

Information Visualization and Visual Analytics (M1522.000500)

Marks and Channels

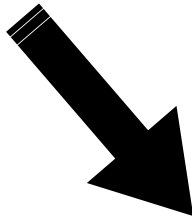
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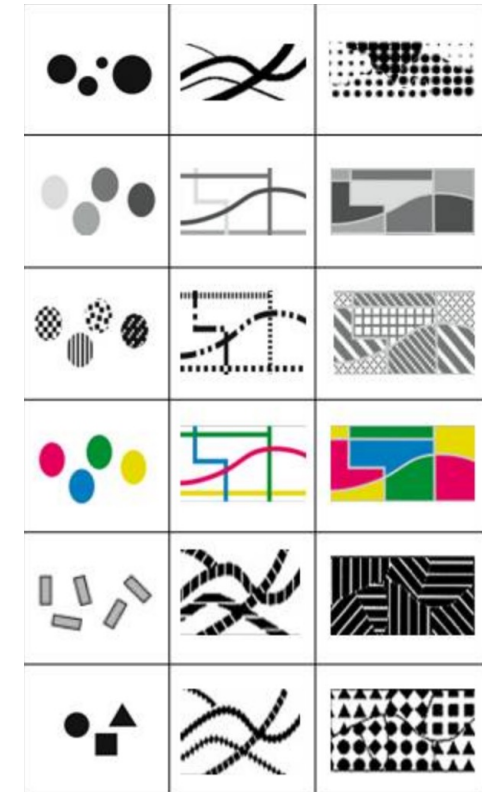
Why Marks and Channels?

- Every complex visual encoding **idiom** can be broken down into two orthogonal components : **Marks** and **Channels**

Idiom



Marks & Channels



Marks

- Basic graphical element
- Classified with their spatial dimension
 - Point (0D), Line (1D), Area (2D), Volume (3D)

➔ Points



➔ Lines



➔ Areas



Marks and Their Types

- Geometric primitives

Marks as Items/Nodes (Marks to represent individual items)

➔ Points



➔ Lines



➔ Areas



Marks as Links (Marks to represent links between items)

➔ Containment



➔ Connection



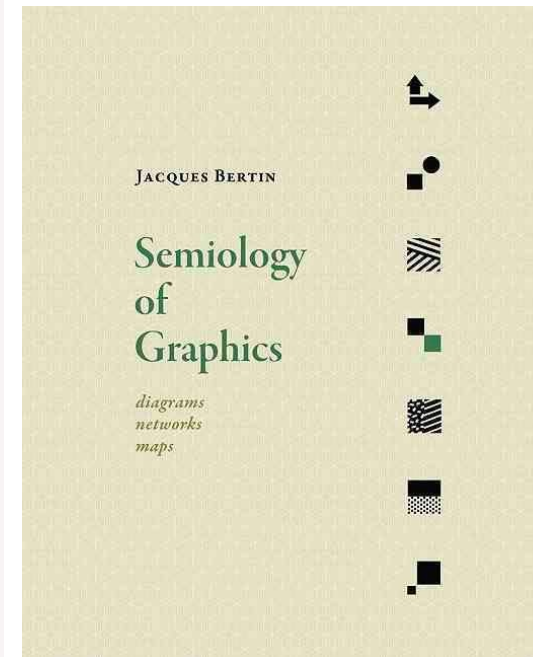
Previous work by Jacques Bertin

Vairables of a Visual Image

	Points	Lines	Areas
X Y 2 Dimensions of A Chart			
Size			
Value			

Variables to Separate Images

Texture			
Colour			
Orientation			
Shape			



Channels

- A way to control the **appearance** of marks
- human perceptual system has two fundamentally different kinds of sensory modalities
 - **Identity** channel (what, where)
 - **Magnitude** channel (how much)

➞ Position

➞ Horizontal



➞ Vertical



➞ Both



➞ Color



➞ Shape



➞ Tilt



➞ Size

➞ Length



➞ Area



➞ Volume



Marks and Channels

- **Marks**

- geometric primitives

- **Channels**

- control appearance of marks
- can redundantly code with multiple channels

- Interactions (marks vs. size and shape channels)

- size and shape channels cannot be used on all types of marks
 - constraints that arise from the way that marks are defined
- **area** marks *fully constrained* (e.g., an area mark denoting a state or province)
 - cannot be size or shape coded
- **line** marks convey position and length
 - can only be size coded in 1D (width)
- **point** marks only convey position; **no area constraints**
 - can be size and shape coded

➔ Points



➔ Lines



➔ Areas



➔ Position

➔ Horizontal



➔ Vertical



➔ Both



➔ Color



➔ Shape



➔ Tilt



➔ Size

➔ Length



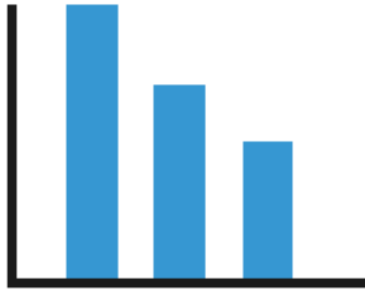
➔ Area



➔ Volume

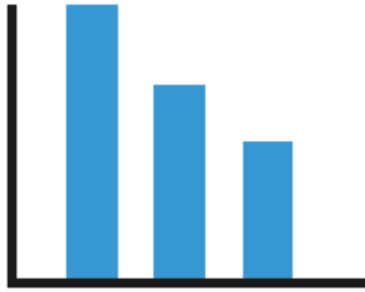


Analyze Idiom Structure



Analyze Idiom Structure

- as combination of marks and channels



1:
vertical position

mark: line



2:
vertical position
horizontal position

mark: point



3:
vertical position
horizontal position
color hue

mark: point

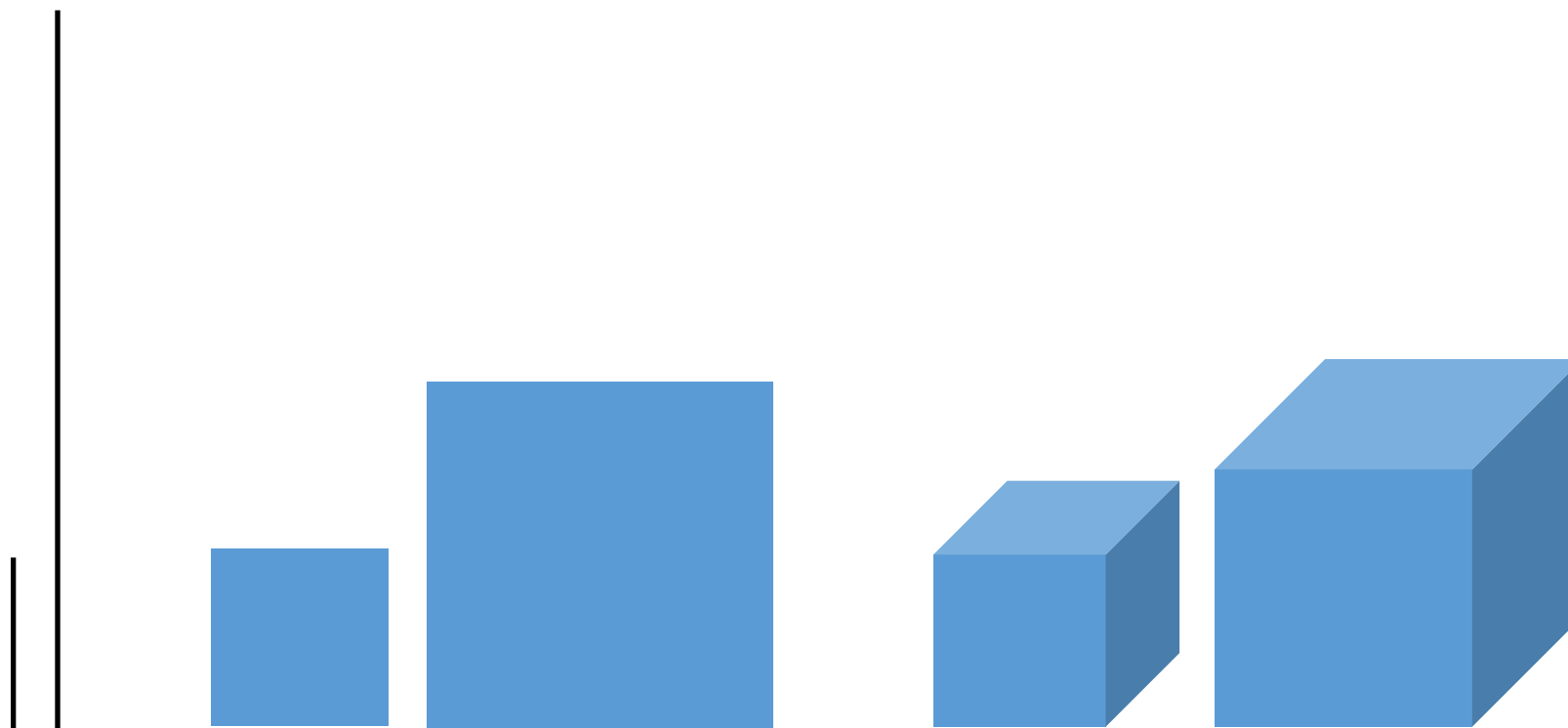


4:
vertical position
horizontal position
color hue
size (area)

mark: point

1D, 2D, and 3D

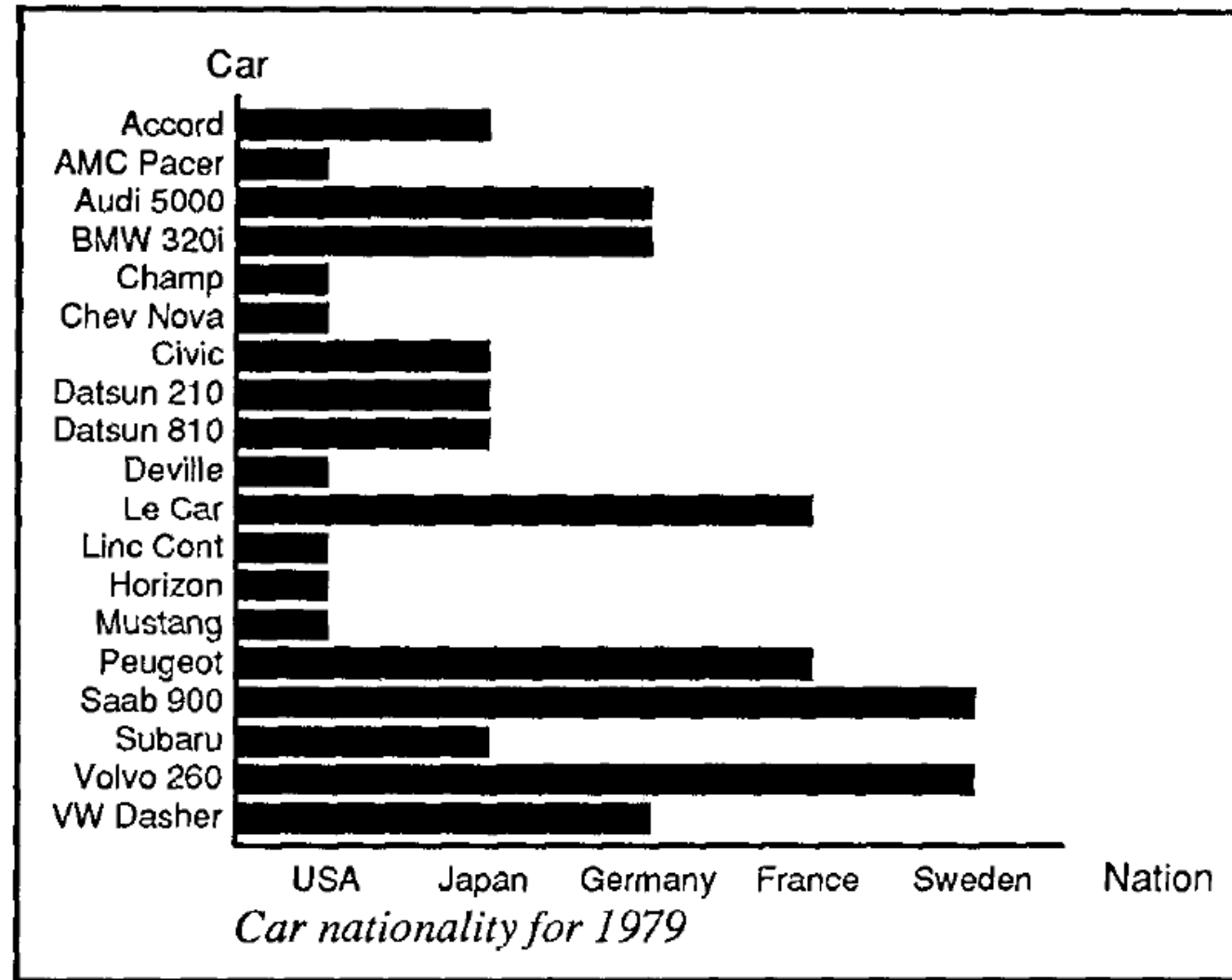
- size ratio for each pair → 1:4



Expressiveness and Effectiveness

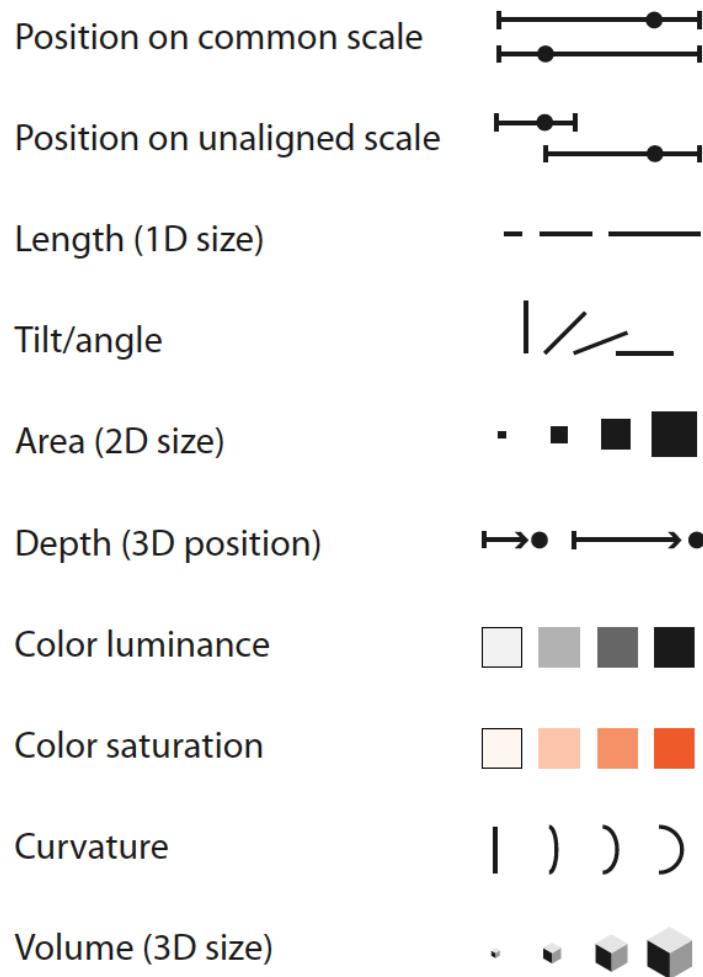
- Expressiveness
 - Vis idiom should express **all** of, and **only**, the information in the dataset attributes
 - match channel and data characteristics
- Effectiveness
 - Most important attributes should be encoded with the most effective channels
 - ranking of channels
 - Ranking of channels: where do they come from?
 - accuracy
 - discriminability
 - separability
 - popout

Any Better Encoding?



Channels: Expressiveness types and effectiveness rankings

➔ **Magnitude Channels: Ordered Attributes**



Same

Effectiveness

➔ **Identity Channels: Categorical Attributes**



외울 필요가 있음

- **Magnitude Channels for Ordered Attributes**
 - Position (aligned scale > unaligned) > Length (1D size) > Tilt/angle > Area (2D size) > Depth > Color (luminance = saturation) > Curvature = Volume (3D size)
- **Identity Channels for Categorical Attributes**
 - Spatial region > Color Hue > Motion > Shape
- Position dominates the user's mental model

Stevens' Power Law

- p : perceived magnitude
- a : actual magnitude
- $p = ka^\alpha$
- $p_1/p_2 = (a_1/a_2)^\alpha$
- length judgment: $\alpha \approx 1$
- area judgment: $\alpha < 1$
- volume judgment: $\alpha \ll 1$

Continuum	Exponent (α)	Stimulus condition
Loudness	0.67	Sound pressure of 3000 Hz tone
Vibration	0.95	Amplitude of 60 Hz on finger
Vibration	0.6	Amplitude of 250 Hz on finger
Brightness	0.33	5° target in dark
Brightness	0.5	Point source
Brightness	0.5	Brief flash
Brightness	1	Point source briefly flashed
Lightness	1.2	Reflectance of gray papers
Visual length	1	Projected line
Visual area	0.7	Projected square
Redness (saturation)	1.7	Red-gray mixture
Taste	1.3	Sucrose
Taste	1.4	Salt
Taste	0.8	Saccharin
Smell	0.6	Heptane
Cold	1	Metal contact on arm
Warmth	1.6	Metal contact on arm
Warmth	1.3	Irradiation of skin, small area
Warmth	0.7	Irradiation of skin, large area
Discomfort, cold	1.7	Whole body irradiation
Discomfort, warm	0.7	Whole body irradiation
Thermal pain	1	Radiant heat on skin
Tactual roughness	1.5	Rubbing emery cloths
Tactual hardness	0.8	Squeezing rubber
Finger span	1.3	Thickness of blocks
Pressure on palm	1.1	Static force on skin
Muscle force	1.7	Static contractions
Heaviness	1.45	Lifted weights
Viscosity	0.42	Stirring silicone fluids
Electric shock	3.5	Current through fingers
Vocal effort	1.1	Vocal sound pressure
Angular acceleration	1.4	5 s rotation
Duration	1.1	White noise stimuli

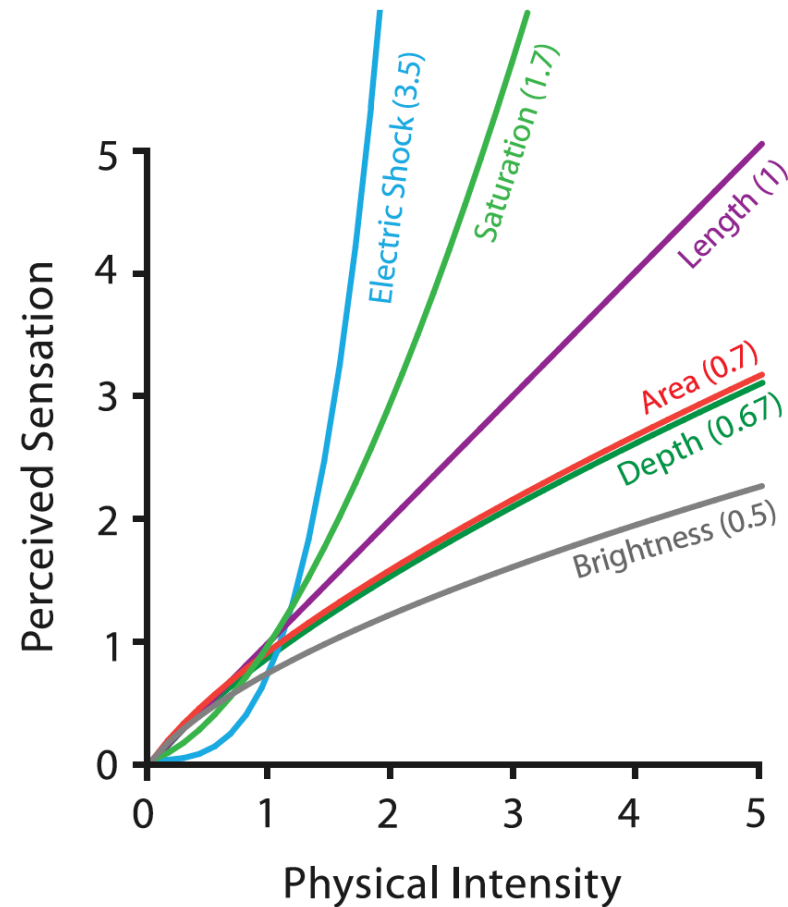
Stevens' Power Law

$$S = I^N$$

S : perceived magnitude

I : actual magnitude

Steven's Psychophysical Power Law: $S = I^N$

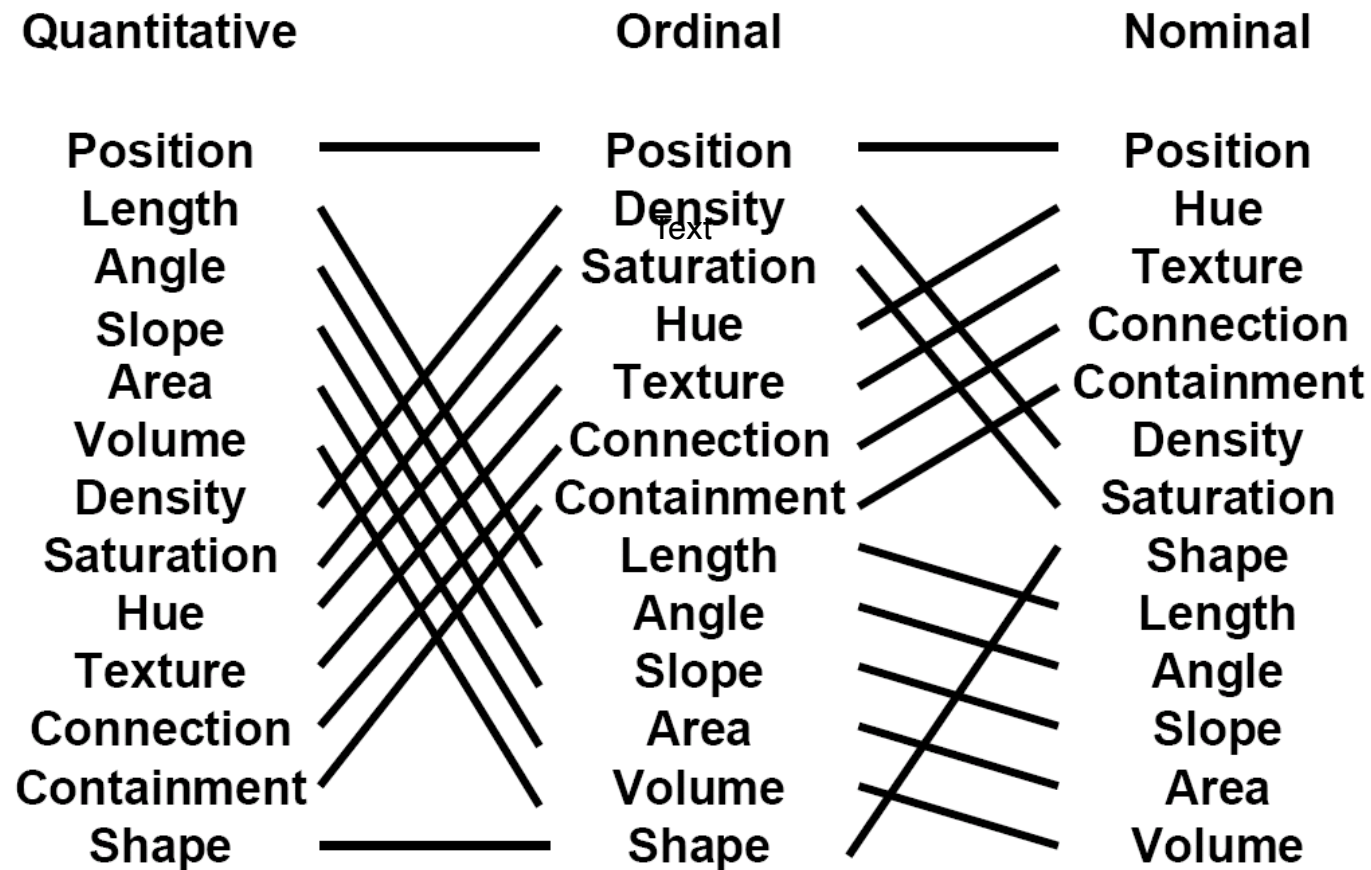


Visual Encoding Principles according to accuracy

1등은 포지션

- Channel Ranking Varies by Data Type

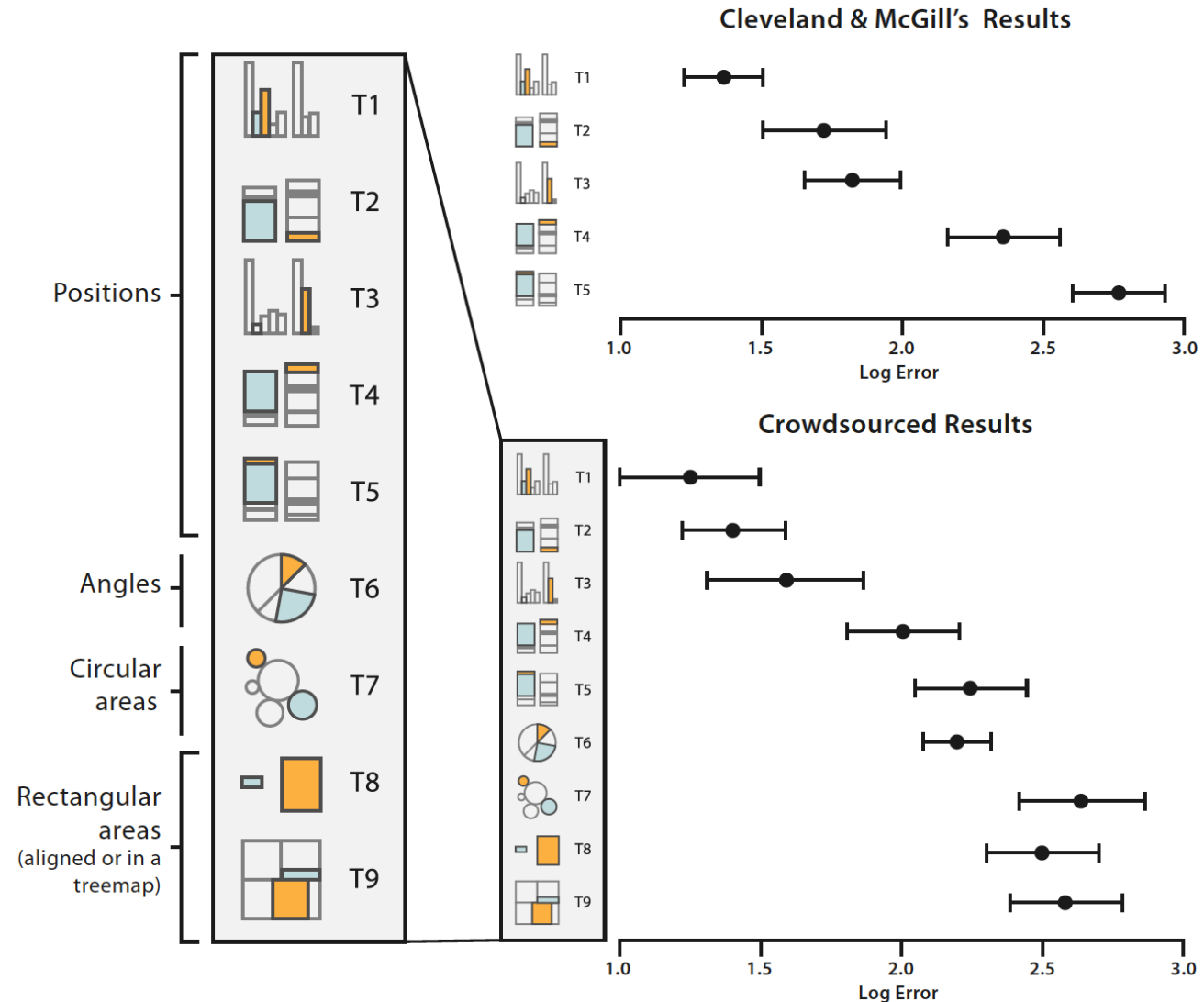
quantitative 꼰똥이 ordinal 윗등
quantative 2-5등이 ordinal 반대



Crowdsourced Results

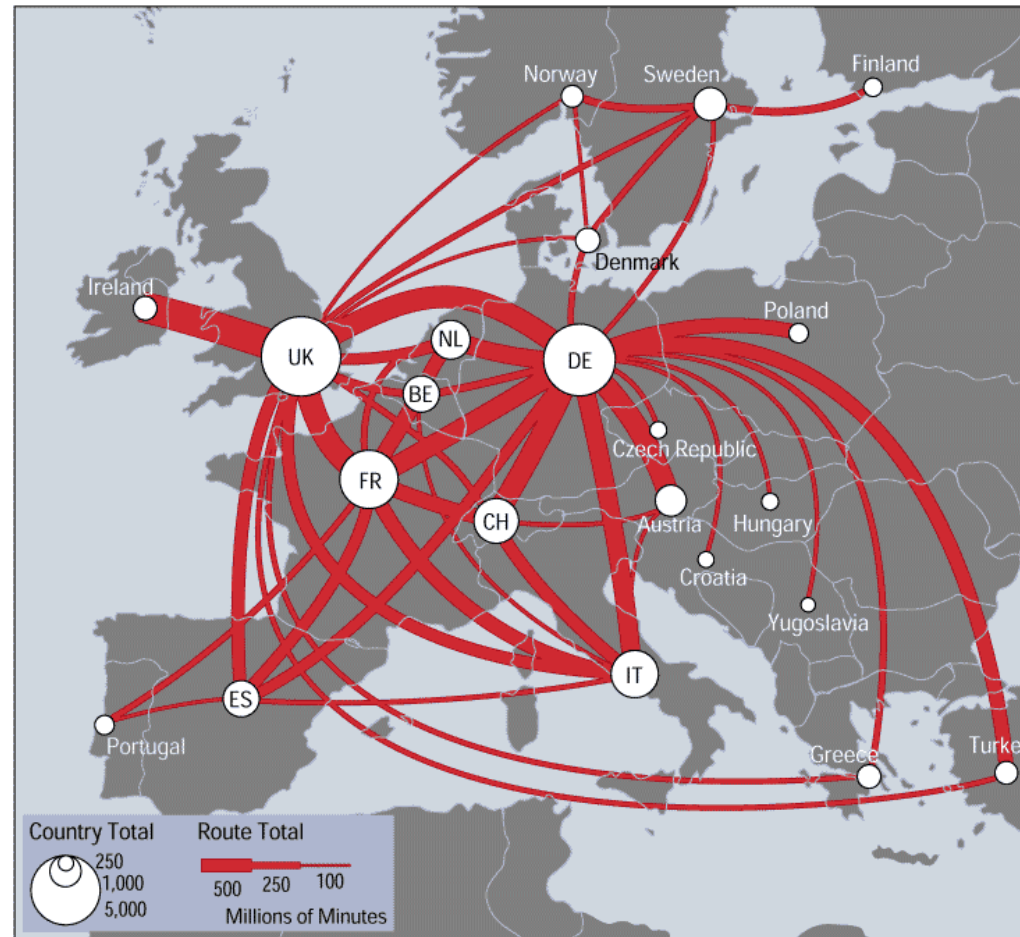
- T1~T3
 - position along a common scale
- T4~T5
 - length encoding
- T6: angle
- T7: circular area
 - rectangular area

Text



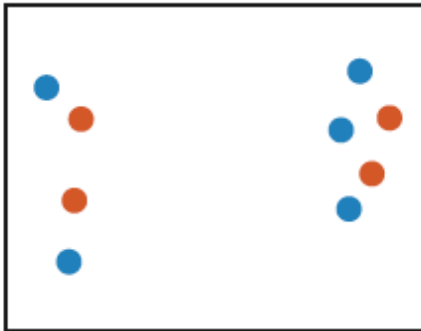
How many usable steps?

- linewidth: only a few



Separable channels vs. Integral channels

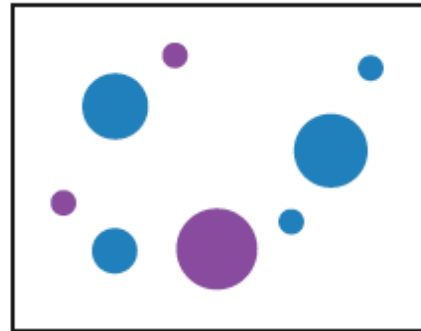
Position
+ Hue (Color)



Fully separable

2 groups each

Size
+ Hue (Color)



Some interference

2 groups each

Width
+ Height



Some/significant
interference

3 groups total:
integral area

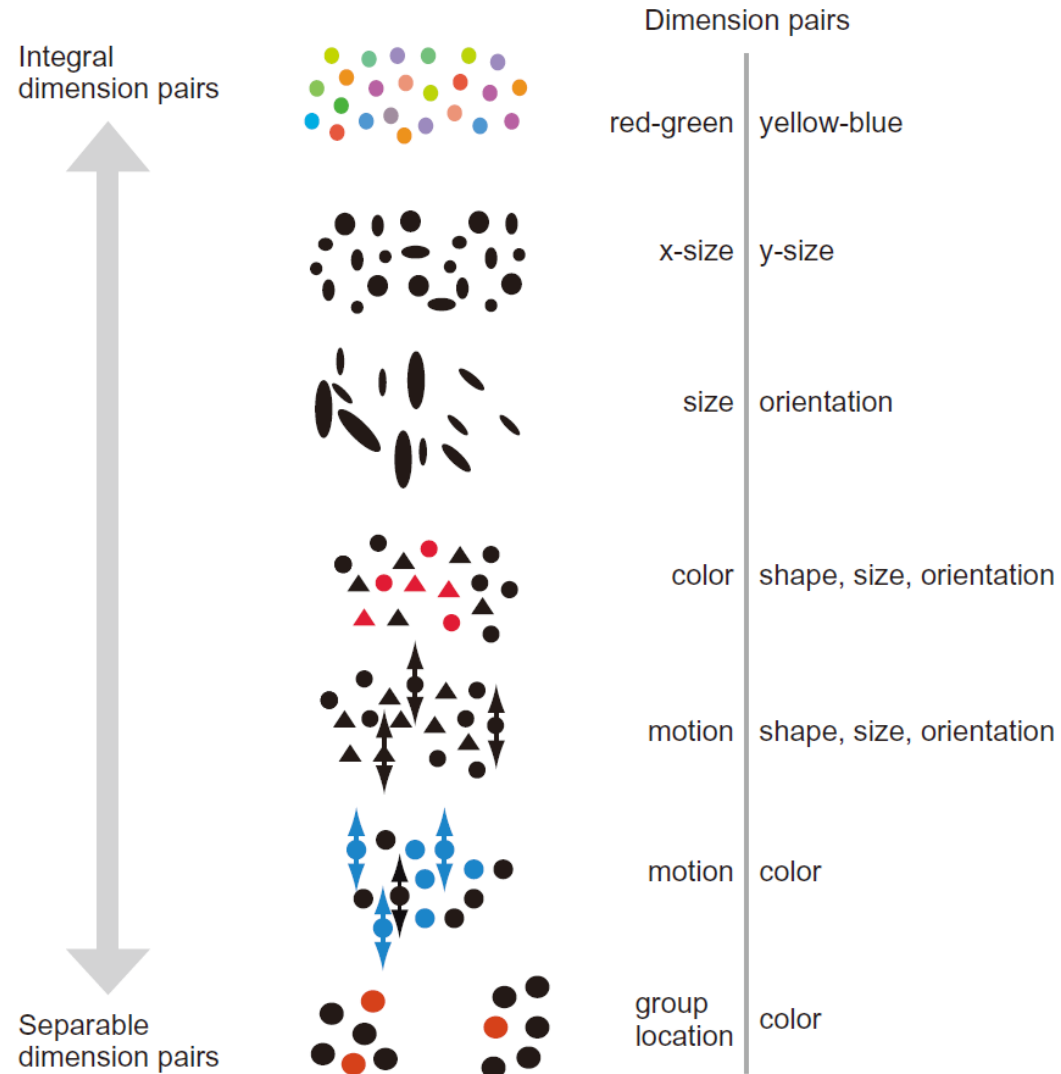
Red
+ Green



Major interference

4 groups total:
integral hue

Separability

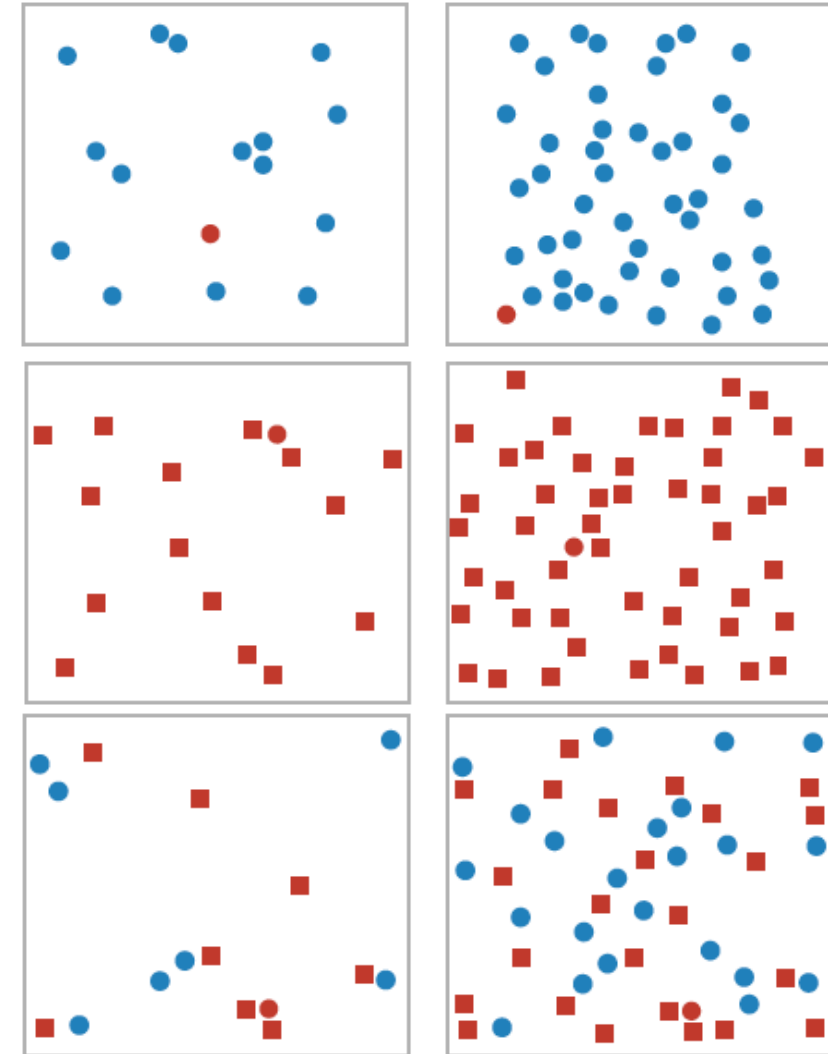


Preattentive Processing

- Cognitive operations done preattentively, without the need for focused attention
 - less than 200-250 ms
 - eye movements take 200 ms
 - minimum time to initiate eye movement
 - involves only information available in a single glance
- Popout effects
- Segmentation effects

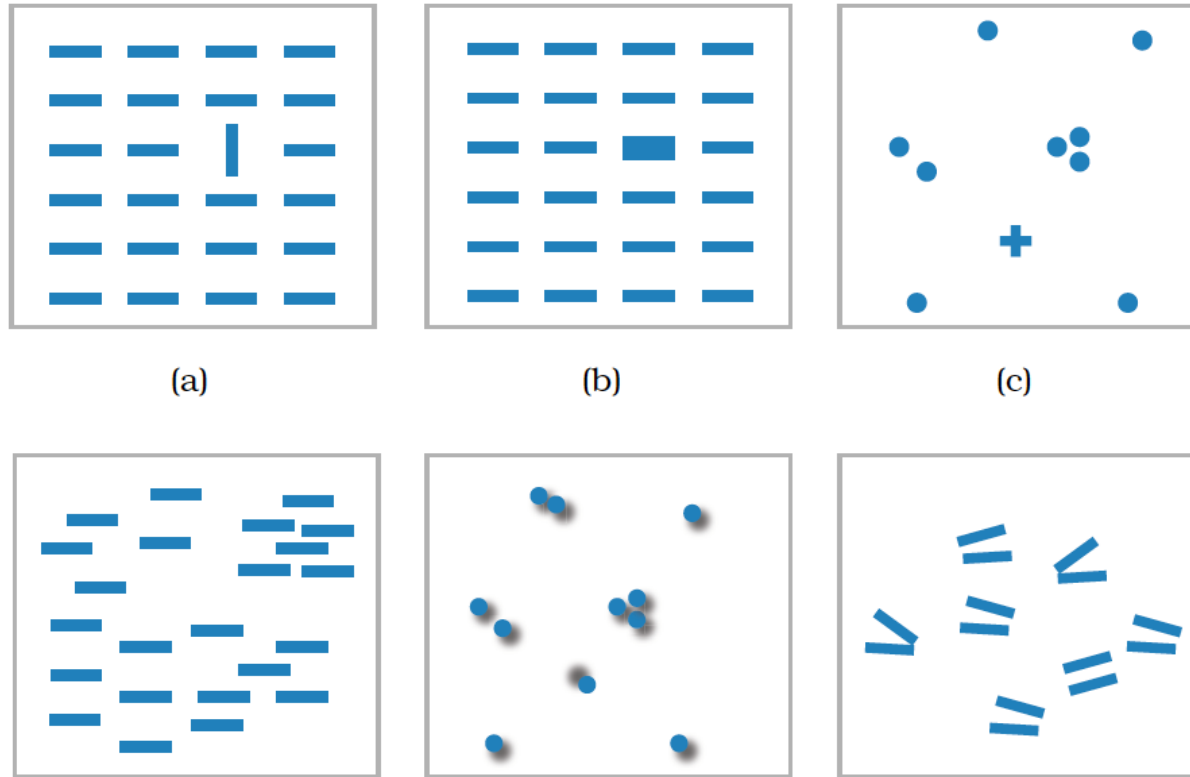
Preattentive Perception

- find the red dot
 - how long does it take?
- **parallel** processing on many individual channels
 - speed *independent* of # of distractors
 - speed *depends* on channel and amount of difference from distractors
- serial search for (almost all) combinations
 - speed depends on number of distractors

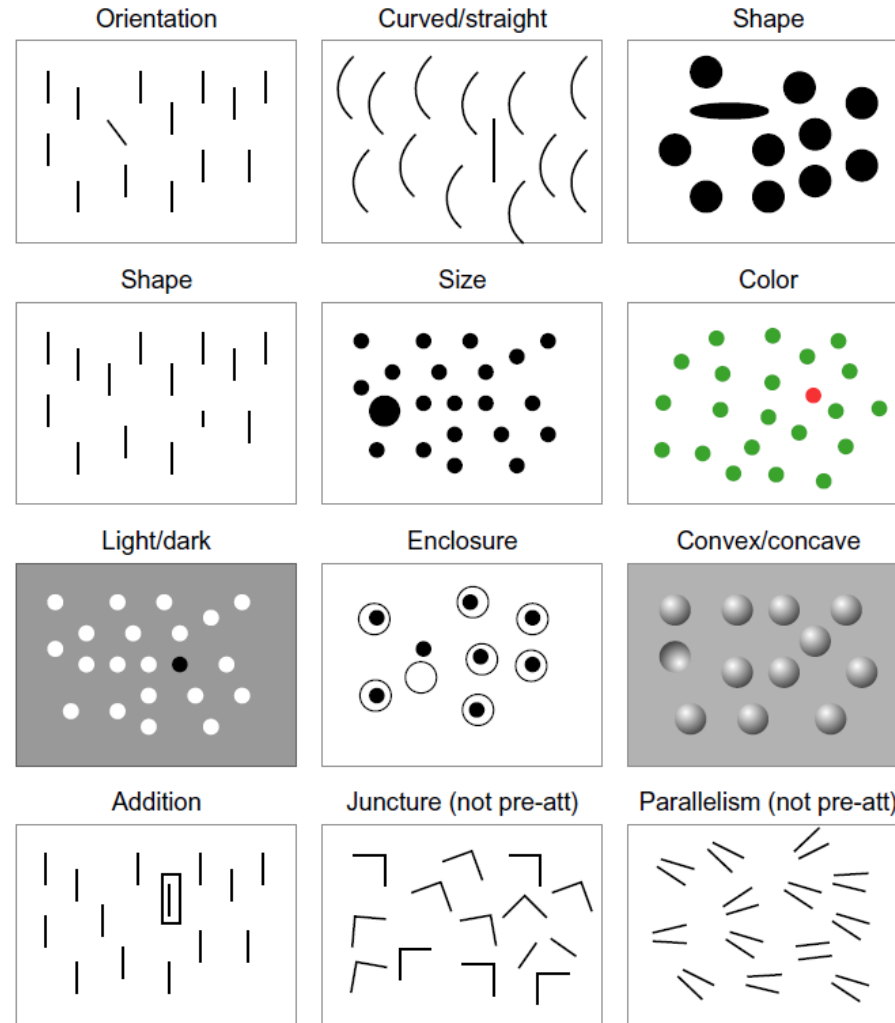


Popout

- many channels: tilt, size, shape, proximity, shadow direction, ...
- but not all! parallel line pairs do not pop out from tilted pairs



Popout

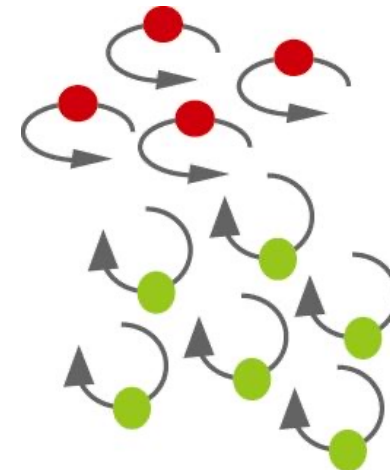
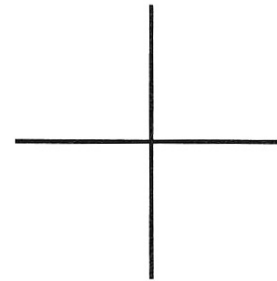
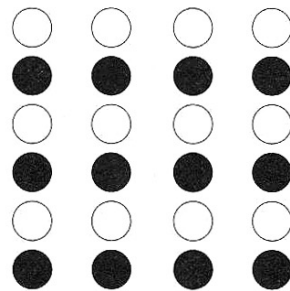
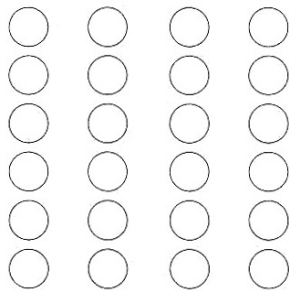


Gestalt Psychology

- Principles of perceptual organization
 - the **whole** is different from the **sum of its parts**
 - how smaller objects are grouped to form larger ones
 - "gestalt": German for "pattern/form/shape"
 - “leaving us with a set of *descriptive* principles, but without a model of perceptual processing”
 - rules themselves still very useful
- Law of Prägnanz
 - law of simplicity, law of good figure
 - fundamental principle of gestalt perception
 - tend to order our experience in a manner that is regular, orderly, symmetric, and simple
 - simplest possibility wins

How do we perceive groups

- **Proximity:** tendency of elements to be associated with nearby elements
- **Similarity:** tendency of elements to be associated with similar elements
- **Continuity:** preference for continuous, unbroken, smoothest contours with the *simplest possible physical explanation*
- **Common Fate:** things moving together



Gestalt Psychology

- containment
- connection
- proximity
 - same spatial region
- similarity
 - same values as other categorical channels

Marks as Links

➞ Containment



➞ Connection



➞ Identity Channels: Categorical Attributes

Spatial region



Color hue



Motion



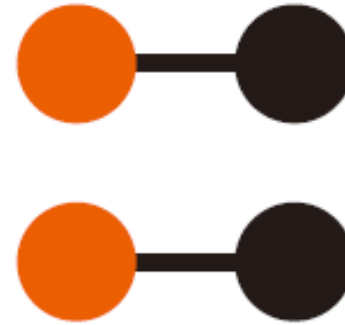
Shape



Gestalt laws - Connectedness



(a)



(b)

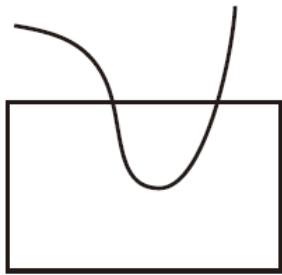


(c)

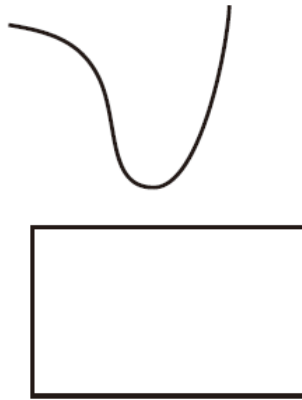


(d)

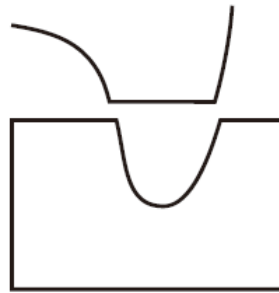
Gestalt laws - Continuity



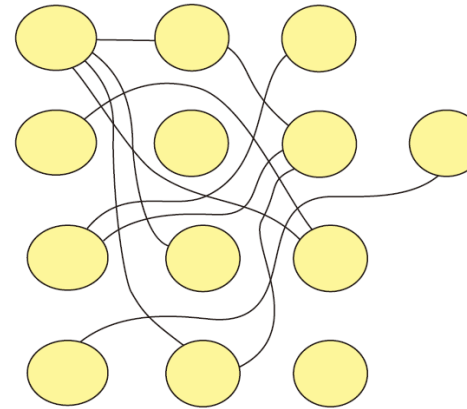
(a)



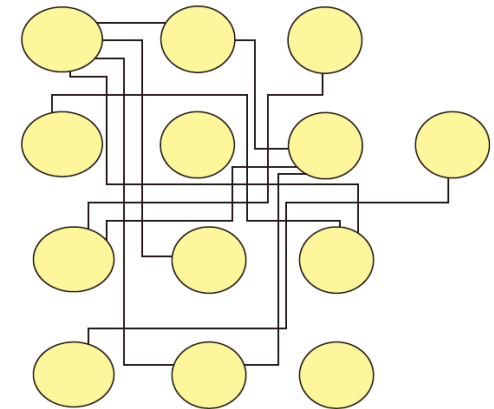
(b)



(c)

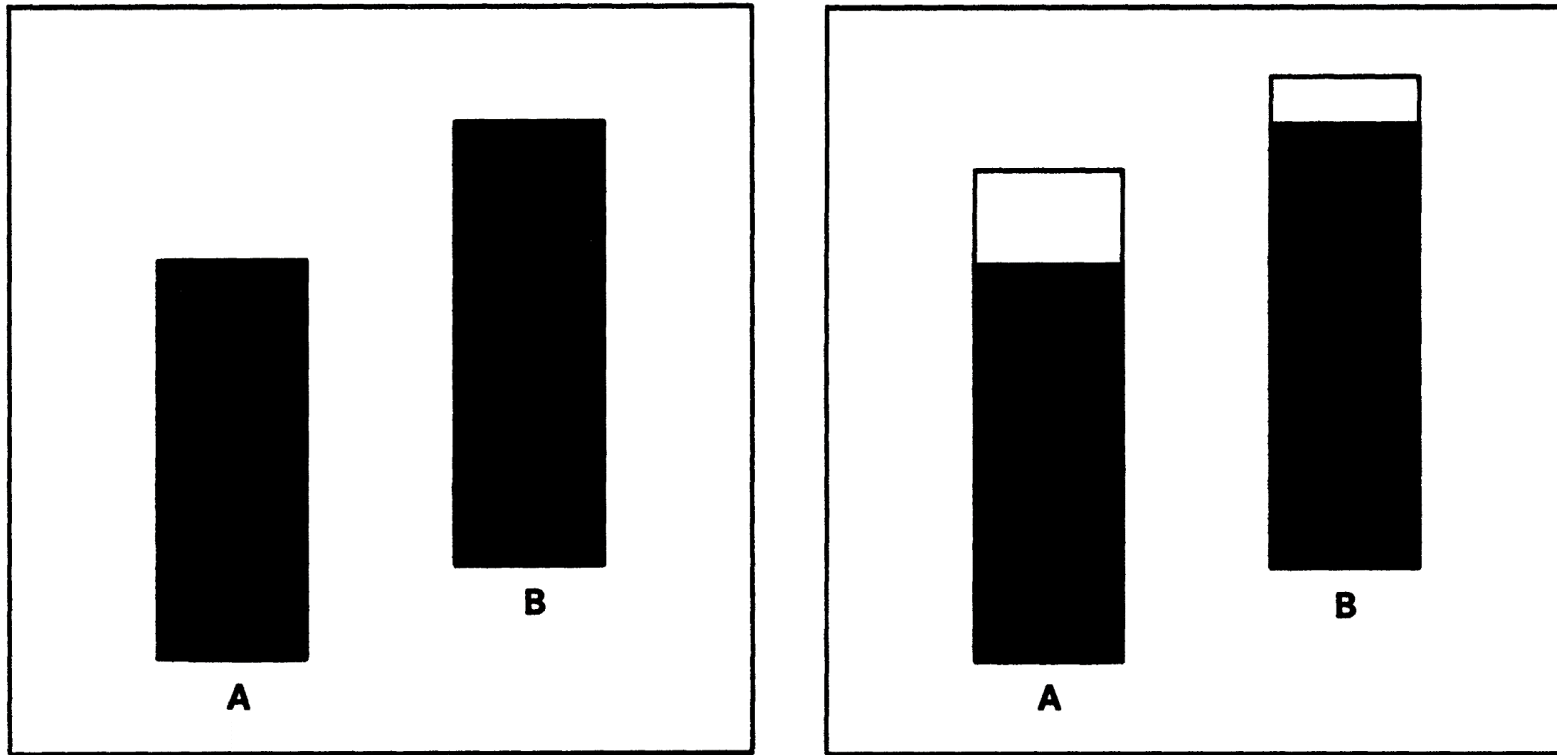


(a)



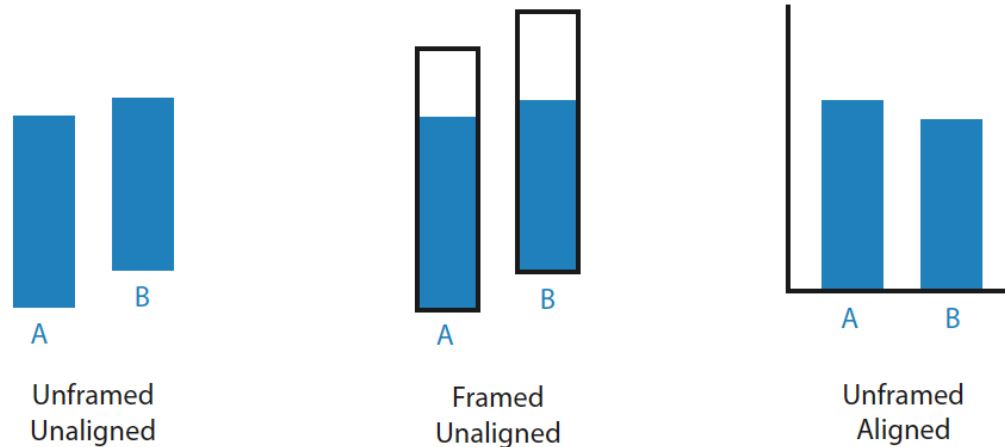
(b)

Which is Longer?



Weber's Law

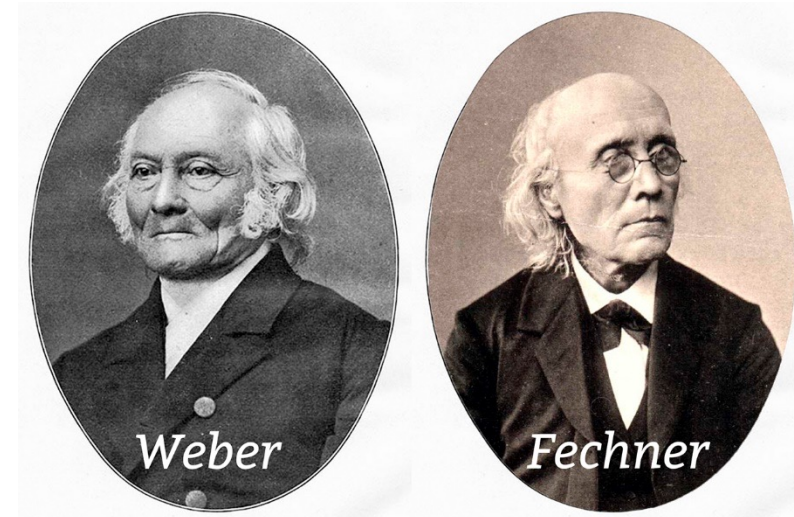
- Perceptual system mostly operates with **relative** judgements, **not absolute**
 - that's why accuracy increases with common frame/scale and alignment
- Weber's Law: the **perceived change** in stimuli is proportional to the **initial stimuli**
 - ratio of increment to background is constant $\frac{(JND)dS}{S} = \text{constant}$
 - filled rectangles are long and differ in length by 15% → difficult judgement
 - white rectangles are show and differ in length by 50% → easy judgement



after [Graphical Perception: Theory, Experimentation, and Application to the Development of Graphical Methods. Cleveland and McGill. Journ. American Statistical Association 79:387 (1984), 531–554.]

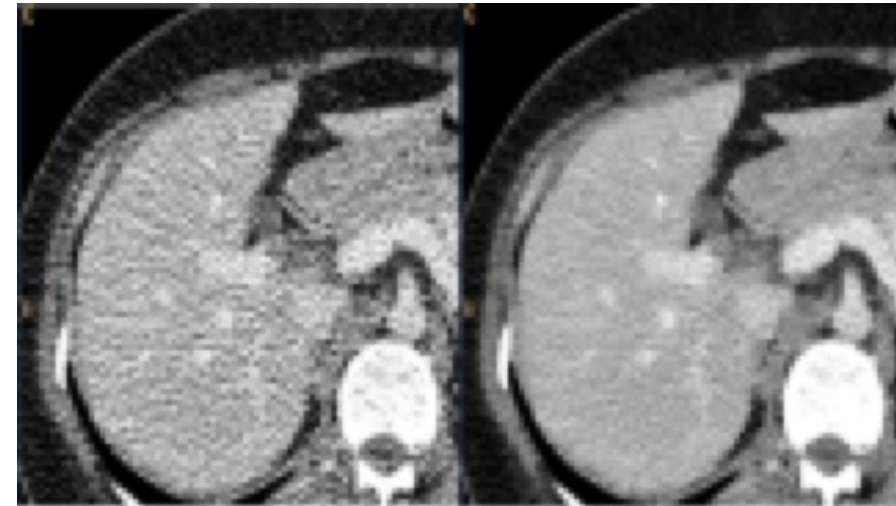
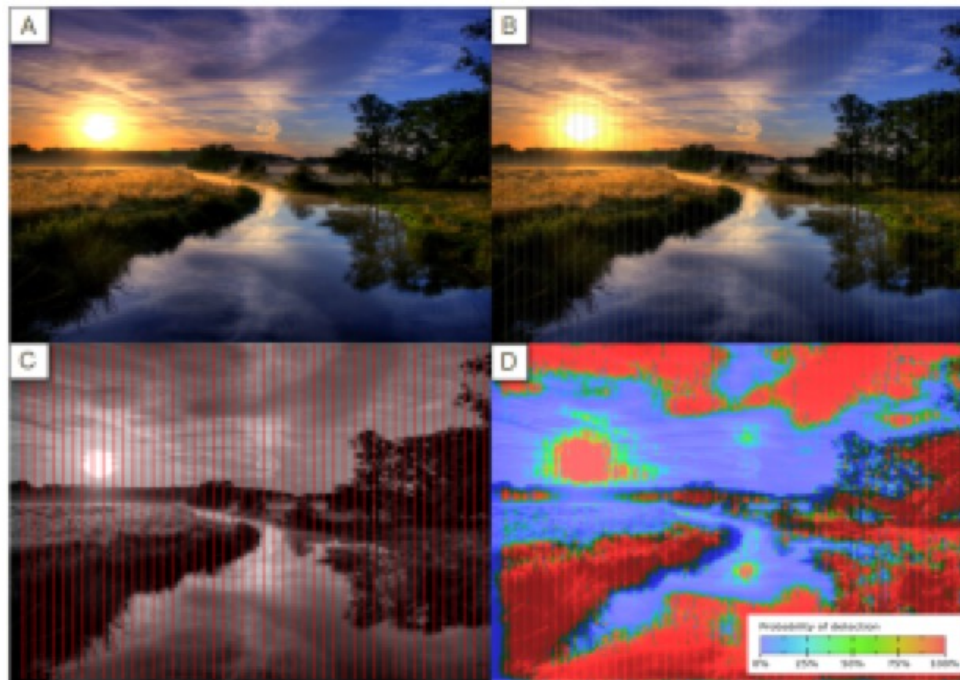
Weber-Fechner's Law

- $\frac{\delta I}{I} = K$, where I is a stimulus intensity and K is a fixed percentage
- **perceived change** in stimuli is proportional to **initial stimuli**
- **detectable difference** in stimulus intensity I as a fixed percentage K of the object magnitude
- *JND*: just noticeable difference



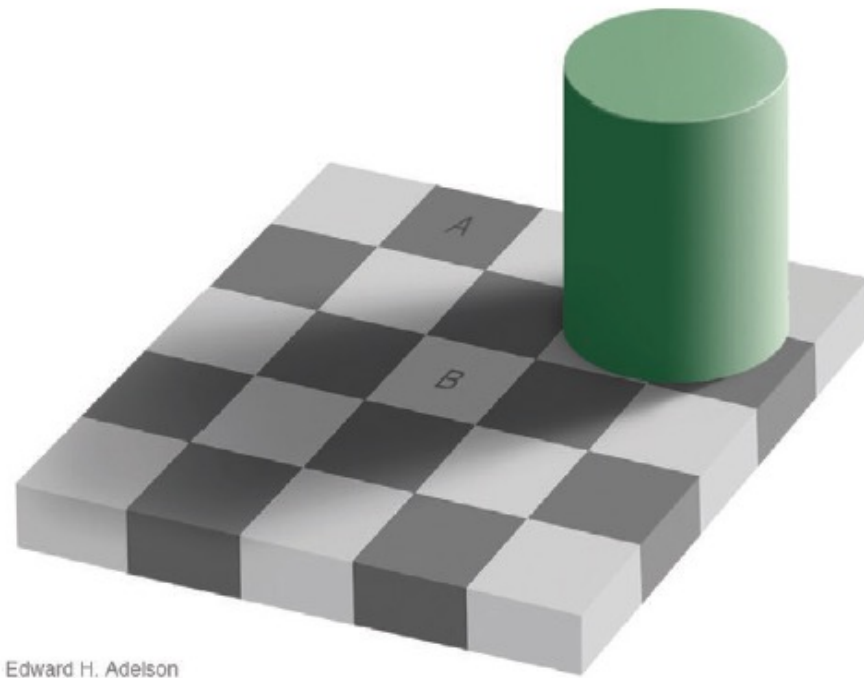
JND and Visual Perception

- Contrast sensitivity function
 - Sensitivity of Visual Perception depends on frequency



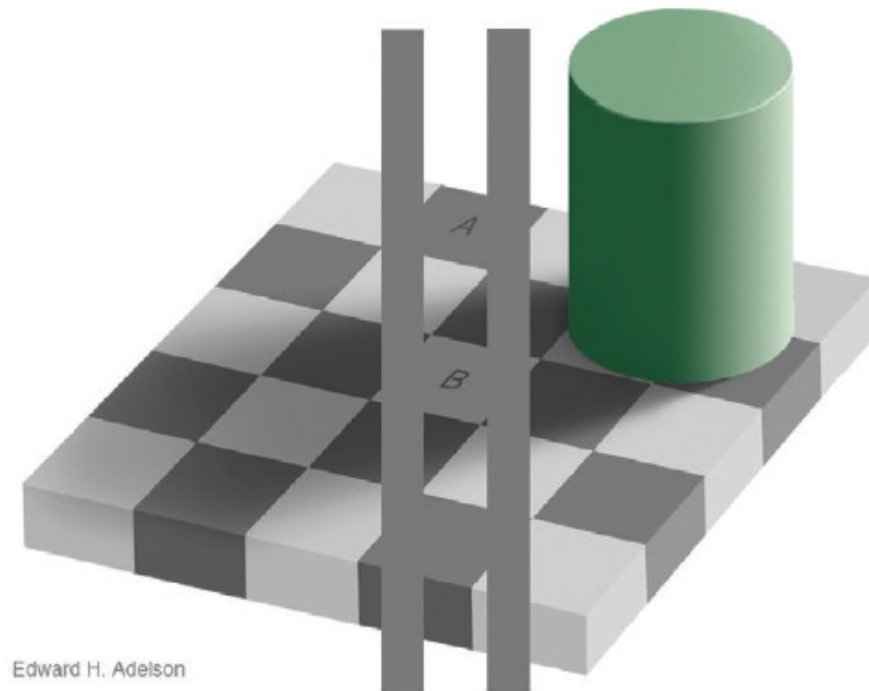
Luminance contrast – Simultaneous Brightness Contrast

- Perception of color and luminance is contextual
- Luminance perception is based on relative judgements



Edward H. Adelson

(a)

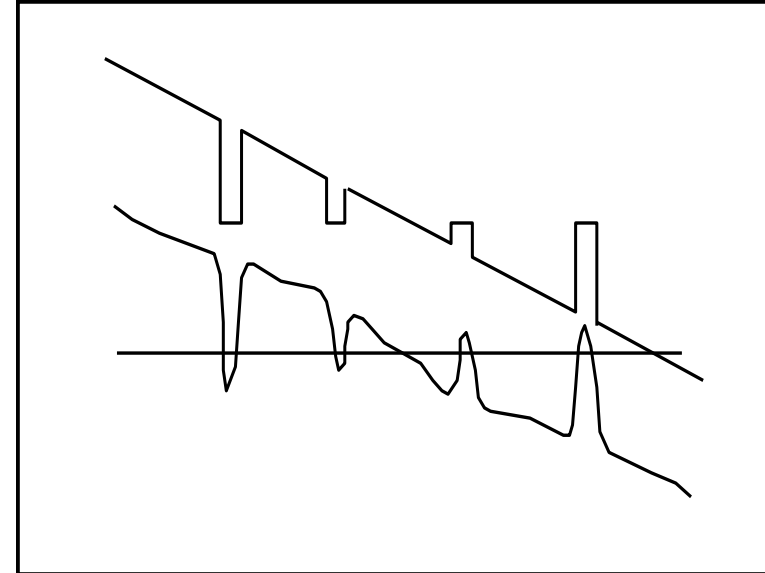
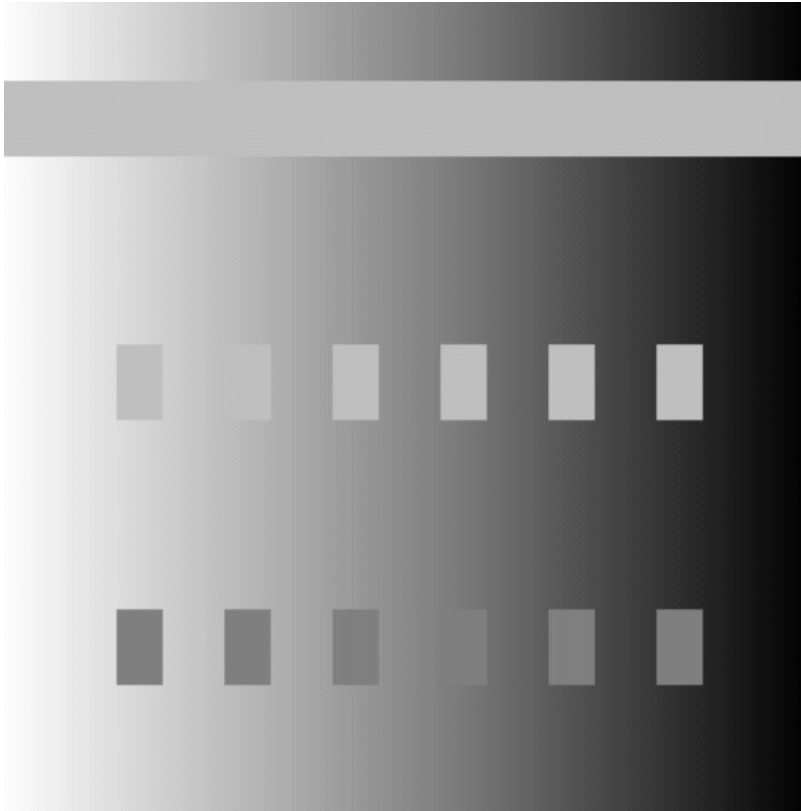


Edward H. Adelson

(b)

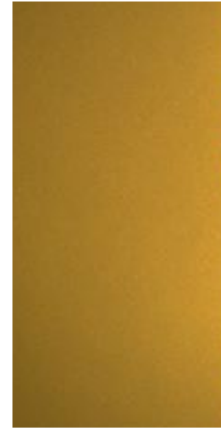
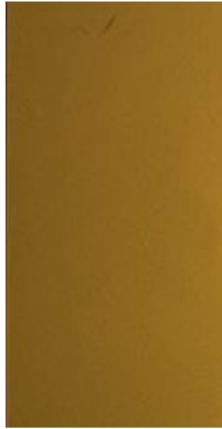
Luminance contrast – Simultaneous Brightness Contrast

- Luminance perception is based on relative judgements



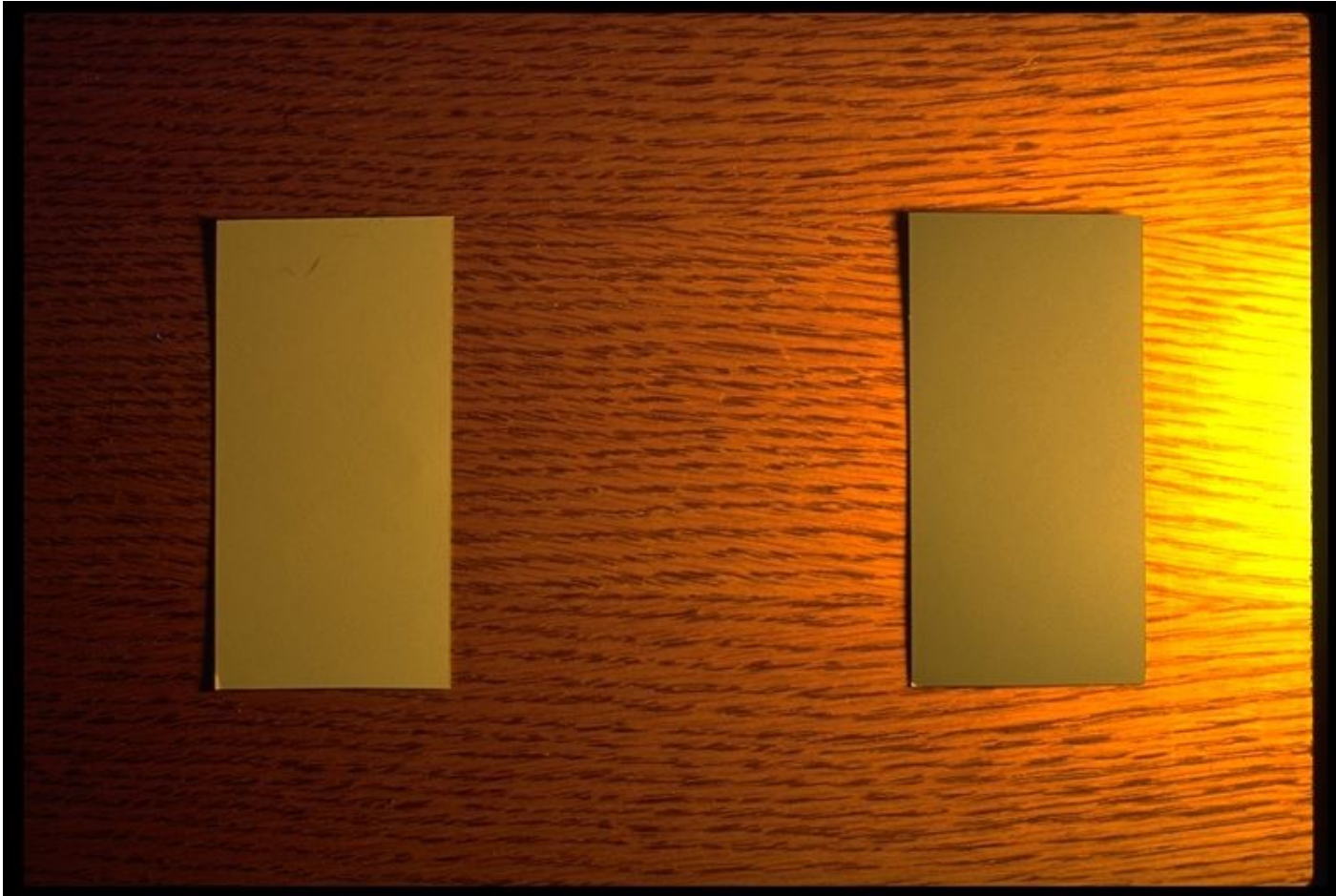
Contrast for constancy

- Does Mild gray paper reflect about the same amount of light as the white paper?



Contrast for constancy

- Does Mild gray paper reflect about the same amount of light as the white paper?



Illumination Discounted

- In bright sunlight or moonlight, we can tell whether a surface is black, white, or gray
- Luminance is **completely unrelated** to perceived lightness (or brightness)
 - black paper in full sunlight – 1000 candelas
 - white paper in an office – 50 candelas
- Visual system extracts surface information
- Discounts illumination level
- Discounts color of illumination
- Mechanisms
 - Adaptation (photopigments in the receptors – bleach/regenerate)
 - Simultaneous brightness contrast (background considered)

Note

- Questions?

References

- Crowdsourcing Graphical Perception: Using Mechanical Turk to Assess Visualization Design. Heer and Bostock. Proc ACM Conf. Human Factors in Computing Systems (CHI) 2010, p. 203–212.
- Automating the Design of Graphical Presentations of Relational Information. Mackinlay. ACM Trans. on Graphics (TOG) 5:2 (1986), 110–141.
- Graphical Perception: Theory, Experimentation and the Application to the Development of Graphical Models. William S. Cleveland, Robert McGill, J. Am. Stat. Assoc. 79:387, pp. 531-554, 1984.
- Many slides from Tamara Munzner's slide deck
- Many figures from Main Textbook by Tamara Munzner