Information Visualization and Knowledge Management

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Theories of Visual Perception

Visual Perception

- Perceiving size and depth
- ? Perceiving brightness
- ? Pattern recognition
- ? Visual variables
- ? Perceptual layers
- ? Arbitrary and sensory images

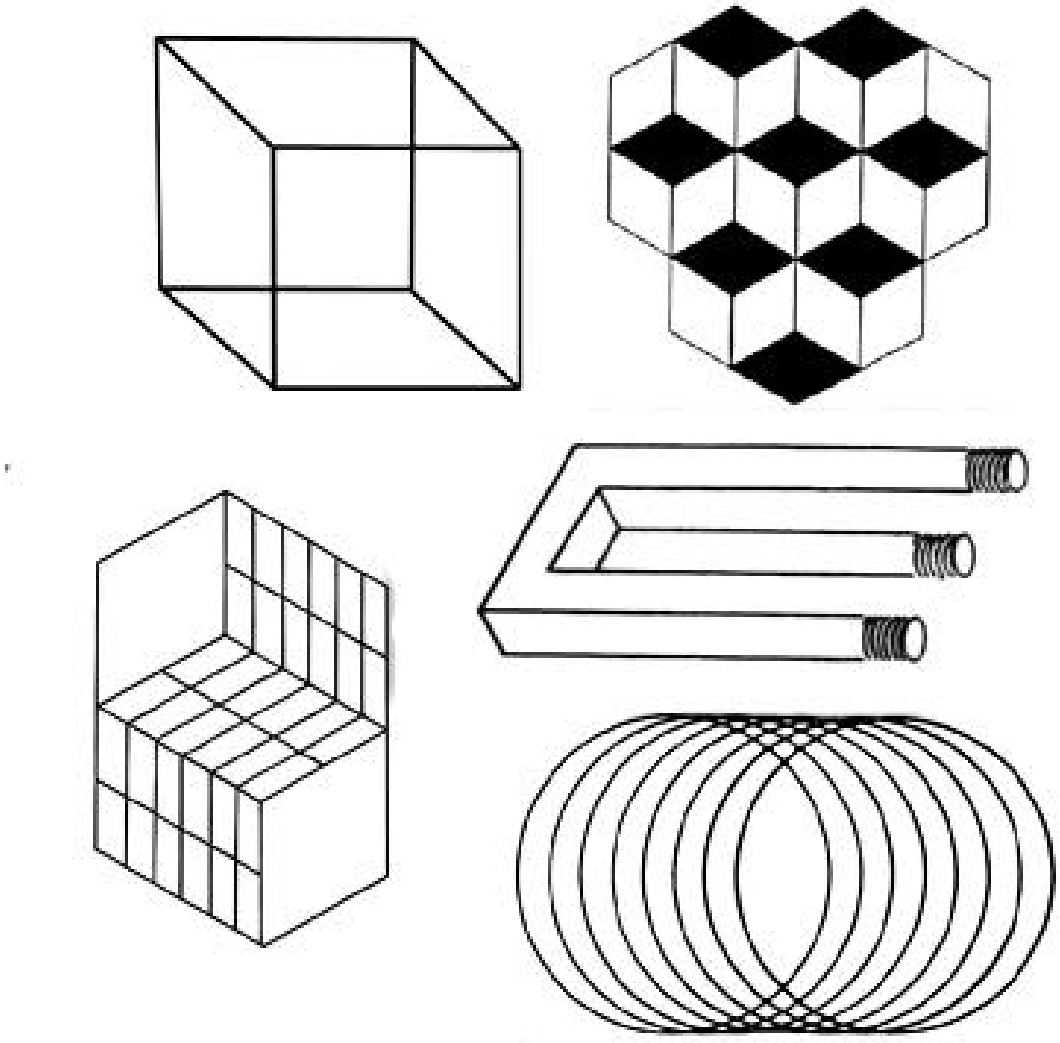
Visual Perception

- Imagine walking around a room, the light changes (for example, the sun moves behind a cloud) but colours are perceived as the same.
- Objects don't change shape or size due to our perception of form, movement and space.

The Capabilities and Limitations of Visual Processing

- visual processing involves the transformation and interpretation of a complete image from light that is thrown onto the retina
- compensates for size and shape as we move around
- color appears constant even in different light levels
- ability to interpret and exploit our expectations used to resolve ambiguity
- context helps us disambiguate the interpretations of the object
- but our visual processing capabilities also create optical illusions

Depth ambiguity



Perceptual ambiguity

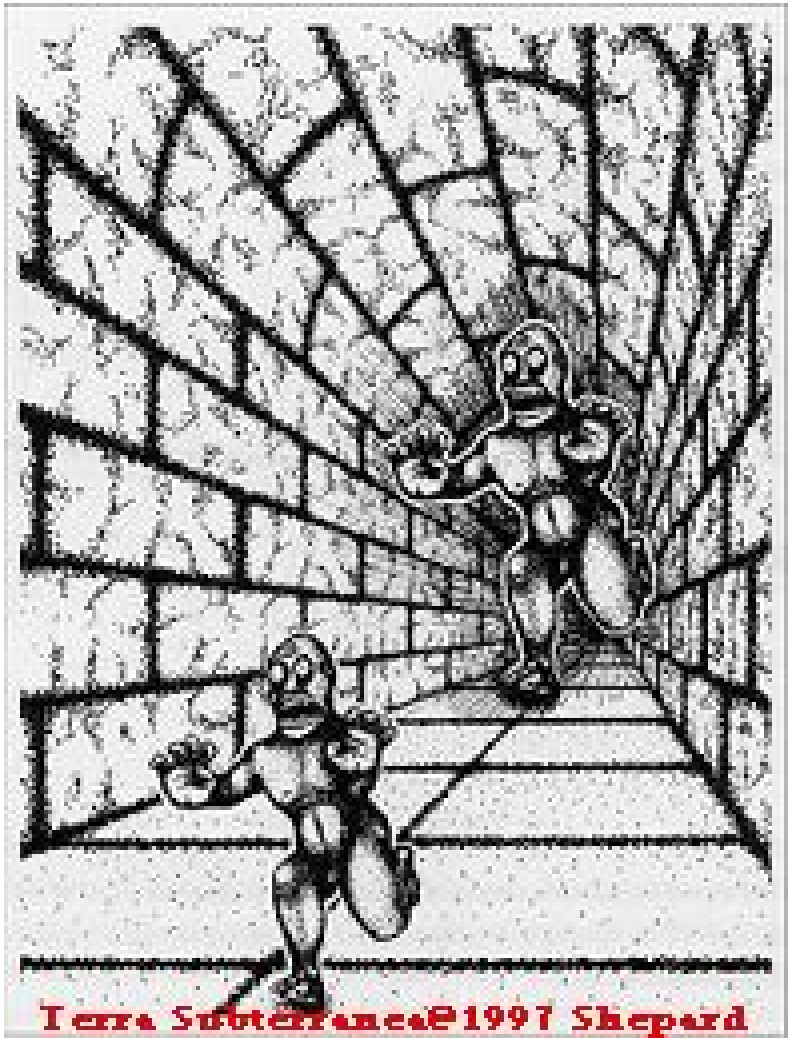
Perceiving Size and Depth

- reflected light from an object forms an upside-down image on the retina
- the size of the image is specified as the *visual angle*
- visual angle is affected by both object size and distance from the eye
- if 2 objects are at the same distance, the larger one will have the larger visual angle
- if the visual angle of an object is too small, we can't perceive the object
- *visual acuity* is the ability of a person to perceive fine detail
- the visual angle of an object gets smaller as the object moves away from you, but we don't perceive it as smaller because of the *law of size constancy*

Law of Size Constancy

- a person's height is perceived as constant even if he moves further away from you
- our perception relies on factors other than visual angle
- one of these factors involves our perception of depth
- there are a number of cues which we use to determine the relative positions and distances of objects that we see
- when objects overlap, the object partially covered is perceived as further away
- when we see an object that is familiar and therefore know its height, we perceive the object as being a certain distance to us

Size constancy



Perception of Form: Figure and Ground

- most of what we perceive can be categorized as objects (figure) or background (ground)
- *familiarity* plays a role in what we perceive as *figure*
- one of the most important aspects of form perception is the existence of a *boundary*, if a space is enclosed by a boundary it will probably be perceived as a figure
- when small elements are arranged in groups, we tend to perceive them as larger figures
- As interface designers, we have to be careful to leave enough space to act as “ground” for the “figure”

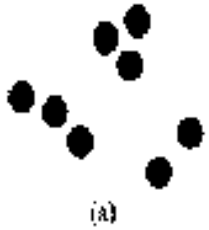
Gestalt Theory

- Gestalt theorists support the thesis that *the whole, in perception, is more than the sum of its parts*
- Organizing laws of Gestalt Psychology enable us to perceive the patterns of stimuli as meaningful wholes:

Organizing laws of Gestalt Psychology

- The law of *proximity* states that elements that are closest together will be perceived as belonging together
- The law of *similarity* states that elements that look similar (shape or colour) will be perceived as part of the same form
- The law of *closure* states that we often supply missing information to close a figure and separate it from its background
- The law of *continuity* refers to predictability or simplicity
- The law of *symmetry* states that regions bounded by symmetrical borders tend to be perceived as coherent figures.

Organizational Laws of Gestalt Psychology

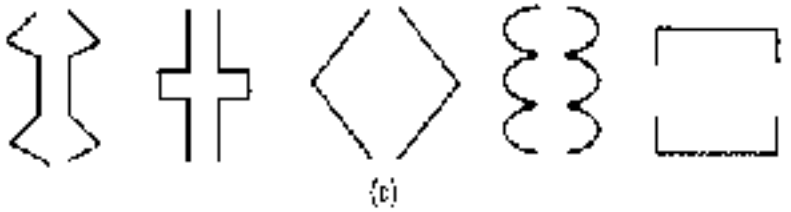


Law of proximity

Law of similarity

Law of continuity

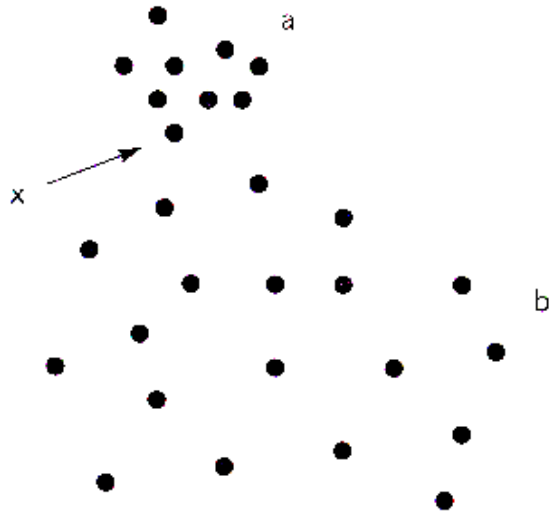
Law of closure



Law of symmetry

Proximity – Concentration principle

- We also perceptually group regions of similar element density
- If we want to show the organization of some set o related items, we should place them in close proximity to each other
- Labels are shown to belong to certain elements by placing them close to the target



Similarity

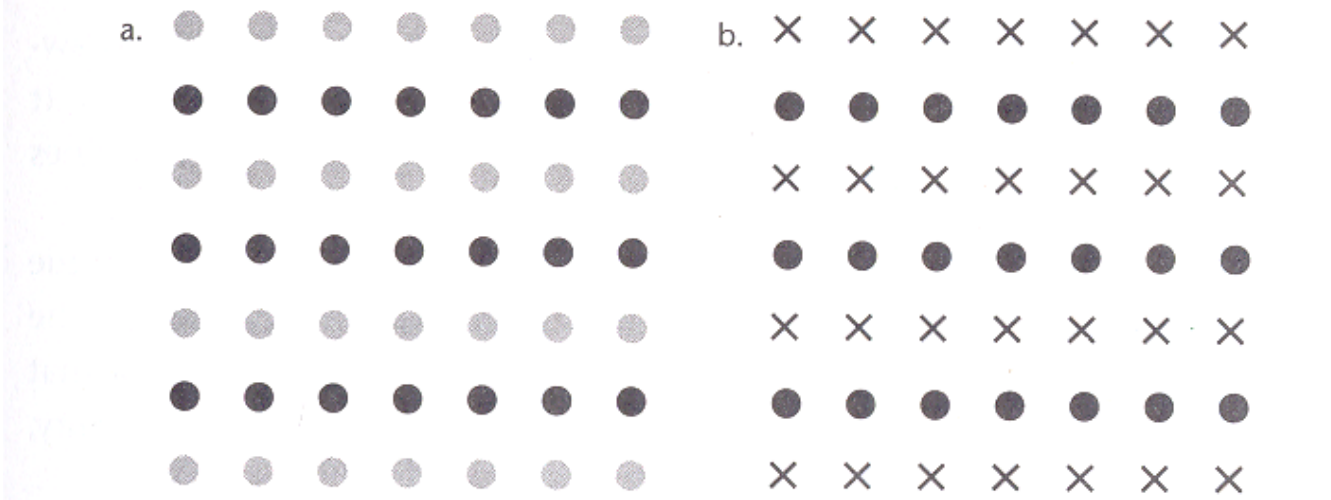
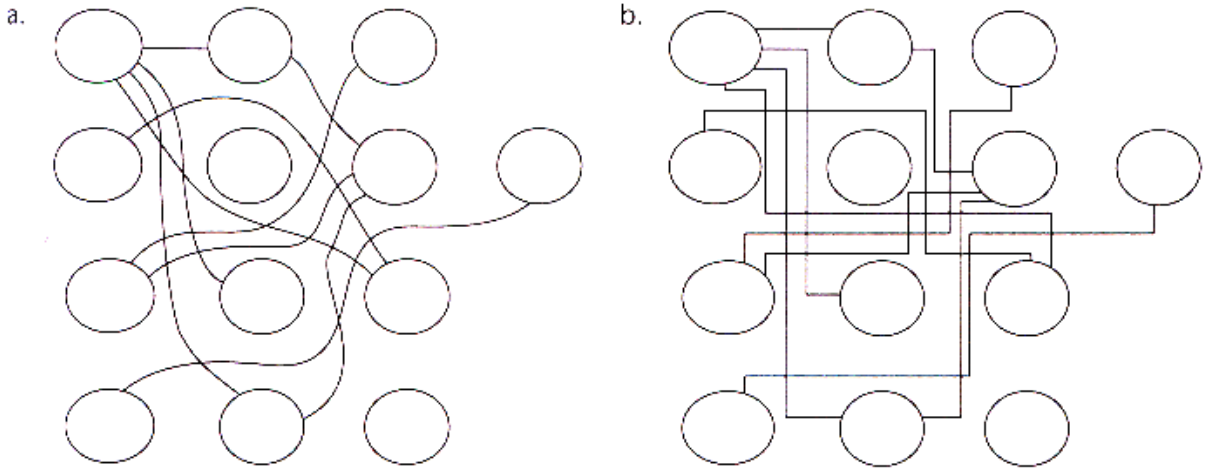


Figure 6.4 According to the Gestalt psychologists, similarity between the elements in alternate rows causes the row percept to dominate.

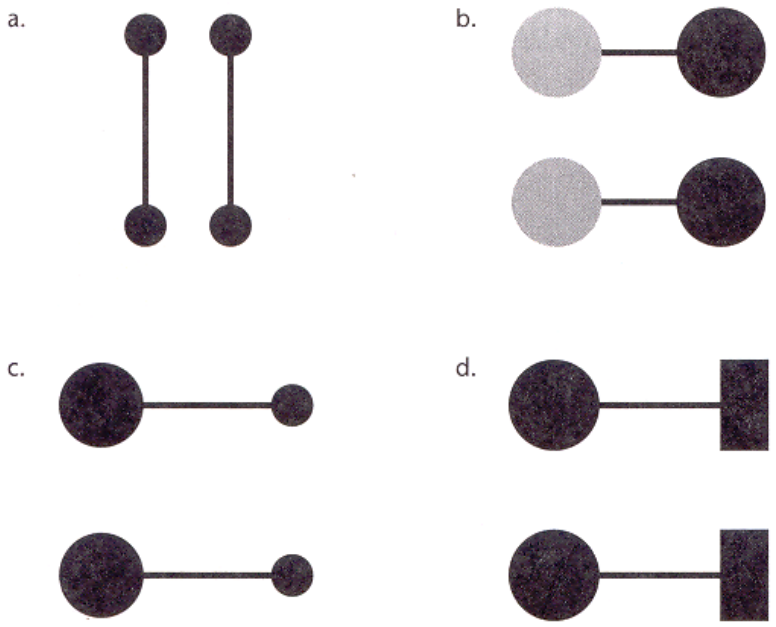
Continuity

- We are more likely to construct visual entities out of elements that are smooth and continuous rather than using ones with abrupt changes in direction
- This principle can be applied to networks of nodes and links – smoother links make it easier to identify sources and destinations of links



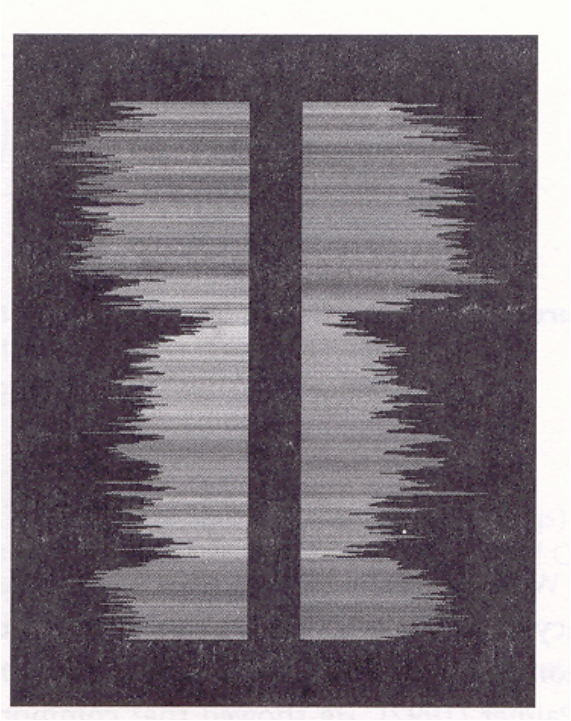
Importance of connectedness

- Some theorists argue that connectedness may be a more important grouping principle than proximity, colour, size and shape

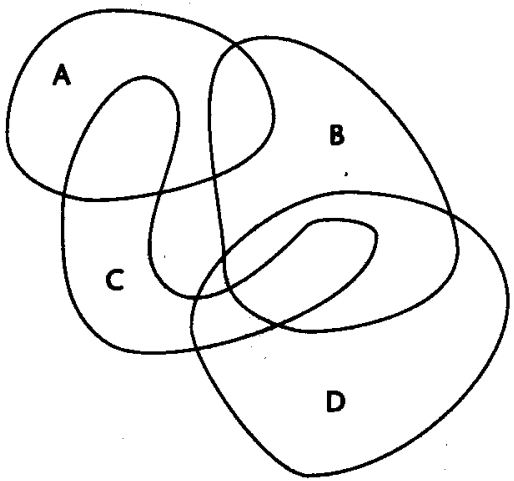


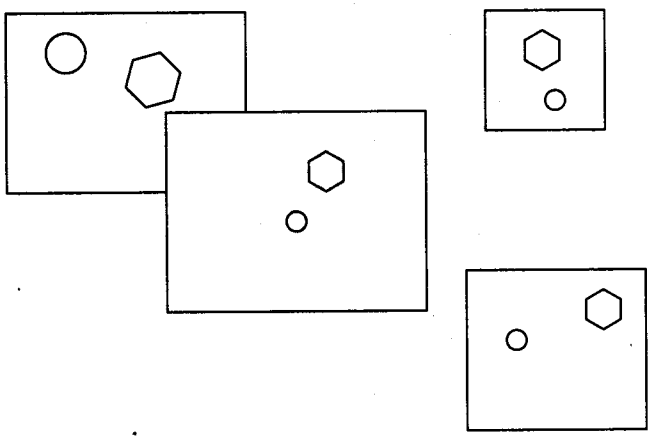
Application of symmetry

- Patterns may be easier to detect if time series data are arranged vertically as shown, rather than using parallel plots



Closure – e.g. Venn diagrams , windows





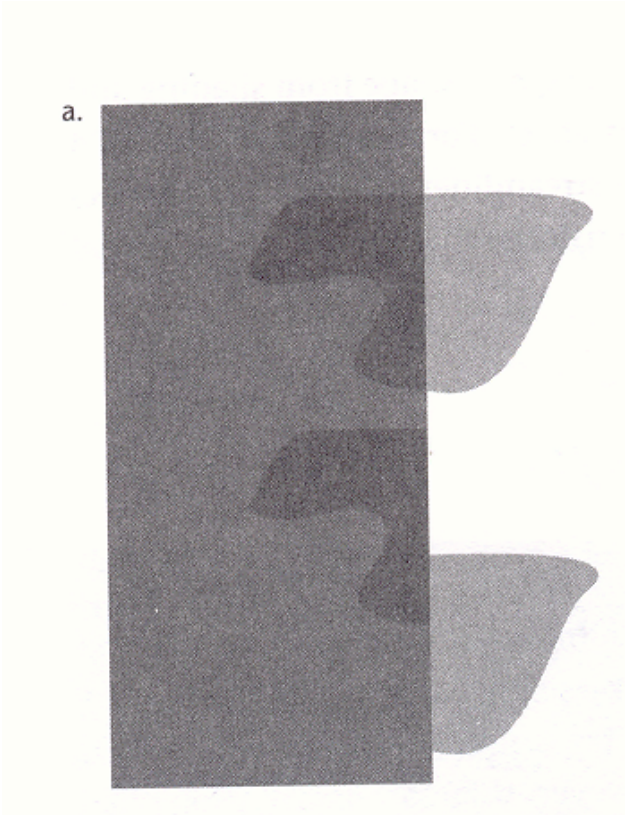
Other properties of Perception

- Peripheral vision can detect patterns (we can exploit this)
- Perception of Transparency
- Automatic processing
- …

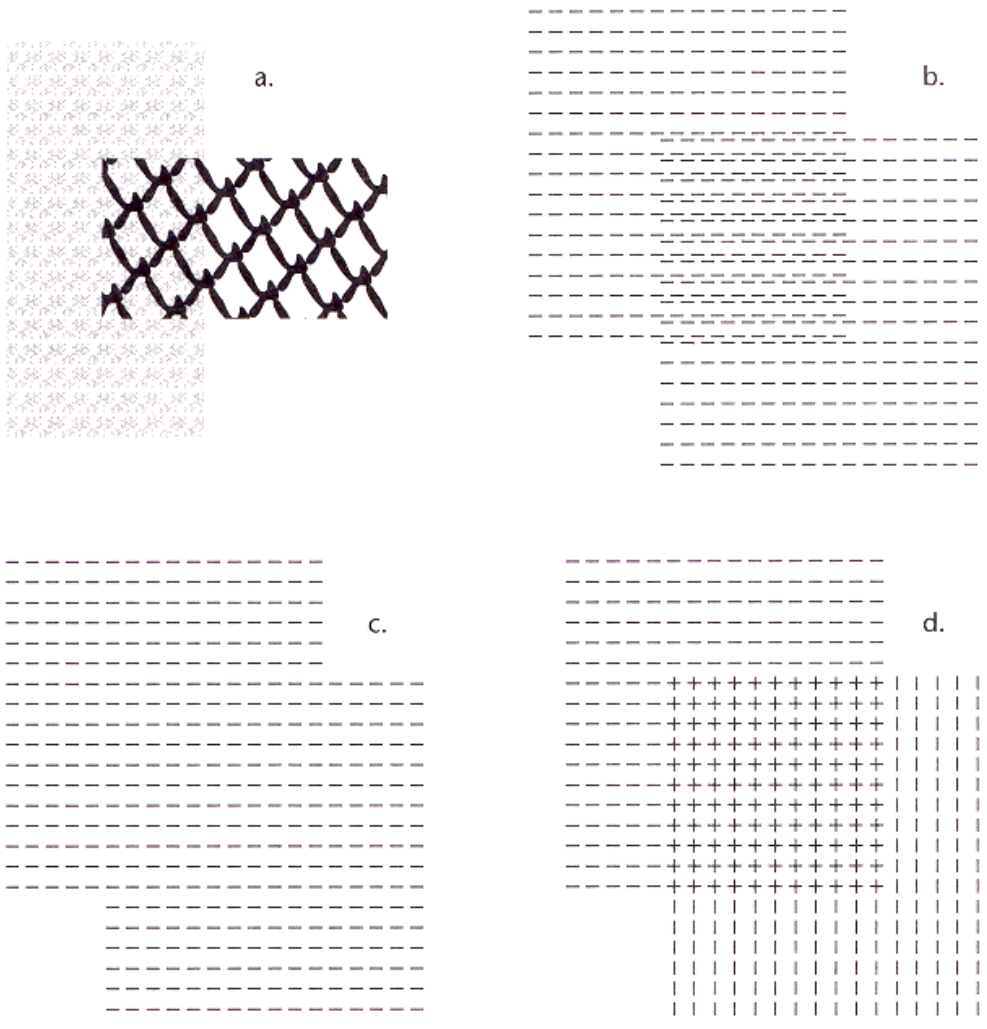
Perception of Transparency – overlapping data

- Often necessary to present data that has a layered form (e.g. GIS)
- Problems with having layers is that content in one layer will interfere with another layer, hard to tell which layer an object is on
- The use of contours and gray values can be used to differentiate between layers
- Another alternative is to use see through textures – but similar patterns will tend to interfere with one another
- Do you think see through menus would be an improvement?

Layering data with transparency



Layering data – using texture

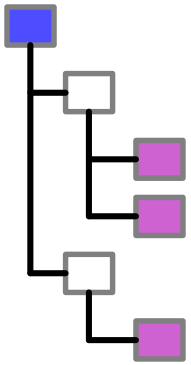


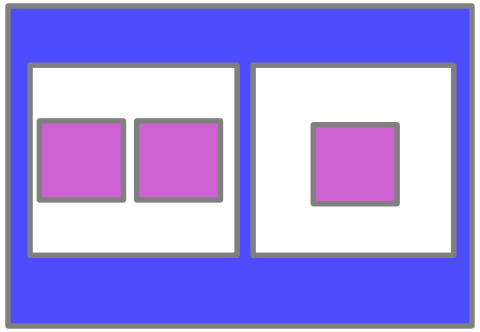
Stroop Effect

ZYP	RED
OLEKF	BLACK
SUWRG	YELLOW
XCIDB	GREEN
WGPR	RED
ZYP	BLACK
OLEKF	RED
XCIDB	YELLOW
SUWRG	GREEN
WQPR	BLUE
SUQRG	YELLOW
ZYP	BLACK
XCIDB	BLUE
QLEKF	RED
WOPR	GREEN
OLEKF	YELLOW
ZYP	BLACK

Connection and enclosure

- Lines can be used to show:
  - Connection
  - Enclosure
- Used in trees and graphs
- Concepts of connection and enclosure are rapidly processed by our perceptual system





Bertin's Retinal Properties

- The eye is sensitive to these properties independent of position
- Six properties, separated into spatial and object properties
- Some are good for expressing the *extent* of a scale others for *differentiating* marks

TABLE **1.21**

Retinal properties.

	Spatial	Object
Extent	(Position) —|—|—| Size ● ● • ·	Gray Scale ■ ■ ■ □
Dif-ferential	Orientation – / | \	Color ■ ■ ■ ■ Texture ■ ▨ ▨ ■ Shape ■ ★ ● ◆

Bertin's Retinal Properties

- Some retinal properties are more effective than others for encoding information

TABLE **1.23**

Relative effectiveness of different retinal properties. Data based on MacEachren (1995, Figure 6.30). Q = Quantitative data, O = Ordinal data, N = Nominal data. Filled circle indicates the property is good for that type of data. Half-filled circle indicates the property is marginally effective, and open circle indicates it is poor.

	Spatial	Q	O	N	Object	Q	O	N
Extent	(Position)	●	●	●	Grayscale	◑	●	○
	Size	●	●	●				
Differential	Orientation	◑	◑	●	Color	◑	◑	●
					Texture	◑	◑	●
					Shape	○	○	●

Other properties…

- Proposed by others:
  - Crispness
  - Resolution
  - Transparency
  - Arrangement
  - Saturation and Hue
- Other features that can be automatically processed
  - Curvature
  - Width
  - Temporal features such as Flicker, change in position/colours

TABLE **1.22**

Visual features that can be automatically processed (Healy, Booth, and Enns, 1995).

Number	Terminators	Direction of motion
Line orientation	Intersection	Binocular luster
Length	Closure	Stereoscopic depth
Width	Color	3D depth cues
Size	Intensity	Lighting direction
Curvature	Flicker	

Temporal encoding

- Human perception is also very sensitive to *changes* in mark position and their retinal properties (blinking, colours, movement…)

One theory: Visualization as a language

- Visualization is about diagrams and how they convey meaning
- Diagrams made up of symbols
- Meaning of symbols normally understood by convention (between people)
- Diagrams can be just as arbitrary as the written word (we have to learn the conventions of both)
- Laws of perception are pretty much irrelevant

Sensory Representations

- *Sensory*: used to refer to symbols and aspects of visualizations that derive their expressive power from their ability to use the perceptual processing power of the brain without learning
  - E.g. dog vs. 
- Sensory representations can be effective (or misleading!)
- They tend to be stable across individuals, cultures, time
- Most graphical languages are hybrid languages

Cave art at Lascaux

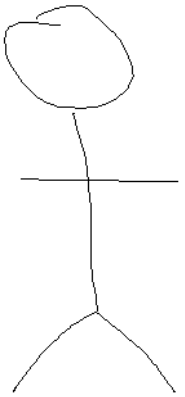
Arbitrariness

Truth is related to its context, Saussure

- Saussure's principle of "arbitrariness" of the relationship between a symbol and thing that is signified

Pictures as sensory languages

- Are pictures just as arbitrary as words?
- Or is there a measure of similarity between pictures and the things that they represent
- If we can't agree on this, then we can't claim that certain diagrams and other visualizations are designed perceptually
- Are pictures just symbols that we have learned and become used to?
- But this would imply that all languages are equally valid if all are learned….
- If you buy this, then we should choose graphical notations early and stick to them?



Stylized drawings

- Pictures can be drawn to make the viewer believe they are real, but often they are highly stylized and we adopt methods of representation that are not realistic
- Some drawings are simply more effective than others…

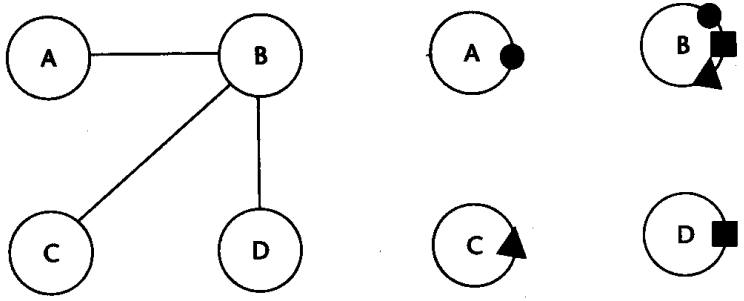
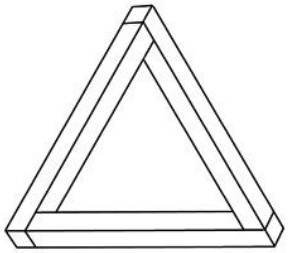


Figure 1.4 Two different graphical methods for showing relationships between entities.

Properties of sensory representations

- Understanding without training
  - But need to know that some communication is intended
- Resistance to instructional bias
  - Many sensory phenomena persist despite the knowledge that they are illusory (www.illusionworks.com)



- Sensory immediacy (see Fig. 1.8)
- Cross-cultural validity
  - But "overloading" can occur, if cultural arbitrary symbols interfere with the sensory representations

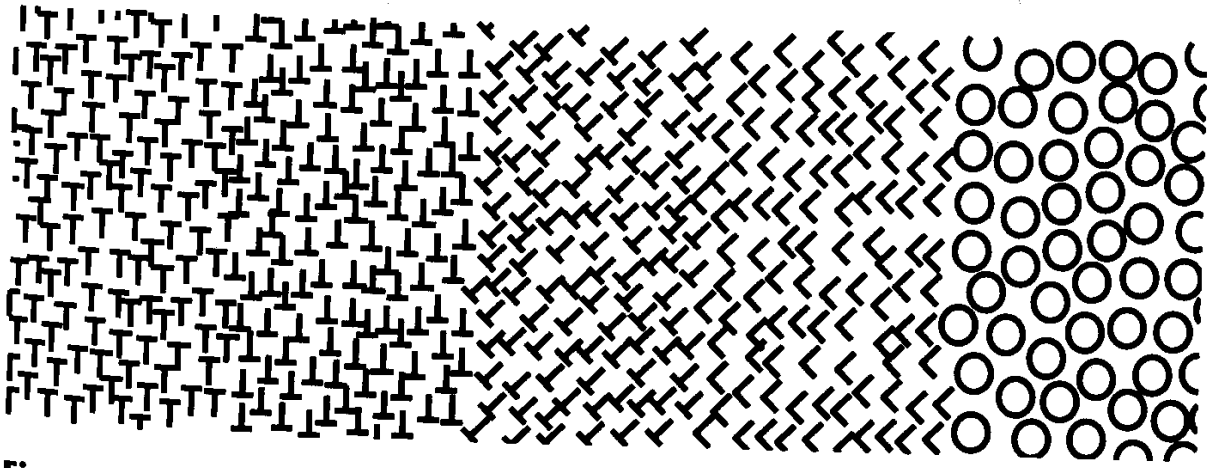


Figure 1.8 Five regions of texture. Some are easier to visually distinguish than others. Adapted from Beck (1966).

Properties of arbitrary conventional representations

- Hard to learn
- Easy to forget (if not overlearned)
- Embedded in culture and applications
- Formally powerful
- Capable of rapid change

Gibson's Affordance Theory

- We perceive in order to operate on the environment (possibilities for action)
  - Handles for pulling
  - Surfaces for walking etc
- Discussed extensively in "Design of Everyday Things" by Don Norman
- Things that have similar (or share) functionality should be grouped
- Also need to consider feedback, visibility, appropriateness of mapping etc.
- Important considerations when we design controls to interact with a visualization

Cost structure

- Keep small amounts of important information where access cost is low
- Voluminous, less used information is kept in secondary storage areas (higher cost of access)
  - Can be categorized and linked to aid retrieval
- “Cost-of-knowledge Characteristic Function”

Interesting illusion

- illusion