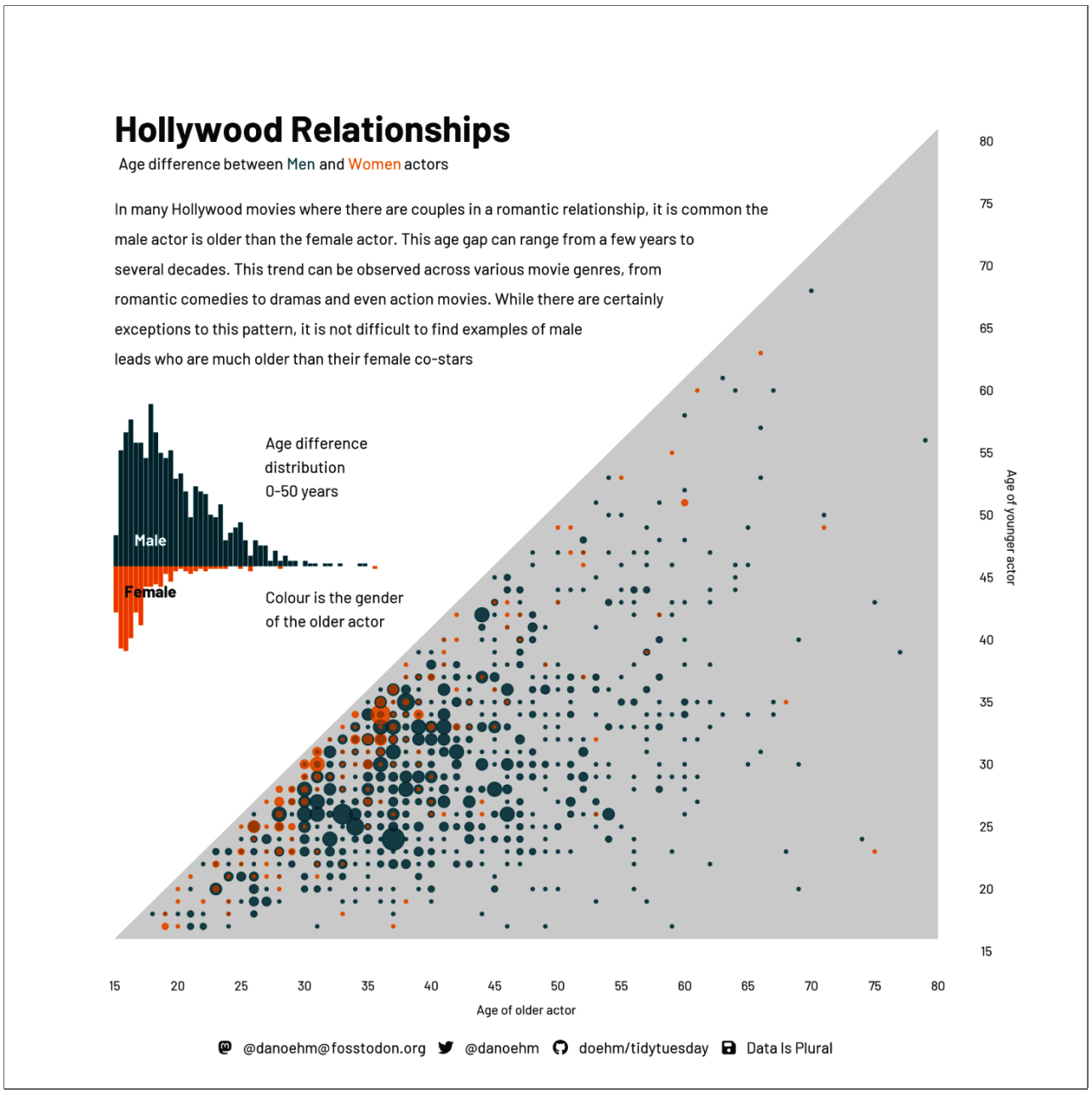
# Lecture 5: Geometric Representation

# Today's Visualization



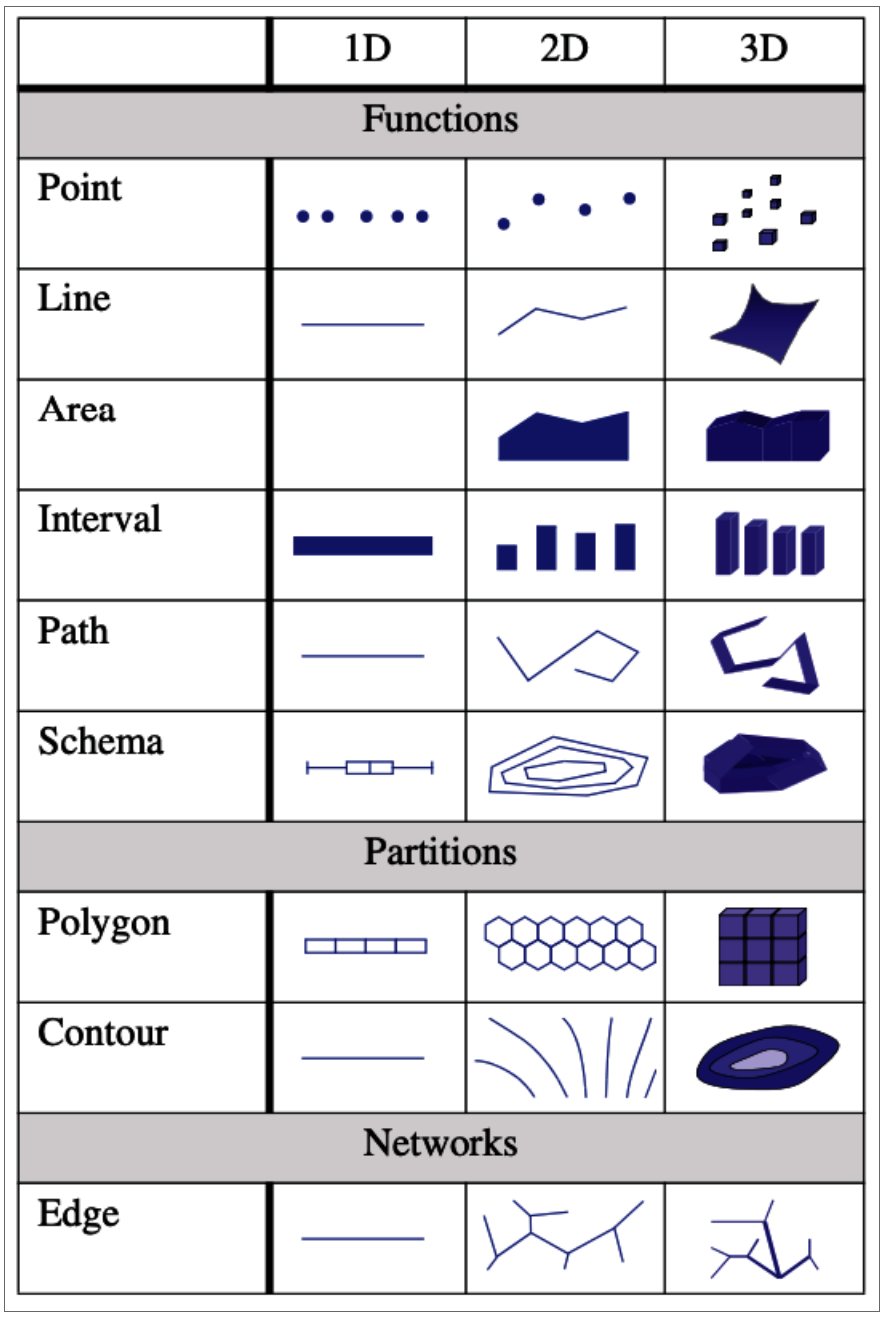
# Marks and Channels

## Marks in data visualization

A **mark** is a basic graphical element in an image.

Munzner shows examples of points, lines, curves, areas.


Wilkinson's taxonomy of marks is bigger



## Channels - the appearance of marks

**Visual channels** are different ways of controlling the appearance of marks. The core of data visualization design lies in the connection between visual channels and data properties.

# Design Principles for Visual Channels

## Expressiveness

> Visual encoding should express all of, and only, the information in the dataset attributes. Ordered data should be shown in a way that our perceptual system intrinsically senses as ordered. Conversely, unordered data should not be shown in a way that perceptually implies an ordering that does not exist.

## Effectiveness

> The importance of the attribute should match the **salience** of the channel. The most important attributes should be encoded with the most effective channels in order to be most noticeable, and then decreasingly important attributes can be matched with less effective channels.

## Visual channels in use

- Code

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Categorical: Shape

## Visual channels in use

- Code

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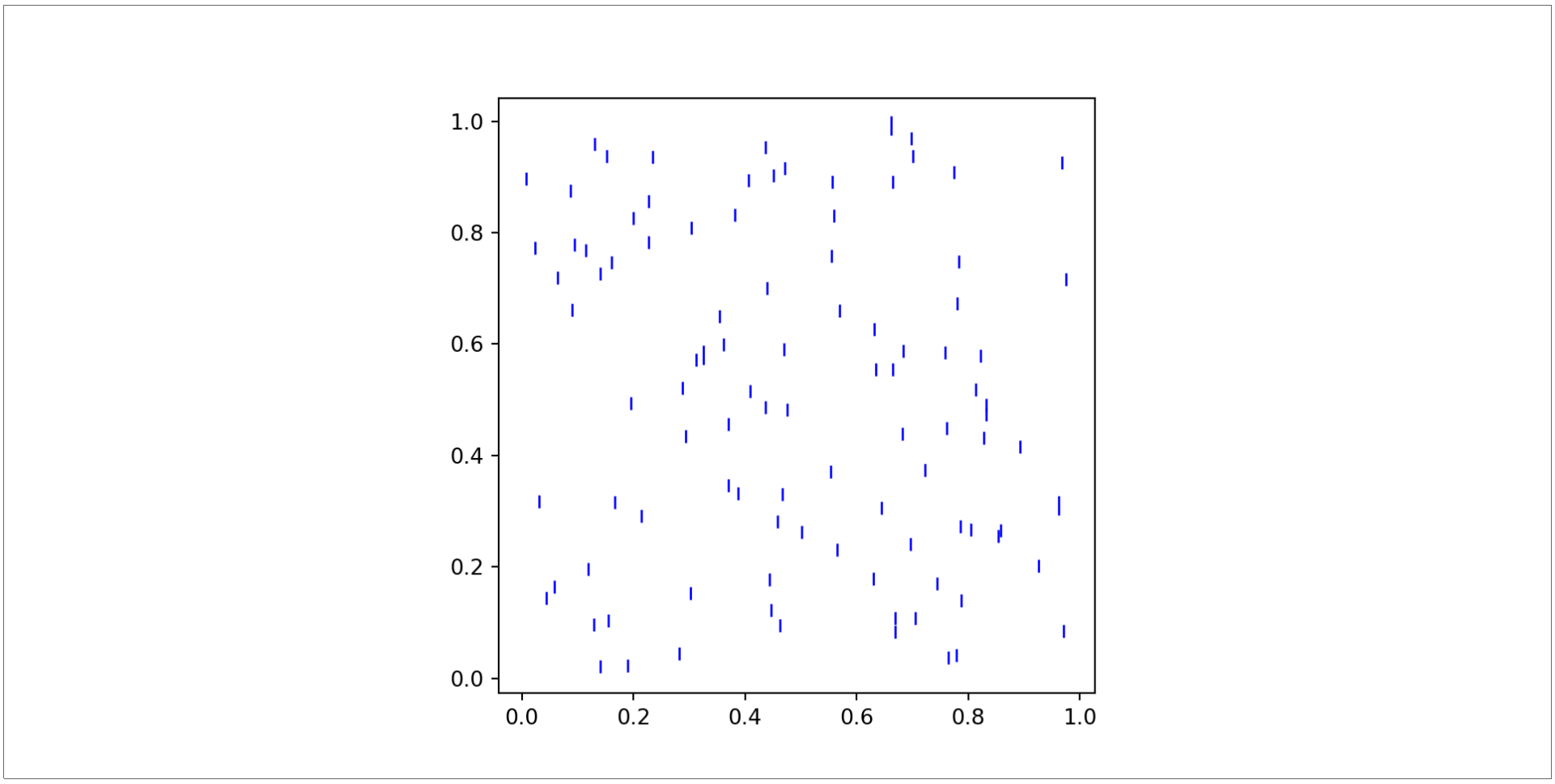
Categorical: Tilt

## Visual channels in use

▶ Code




Categorical: Size

## Visual channels in use

- Code

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Categorical: Color

## Visual channels in use

- Code

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Ordinal: Tilt

## Visual channels in use

- Code

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Ordinal: Area

## Visual channels in use

- Code

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Ordinal: Transparency

## Visual channels in use

- Code

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Ordinal: Luminance

## Visual channels in use

- Code

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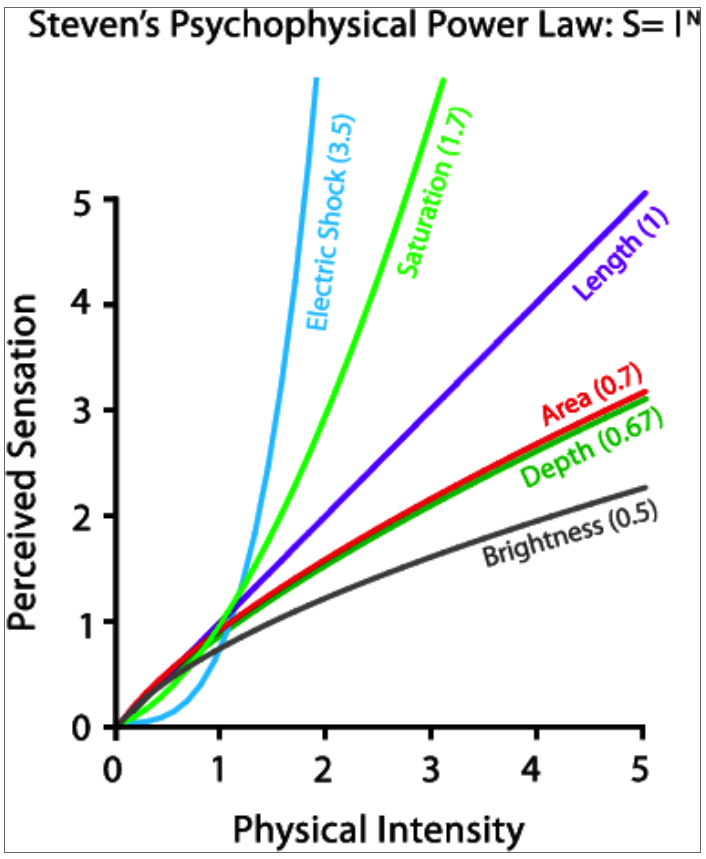
Ordinal: Saturation

## Channel Efficiency: experiments

Stevens (1975): human response to sensory stimulus is characterized by a power law, with different exponents for different stimulus modality. Asked ratio judgements and fitted power law curves.




| Continuum | Exponent () | Stimulus condition |
|---|---|---|
| Loudness | 0.67 | Sound pressure of 3000 Hz tone |
| Vibration | 0.95 | Amplitude of 60 Hz on finger |
| Vibration | 0.60 | Amplitude of 250 Hz on finger |
| Brightness | 0.33 | 5° target in dark |
| Brightness | 0.50 | Point source |
| Brightness | 0.50 | Brief flash |
| Brightness | 1.00 | Point source briefly flashed |
| Lightness | 1.20 | Reflectance of gray papers |
| Visual length | 1.00 | Projected line |
| Visual area | 0.70 | Projected square |
| Redness (saturation) | 1.70 | Red–gray mixture |
| Taste | 1.30 | Sucrose |
| Taste | 1.40 | Salt |
| Taste | 0.80 | Saccharin |
| Smell | 0.60 | Heptane |
| Cold | 1.00 | Metal contact on arm |
| Warmth | 1.60 | Metal contact on arm |
| Warmth | 1.30 | Irradiation of skin, small area |
| Warmth | 0.70 | Irradiation of skin, large area |

| Continuum | Exponent () | Stimulus condition |
|---|---|---|
| Discomfort, cold | 1.70 | Whole-body irradiation |
| Discomfort, warm | 0.70 | Whole-body irradiation |
| Thermal pain | 1.00 | Radiant heat on skin |
| Tactual roughness | 1.50 | Rubbing emery cloths |
| Tactual hardness | 0.80 | Squeezing rubber |
| Finger span | 1.30 | Thickness of blocks |
| Pressure on palm | 1.10 | Static force on skin |
| Muscle force | 1.70 | Static contractions |
| Heaviness | 1.45 | Lifted weights |
| Viscosity | 0.42 | Stirring silicone fluids |
| Electric shock | 3.50 | Current through fingers |
| Vocal effort | 1.10 | Vocal sound pressure |
| Angular acceleration | 1.40 | 5 s rotation |
| Duration | 1.10 | White-noise stimuli |

## Channel Efficiency: experiments

Cleveland and McGill (1984) and Heer and Bostock (2010): controlled experiments ranking perceptual accuracy in reading visualizations.

# Perceptual ranking of channels

## Measures of efficiency

### Accuracy

The preceding examples all focus on **accuracy**.

### Discriminability

Are the intended differences perceptible to the human? How many bins can be used in a particular channel?

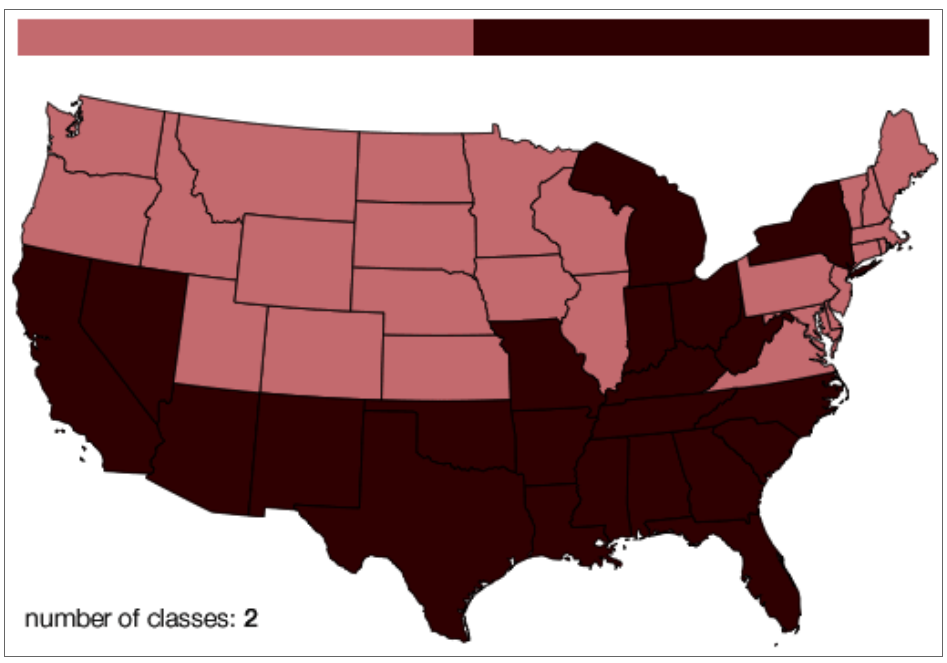
### Separability

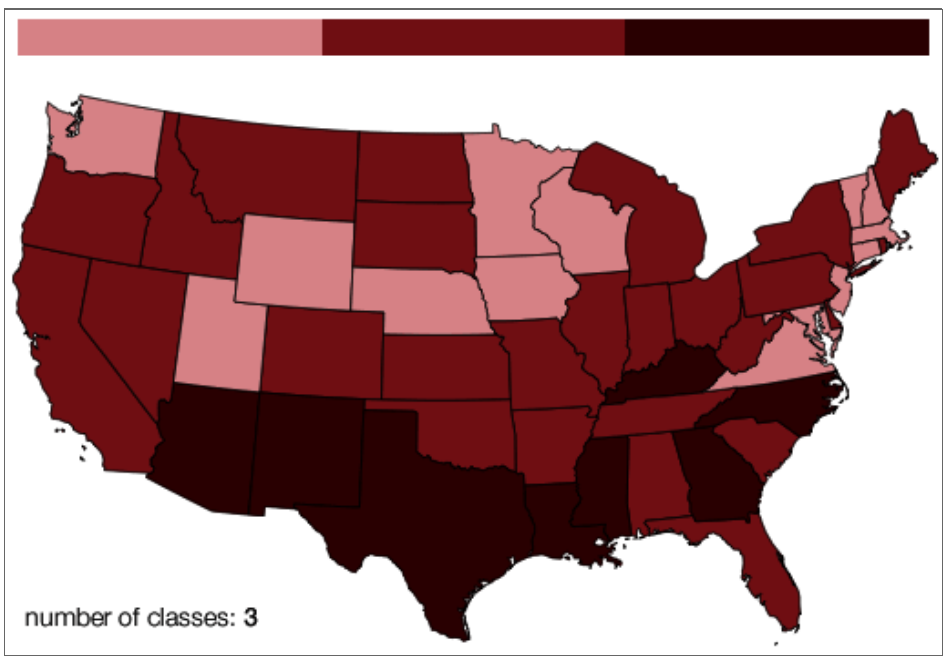
Different channels **interact** with each other.

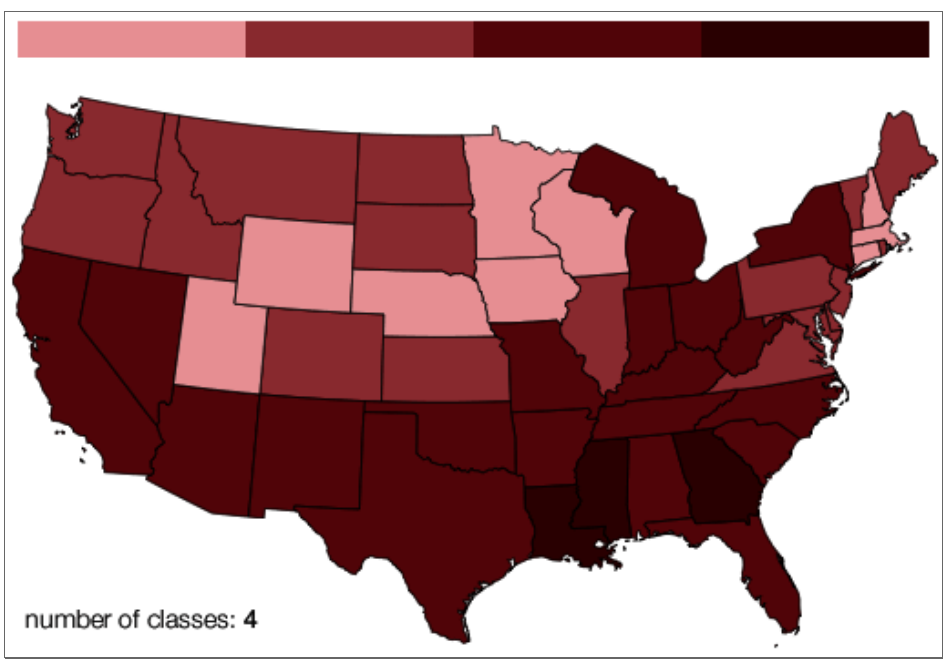
### Popout

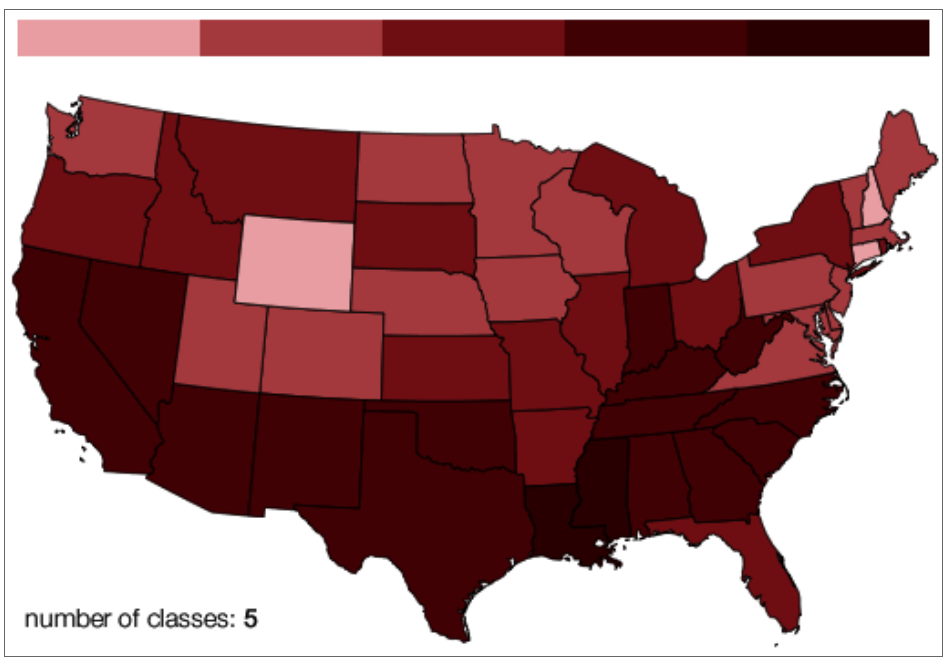
How much does a distinct item stand out from many other items? This leverages the parallel processing in the low-level visual system.

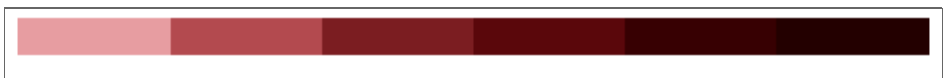
# Discriminability

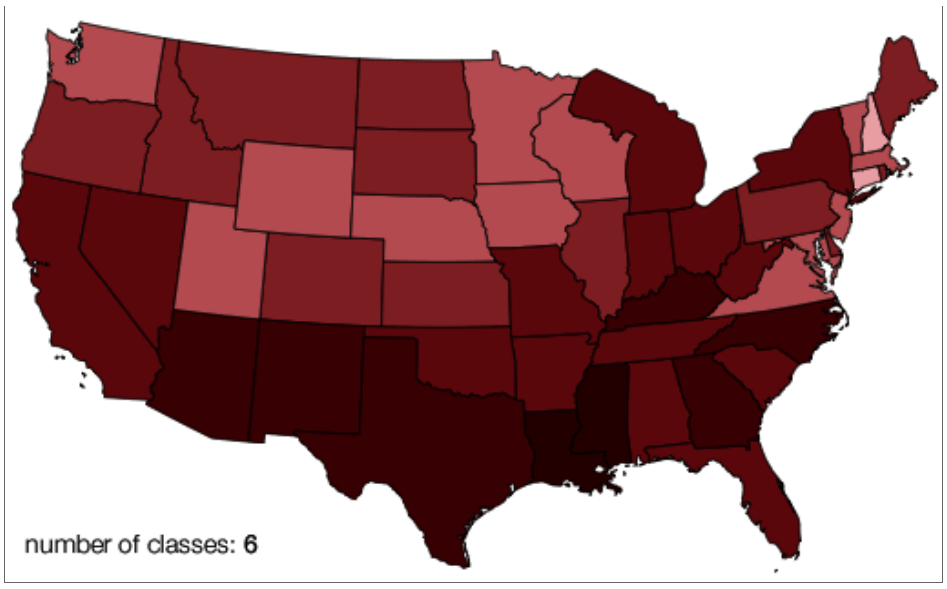


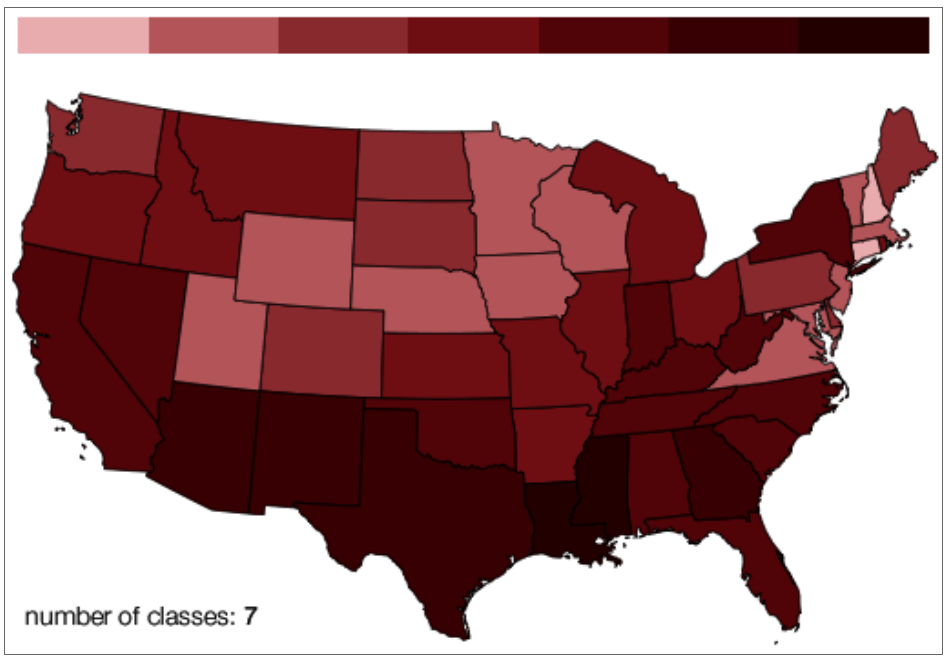




number of classes: 6


number of classes: 7

## Separability

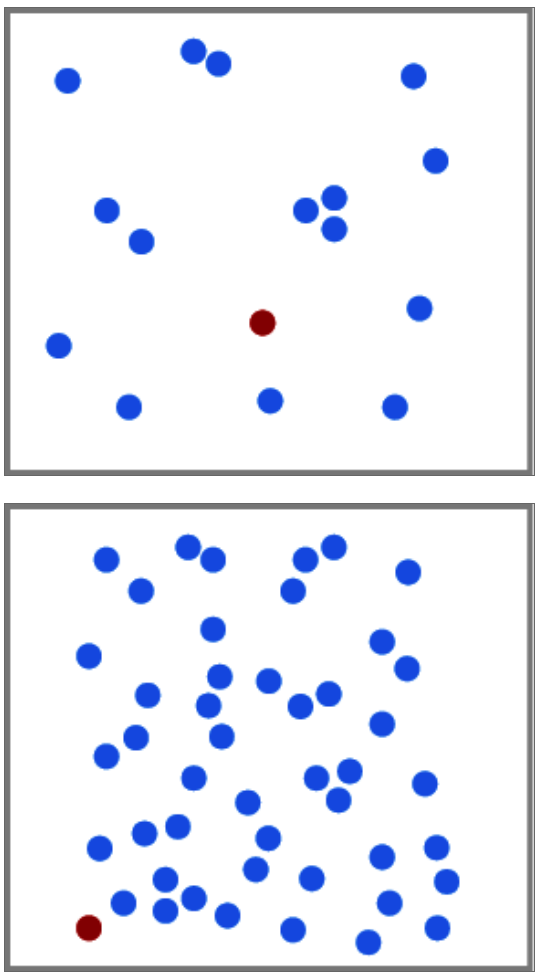
Visual channels are:

- **separable** if they are orthogonal and independent.
- **integral** if they are inextricably combined.

If you try to encode *different* information in integral channels, the encoding will fail. Instead of accessing the desired information about each attribute, an unanticipated combination is perceived.
**Example:** vertical position, horizontal position and proximity. Once you have two of these, you cannot encode an independent attribute in the third.
**Example:** red, green, blue color channels have a lot of integration.

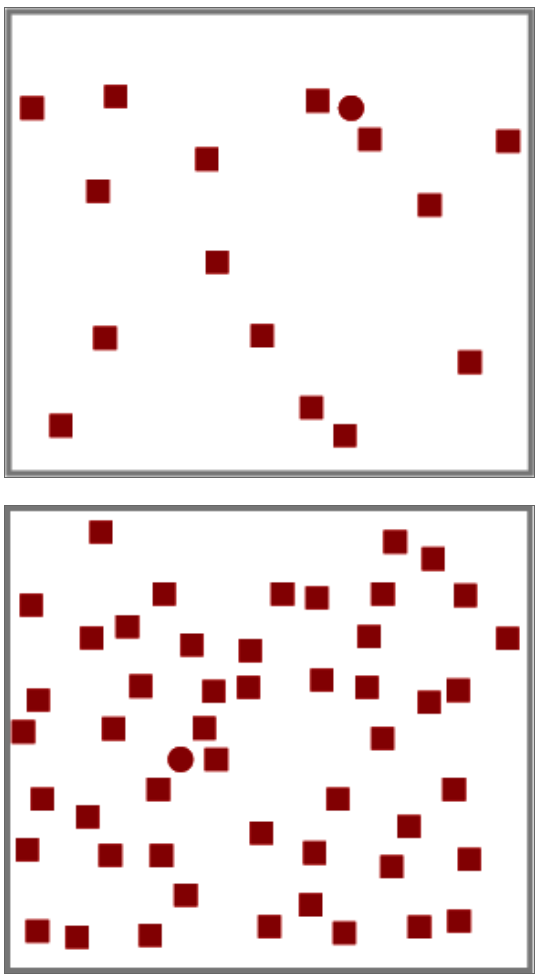
# Separability

# Popout



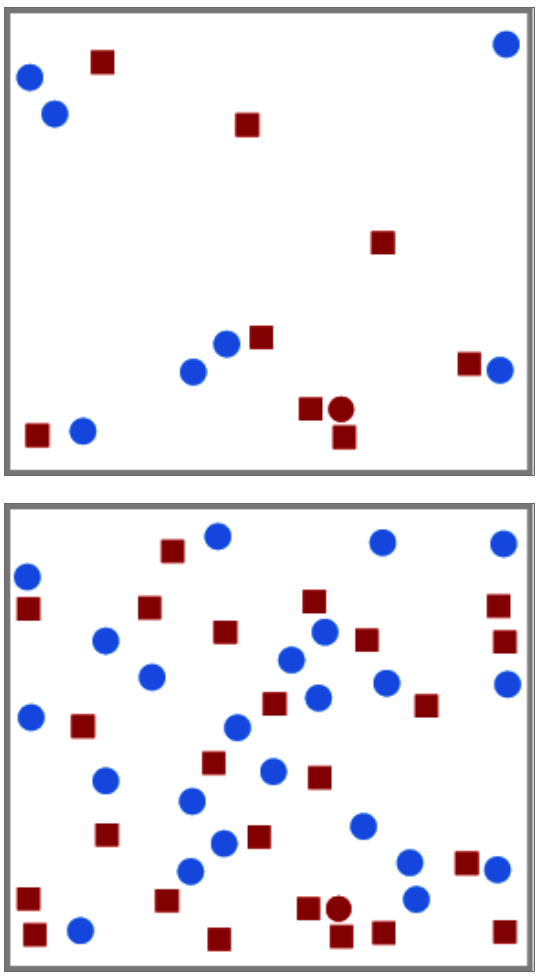
Detection time for the red circle approximately constant wrt # distractors.

# Popout



Detection time for the red circle approximately linear wrt # distractors. Square vs circle yields less popout than blue vs red.

# Popout



Detection time for the red circle approximately linear wrt # distractors. A mix of visual channels does not preserve popout properties.

## Minard's March on Moscow

Work in pairs. Carefully describe all aspects of this graphic. What do you notice?

## Minard's March on Moscow

Some things MVJ notices:

- Time is represented by east-west position
- Temperature line graph at the bottom synched with return march progress.
- Very sparse geography representation to help a reader orient.
- Chart-crossing lines to guide the reader associating temperature chart to army positions.

## Minard's March on Moscow

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**Homework:** Recreate Minard's March on Moscow chart as faithfully as you can on your chosen platform. Blackboard has data files with positions of the cities, extents of the paths, and data for the temperature chart.
If you want the rivers, you may have to find corresponding data yourself.