# Visual Variables

SWEN422
Human Computer Interaction
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# Visual Variables

- What are visual variables?
- Why do they matter?

Sheelagh Carpendale. **Considering Visual Variables as a Basis for Information Visualisation**.
Research report 2001-693-16, Department of Computer science, University of Calgary, Calgary, AB, Canada, 2003.

- Based on Bertin's visual variables, 1967.

# How Do We Visualize?

- **Know** the Data:
  - Number of attributes
  - Weather: *date/time, temperature, precipitation, humidity, wind, forecast, pressure, cloud cover.*
  - Real Estate: *price, location, square feet, lot size, floors, # bathrooms, # bedrooms, etc.*
- Decide how to **visually encode** the data
  - Requires awareness of:
    - Human perceptual system
    - Display capacity
    - Characteristics of data (size, type)
    - Task

# Visual Encoding - Data

Data Types:

- Categorical

- Ordered
  - Ordinal
  - Quantitative

Small Medium Large

1 2 5.29 42 101

# Visual Encoding

## Visual Channels:

- *Position*
- *Angle*
- *Slope*
- *Length*
- *Area*
- *Volume*
- *Shape*

Size

- *Lightness*
- *Saturation*
- *Hue*

Colour

- *Texture*
- *Connection*
- *Containment*

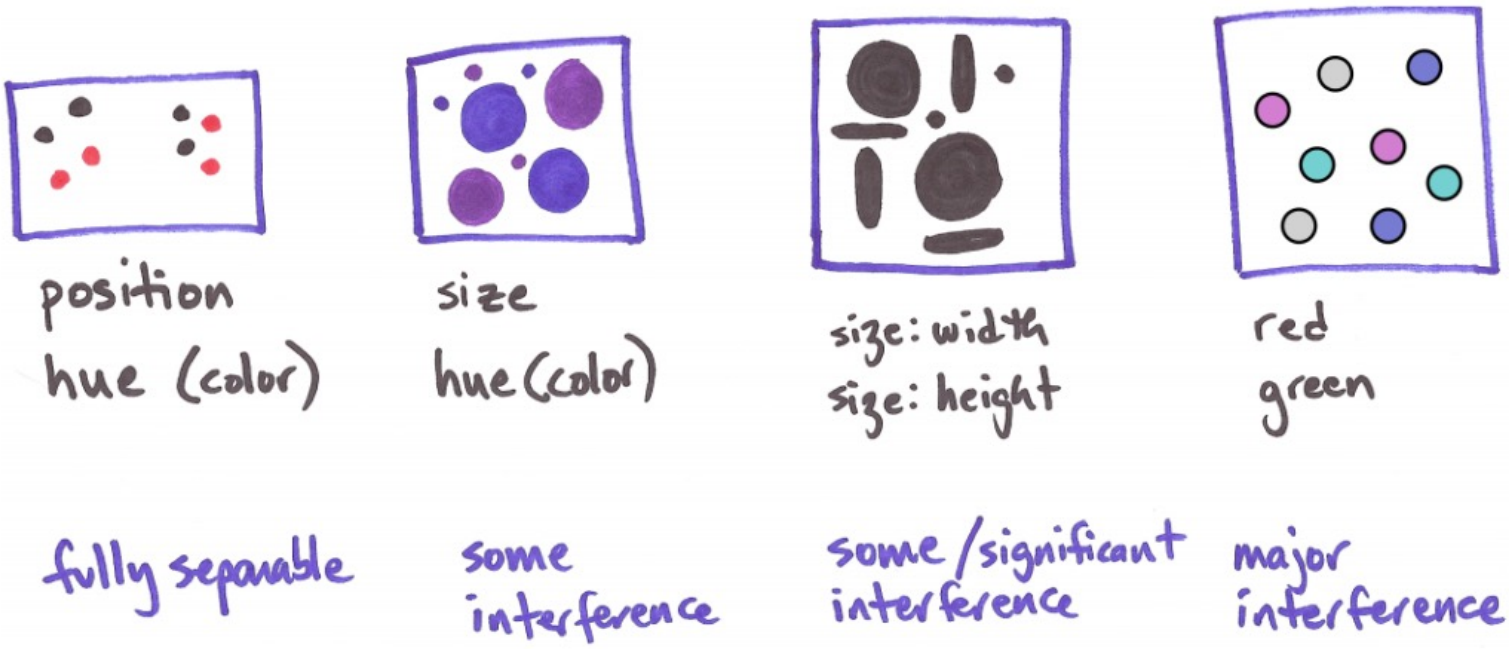
Independent?

?

- *Opacity*
- *“Sketchiness”*

# Visual Encoding

- How well can we judge a channel's magnitude
- Are differences perceivable?
- How many bins?
- Ideally all channels would be independent (not so)
  - Interactions between channels



# Visual Variable **Properties**

1. **Selective**

2. **Associative**

3. **Quantitative**

4. **Order**

5. **Length**

# Visual Variable Properties

1. **Selective**
   - Is a change of a mark in this variable alone enough to allow us to select it from other marks?
2. **Associative**
3. **Quantitative**
4. **Order**
5. **Length**

# Is **Visual Channel** ***Size*** Selective?

Can you find the big & small Muppets?

# Is **Visual Channel** ***Size*** Selective?

Can you find the big & small Muppets?

# Visual Variable Properties

1. **Selective**
   - Is a change of a mark in this variable alone enough to allow us to select it from other marks?
2. **Associative**
   - Can we identify a group of marks by this variable?
3. **Quantitative**
4. **Order**
5. **Length**

# Is **Visual Channel** ***Size*** Associative?

Can you find the small Muppets?

# Is **Visual Channel** ***Size*** Associative?

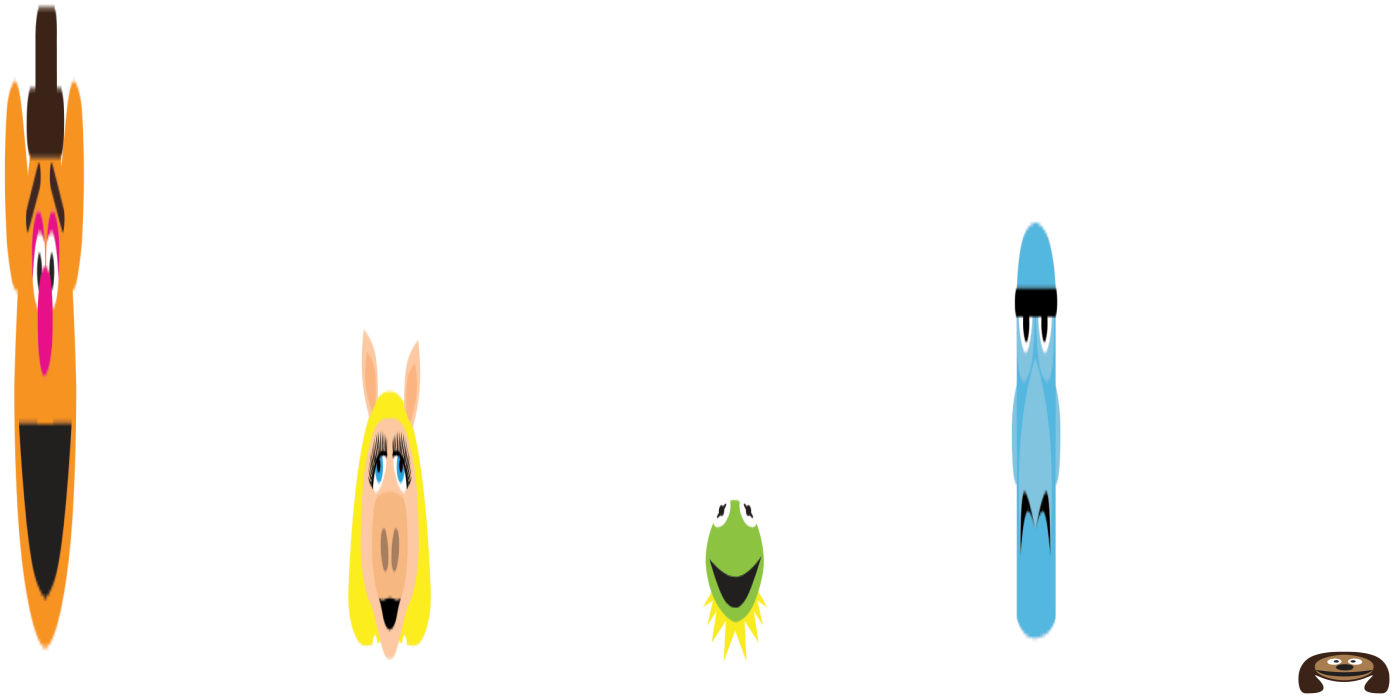
Can you find the small Muppets?

# Visual Variable Properties

1. **Selective**
   - Is a change of a mark in this variable alone enough to allow us to select it from other marks?
2. **Associative**
   - Can we identify a group of marks in this variable?
3. **Quantitative**
   - Can the relation between two of these marks be seen as numeric? Can we tell if one is 3X another?
4. **Order**
5. **Length**

# Is **Visual Channel** ***Size*** Quantitative?

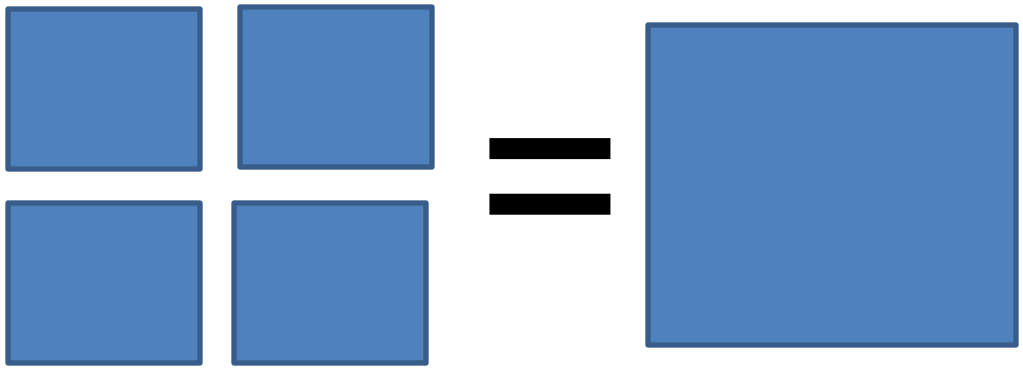
What value is Kermit compared to Fozzie?

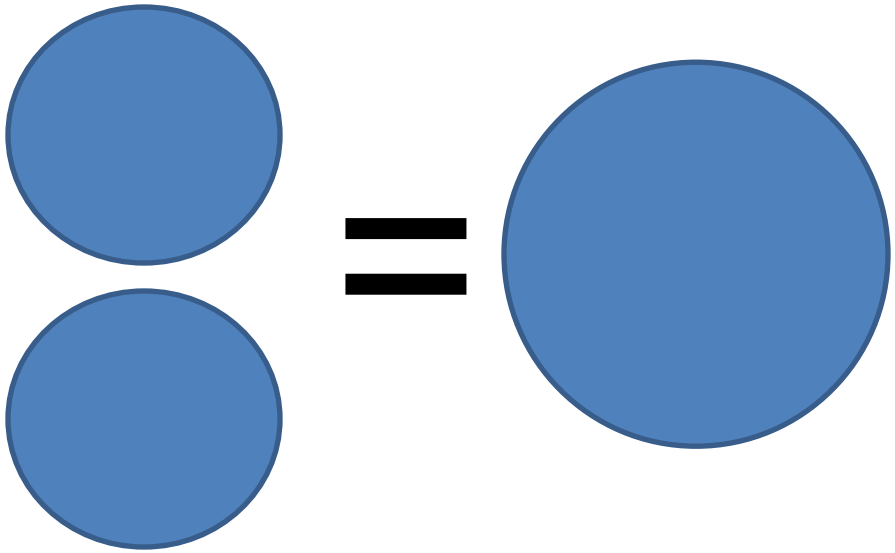


# Is **Visual Channel** ***Size*** Quantitative?

What value is Kermit compared to Fozzy?

# Is **Visual Channel** ***Size*** Quantitative?





# Visual Variable Properties

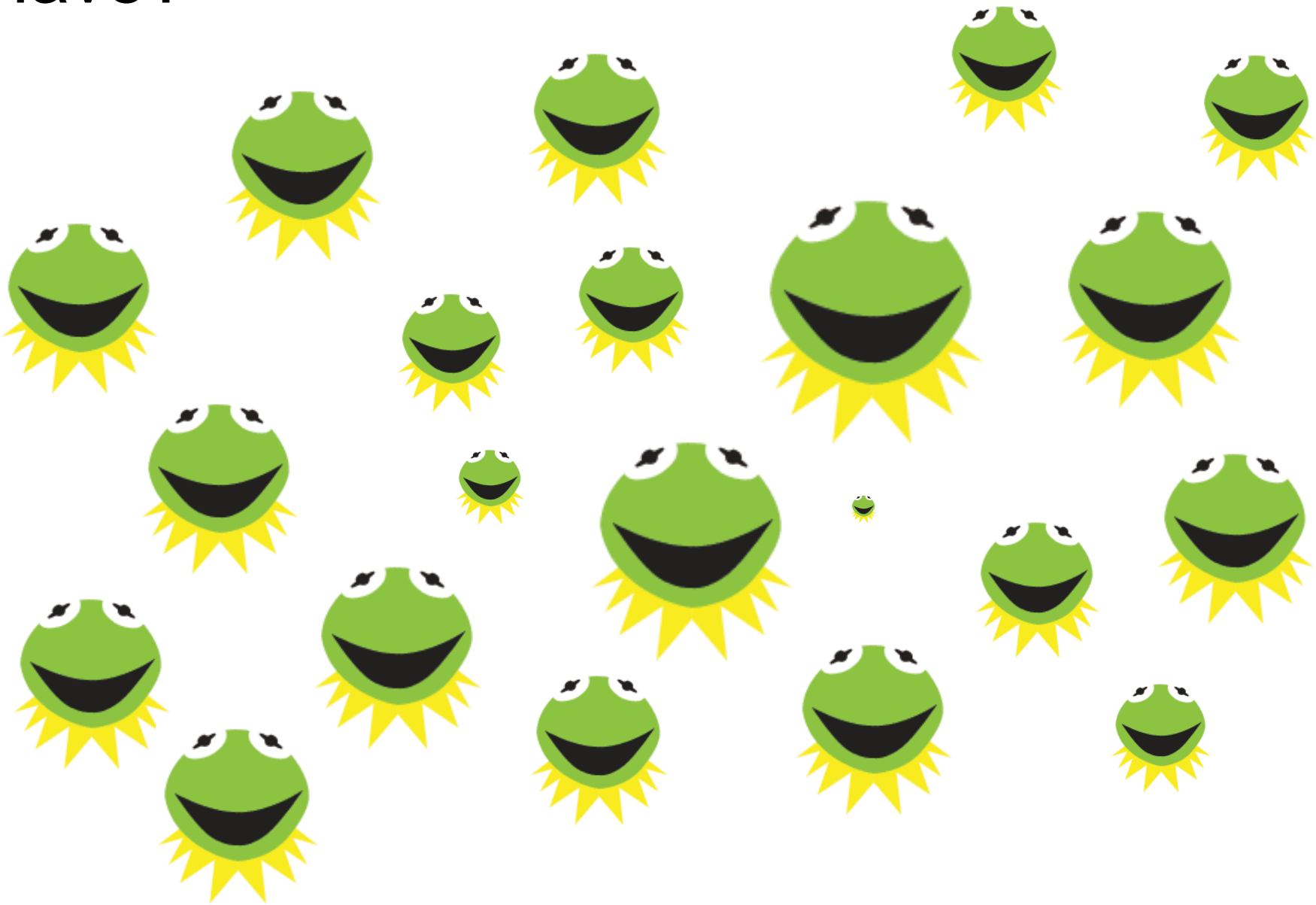
1. **Selective**
   - Is a change of a mark in this variable alone enough to allow us to select it from other marks?
2. **Associative**
   - Can we identify a group of marks in this variable?
3. **Quantitative**
   - Can the relation between two of these marks be seen as numeric? Can we tell if one is 3X another?
4. **Order**
   - Does this variable support ordered reading (more/less)?
5. **Length**

# Is **Visual Chanel** ***Size*** Ordered?

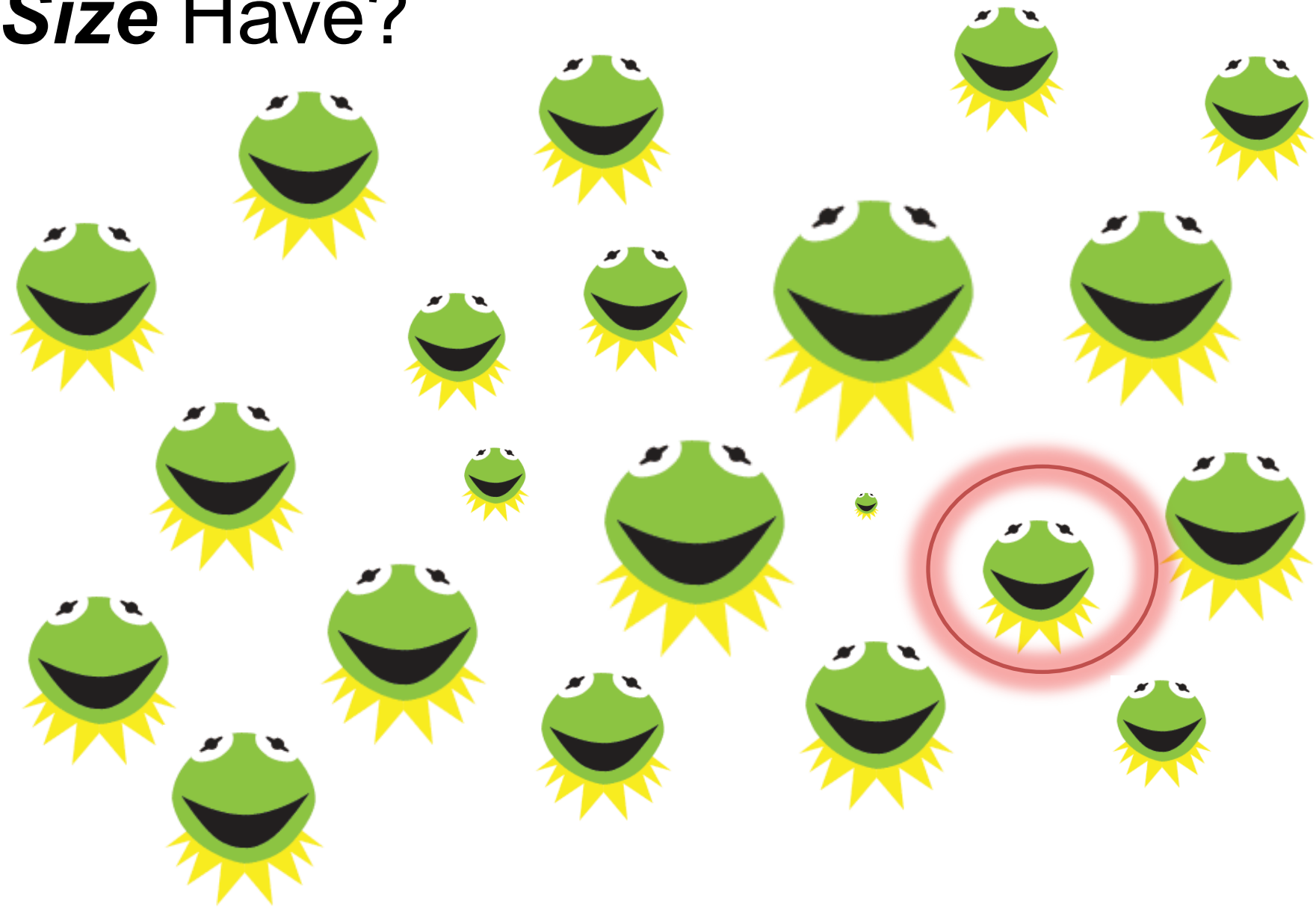
# Visual Variable Properties

1. **Selective**
   - Is a change of a mark in this variable alone enough to allow us to select it from other marks?
2. **Associative**
   - Can we identify a group of marks in this variable?
3. **Quantitative**
   - Can the relation between two of these marks be seen as numeric? Can we tell if one is 3X another?
4. **Order**
   - Does this variable support ordered reading (more/less)?
5. **Length**
   - How many differences in this variable can be discerned?

# What Length Does **Visual Chanel** ***Size*** Have?

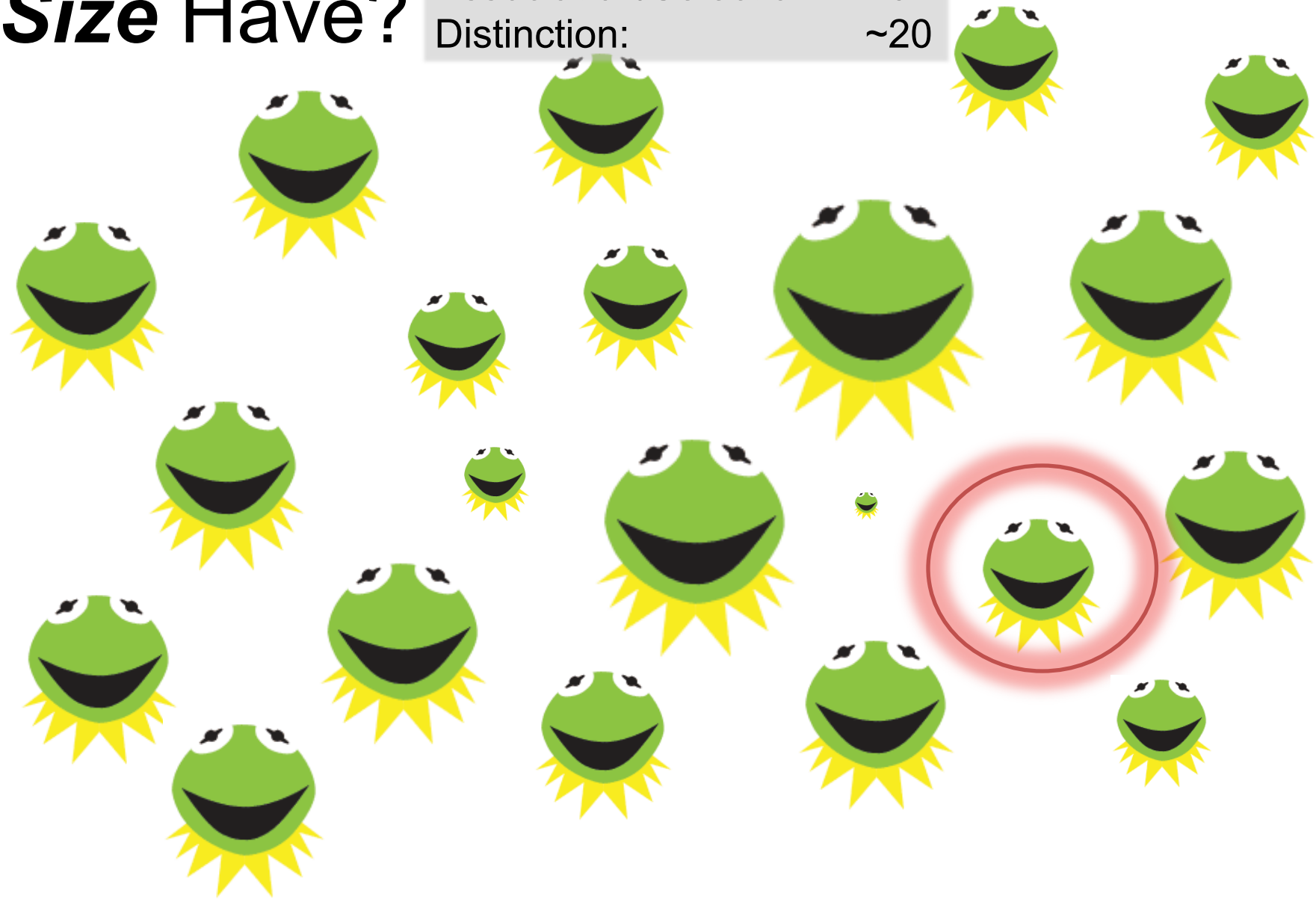


# What Length Does **Visual Chanel** ***Size*** Have?



# What Length Does **Visual Chanel** ***Size*** Have?

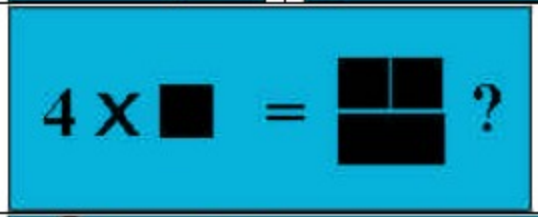
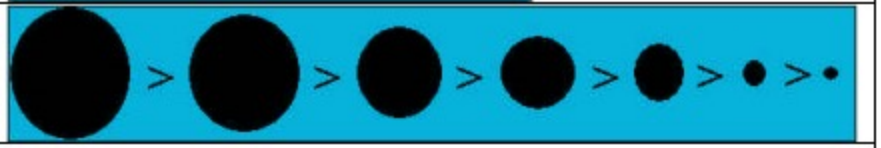
Association/Selection: ~5
Distinction: ~20



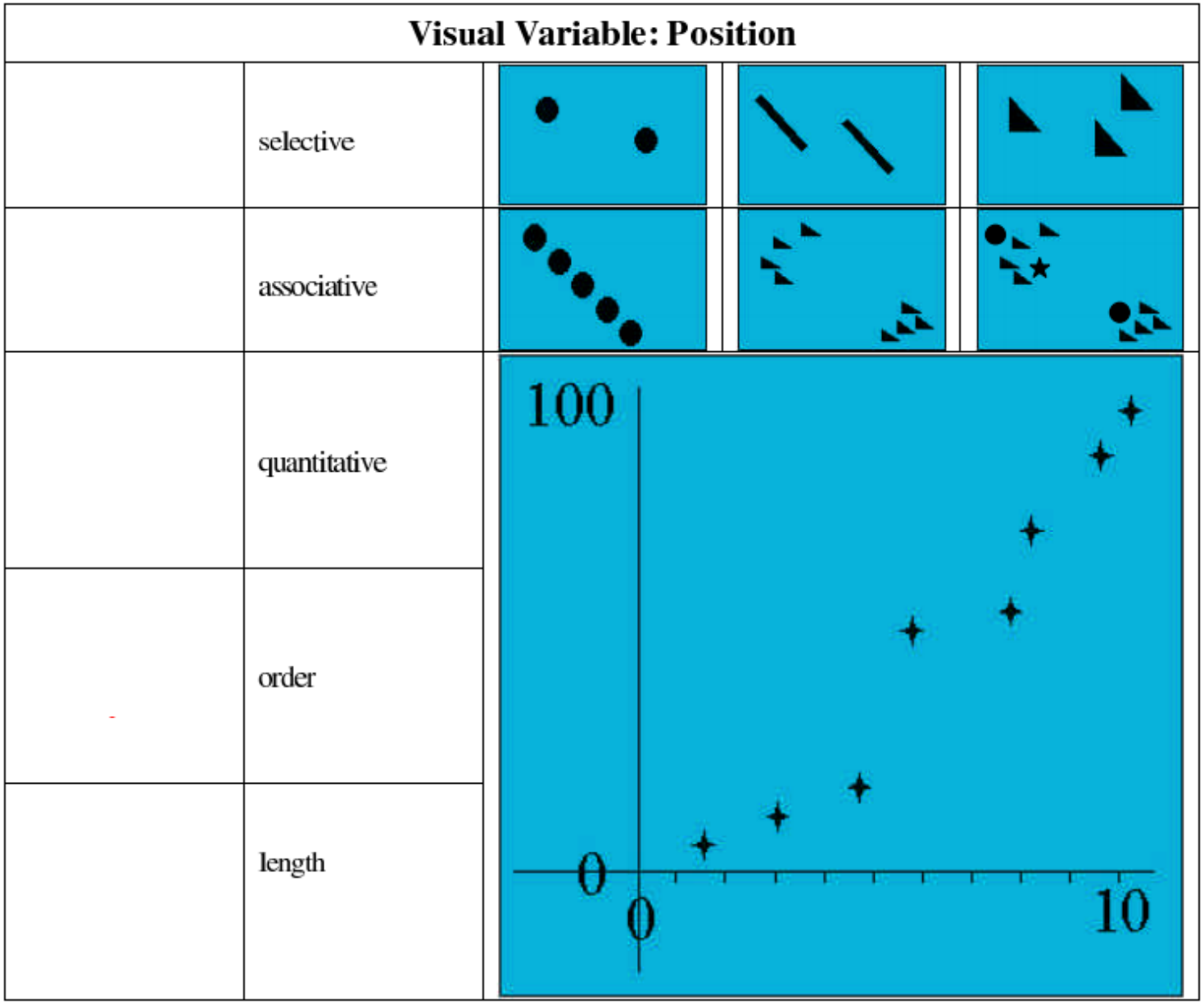
# Visual Variable Properties

1. **Selective**
   - Is a change in this variable alone enough to allow us to select it from a group?
2. **Associative**
   - Can we identify a group of these marks?
3. **Quantitative**
   - Can the relation between two of these marks be seen as numeric? Can we tell if one is 3X as much as another?
4. **Order**
   - Does this variable support ordered reading (more/less)?
5. **Length**
   - How many differences in this variable can be discerned?

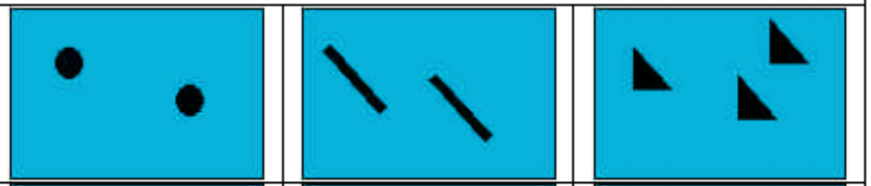
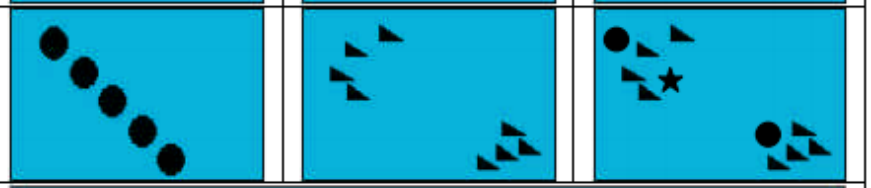
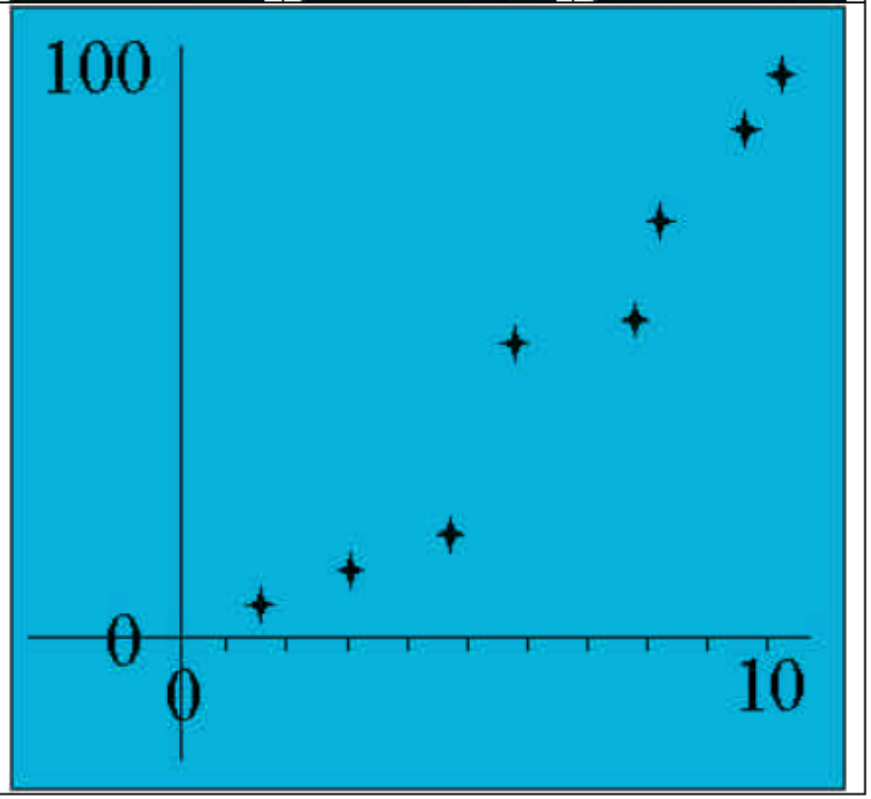
# Channel Properties: Size

| Visual Variable: Size | | |
|---|---|---|
| ✓ | selective |  |
| ✓ | associative |  |
| ≃ | quantitative |   |
| ✓ | order |   |
| ✓ | Length | • theoretically infinite but practically limited<br>• association and selection ~ 5 and distinction ~ 20 |

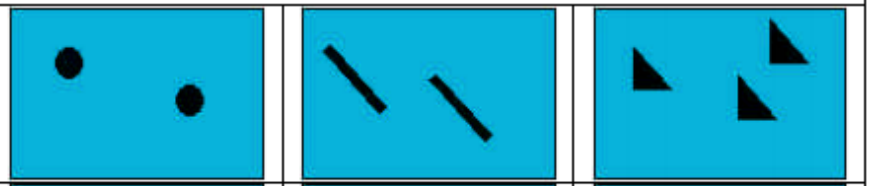
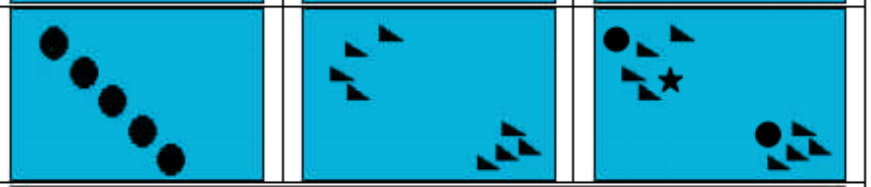
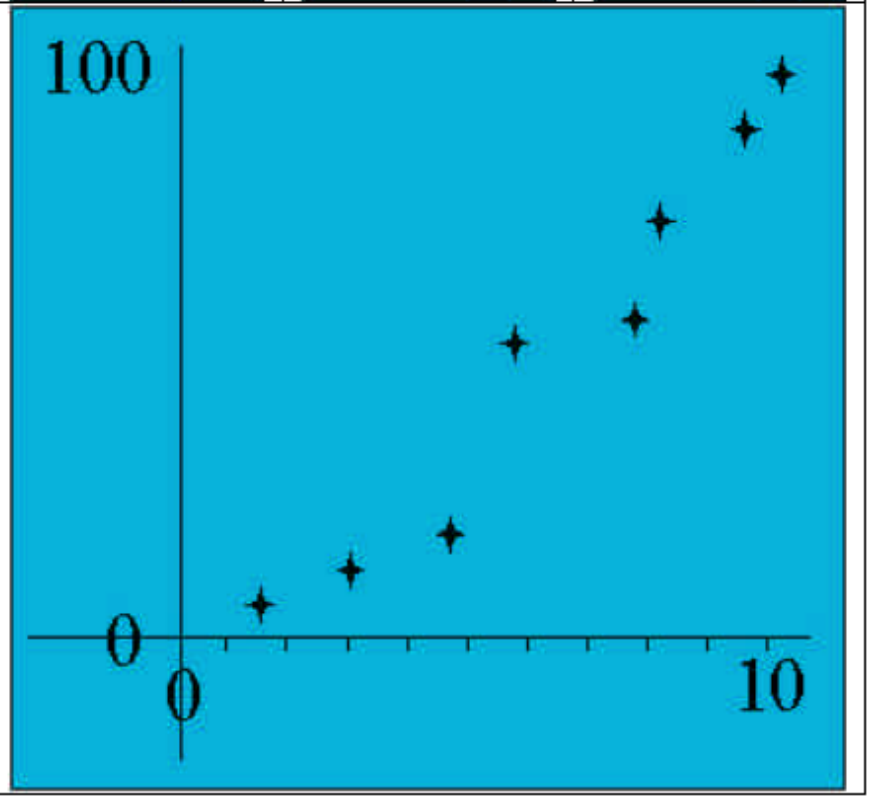
# Channel Properties: Position



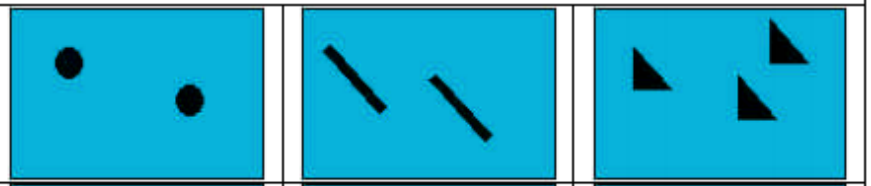
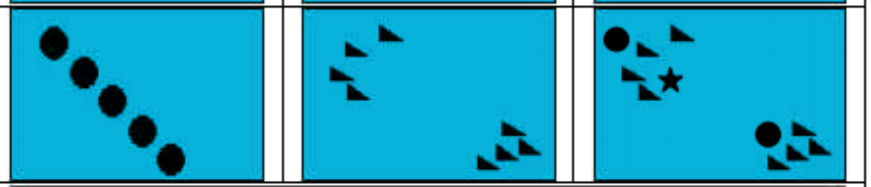
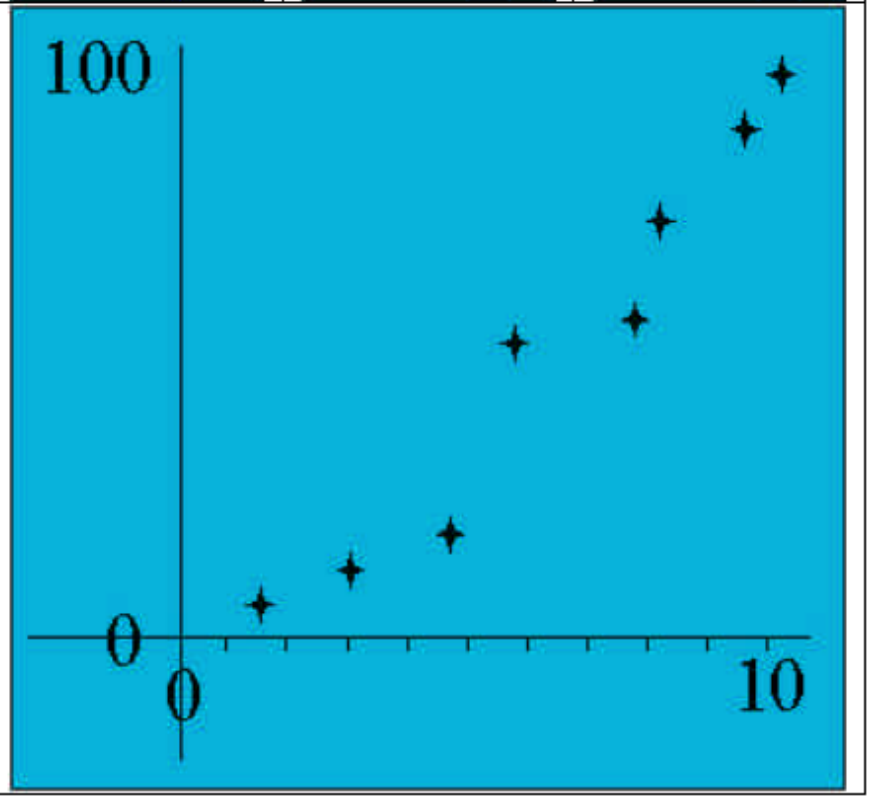
# Channel Properties: Position

| Visual Variable: Position | | |
|---|---|---|
| ✓ | selective |  |
| | associative |  |
| | quantitative |   |
| | order | |
| | length | |

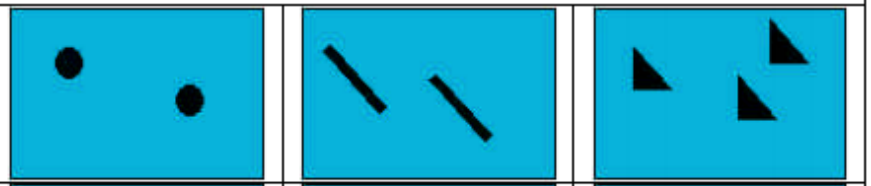
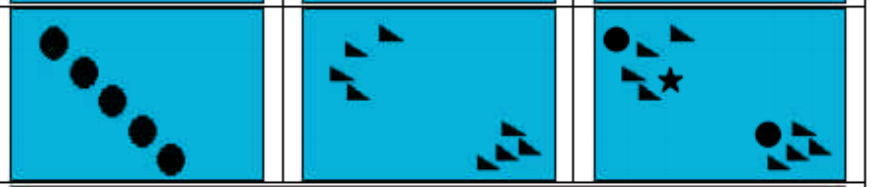
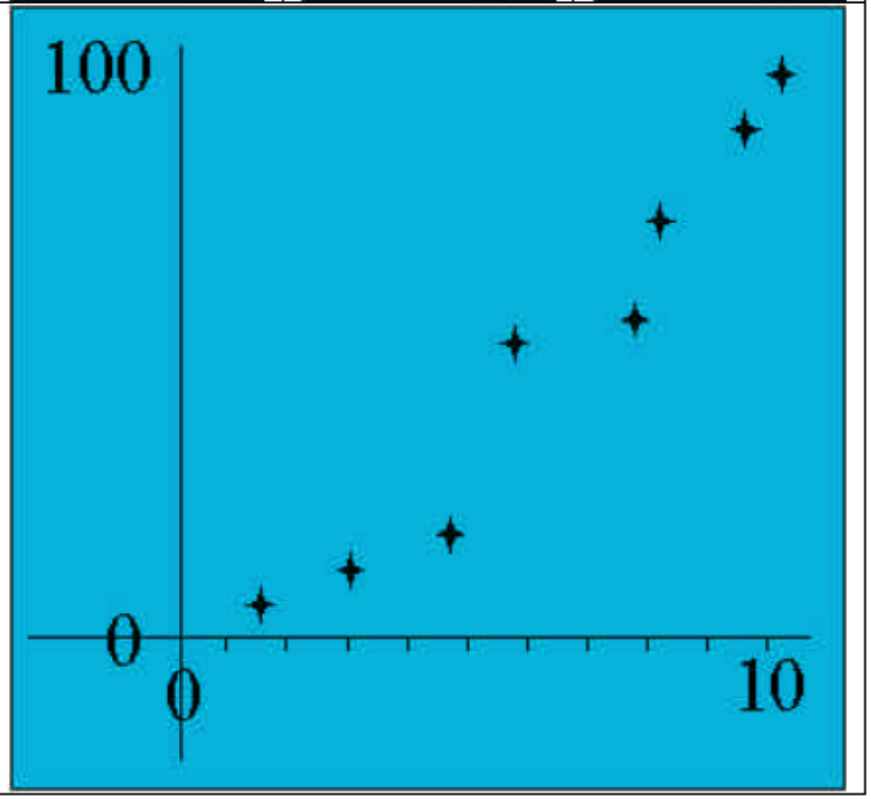
# Channel Properties: Position

| Visual Variable: Position | | |
|---|---|---|
| ✓ | selective |  |
| ✓ | associative |  |
| | quantitative |   |
| | order | |
| | length | |

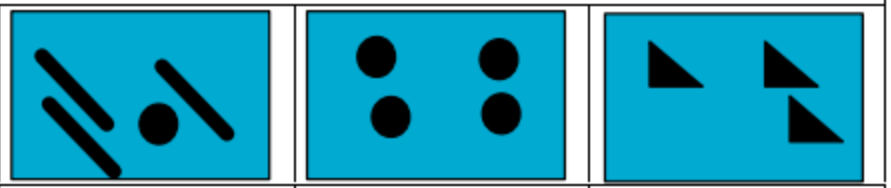
# Channel Properties: Position

| Visual Variable: Position | | |
|---|---|---|
| ✓ | selective |  |
| ✓ | associative |  |
| ✓ | quantitative |   |
| | order | |
| | length | |

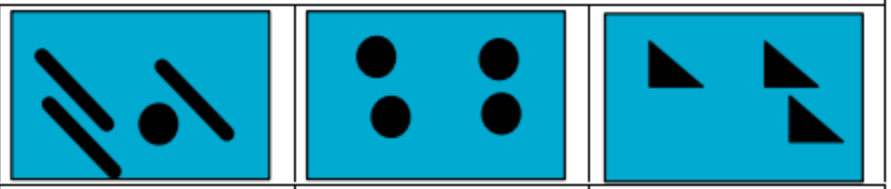
# Channel Properties: Position

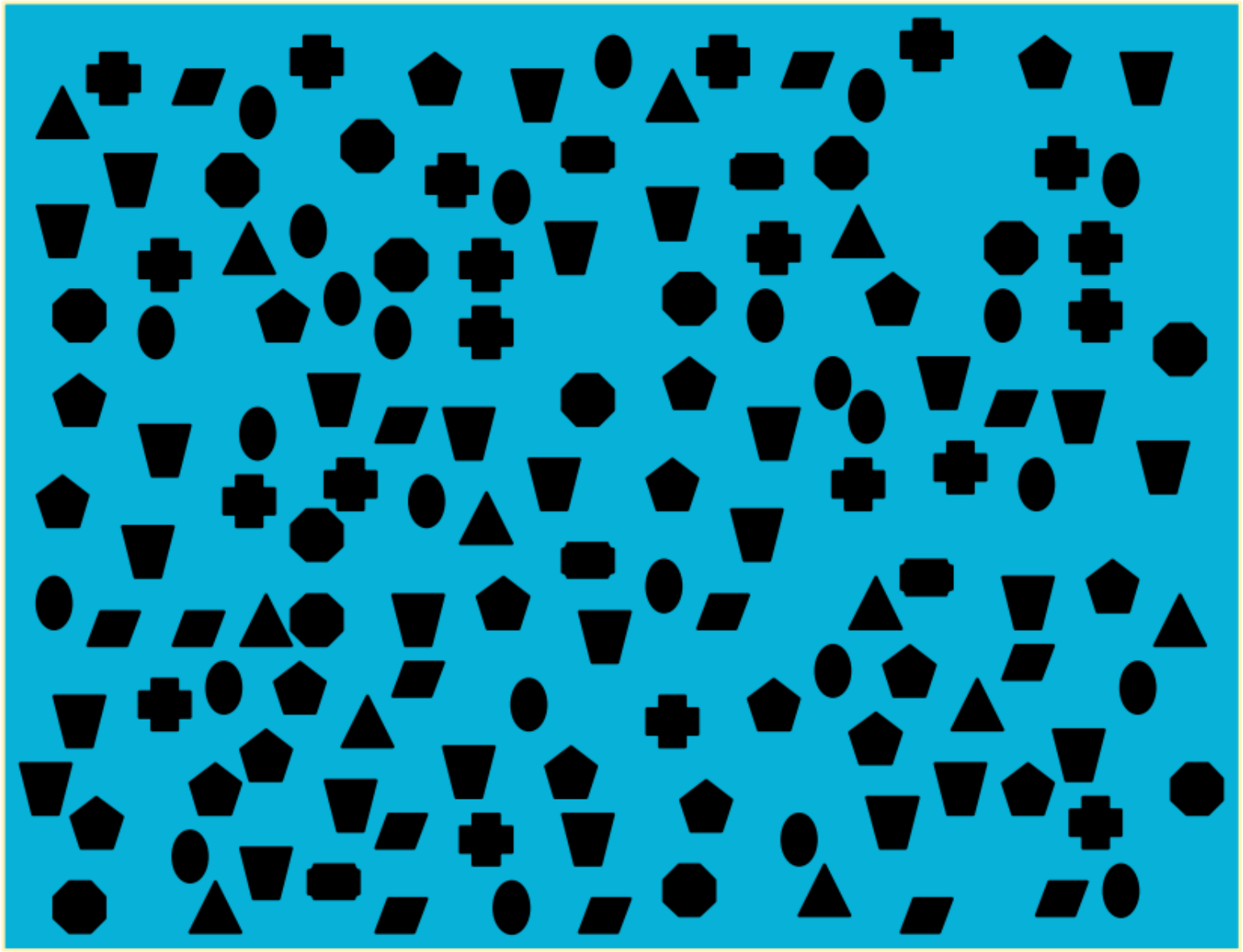
| Visual Variable: Position | | |
|---|---|---|
| ✓ | selective |  |
| ✓ | associative |  |
| ✓ | quantitative |   |
| ✓ | order | |
| ✓ | length | |

# Channel Properties: Shape

| Visual Variable: Shape | | |
|---|---|---|
| | selective |  |
| | associative |  |
| | quantitative | |
| | order |  |
| | length | |

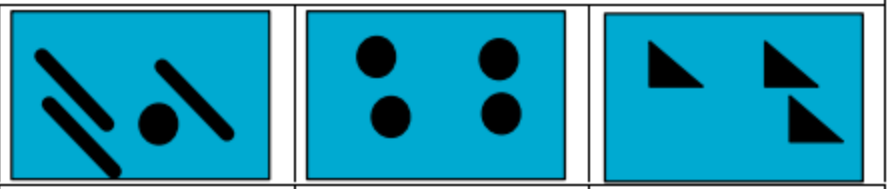
# Channel Properties: Shape

| Visual Variable: Shape | | |
|---|---|---|
| ≈ | selective |  |
| ≈ | associative |  |
| | quantitative | |
| | order |  |
| | length | |

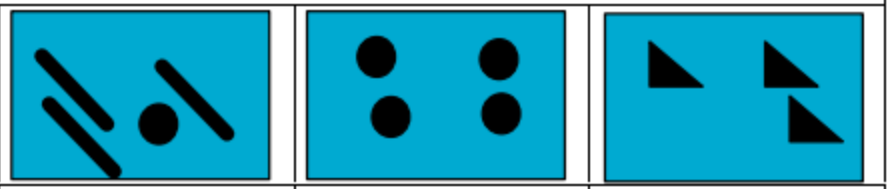


Associative – group this shape

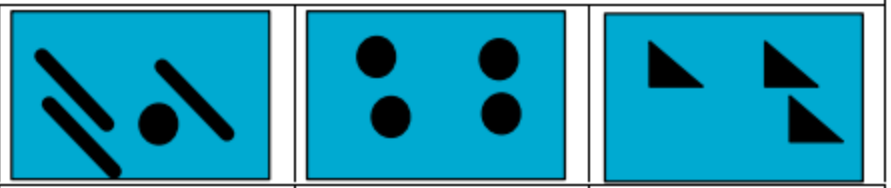
# Channel Properties: Shape

| Visual Variable: Shape | | |
|---|---|---|
| ≈ | selective |  |
| ≈ | associative |  |
| | quantitative | |
| | order |  |
| | length | |

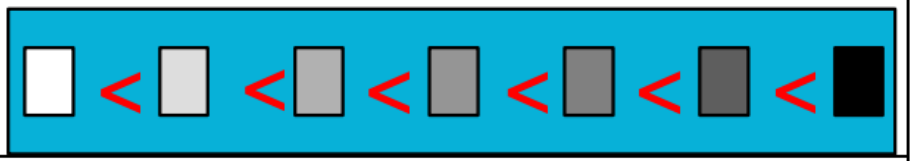
# Channel Properties: Shape

| Visual Variable: Shape | | |
|---|---|---|
| ≠ ≃ | selective |  |
| ≠ ≃ | associative |  |
| ≠ | quantitative | |
| ≠ | order |  |
| | length | |

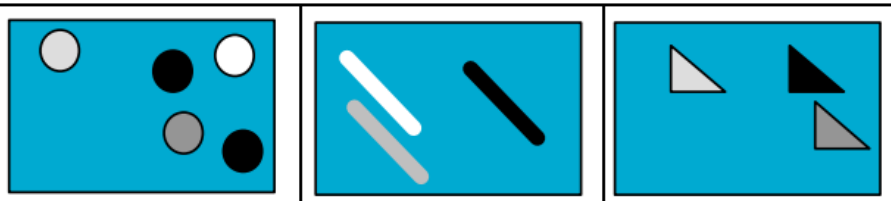
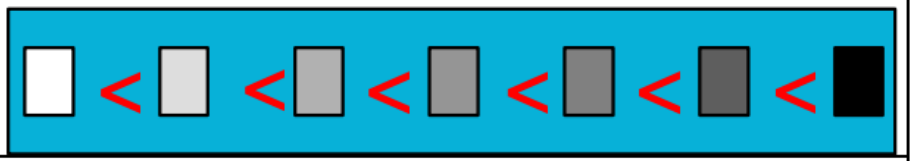
# Channel Properties: Shape

| Visual Variable: Shape | | |
|---|---|---|
| ≁ | selective |  |
| ≁ | associative |  |
| ≠ | quantitative | |
| ≮ | order |  |
| ✓ | length |  theoretically infinite |

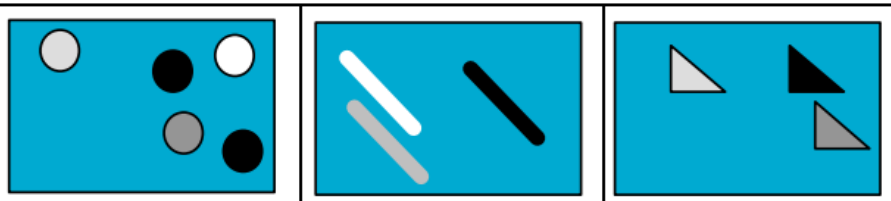
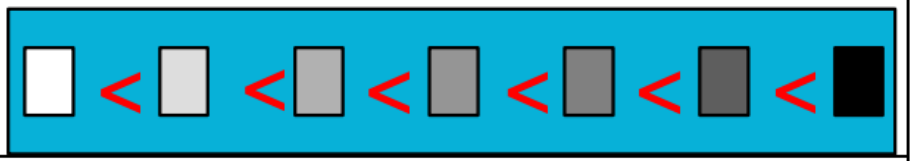
# Channel Properties: Lightness

| Visual Variable: Lightness | | |
|---|---|---|
| | selective |  |
| | associative |  |
| | quantitative | |
| | order |  |
| | length | |

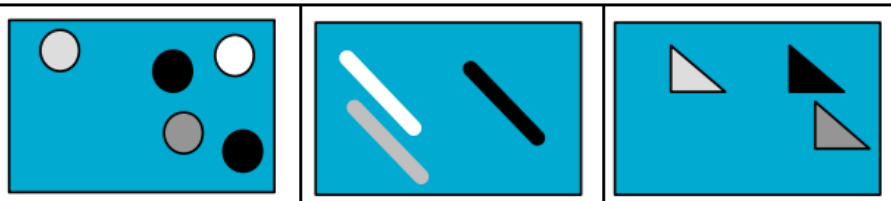
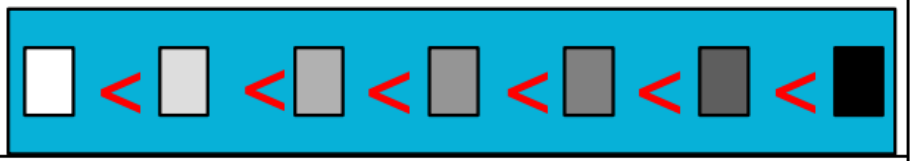
# Channel Properties: Lightness

| Visual Variable: Lightness | | |
|---|---|---|
| ✓ | selective |  |
| ✓ | associative |  |
| | quantitative | |
| | order |  |
| | length | |

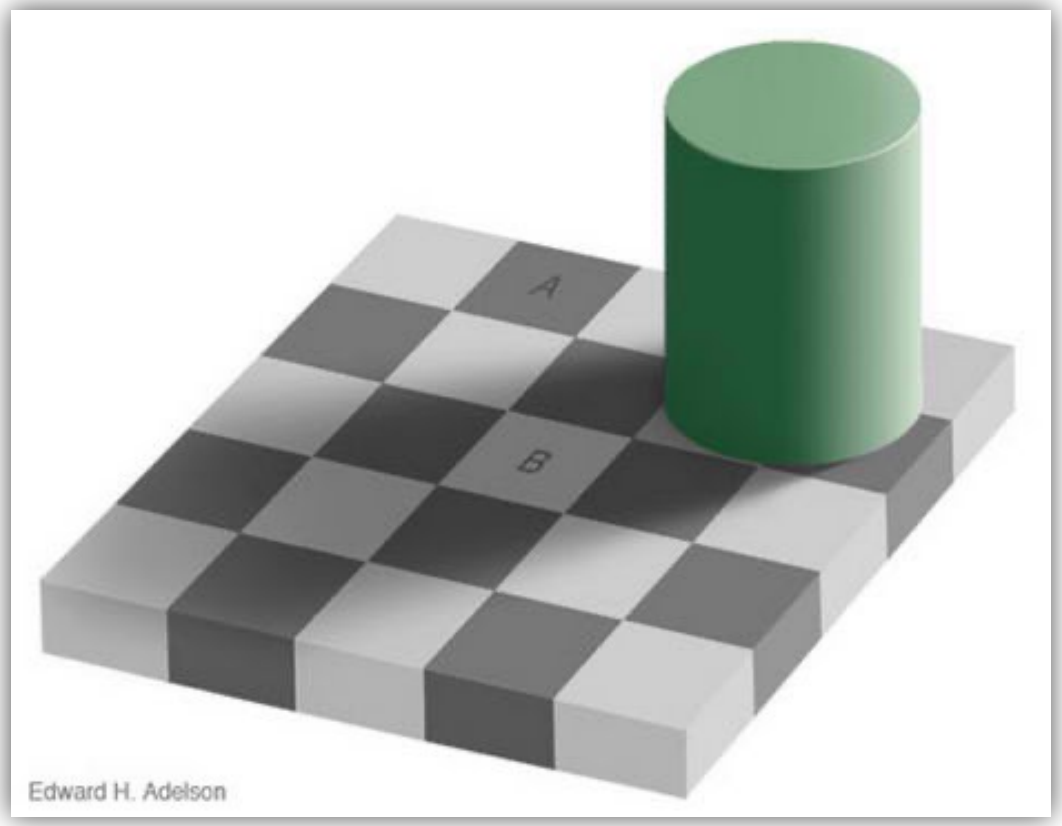
# Channel Properties: Lightness

| Visual Variable: Lightness | | |
|---|---|---|
| ✓ | selective |  |
| ✓ | associative |  |
| ≠ | quantitative | |
| | order |  |
| | length | |

# Channel Properties: Lightness

| | Visual Variable: Lightness | |
|---|---|---|
| ✓ | selective |  |
| ✓ | associative |  |
| ≠ | quantitative | |
| ✓ | order |  |
| | length | |

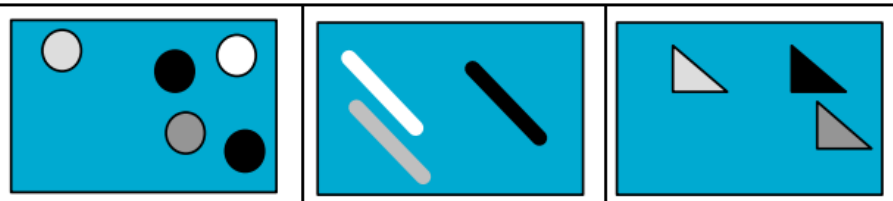
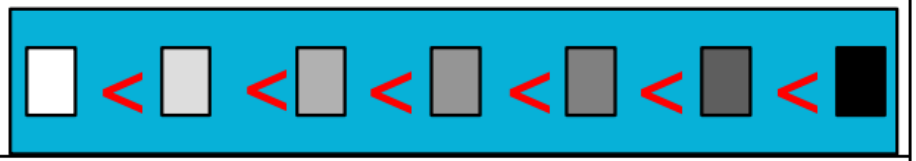
# Adelson's Checker-Shadow Illusion



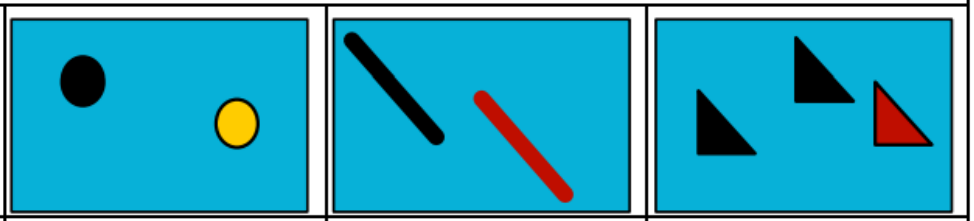
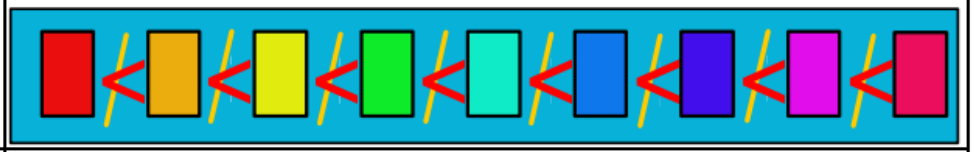

Weber's Law: human perception is fundamentally based on relative judgments, not absolute values.

https://www.illusionsindex.org/ir/20-checkershadow
https://www.youtube.com/watch?v=GALLMJxLvgA

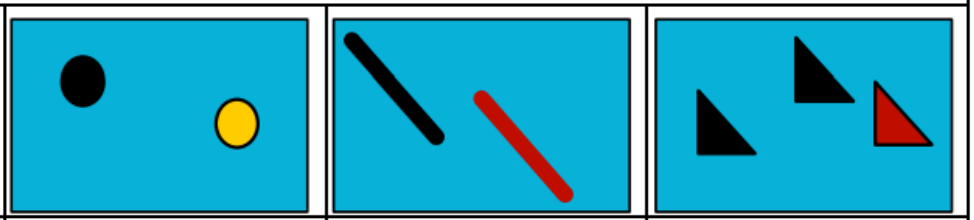
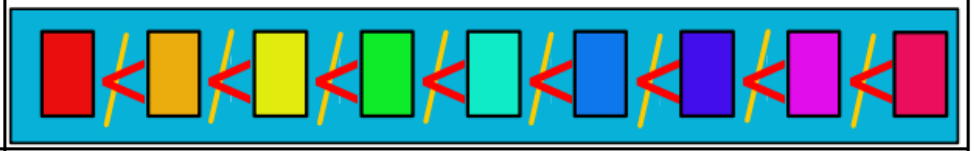
# Channel Properties: Lightness

| Visual Variable: Lightness | | |
|---|---|---|
| ✓ | selective |  |
| ✓ | associative |  |
| ≠ | quantitative | |
| ✓ | order |  |
| ✓ | length | • theoretically infinite but practically limited<br>• association and selection ~ < 7 and distinction ~ 10 |

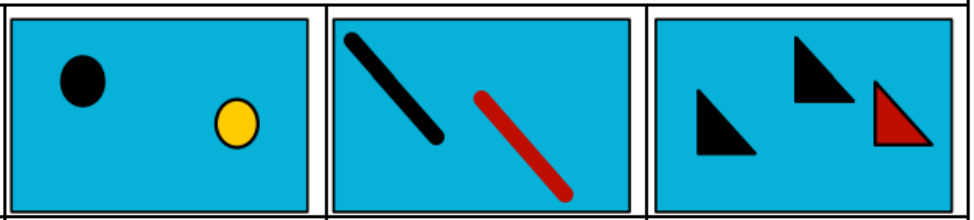
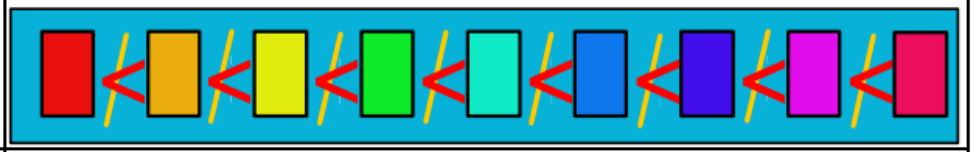
# Channel Properties: Colour

| Visual Variable: Colour | | |
|---|---|---|
| | selective |  |
| | associative |  |
| | quantitative | |
| | order |  |
| | length |  |

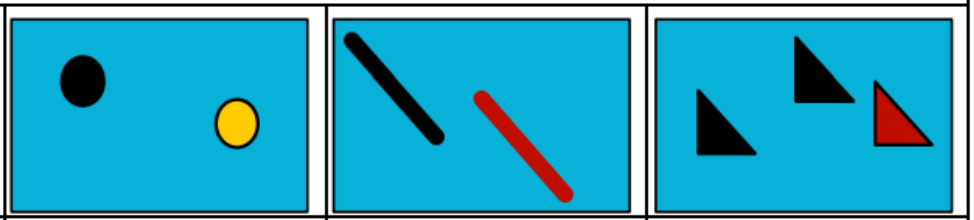
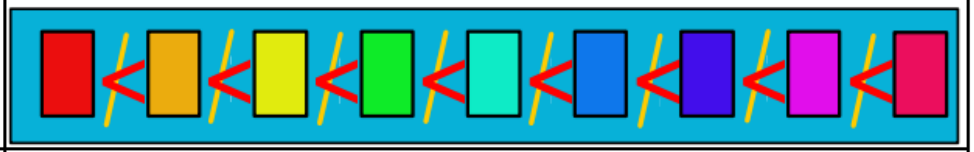
# Channel Properties: Colour

| Visual Variable: Colour | | |
|---|---|---|
| ✓ | selective |  |
| ✓ | associative |  |
| | quantitative | |
| | order |  |
| | length |  |

# Channel Properties: Colour

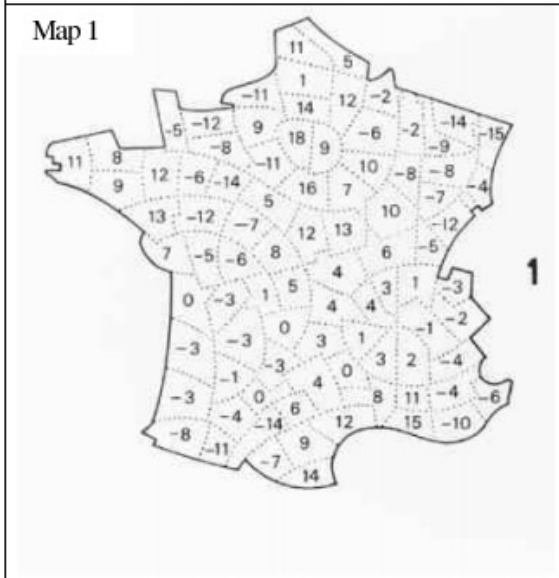
| Visual Variable: Colour | | |
|---|---|---|
| ✓ | selective |  |
| ✓ | associative |  |
| ≠ | quantitative | |
| | order |  |
| | length |  |

# Channel Properties: Colour

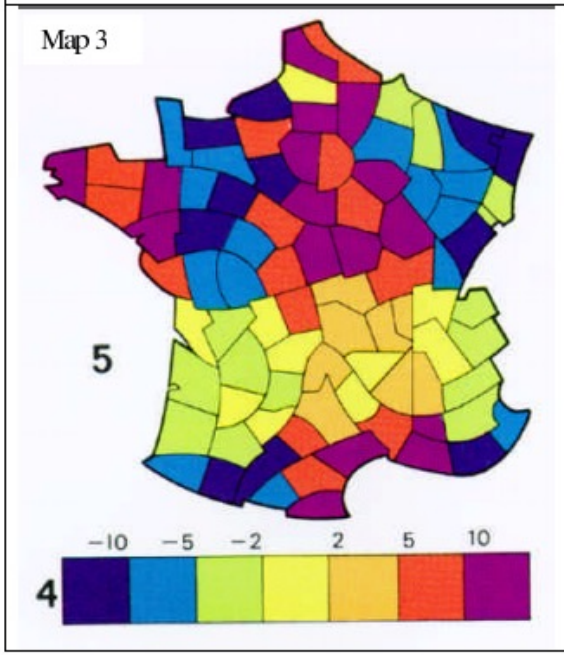
| Visual Variable: Colour | | |
|---|---|---|
| ✓ | selective |  |
| ✓ | associative |  |
| ≠ | quantitative | |
| ≠ | order |  |
| | length |  |

## Rainbow Scale Considerations

Map 1



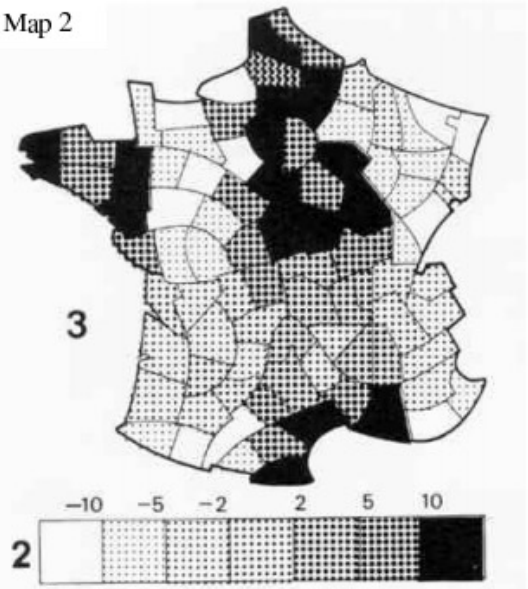

Map 3



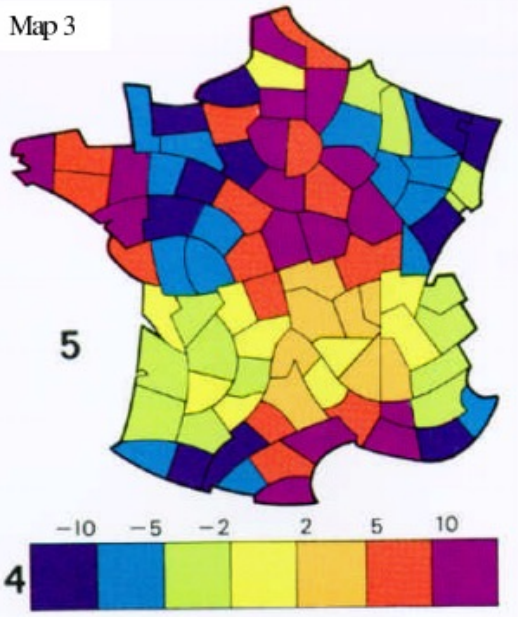
## Rainbow Scale Considerations

Map 1

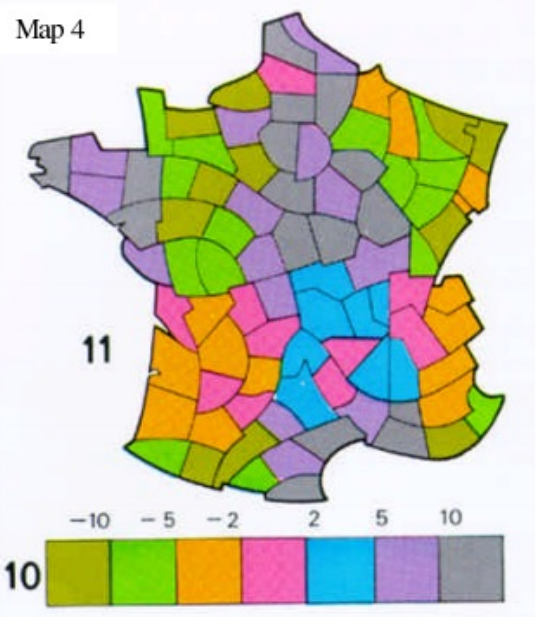

Map 2

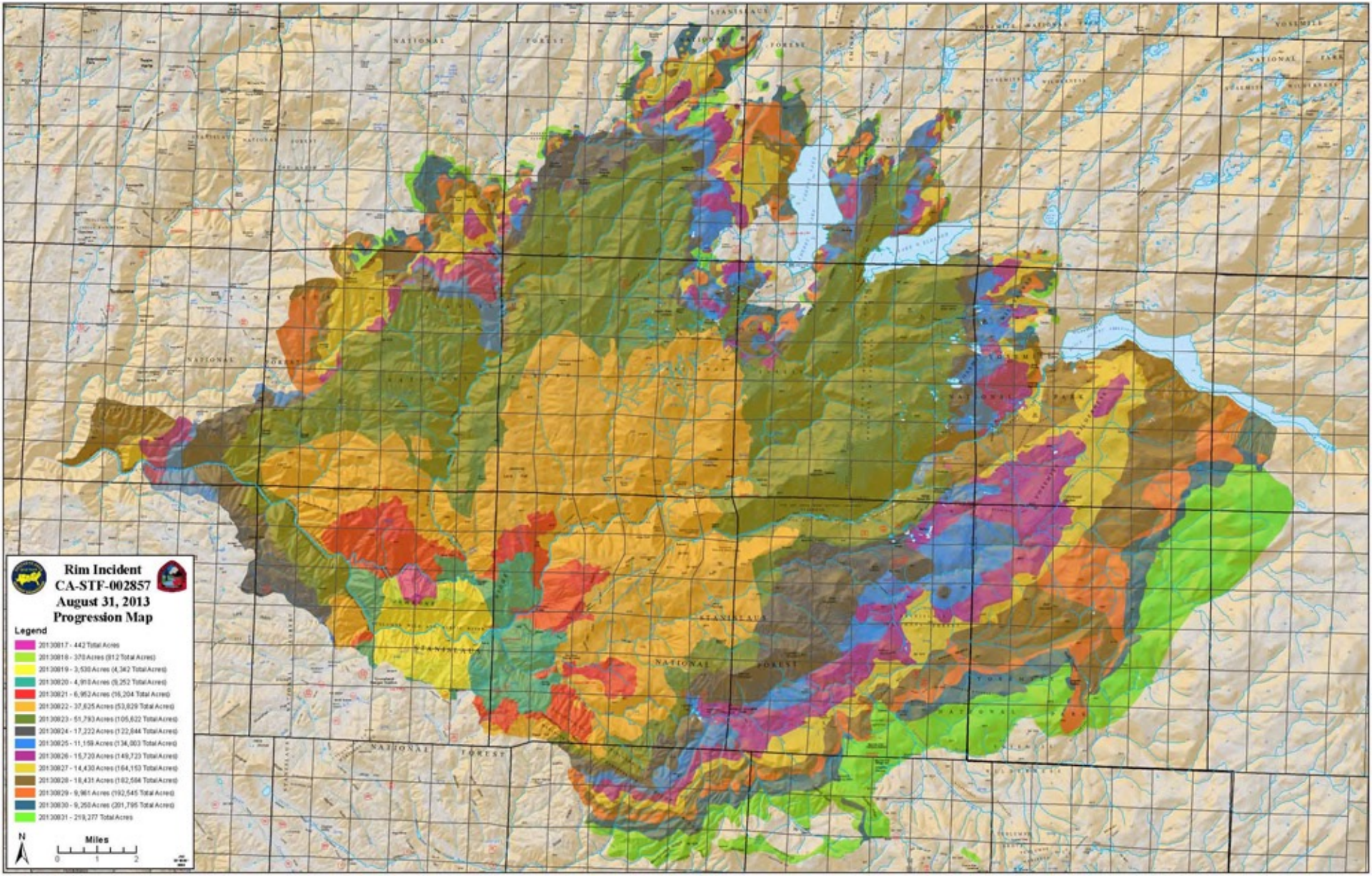


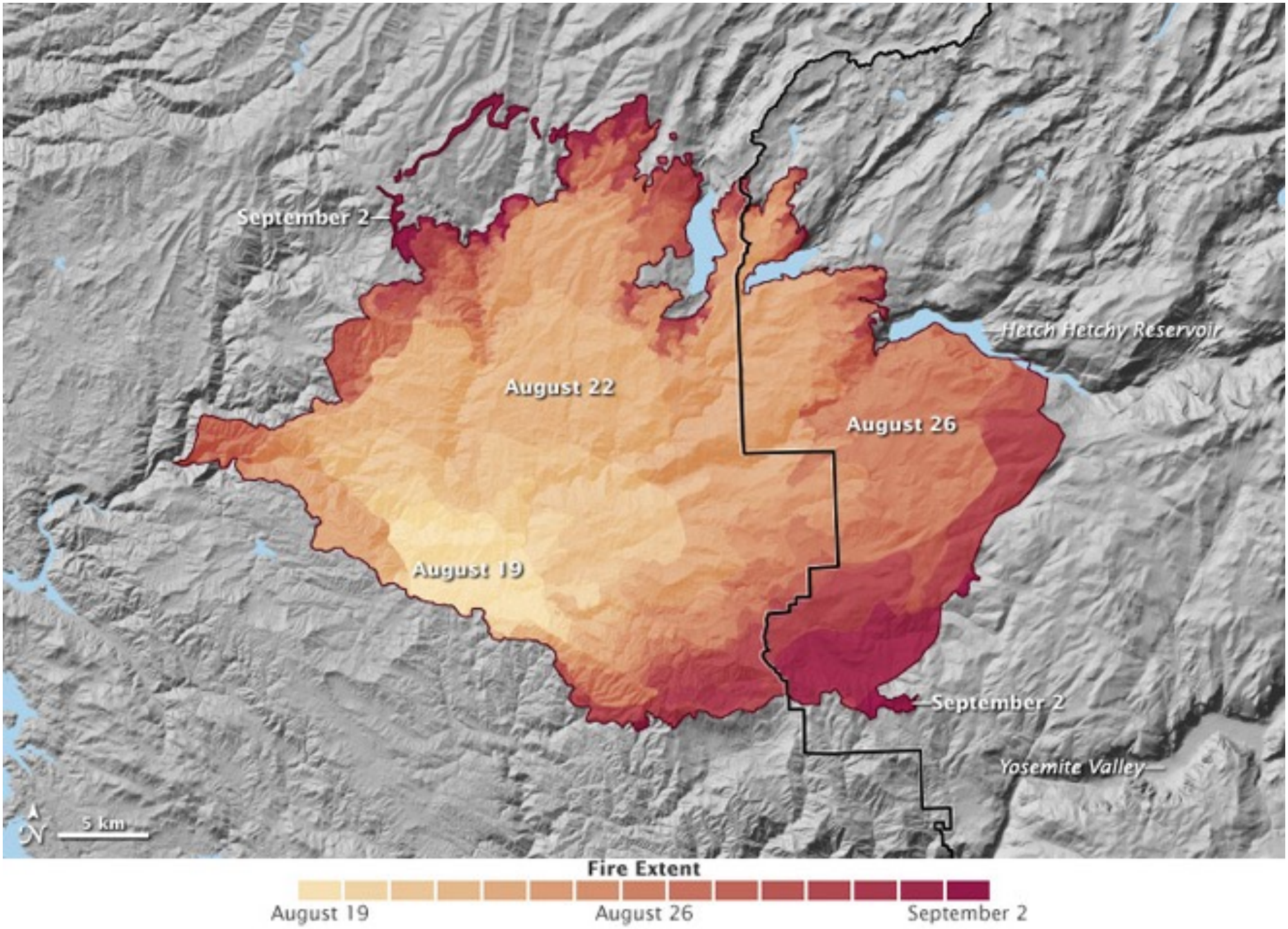

Map 3



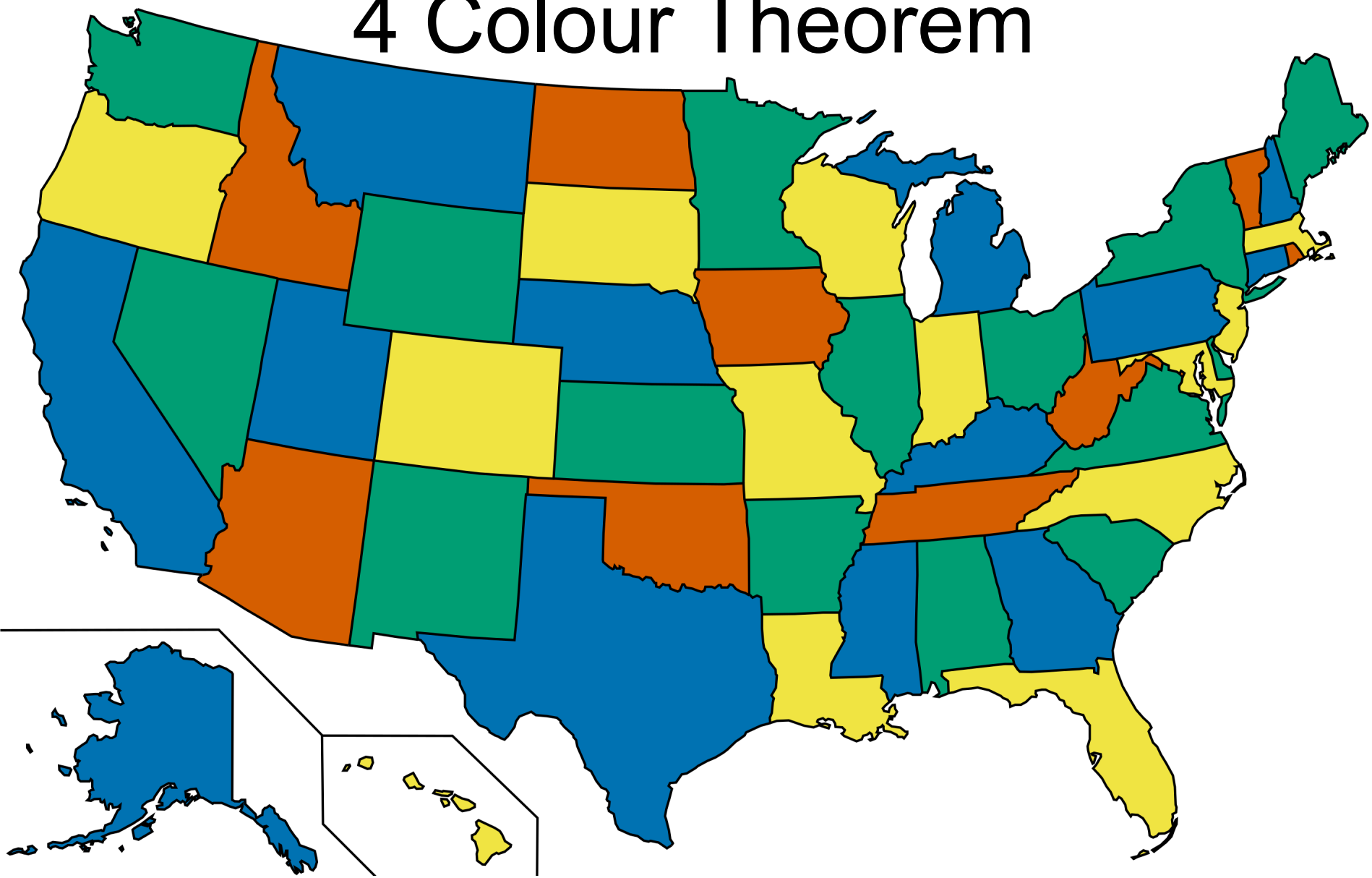

Map 4




Rim Incident
CA-STF-002857
August 31, 2013
Progression Map
Legend
20130817 - 442 Total Acres
20130818 - 370 Acres (812 Total Acres)
20130819 - 3,530 Acres (4,342 Total Acres)
20130820 - 4,910 Acres (9,252 Total Acres)
20130821 - 6,952 Acres (16,204 Total Acres)
20130822 - 37,625 Acres (53,829 Total Acres)
20130823 - 51,793 Acres (105,622 Total Acres)
20130824 - 17,222 Acres (122,844 Total Acres)
20130825 - 11,159 Acres (134,003 Total Acres)
20130826 - 15,720 Acres (149,723 Total Acres)
20130827 - 14,430 Acres (164,153 Total Acres)
20130828 - 18,431 Acres (182,584 Total Acres)
20130829 - 9,961 Acres (192,545 Total Acres)
20130830 - 9,250 Acres (201,795 Total Acres)
20130831 - 219,277 Total Acres
N
Miles
0
1
2

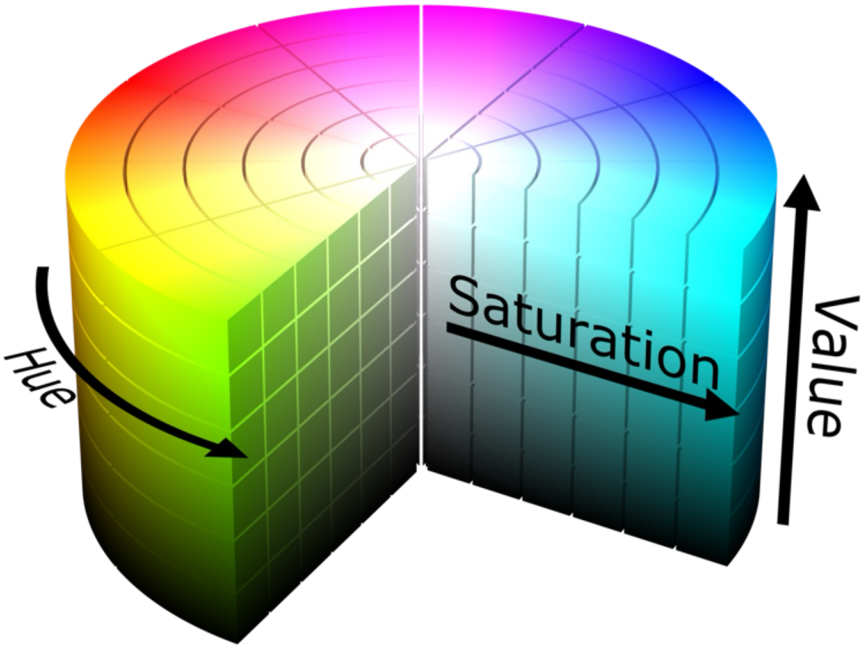

September 2
August 22
August 26
Hetch Hetchy Reservoir
August 19
September 2
Yosemite Valley
5 km
Fire Extent
August 19
August 26
September 2

# 4 Colour Theorem



https://en.wikipedia.org/wiki/Four_color_theorem

# Hue, Saturation & Value




**Hue**: the degree to which a stimulus can be described as similar to or different from stimuli that are described as red, orange, yellow, green, blue, violet

# Destroys Detail

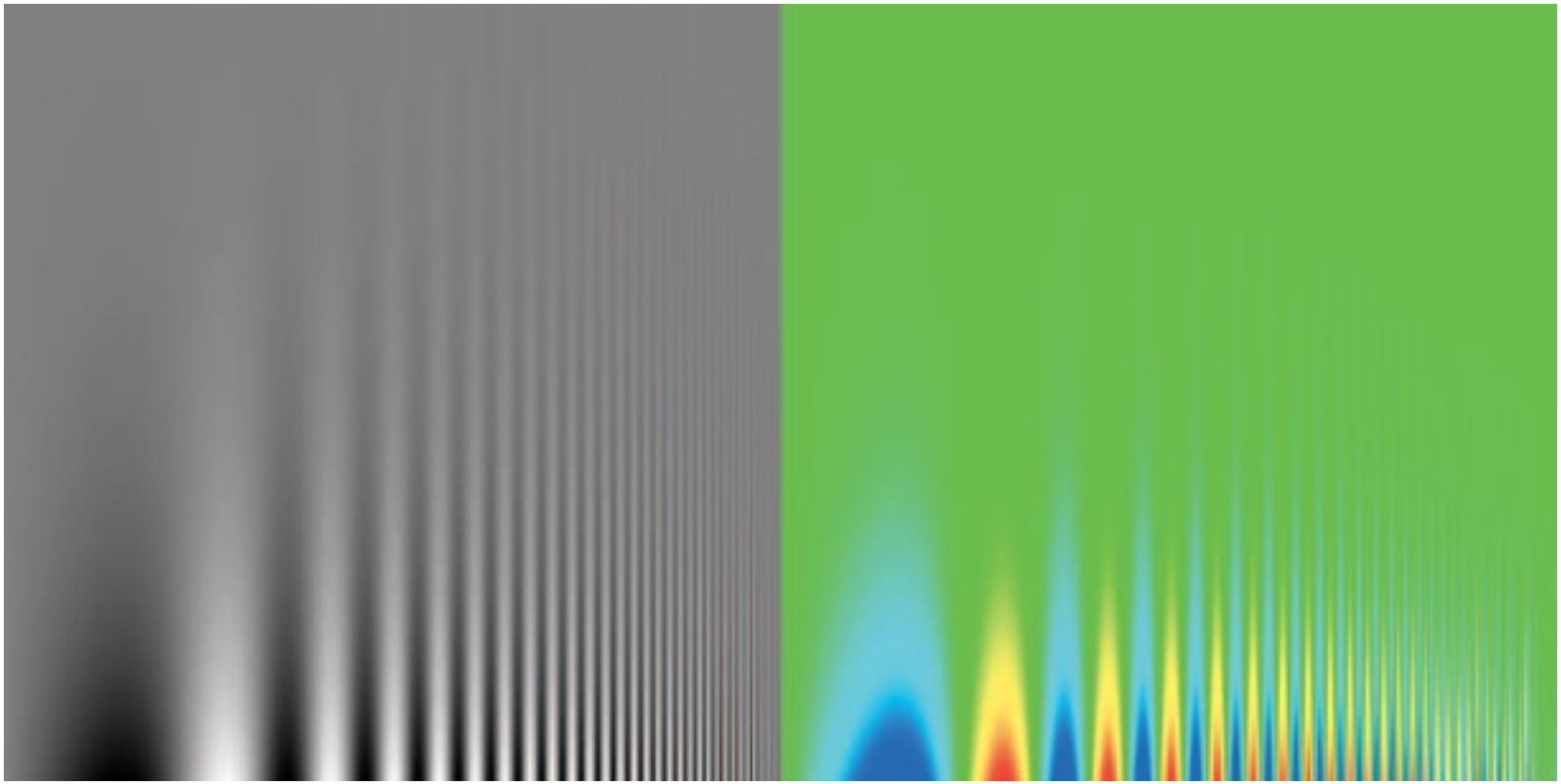


Image from *Borland & Taylor II (2007), Rainbow Color Map (Still) Considered Harmful. IEEE Visualization Viewpoints, pp 14-17.*

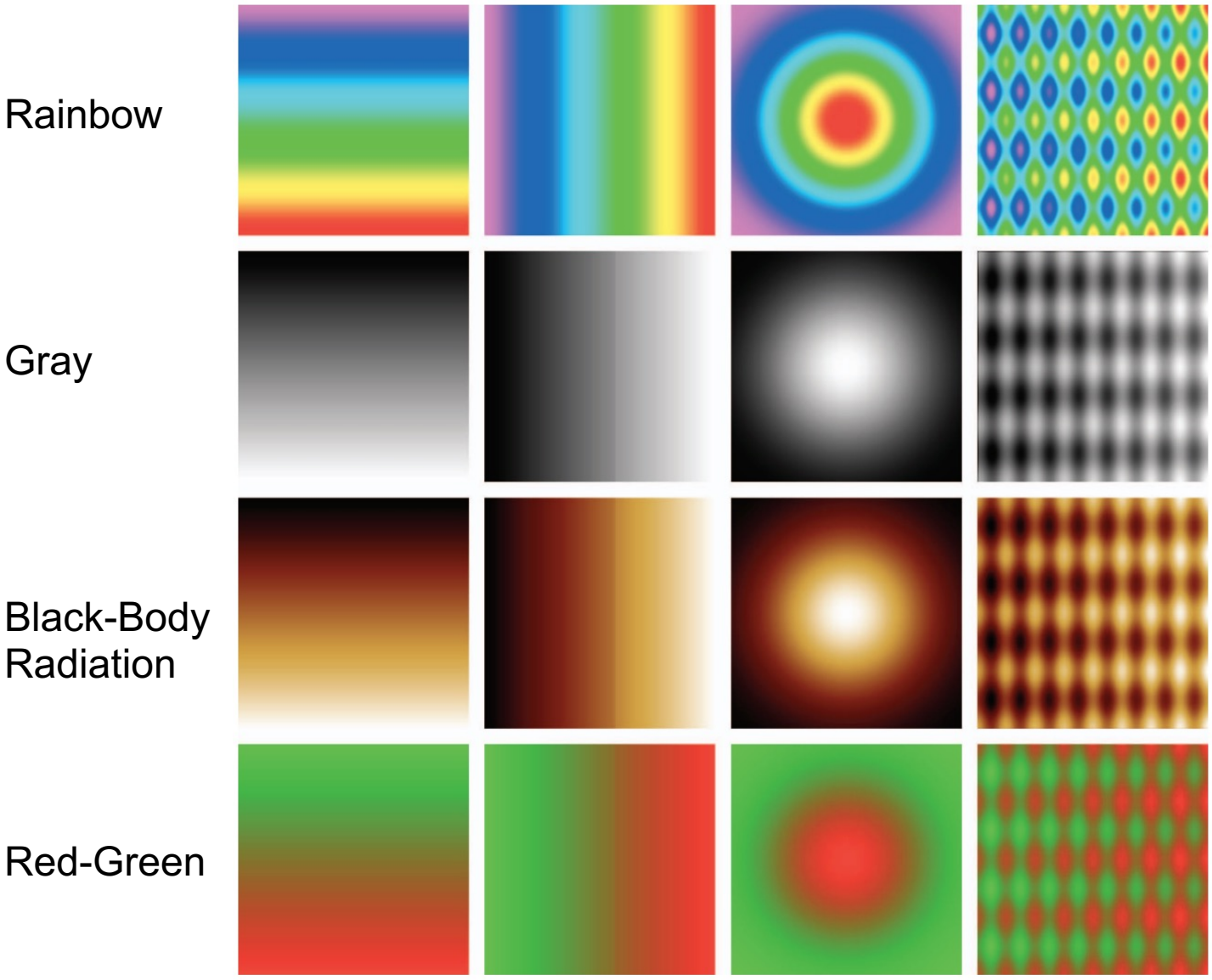
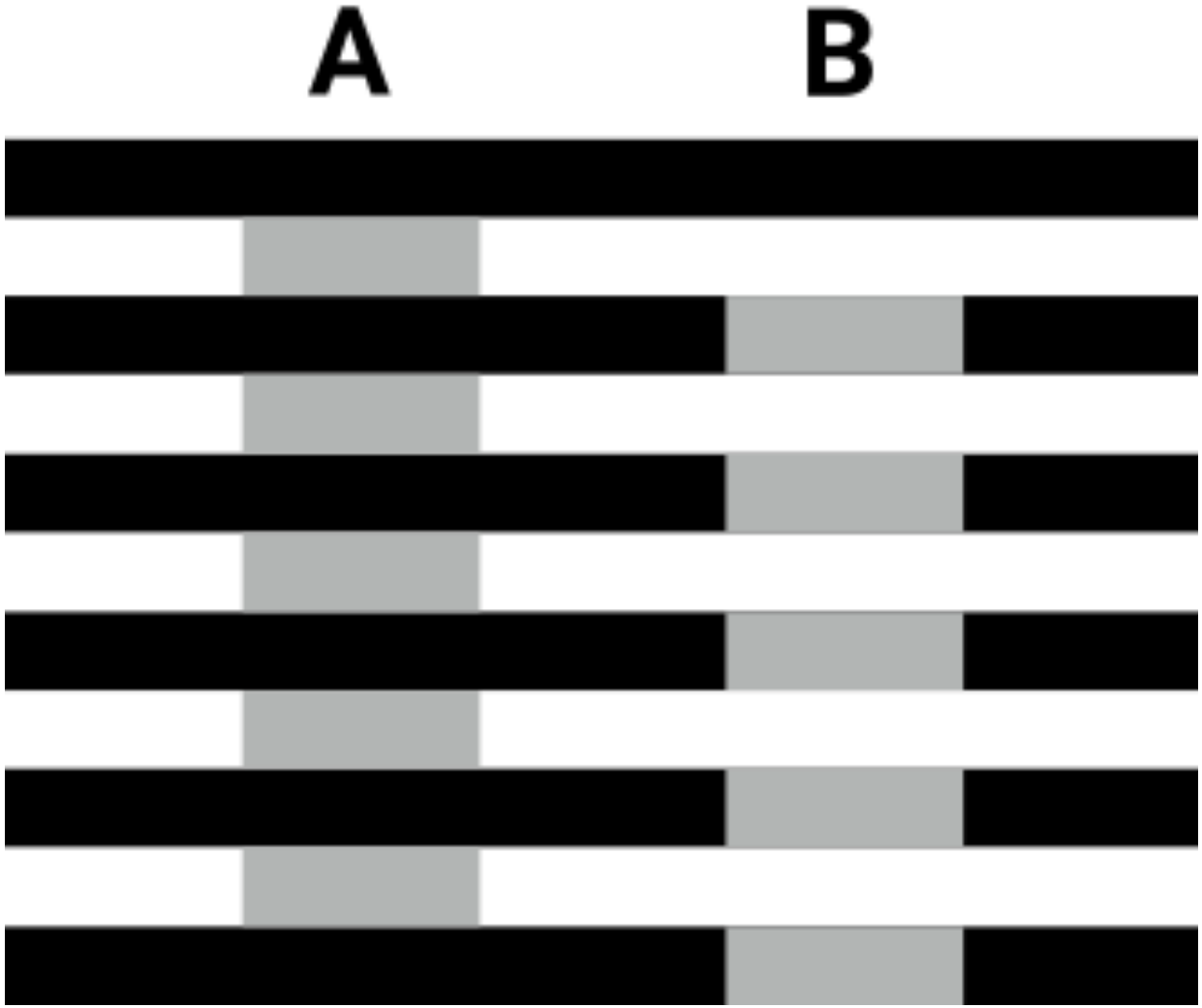



Image from *Borland & Taylor II (2007), Rainbow Color Map (Still) Considered Harmful. IEEE Visualization Viewpoints, pp 14-17.*

# White's illusion

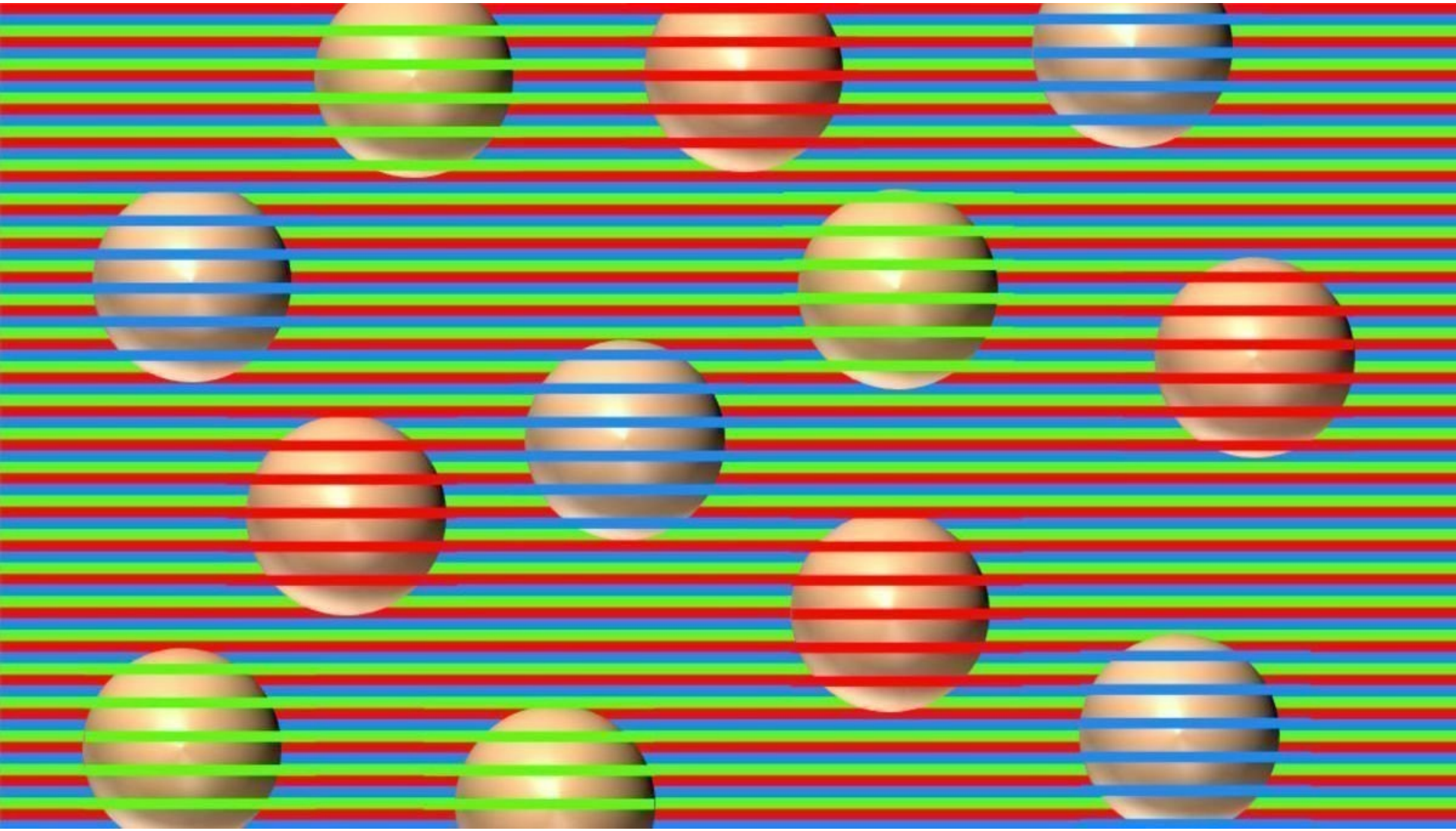



https://en.wikipedia.org/wiki/White%27s_illusion

# The Dress 2015

https://en.wikipedia.org/wiki/The_dress
https://www.youtube.com/watch?v=I0OPNOpU6SY

# David Novick's three color confetti illusion



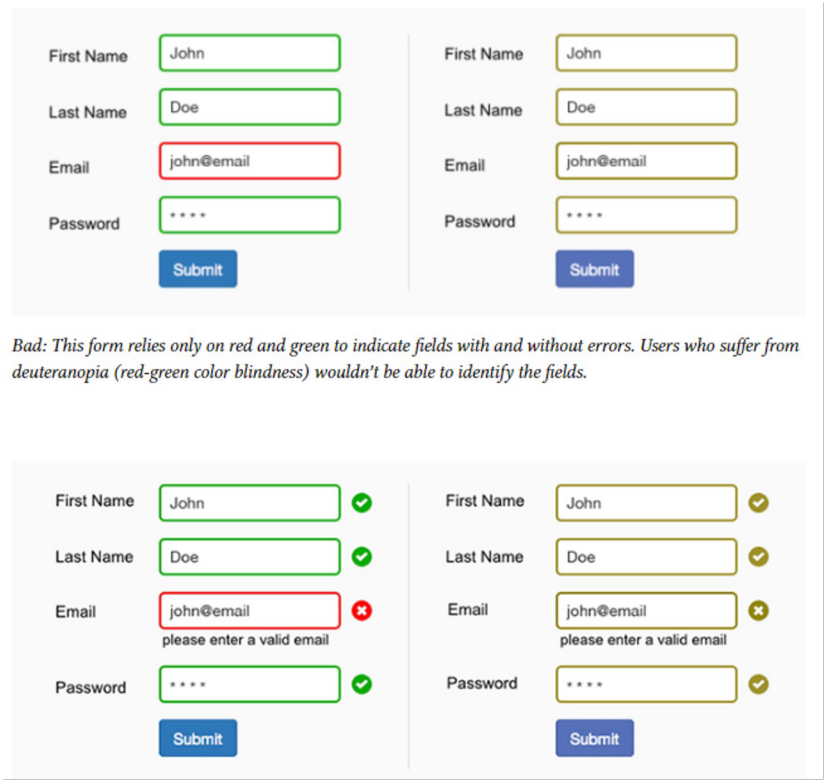
https://journalofillusion.net/index.php/joi/article/view/6152/13749
https://www.youtube.com/watch?v=SvEiEi8O7QE

# Colours

- Humans are mostly the same
- Some have different ability to see colour - even gender differences
- Some rules are about humans some about culture.

# Colour Blind

Always 2 cues




https://www.cs.umd.edu/users/ben/goldenrules.html

# Color in culture

**Different colours mean different things**

Blue - calm

Green - growth: Indonesia forbidden

Red - energy/danger: Asia luck

Yellow - happiness - Germany envy

Purple - royalty: Brazil mourning

White - purity: China death

# Tino Rangatiratanga

https://commons.wikimedia.org/wiki/File:Tino_Rangatiratanga_Maori_sovereignty_movement_flag.svg

# Māori colour signifiers

- **RED represents**
  - Te Whei Ao (coming into being). It symbolises Papatuanuku, the earth-mother, the sustainer of all living things, both the land and active forces.
- **BLACK represents**
  - Te Korekore (the realm of potential being). Symbolising the long darkness from which the earth emerged, as well as signifying Ranginui, the sky father floating above the earth.
- **WHITE represents**
  - Te Ao Marama (the realm of being and light) was created when Rangi and Papa were separated by their children. It symbolises the physical world, purity, harmony, enlightenment and balance.

# Colours link to Emotions

Green: Sparks creativity

Red: Reduces analytical thinking

Blue: is most accepted

Yellow: isn't usually a hit

Orange: is associated with good value

Pink: Calms people down

White: May lead to boredom

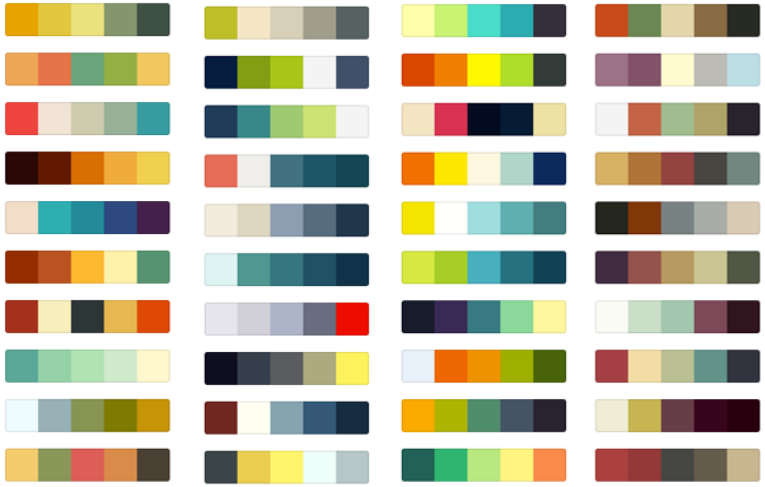
https://www.forbes.com/sites/amymorin/2014/02/04/how-to-use-color-psychology-to-give-your-business-an-edge/#55ae55c3170a

# Harmony and contrast

- Colours are similar to sound
- Music has Harmony and discord
- Music links to emotions - often by memories

# Colour palettes

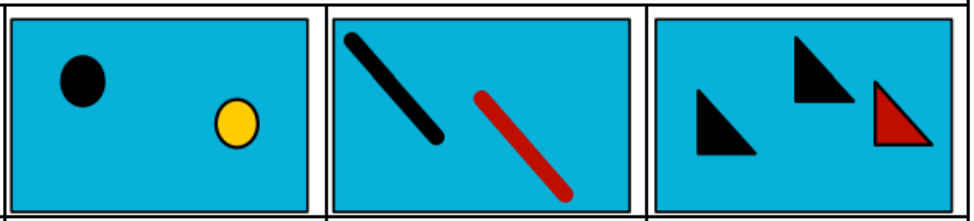
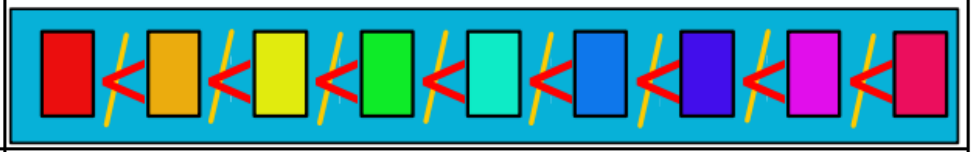
- Finding a set of colours for your product
- Continuity - keeping your site consistent
- Color Brewer
  - https://colorbrewer2.org/



# Generators

- From a Photo
  - https://www.adobe.com/nz/products/capture.html
- From a start colour
  - https://coolors.co/
- From examples
  - https://www.canva.com/learn/100-color-combinations

# Channel Properties: Colour

| Visual Variable: Colour | | |
|---|---|---|
| ✓ | selective |  |
| ✓ | associative |  |
| ≠ | quantitative | |
| ≠ | order |  |
| ✓ | length |  • theoretically infinite but practically limited<br>• association and selection ~ < 7 and distinction ~ 10 |

# Channel Properties: Orientation

| Visual Variable: Orientation | | |
|---|---|---|
| ✓ | Selective |  |
| ✓ | associative |  |
| ≠ | Quantitative |  |
| ≠ | Order |  |
| ✓ | Length |  |

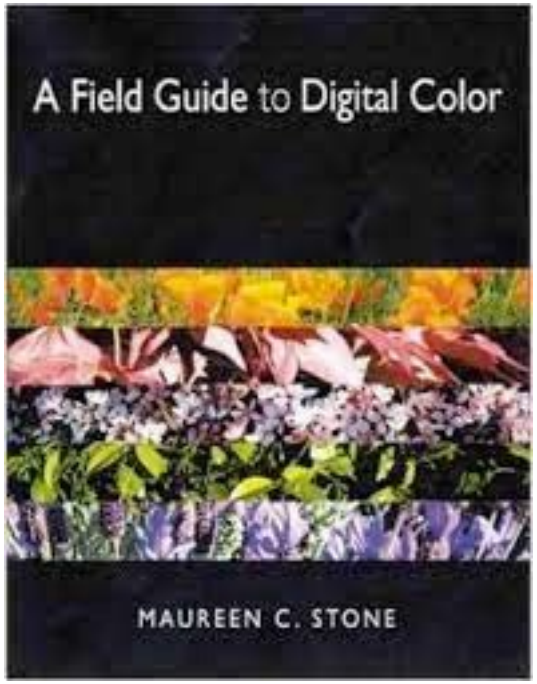
# Channel Properties: Texture

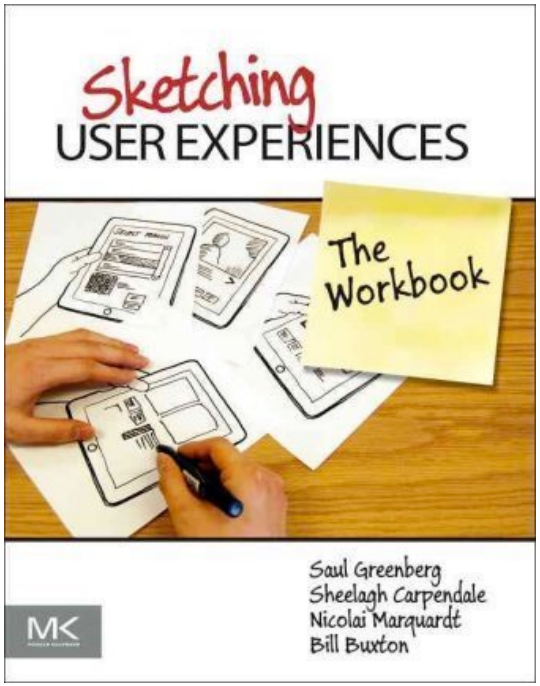
| Visual Variable: Texture | | |
|---|---|---|
| ✓ | selective |  |
| ✓ | associative |  |
| ≠ | quantitative | |
| ≠ | order |  |
| ✓ | Length | • theoretically infinite |

# Recommended Reading

Sheelagh Carpendale, Considering Visual Variables as a Basis for Information Visualisation. Research report 2001-693-16, Department of Computer science, University of Calgary, Calgary, AB, Canada, 2003.

Ben Shneiderman, The eyes have it: a task by data type taxonomy for information visualizations, VL 1996



# Summary - How Do We Visualize?

- **Know the Data**
  - Number of attributes
  - Date types: ordinal vs ordered (ordinal or quantitative)
  - Trustworthiness: bad fields, inaccuracies, missing values
- **Know your purpose (& audience)**
  - What do you/they want to see?
  - What might you/they want to focus on?
- **Decide how to use the visual variables to encode the data**
  - Requires awareness of:
    - Human perceptual system
    - Display capacity
    - Characteristics of data (size, type)
    - Task