hCV2Ba5wrcs

https://www.youtube.com/watch?v=gJhyu6nlGt8

Human Visual System

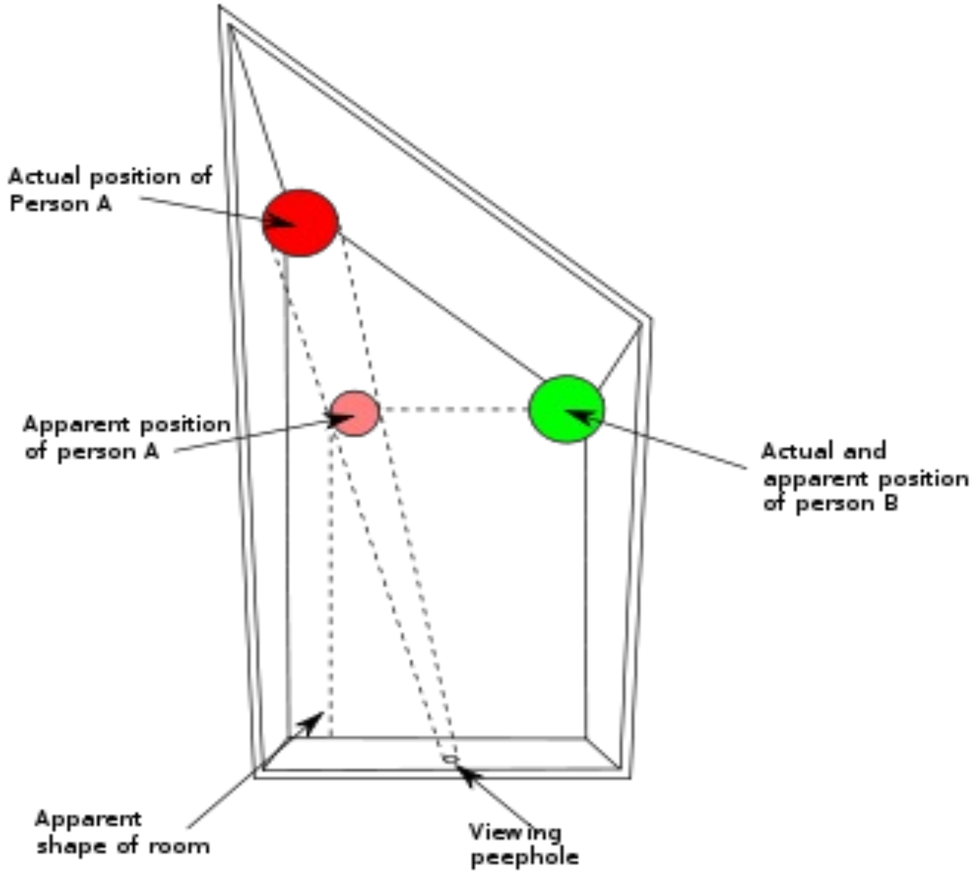
No general purpose vision

What we see depends on our goals and expectations

Relative judgments: strong

Absolute judgments: weak

Ames Room



Change Blindness

An interruption in what is being seen renders us “blind” to significant changes that occur in the scene during the interruption.

- Details of an image cannot be remembered across separate scenes except in areas with focused attention
- Interruption (e.g. a blink, eye saccade or blank screen) amplifies this effect
- Not failure of vision system
- failure due to inappropriate **attentional** guidance

https://www.csc2.ncsu.edu/faculty/healey/PP/movies/Airplane.gif

https://www.csc2.ncsu.edu/faculty/healey/PP/movies/Dinner.gif

https://www.csc2.ncsu.edu/faculty/healey/PP/movies/Harborside.gif

Causes of Change Blindness Theories

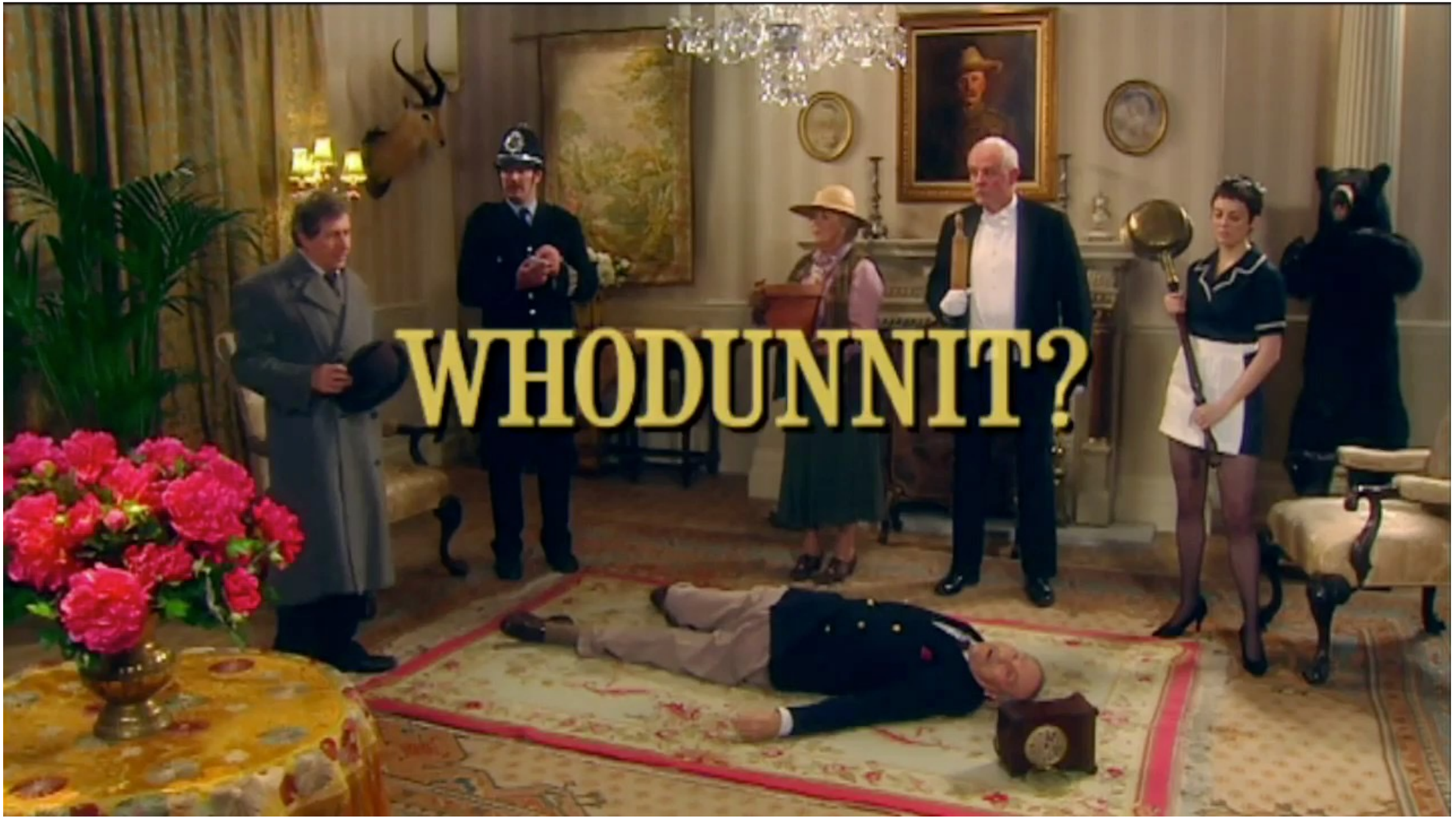
- **Overwriting**: the blank screen overwrites the image so information that was not abstracted from it is lost
- **First Impression**: initial view is abstracted, if scene is not perceived to have changed, then features of the scene should not need to be re-encoded
- **Nothing is Stored:** there is no internal representation of the details, only abstract concepts are committed to memory. If we need something specific we go back to the image.
- **Everything is Stored, Nothing is Compared:** we compare only when we are forced to (e.g. asked a question)
- **Feature Combination:** details across views are combined to form one holistic representation of the scene (as long as they make sense)
- **Emerging Theories:** attention is required to detect changes, changes that are unexpected can be missed. Changes to semantically important objects are detected faster than changes elsewhere.

(In)Attentional/Perceptual Blindness

Occurs when a person fails to perceive an unexpected stimulus in plain sight, primarily because their attention is on something else and/or it is impossible to focus on all the stimuli in the scene.

https://www.youtube.com/watch?v=vJG698U2Mvo

https://www.youtube.com/watch?v=ubNF9QNEQLA


WHODUNNIT?

Take Home Points

- To find meaning in what we see **we must selectively pay attention** to what is important
- Low-level vision is driven by object features rather than a conscious effort where to look (e.g., pre-attentive processing)
- Attention is driven by preexisting knowledge, expectations, and goals stored in long-term memory

https://www.youtube.com/watch?v=VkrrVozZR2c

Social Learning

Why do you think all of this matters when it comes to visualization? (be specific)

Discuss on your tables your top three takeaways from this lecture

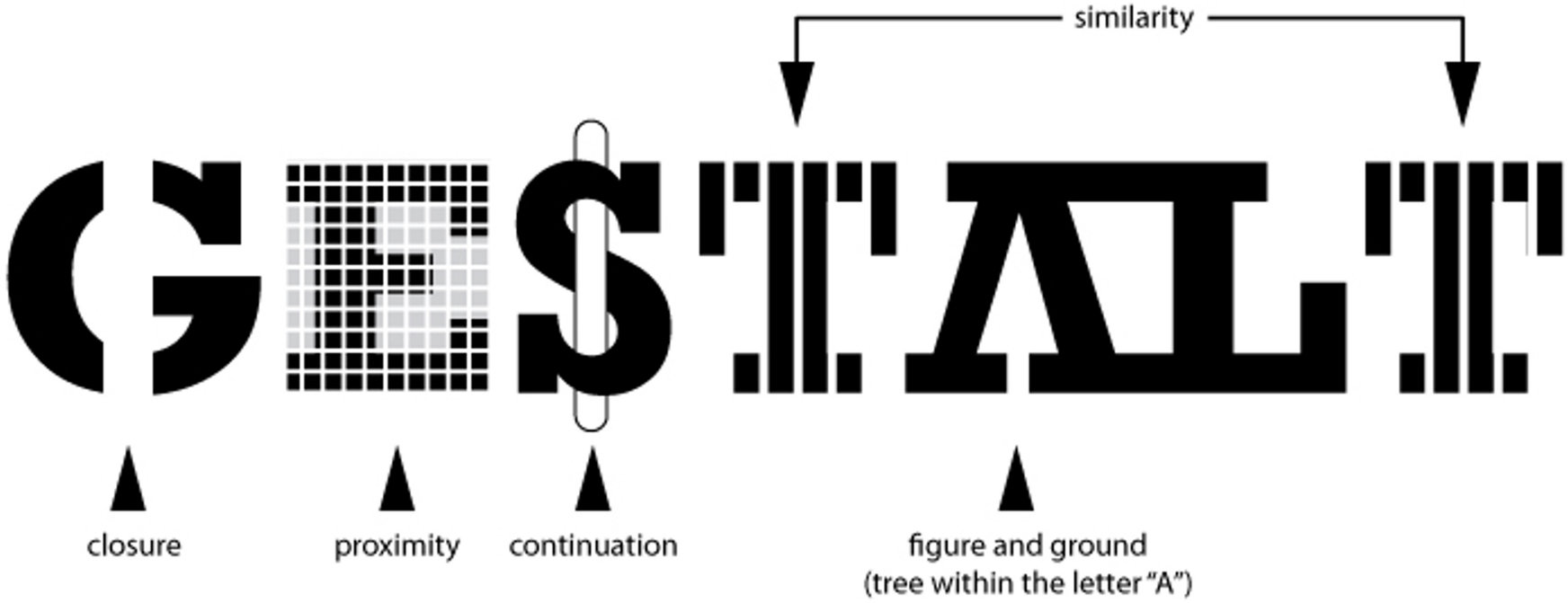
Post on Ed Discussion.

Learning Outcomes

- Describe various grouping gestalt principles
- Describe various emergent gestalt principles
- Identify and critique visualization techniques based on their usage of gestalt principles.

Gestalt Principles

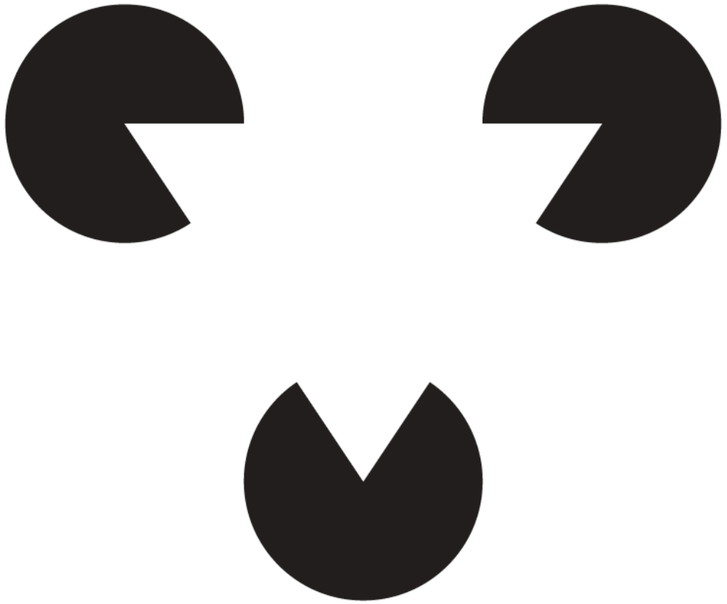
Theories/principles proposed by psychologists in the 1920s to explain how people organize/group information visually, in other words, the ways we visually assemble objects into groups.



Gestalt Basics

*“The whole is ‘**other**’ than the sum of its parts.”*
- Dr. Kurt Koffka

This is different from *‘the whole is **greater** than the sum of its parts’.*



Patterns that transcend the visual stimuli that produced them

Emergent semantics – by this we mean how we ascribe meaning to patterns that emerge from the combination of visual artifacts.

A non-visual representation of Gestalt principles

- **Similarity**: people tend to see things that physically resemble each other as part of the same object
- **Proximity**: how close elements are to one another. Similar things should be close to each other
- **Connection**: grouping effect; we perceive elements as connected to each other thanks to colors, lines, frames, or other shapes
- **Enclosure/Common Region** : we group elements that are in the same closed region
- **Continuity**: objects that create a continuous pattern or are seen as being connected appear to be grouped together
- **Symmetry**: elements that are symmetrical tend to be perceived as a unified group
- **Figure & Ground**: Your brain distinguishes the foreground and the background
- **Closure**: our eyes tend to add any missing pieces of a familiar shape
- **Common Fate**: people will group together things that point to or are moving in the same direction

Basic 4: Similarity, Proximity, Connection & Enclosure

Perceive objects that

- look alike,
- are placed close together,
- connected by lines or
- enclosed in a common space

as belonging together.

Similarity

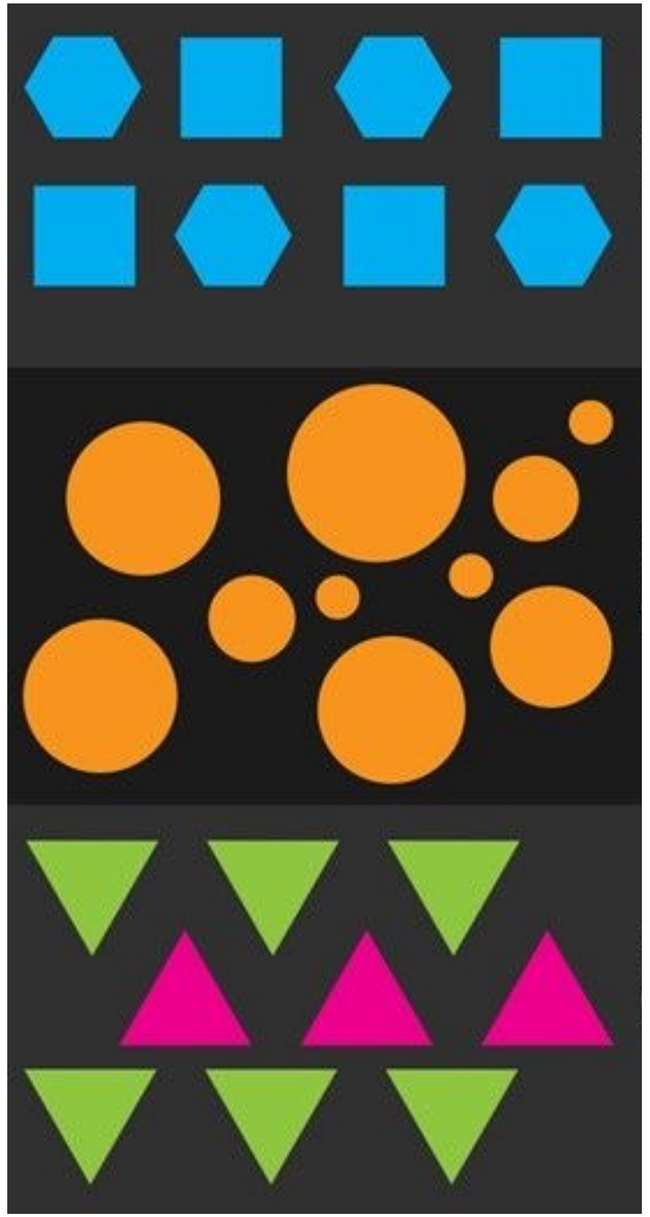
People tend to see things that physically resemble each other as part of the same group.

We typically use

- Shape
- Size
- Color

To organize visual items into groups.

Design Tip: Use the channel that is most effective to highlight the similarities in the data

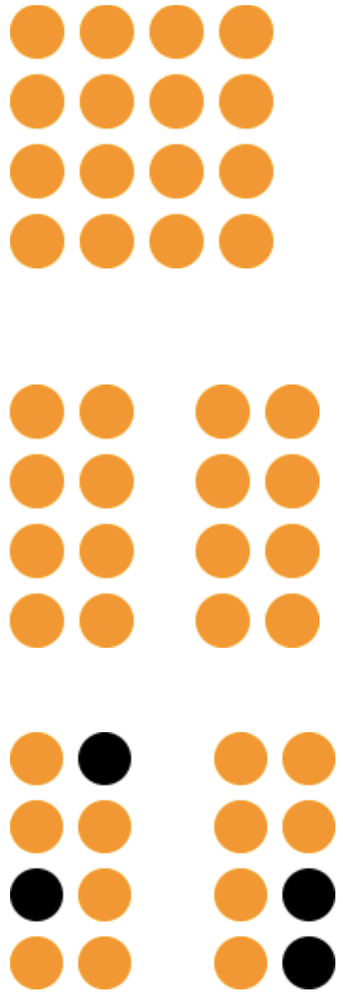


https://www.interaction-design.org/literature/article/the-law-of-similarity-gestalt-principles-1

Proximity

How close elements are to one another

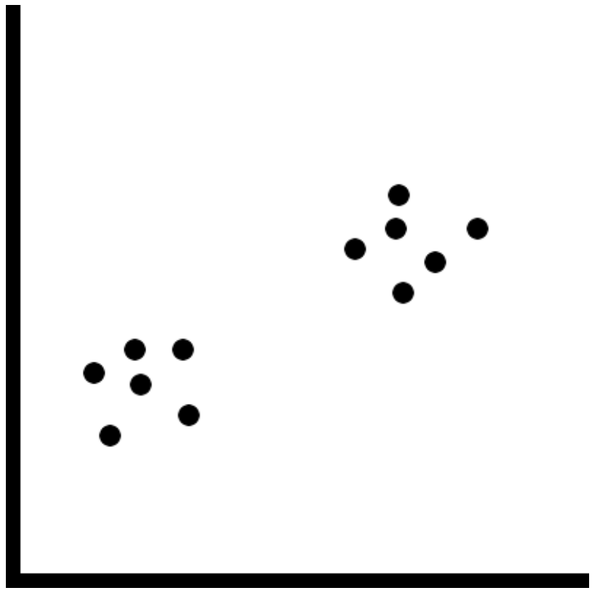
Could be categorized as a special case of similarity (focus is on spatial similarities)

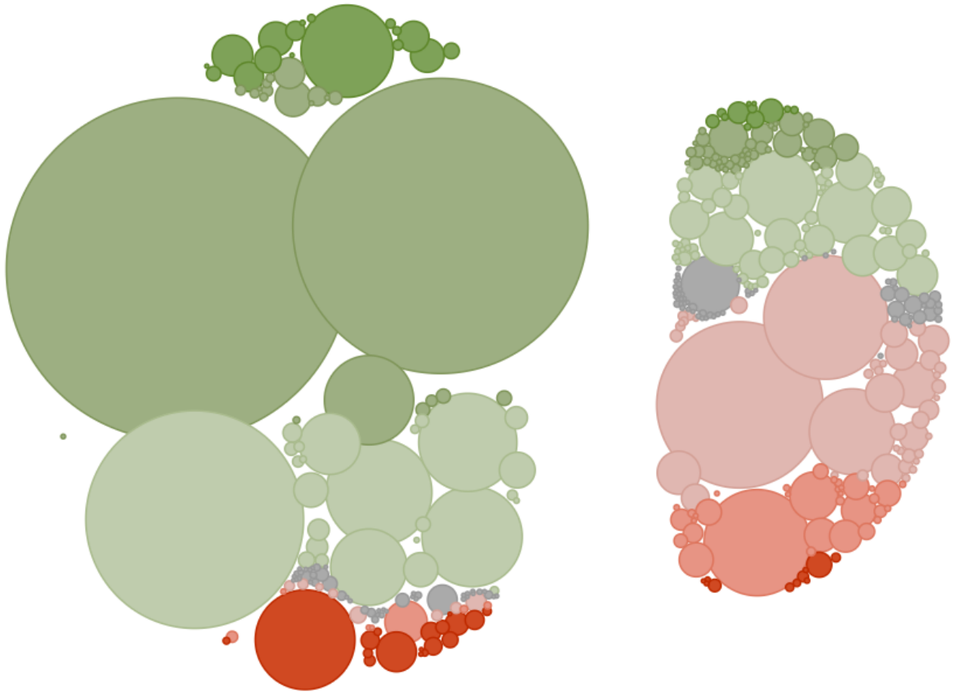


Andy Rutledge,“Gestalt Principles of Perception”

Proximity

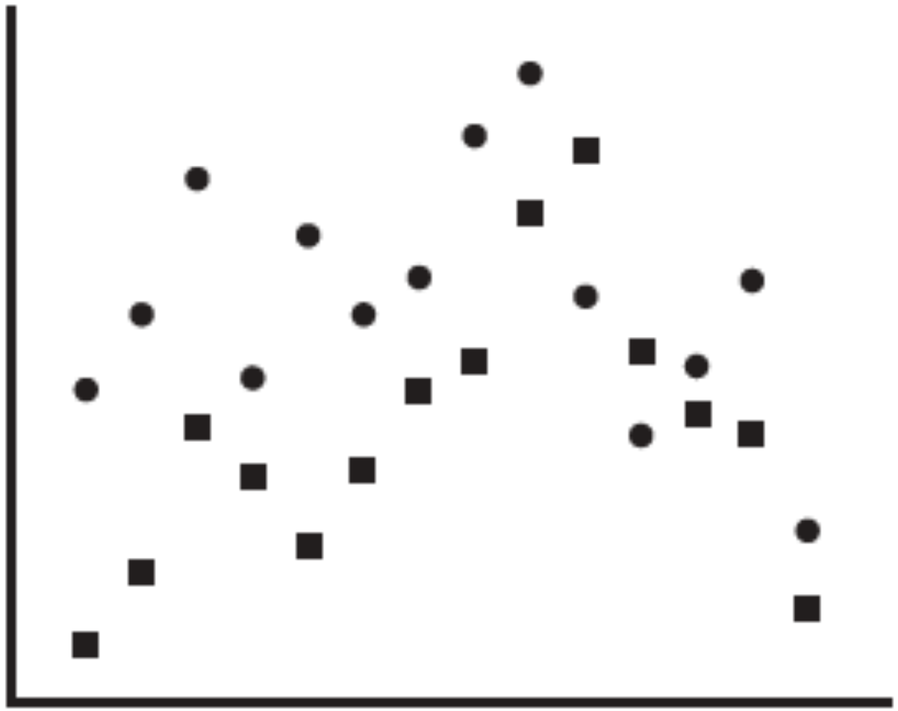
Design Tip: Similar things should be close to each other, group entities in close proximity

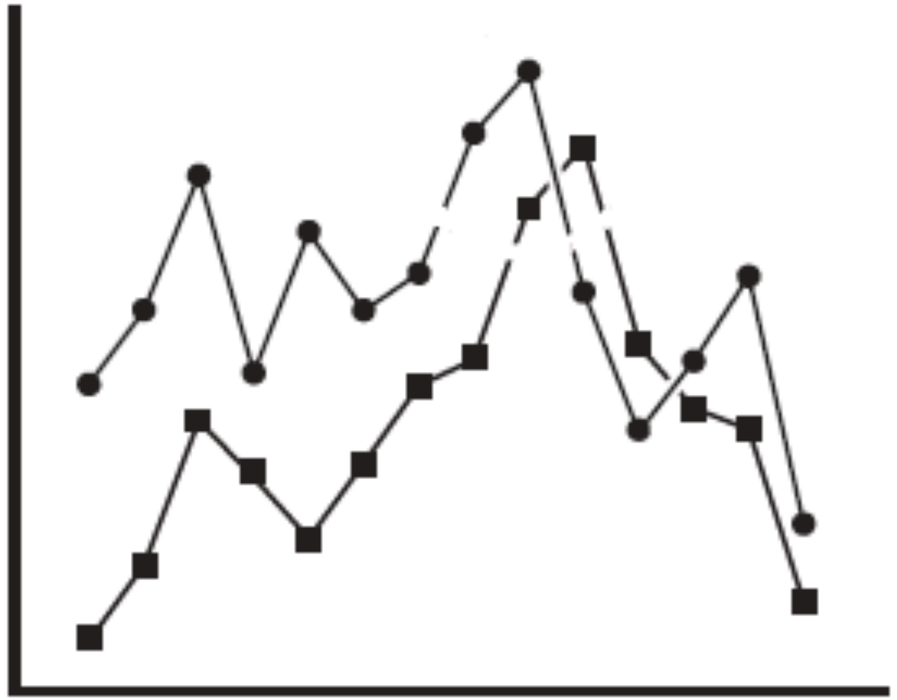




Connectedness

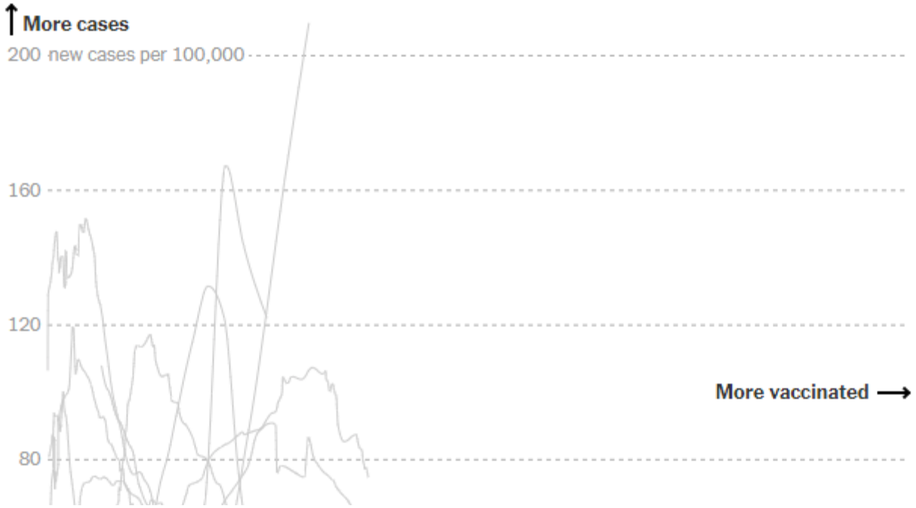
We perceive elements as connected to each other thanks to colors, lines, frames, or other shapes

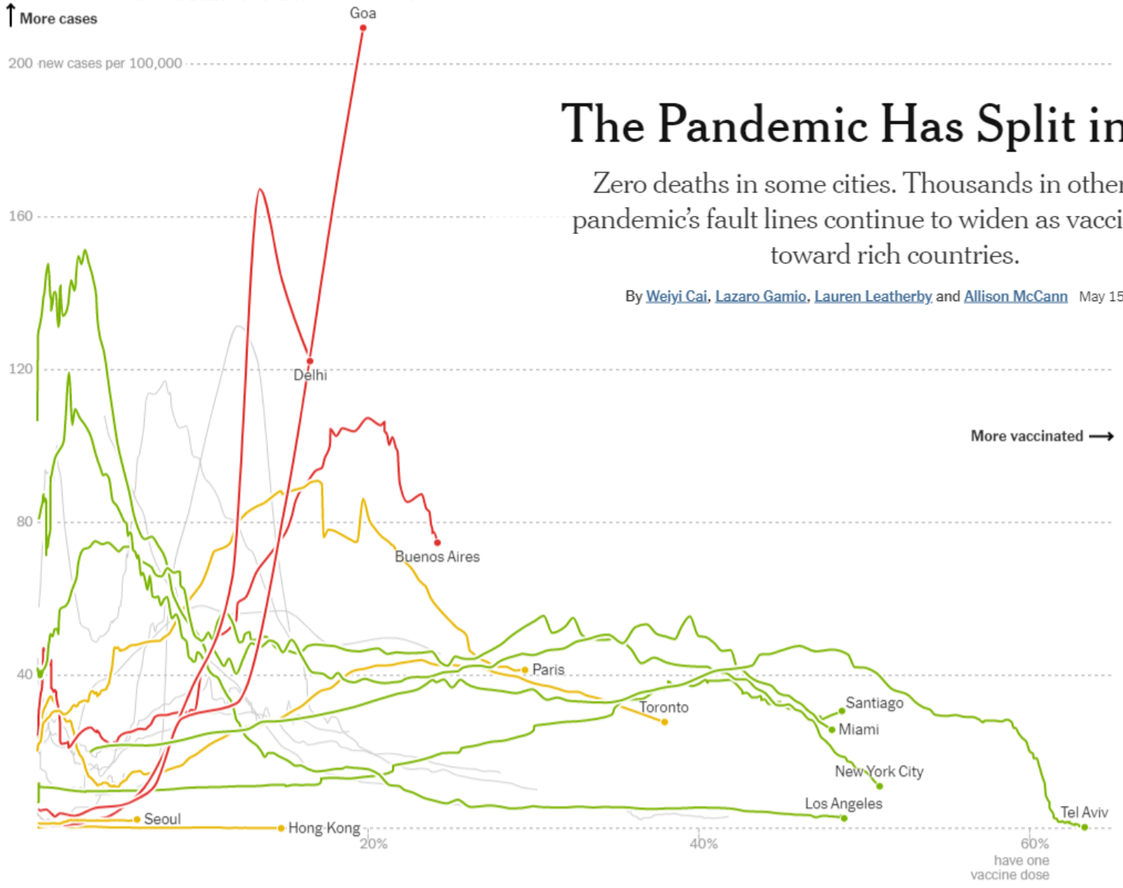




Visit for another example: https://www.nytimes.com/interactive/2021/03/05/us/vaccine-racial-disparities.html

Bang Wong, "Gestalt Principles, 1", Nature Methods

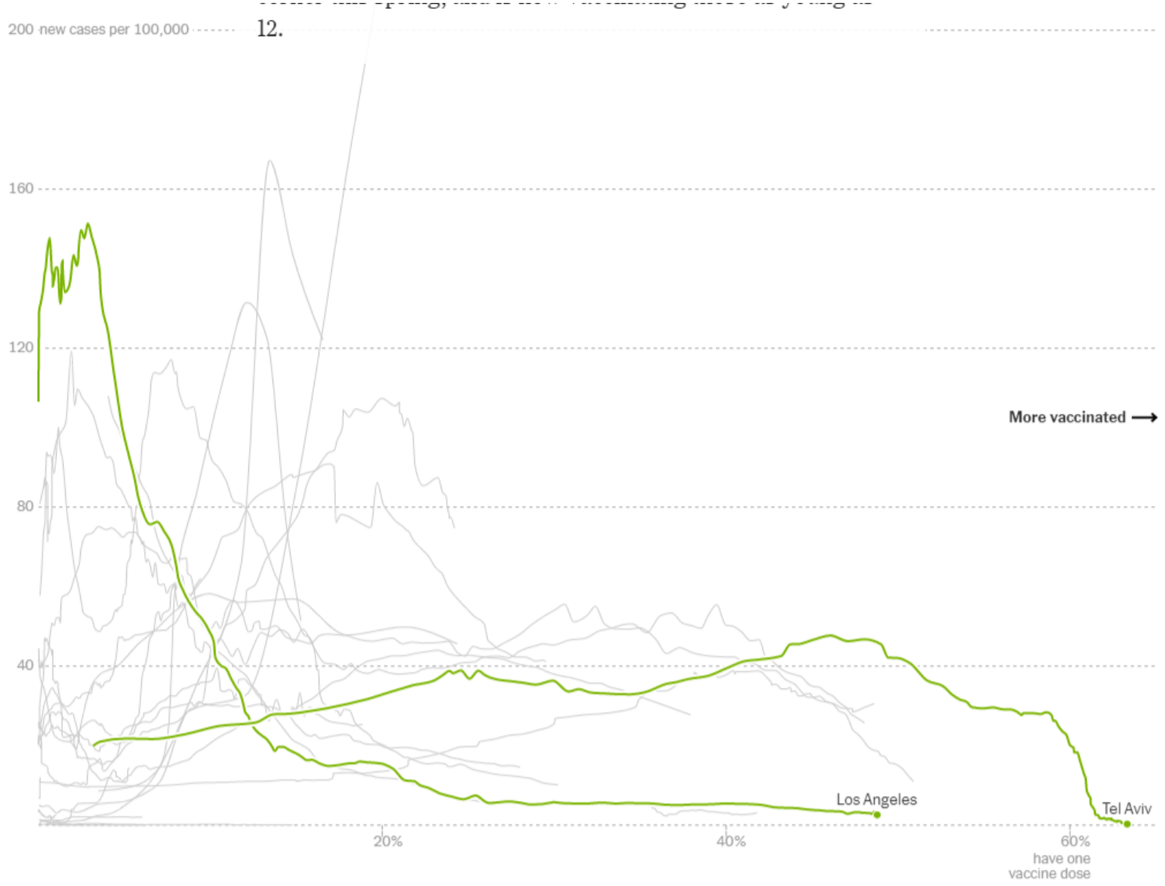




The Pandemic Has Split in Two

Zero deaths in some cities. Thousands in others. The pandemic's fault lines continue to widen as vaccines flow toward rich countries.

By Weiyi Cai, Lazaro Gamio, Lauren Leatherby and Allison McCann May 15, 2021



w.nytimes.com/interactive/2021/05/15/world/covid-inequality-vaccines.html

Connectedness Varieties

Bubble Sets

Image by [Dinkla et al., 2011]
Technique by [Collins et al.,2009]

Line Sets

[Alper et al., 2011]

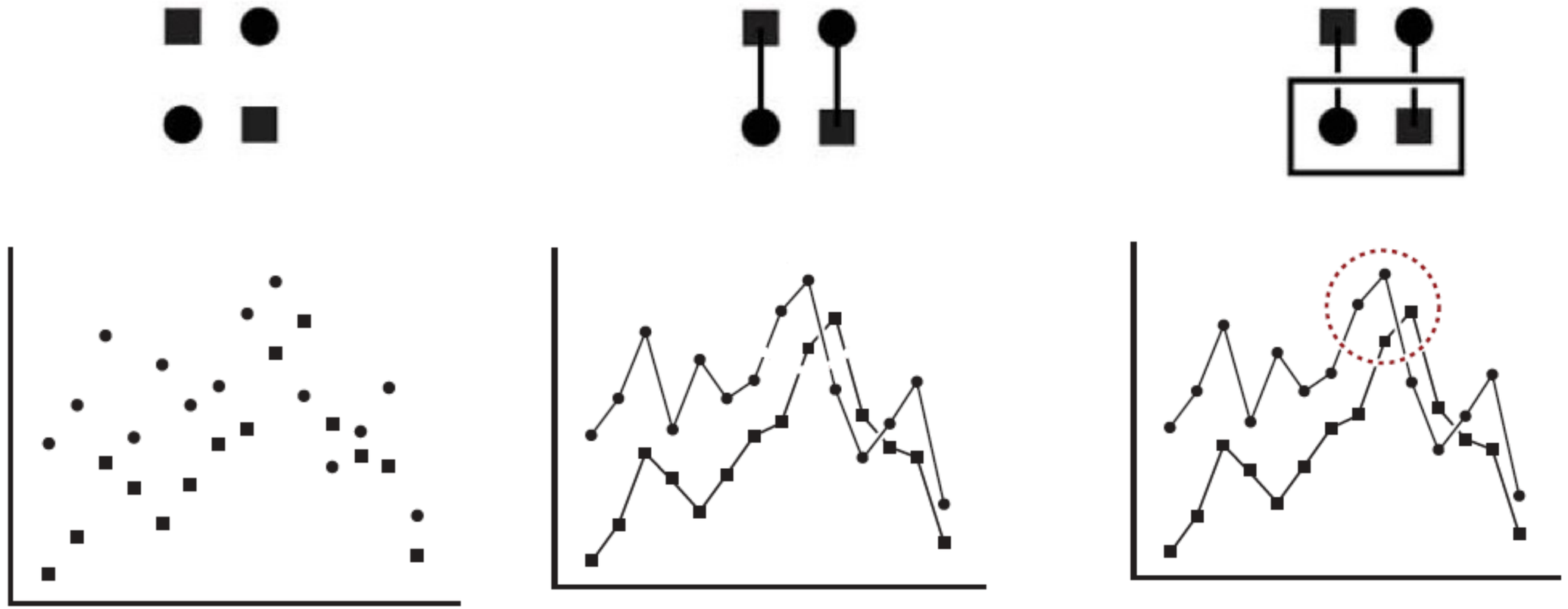
Kelp Diagrams

[Dinkla et al., 2012]

Enclosure / Common Region

We group elements that are in the same closed region

Enclosure is an effective way to draw attention to a group of objects.



Design Tip: Use Gestalt principles of proximity, connectedness, and common region to associate written labels with graphical elements.

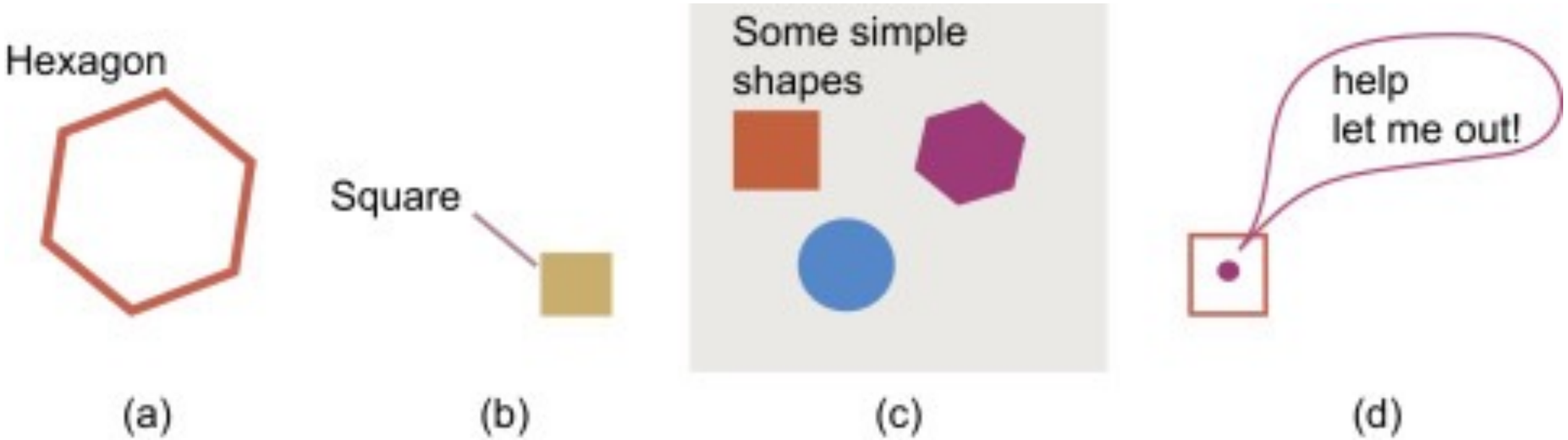


Figure 8.24. Gestalt principles used to guide the linking of text and graphics: (a) Proximity. (b) Continuity/connectedness. (c) Common region. (d) Common region combined with connectedness.

Information Visualization. Colin Ware.

Gestalt principles

- Similarity: people tend to see things that physically resemble each other as part of the same object
- Proximity: how close elements are to one another. Similar things should be close to each other
- Connection: grouping effect; we perceive elements as connected to each other thanks to colors, lines, frames, or other shapes
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- **Figure & Ground**: Your brain distinguishes the foreground and the background
- **Common Fate**: people will group together things that point to or are moving in the same direction

Gestalt Effects for “Emergence”

“Our visual system attempts to structure what we see into patterns to make sense of information” Bang Wong

Objects emerge and we assign meaning to them, through

- Visually interpolation
- Visually completion

We perceive things that may not exist

Continuity

Due to visual interpolation, our internal visual representation tends to be smooth and continuous.

Objects that form a continuous pattern or seem connected are perceived as grouped together.

Our gaze naturally transitions from one object to another.

Bang Wong, “Gestalt Principles, II”, Nature Methods

Continuity

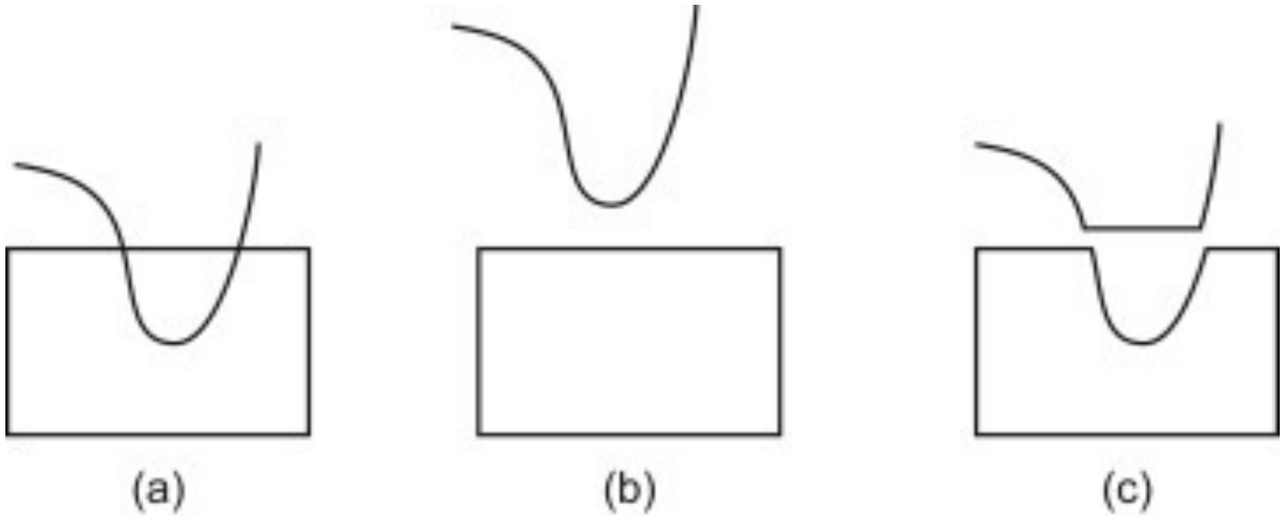
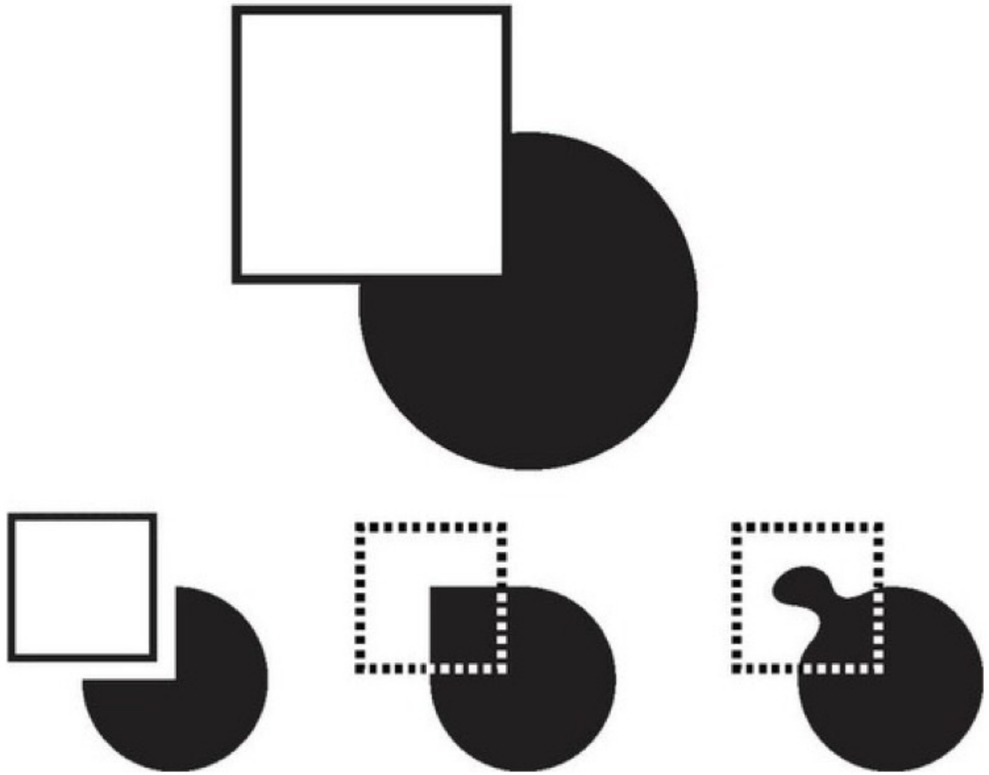


Figure 6.6. Information Visualization. Perception for Design Colin Ware

Closure

Because of visual completion we have a strong tendency to seen shapes as continuous, our eyes (remember the 3 stages of visual processing) tends to add any missing pieces and forms familiar shapes

A closed contour tends to be seen as an object.



Bang Wong, “Gestalt Principles, II”, Nature Methods

Closure / Completion

Symmetry

Elements that are symmetrical tend to be perceived as a unified group

"The pairs of lines shown in Fig. 6.9(b) are perceived more strongly as forming a visual whole than the lines with parallel symmetry (Fig. 6.9a). Also, when edges instead of lines are used, symmetry is more difficult to perceive if the polarity is reversed on the edges (Fig. 6.9(c))."

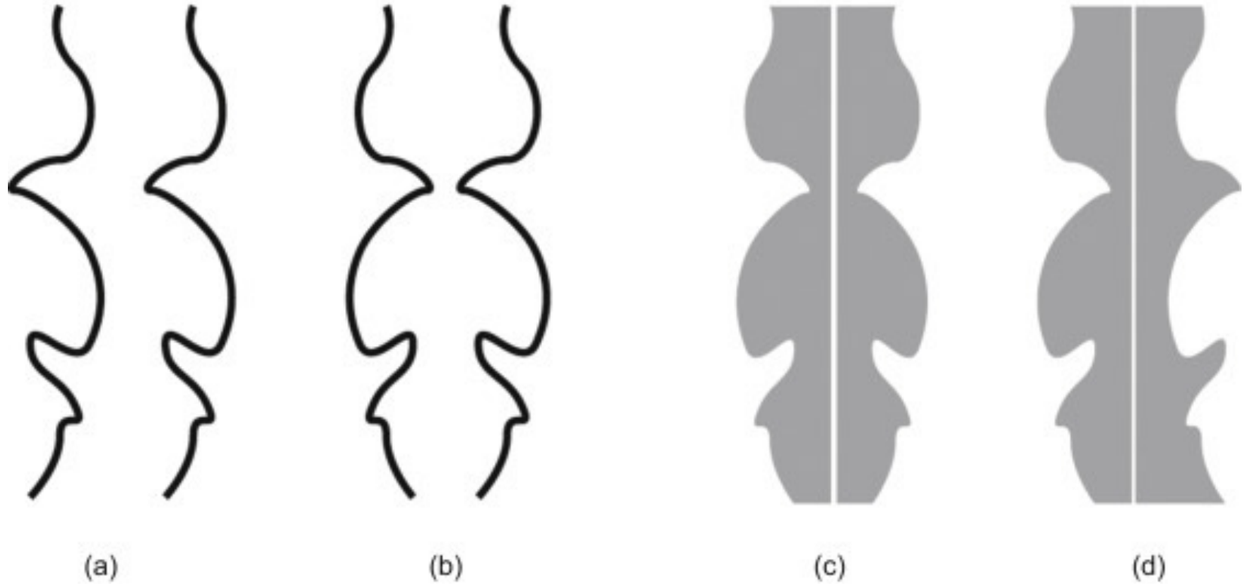
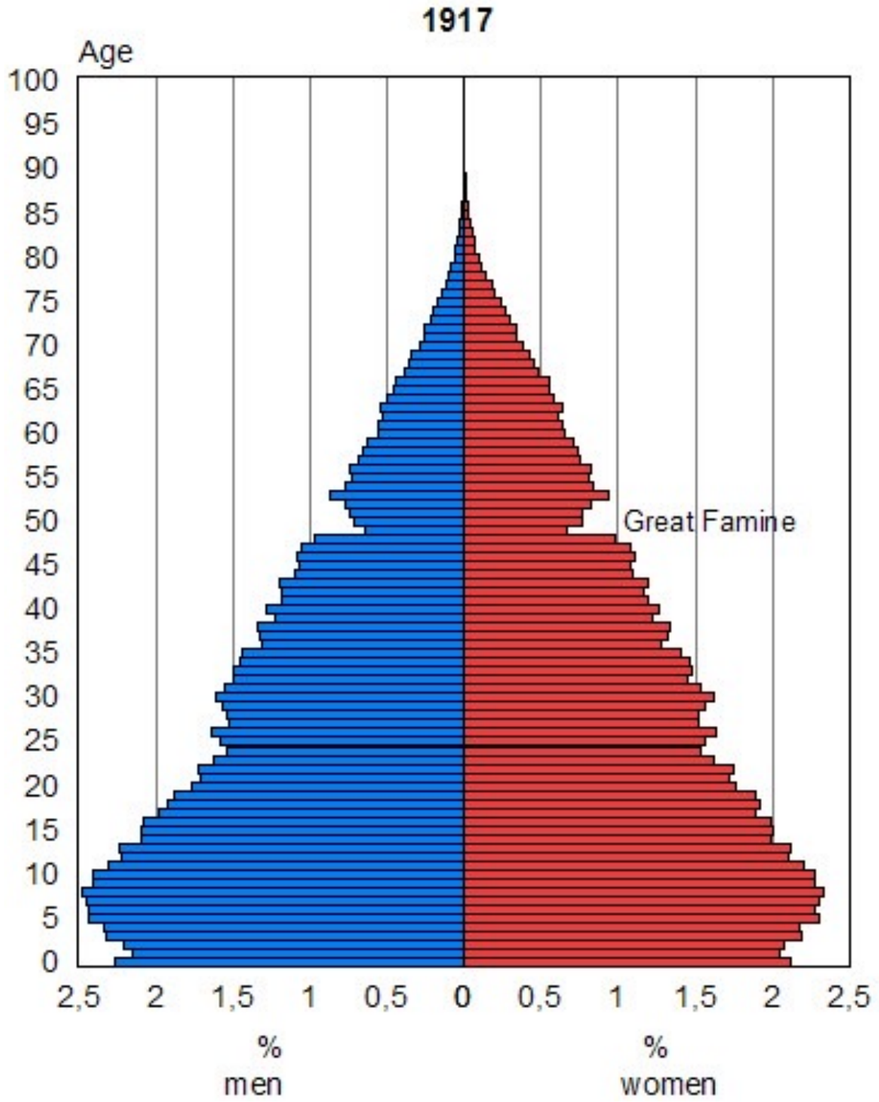
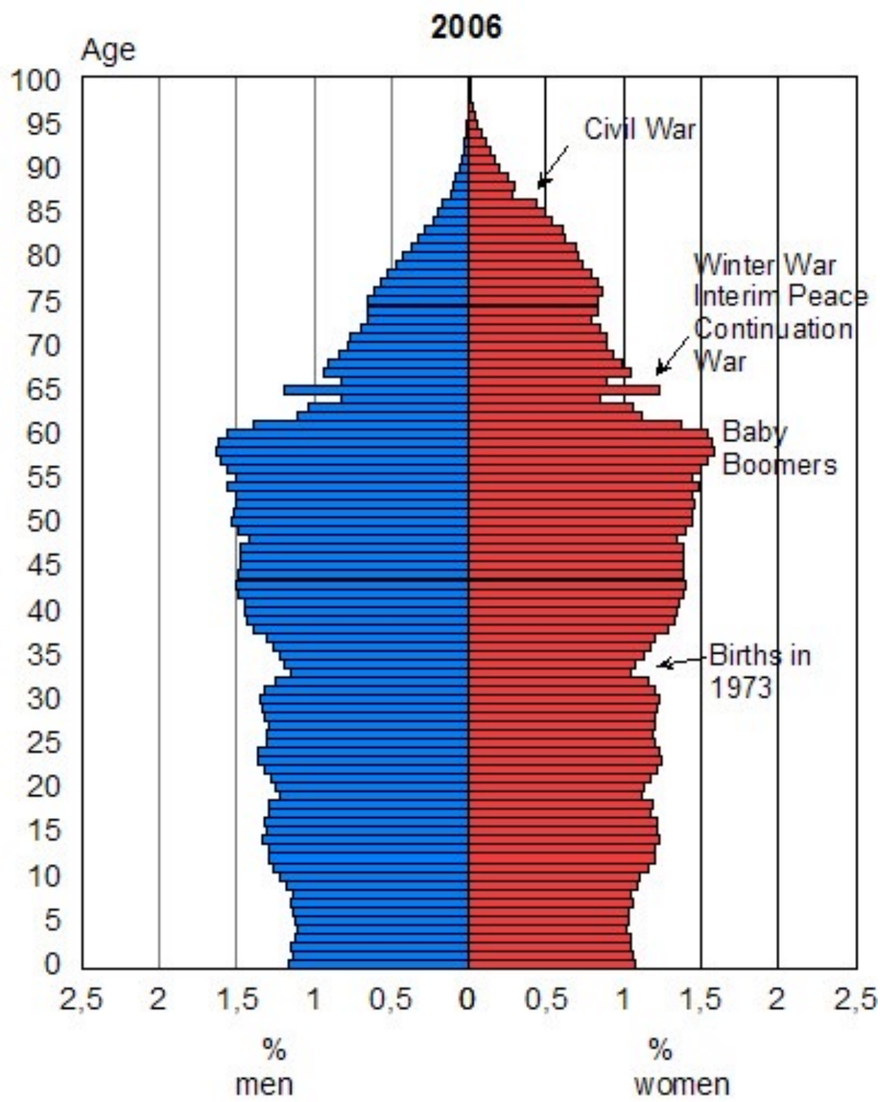


Figure 6.9. Information Visualization. Perception for Design Colin Ware

Symmetry Example: Population Pyramid





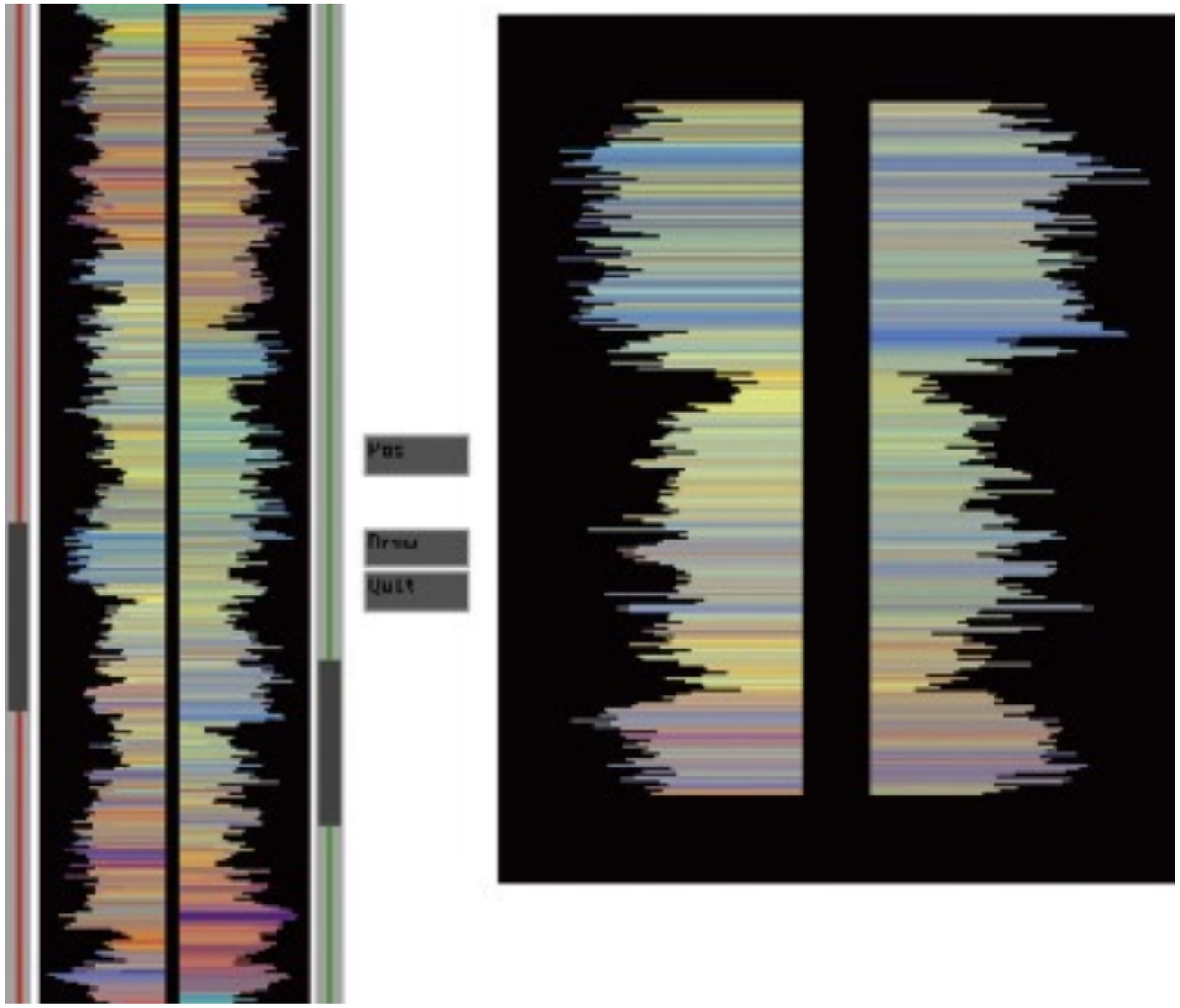


Figure 6.10. Information Visualization. Perception for Design Colin Ware

Figure / Ground

Your brain distinguishes the foreground and the background

CQ: Which Gestalt Principle is Used in the Following Image

A. Figure-Ground
B. Closure
C. Similarity
D. Proximity
E. Connection

CQ: Which Gestalt Principle is Used in the Following Image

A. Enclosure
B. Closure
C. Similarity
D. Continuity
E. Connection

CQ

Emma designed a network diagram to represent the connections between different computers in a system. Computers close to one another in the physical layout are also placed close in the diagram. As a result, viewers easily group these computers and understand their close relationship in the network. Which Gestalt principle is Emma applying?

A. Figure-Ground
B. Closure
C. Proximity
D. Continuity
E. Similarity

CQ: Which Gestalt Principle is Used in the Following Image

A. Figure-Ground
B. Closure
C. Similarity
D. Proximity
E. Connection

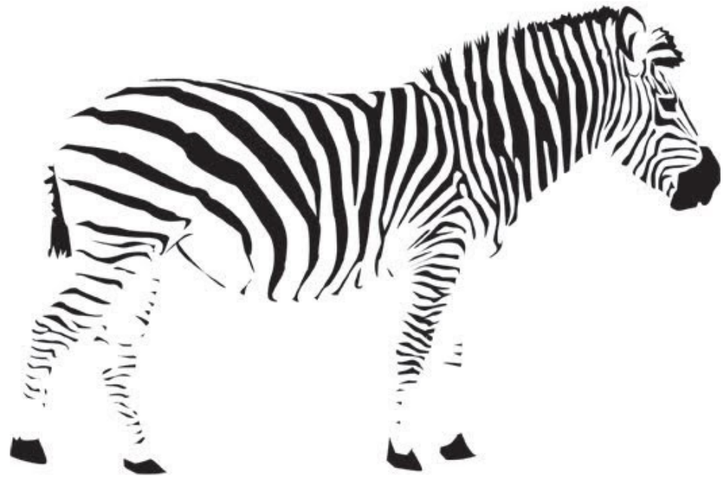
CQ

When observing a series of dots, if the dots are arranged in a way that they form a recognizable shape, like a circle or a square, individuals tend to perceive the entire shape instead of the individual dots. Which Gestalt principle does this scenario illustrate?

A. Figure-Ground
B. Closure
C. Similarity
D. Proximity
E. Connection

CQ: Which Gestalt Principle is Used in the Following Image

A. Figure-Ground
B. Closure
C. Similarity
D. Proximity
E. Connection



CQ

Jake is creating a bar chart to display sales data from various regions. He decides to use different shades of the same color to represent sales from each region. Users can quickly identify and group bars corresponding to each region. Which Gestalt principle is Jake leveraging in this scenario?

A. Closure
B. Continuity
C. Proximity
D. Similarity
E. Figure-Ground

CQ: Which Gestalt Principle is Used in the Following Image

A. Figure-Ground
B. Closure
C. Similarity
D. Proximity
E. Connection