

# Visual perception

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## Visualizzazione dell'Informazione Quantitativa

<http://softeng.polito.it/courses/VIQ>



**SoftEng**  
<http://softeng.polito.it>

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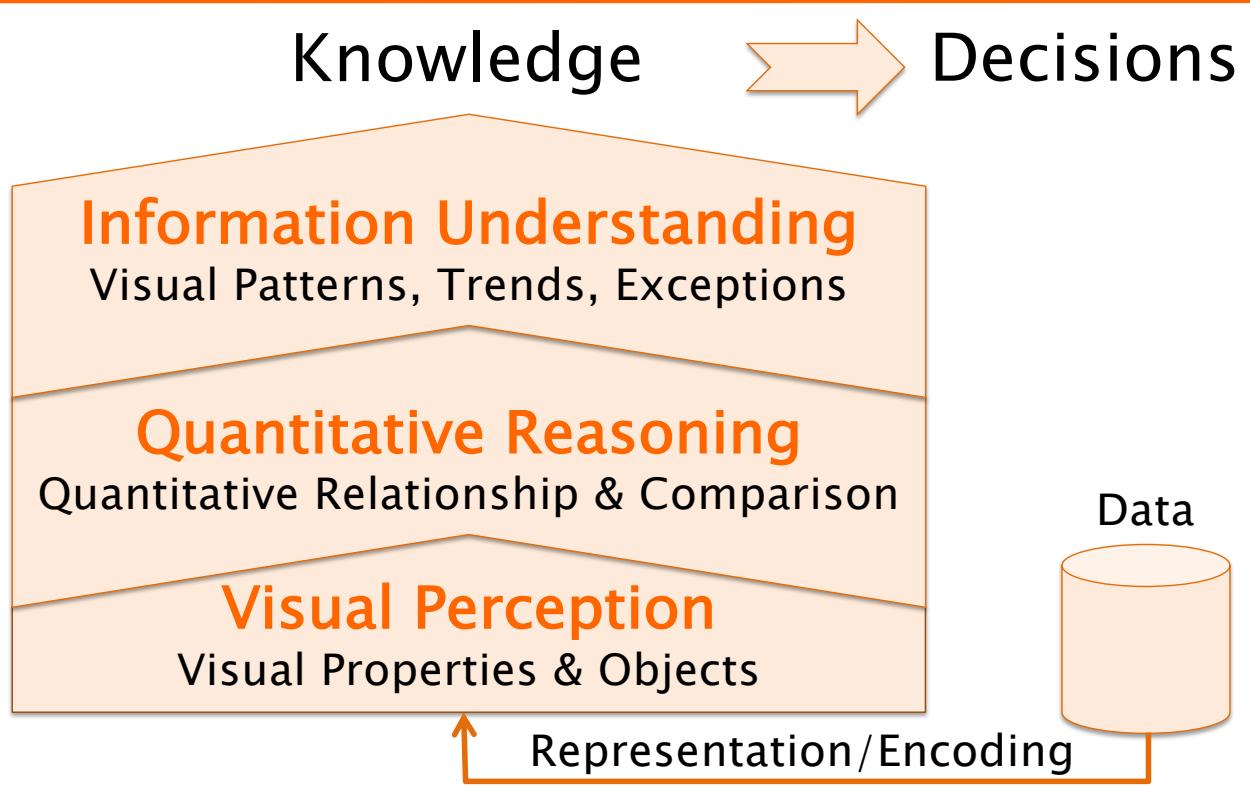
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# VISUALIZATION PIPELINE

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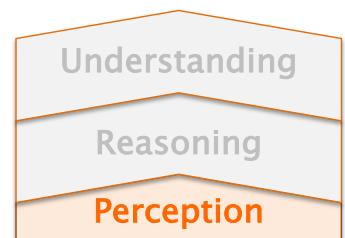
## Visualization Pipeline



# Visual Perception

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- Any variable (measure) must be **visually encoded**, i.e. we need to identify:
  - ◆ Visual object to represent entity
  - ◆ Visual attribute to represent the measure



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## Example

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Votes received by four candidates in recent elections

| Candidate | Votes  | Proportion |
|-----------|--------|------------|
| Sergio    | 197800 | 50.09%     |
| Alberto   | 140545 | 35.59%     |
| Giorgio   | 53748  | 13.61%     |
| Valter    | 2759   | 0.70%      |

# Encoding

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- Visual object: line
- Visual attribute: length



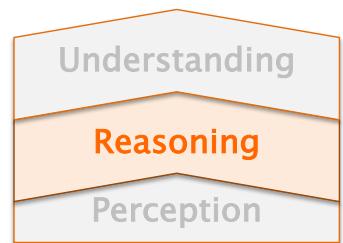
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# Visual Reasoning

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Layout and visual attributes allow:

- **Discrimination**
  - ◆ Distinguish visual objects or group of –
- **Comparison**
  - ◆ Place visual objects in order
- **Magnitude assessment**
  - ◆ Evaluate the (relative) magnitude of visual objects



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# Reasoning

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Alberto

Valter

Sergio

Giorgio

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# Reasoning

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## ▪ Discrimination

Alberto

Valter

Giorgio

Sergio

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# Reasoning

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- Comparison

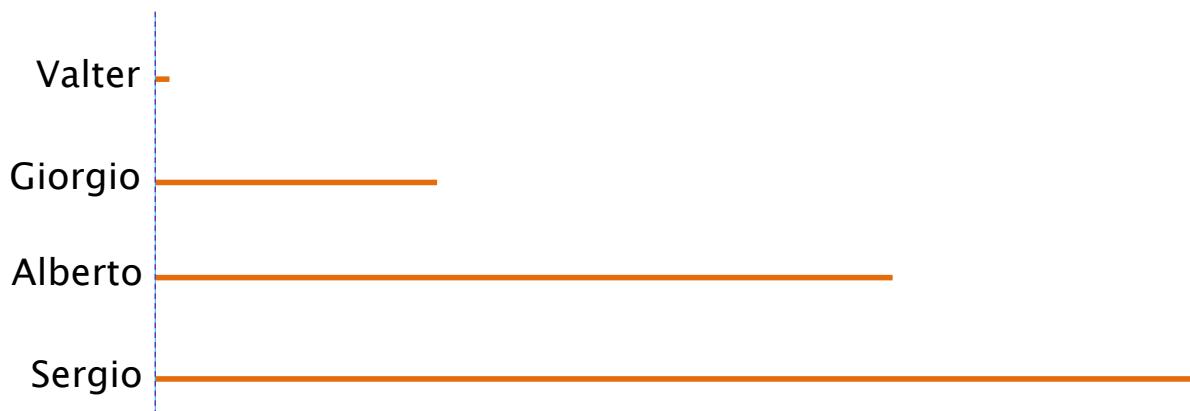


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# Reasoning

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- Assessment

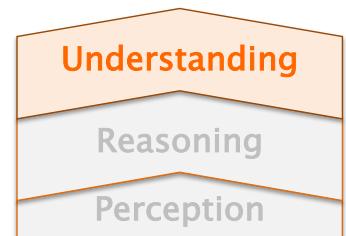


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# Understanding

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- Variation within quantitative measures
  - ◆ Distribution
  - ◆ Deviation
  - ◆ Correlation
- Variation within category
  - ◆ Ranking
  - ◆ Part-to-whole
  - ◆ Time
  - ◆ Space
- Multivariate



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# Understanding

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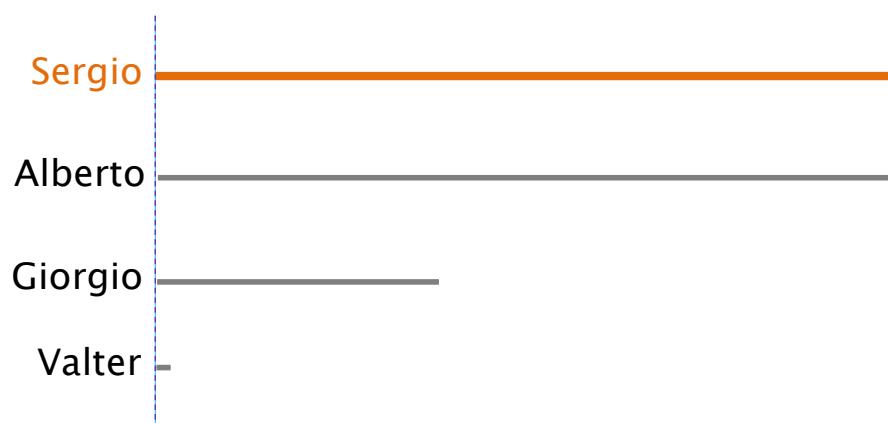
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# Understanding

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## ■ Ranking



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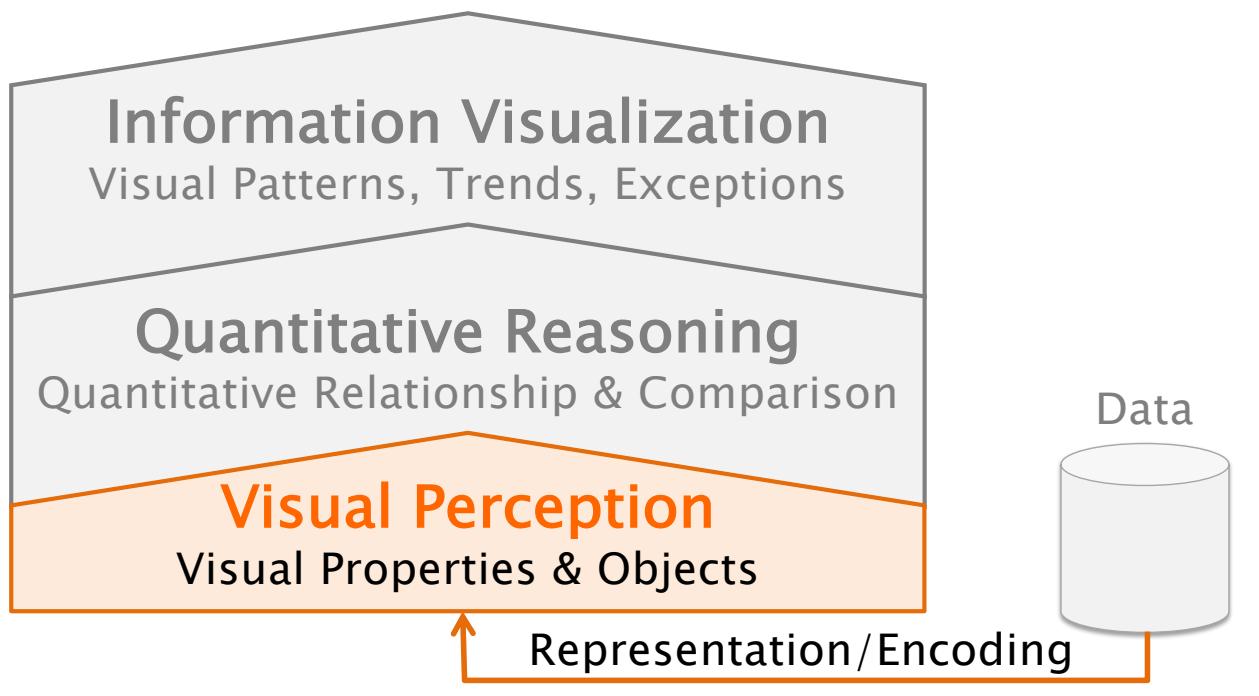
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# VISUAL PERCEPTION

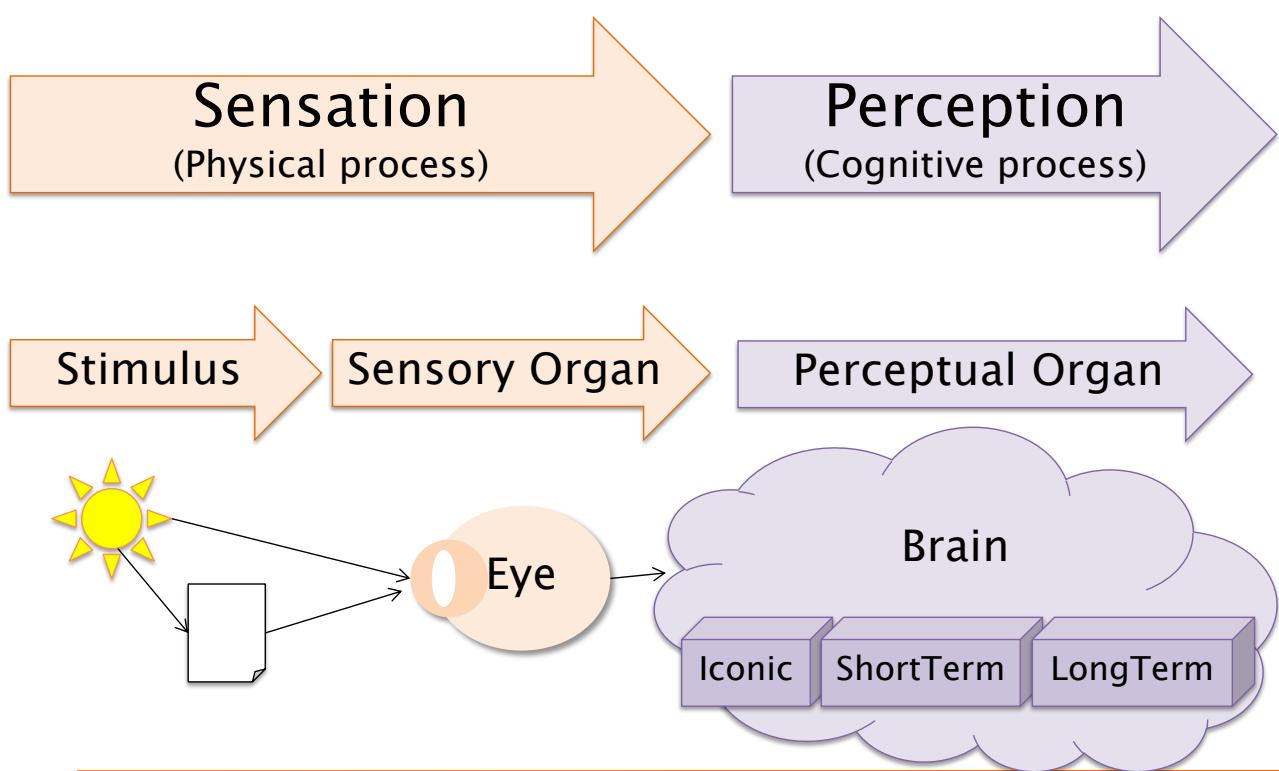
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# Data Visualization

## Understanding



## Visual perception



# Memory Hierarchy

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- Iconic memory (visual sensory register)
  - ◆ Pre-attentive processing
  - ◆ Detects a **limited number of attributes**
- Short-term memory (working memory)
  - ◆ Store visual chunks
  - ◆ Limited number
- Long-term memory
  - ◆ Store high-level knowledge

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## Simplified Model

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- The three levels of memory represent a simplified model
  - ◆ does not correspond to “real” physical structure
- Useful to explain a few phenomena
  - ◆ The  $7 \pm 2$  rule
  - ◆ Change blindness

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# Change blindness

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<http://www2.psych.ubc.ca/~rensink/flickr/download/index.html>

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## Pre-Attentive Attributes

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|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 7 | 8 | 4 | 9 | 8 | 3 | 1 | 1 | 0 | 6 | 8 | 8 | 2 | 1 | 1 | 5 | 2 | 6 | 6 | 5 |
| 9 | 5 | 1 | 8 | 4 | 6 | 8 | 4 | 9 | 3 | 0 | 4 | 5 | 3 | 4 | 9 | 2 | 5 | 8 | 5 | 8 |
| 5 | 0 | 5 | 4 | 6 | 2 | 6 | 5 | 7 | 3 | 7 | 8 | 6 | 5 | 3 | 7 | 2 | 6 | 3 | 1 | 5 |
| 5 | 8 | 6 | 6 | 8 | 3 | 7 | 6 | 5 | 0 | 9 | 6 | 3 | 4 | 6 | 1 | 9 | 5 | 6 | 6 | 4 |
| 1 | 6 | 7 | 3 | 9 | 9 | 2 | 8 | 3 | 4 | 0 | 3 | 5 | 1 | 6 | 3 | 5 | 3 | 9 | 3 | 4 |
| 8 | 6 | 9 | 7 | 5 | 4 | 2 | 4 | 7 | 4 | 9 | 5 | 8 | 5 | 3 | 0 | 7 | 6 | 0 | 6 | 7 |
| 0 | 3 | 1 | 5 | 3 | 2 | 3 | 5 | 6 | 7 | 2 | 8 | 9 | 8 | 5 | 3 | 7 | 8 | 8 | 2 | 4 |
| 5 | 5 | 3 | 4 | 8 | 1 | 5 | 6 | 2 | 3 | 5 | 5 | 1 | 2 | 1 | 0 | 8 | 7 | 2 | 6 | 3 |
| 7 | 4 | 3 | 8 | 4 | 8 | 2 | 6 | 7 | 9 | 5 | 6 | 2 | 3 | 6 | 7 | 8 | 0 | 8 | 3 | 6 |
| 4 | 9 | 5 | 6 | 7 | 2 | 2 | 2 | 8 | 3 | 1 | 1 | 0 | 1 | 8 | 6 | 2 | 6 | 2 | 1 | 4 |

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# Pre-Attentive Attributes

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|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 7 | 8 | 4 | 9 | 8 | 3 | 1 | 1 | 0 | 6 | 8 | 8 | 2 | 1 | 1 | 5 | 2 | 6 | 6 | 5 |
| 9 | 5 | 1 | 8 | 4 | 6 | 8 | 4 | 9 | 3 | 0 | 4 | 5 | 3 | 4 | 9 | 2 | 5 | 8 | 5 | 8 |
| 5 | 0 | 5 | 4 | 6 | 2 | 6 | 5 | 7 | 3 | 7 | 8 | 6 | 5 | 3 | 7 | 2 | 6 | 3 | 1 | 5 |
| 5 | 8 | 6 | 6 | 8 | 3 | 7 | 6 | 5 | 0 | 9 | 6 | 3 | 4 | 6 | 1 | 9 | 5 | 6 | 6 | 4 |
| 1 | 6 | 7 | 3 | 9 | 9 | 2 | 8 | 3 | 4 | 0 | 3 | 5 | 1 | 6 | 3 | 5 | 3 | 9 | 3 | 4 |
| 8 | 6 | 9 | 7 | 5 | 4 | 2 | 4 | 7 | 4 | 9 | 5 | 8 | 5 | 3 | 0 | 7 | 6 | 0 | 6 | 7 |
| 0 | 3 | 1 | 5 | 3 | 2 | 3 | 5 | 6 | 7 | 2 | 8 | 9 | 8 | 5 | 3 | 7 | 8 | 8 | 2 | 4 |
| 5 | 5 | 3 | 4 | 8 | 1 | 5 | 6 | 2 | 3 | 5 | 5 | 1 | 2 | 1 | 0 | 8 | 7 | 2 | 6 | 3 |
| 7 | 4 | 3 | 8 | 4 | 8 | 2 | 6 | 7 | 9 | 5 | 6 | 2 | 3 | 6 | 7 | 8 | 0 | 8 | 3 | 6 |
| 4 | 9 | 5 | 6 | 7 | 2 | 2 | 2 | 8 | 3 | 1 | 1 | 0 | 1 | 8 | 6 | 2 | 6 | 2 | 1 | 4 |

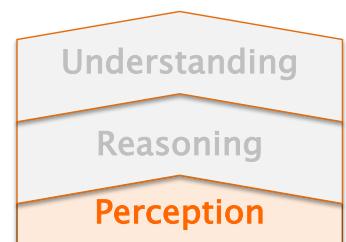
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## Encoding

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- Encoding is the key to enable visual perception
  - ◆ Visual object to represent entity
  - ◆ Visual attribute to represent the measure
- Two main types
  - ◆ Quantitative (different properties)
  - ◆ Categorical (ordinal or not)



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# Pre-Attentive attributes

| Category         | Attribute  |
|------------------|--|
| Form             | Orientation<br>Length/distance<br>Line width<br>Size<br>Shape<br>Curvature<br>Added marks<br>Enclosure |
| Color            | Hue<br>Intensity   |
| Spatial position | 2-D position   |
| Motion           | Flicker<br>Direction<br>Speed  |

## Perception task

Visual attributes allow:

- **Discrimination**
  - ◆ Distinguish visual objects
- **Comparison**
  - ◆ Place visual objects in order
- **Magnitude assessment**
  - ◆ Evaluate the (relative) magnitude of visual objects

# Just noticeable difference

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- Given a physical dimension (length, brightness, etc.) xx
- $d$  is the **just noticeable difference** if:
  - ◆ difference between  $x$  and  $x+d$  is perceivable
  - ◆ but not smaller differences
- $d$  depends on many factors:
  - ◆ Subject
  - ◆ Environment
  - ◆ Physical dimension

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## Weber's law

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- Just noticeable difference  $d$  is:

$$d_p(x) = k_p \cdot x$$

- Where
  - ◆  $x$ : dimension
  - ◆  $d_p(x)$ : just noticeable difference
  - ◆  $k_p$ : constant
    - Subjective
    - Environmental

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# Consequences of Weber's law

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- It is easier to compare lengths that differ by a large percentage
- The same difference is easier to notice between smaller measures
  - ◆ More likely to be larger than just noticeable difference

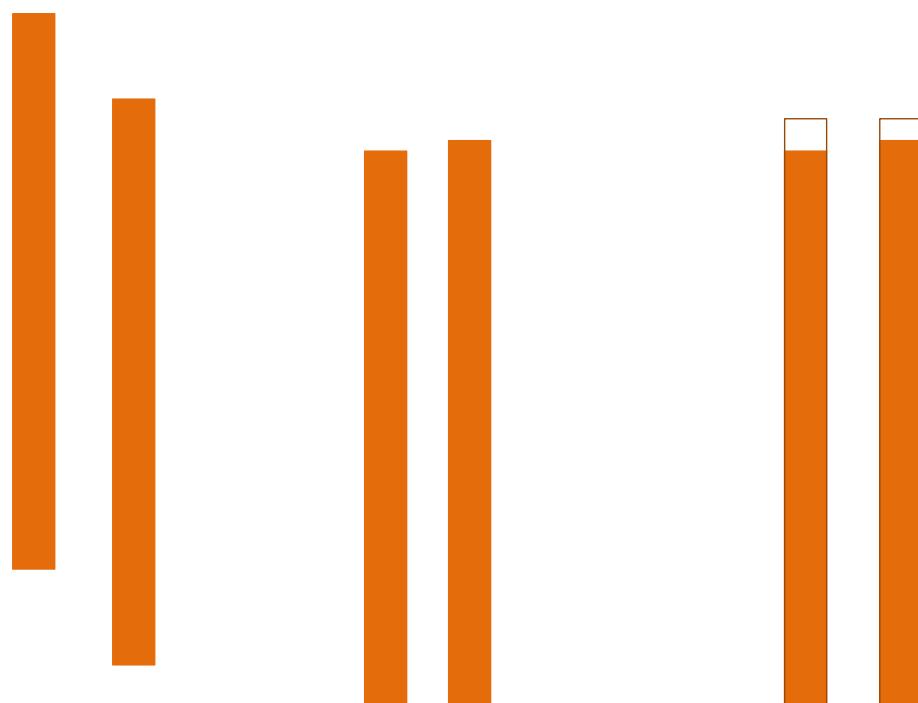
$$x < y \implies d_p(x) < d_p(y)$$

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## Non-aligned objects lengths

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# Non-aligned objects lengths

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- Additional references my help comparison
  - ◆ They provide alternative possible comparisons
- If lengths range between 0 and a maximum ( $L$ ), e.g. percentages
- Comparing  $l_1$  and  $l_2$  (close to  $L$ ) that differ by a small amount  $d$ 
  - ◆ Difference  $L-l_1$  vs.  $L-l_2$  easier to notice than  $l_1$  vs.  $l_2$

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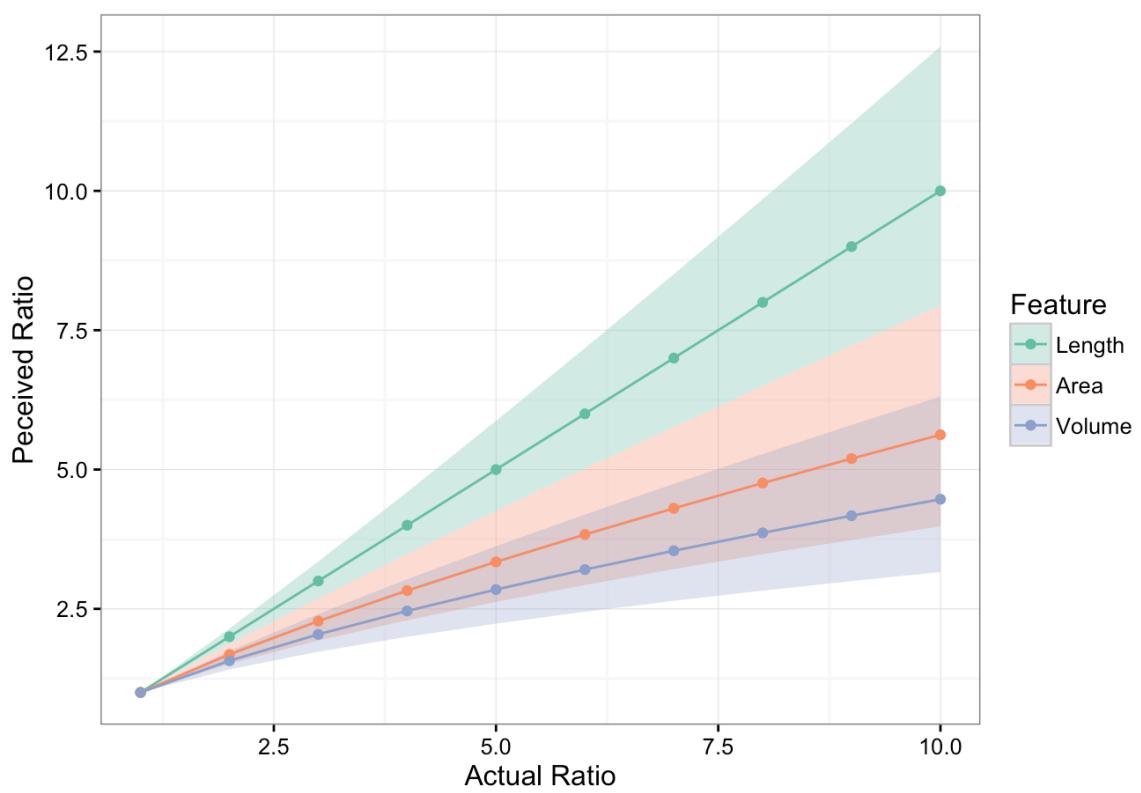
## Stevens's law

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- Perceive scale (magnitude ratio)
$$p(x) = c \cdot x^\beta$$
- Where  $\beta$  depends on spatial dimension
  - ◆ 1D: Length  $\rightarrow \beta$  in [0.9, 1.1]
  - ◆ 2D: Area  $\rightarrow \beta$  in [0.6, 0.9]
  - ◆ 3D: Volume  $\rightarrow \beta$  in [0.5, 0.8]

# Steven's law

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# Steven's law

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# Consequences

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- Prefer comparing lengths
- Avoid comparison between areas
  - ◆ Except for ordinal measures
- Never-ever make volume comparisons

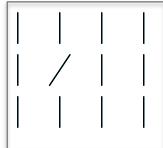
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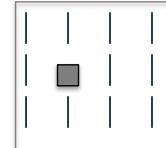
## Attributes of form

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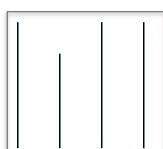
Orientation



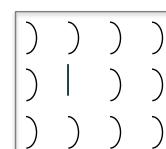
Shape



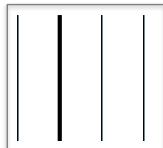
Line Length



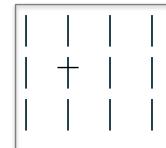
Curvature



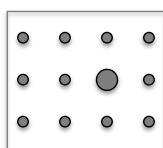
Line Width



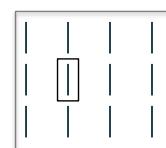
Added mark



Size



Enclosure



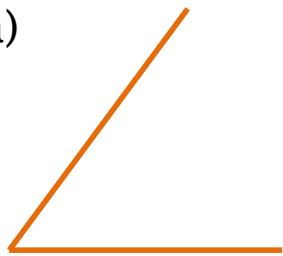
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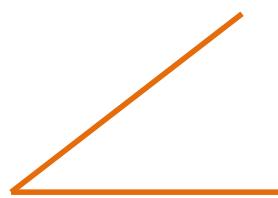
# Orientation (angle or slope)

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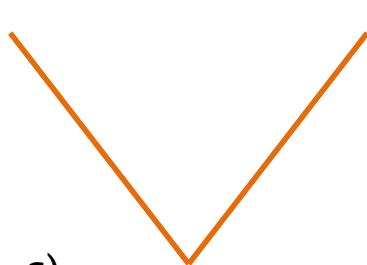
a)



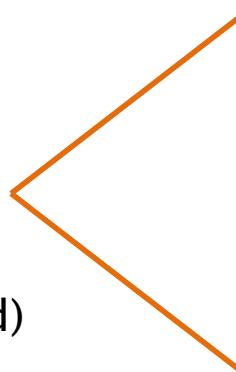
b)



c)



d)



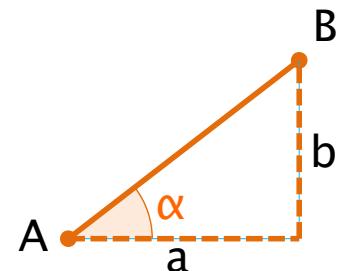
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## Angle vs. Slope

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- Slope of A-B is  $b/a$ 
  - ◆  $\tan(\alpha)$
- Slope judgment typically falls back to an angle judgment
  - ◆ Given an error  $\epsilon$  in the angle judgment
  - ◆ It is reflected in a slope error



$$\tan(\alpha + \epsilon) - \tan(\alpha) = \epsilon \cdot \tan'(\alpha) = \frac{\epsilon}{\cos^2(\alpha)}$$

- Getting infinite as  $\alpha$  approaches to  $\pi/2$

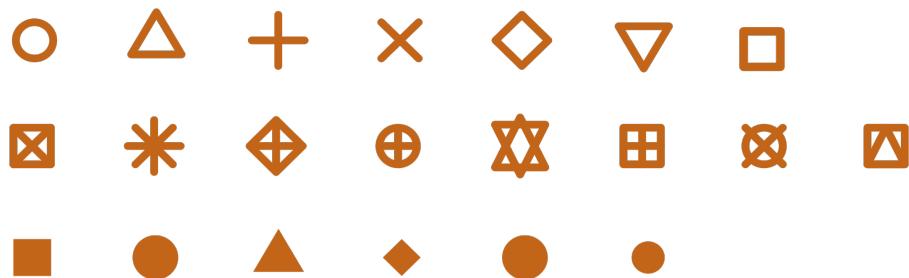
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# Shape

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- There is no common quantitative semantics for the shapes
  - Unless they are characters...
- ◆ Fill textures are shapes too

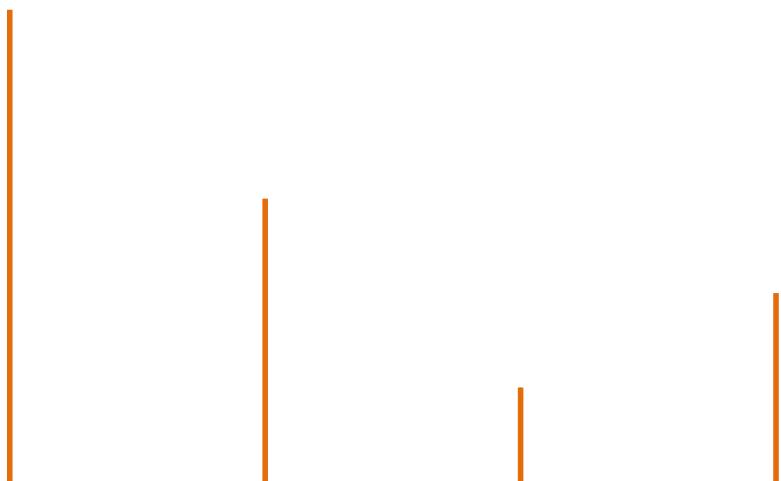


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# Length

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# Effect of context

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# Curvature

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- There is no common magnitude assessment for the curvature



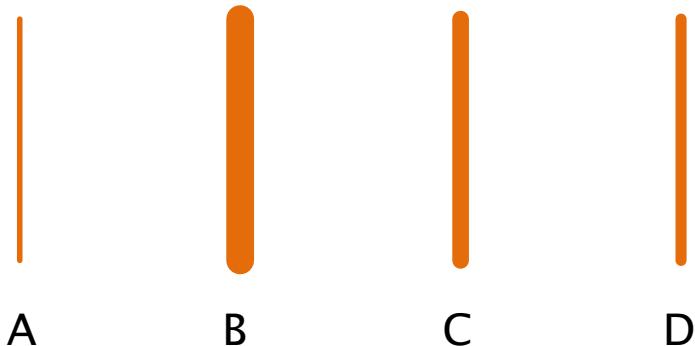
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# Width

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- Order can be identified
  - ◆ Difficult to appreciate actual magnitude



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# Mark

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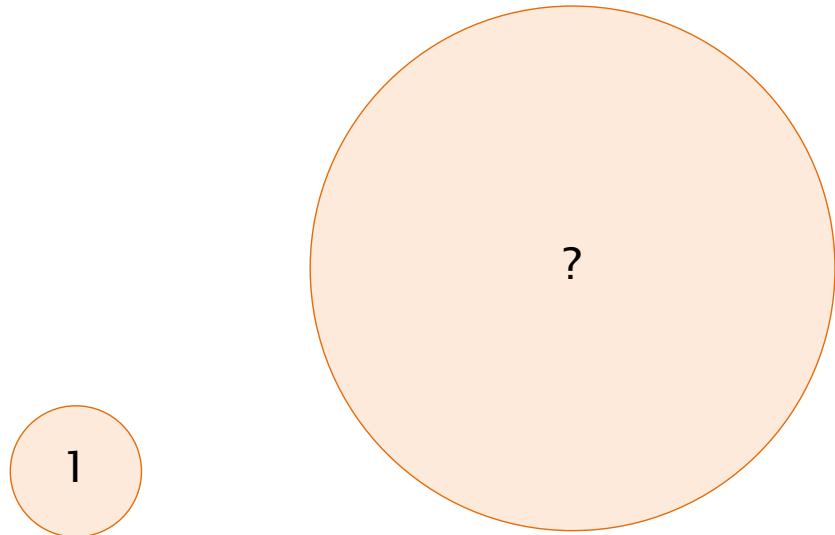
- No common quantitative semantics of marks
- Number of marks could encode a natural number
  - ◆ Harder to read than a cipher

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# Size / Area

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# Enclosure

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- No common quantitative semantics for enclosure
  - ◆ Except counting items enclosed

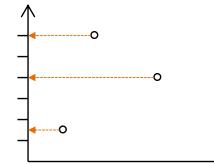
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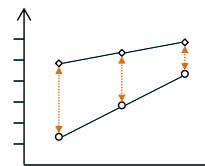
# Spatial Position

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- Position along axis
  - ◆ Common scale
  - ◆ Distinct identical scales
    - Possibly un-aligned



- Distance



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# Position

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- A common scale

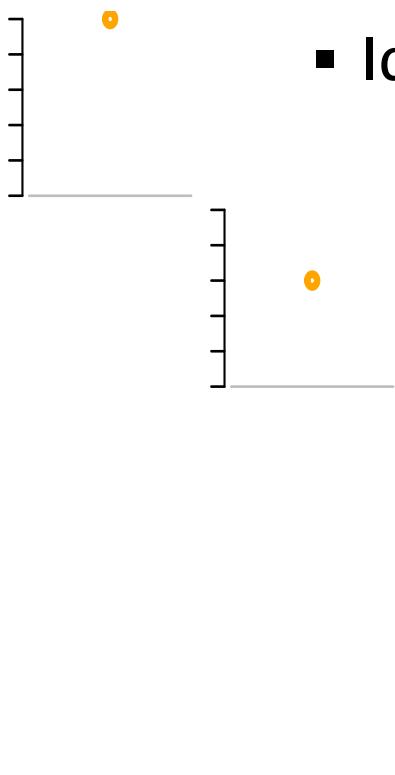


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# Position

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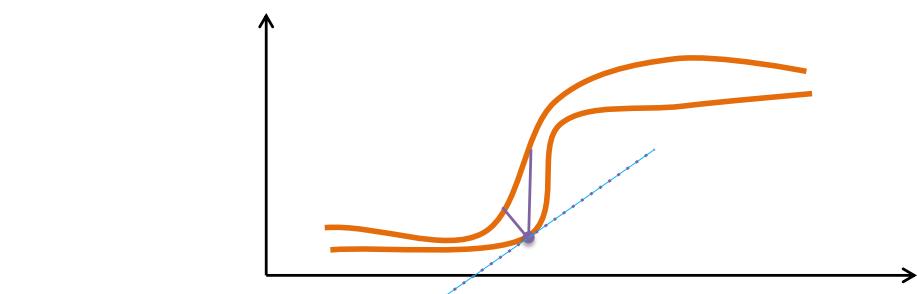
- Identical non-aligned scales

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# Distance

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- Points
  - ◆ Use length of imaginary connecting lines
- Lines
  - ◆ Distance orthogonal to tangent
    - Not what is meant in xy plots



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# Detection and Separation

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Comparison is affected by:

- Detection
  - ◆ The capability to visually identify the objects that represent the data to be compared
- Separation
  - ◆ The distance between the objects to be compared
    - affects negatively the accuracy

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## Attributes of color

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- Hue



- Saturation



- Intensity



- ◆ Luminance
- ◆ Value

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# Hue

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- There is no common ordering semantics for hues
  - ◆ High spatial frequencies are perceived through intensity changes
  - ◆ Often perceived as separated into bands of almost constant hue, with sharp transitions between hues
- Nominal values can be represented by suitably spaced values



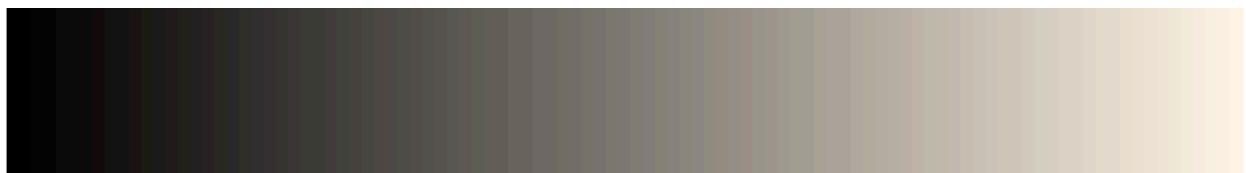
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# Intensity

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- ◆ a.k.a. Luminance, Value
- Provides a perceptually unambiguous ordering
  - ◆ Context can affect accuracy



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# Saturation

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- Perceptually difficult to associate an ordered semantics
  - ◆ Can be combined with hue to increase discrimination

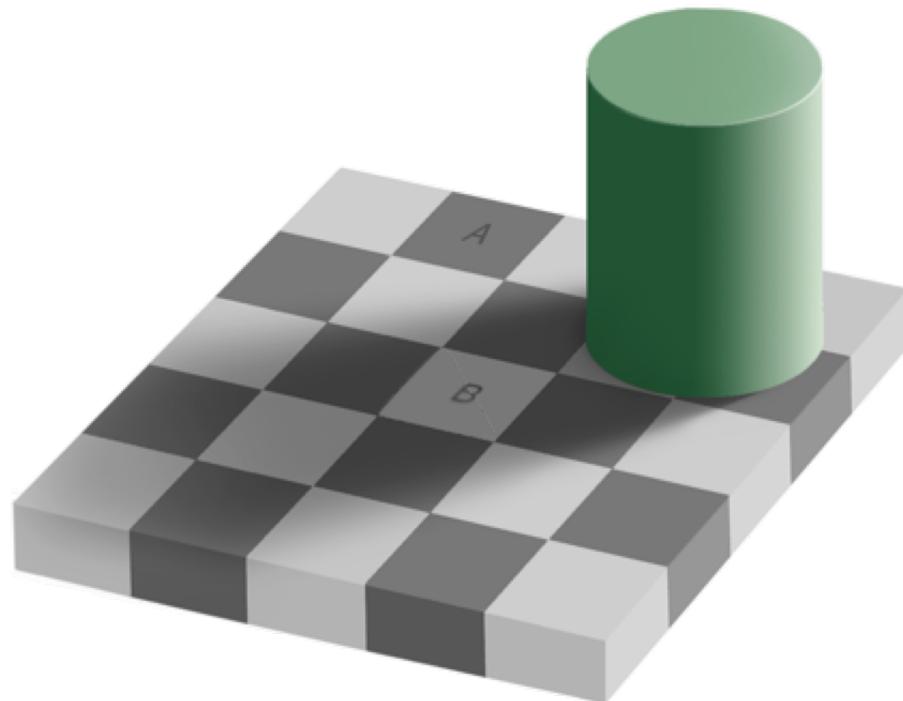


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## Effect of Context

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# Effect of Context

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- Use uniform background
  - ◆ To make distinct visual objects for the same feature look the same
- Use a background color that is contrasting enough with the visual objects' color
  - ◆ To make visual objects easily seen
- Avoid non-uniform background

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## Color usage

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- Ordinal measure should be mapped to increasing saturation **and** intensity
  - ◆ Avoid rainbow palette
- Use sequential or diverging palette
  - ◆ E.g.



- <http://colorbrewer2.org/>

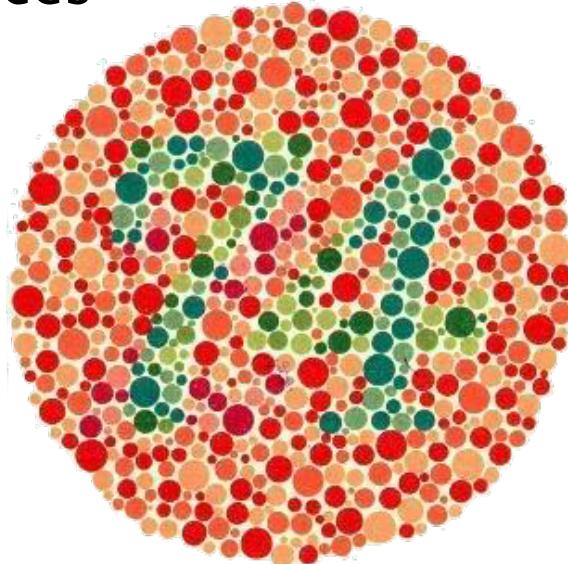
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# Color Blindness

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- Inability so see colors or perceive color differences



<http://www.color-blindness.com>

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## Pre-Attentive attributes

| Category         | Attribute    | Quantitative |
|------------------|--------------|--------------|
| Form             | Orientation  | Partly       |
|                  | Length       | Yes          |
|                  | Line width   | No           |
|                  | Size         | Partly       |
|                  | Shape        | No           |
|                  | Curvature    | No           |
|                  | Added marks  | No           |
|                  | Enclosure    | No           |
| Color            | Hue          | No           |
|                  | Intensity    | Limited      |
| Spatial position | 2-D position | Yes          |
| Motion           | Flicker      | No           |
|                  | Direction    | No           |

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# Visual Encoding: Quantitative

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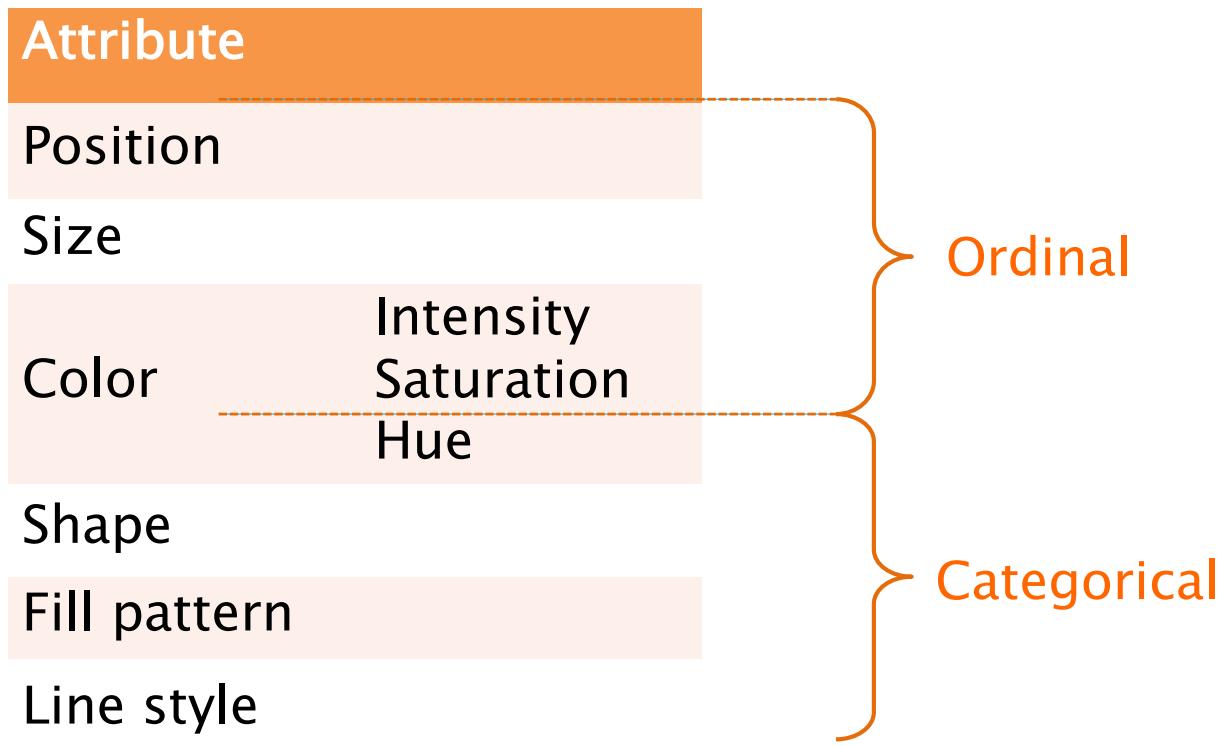
| Object | Attribute                                      |
|--------|--|
| Point  | Position (w.r.t. axis/axes)                    |
| Line   | Length<br>Position (w.r.t. axis/axes)<br>Slope |
| Bar    | Length   |
| Shape  | Size (area)<br>Count                           |

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# Visual Encoding: Categorical

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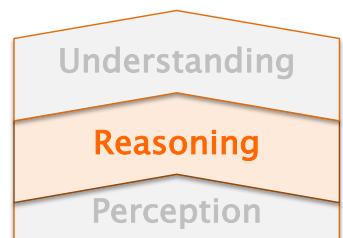


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# VISUAL REASONING



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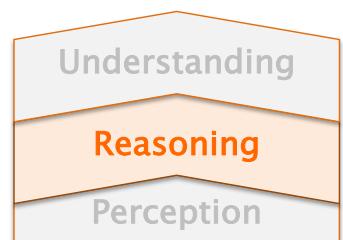
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## Graph layout

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Layout + visual attributes should allow:

- **Discrimination**
  - ◆ Distinguish visual objects or group of –
- **Comparison**
  - ◆ Place visual objects in order
- **Magnitude assessment**
  - ◆ Evaluate the (relative) magnitude of visual objects



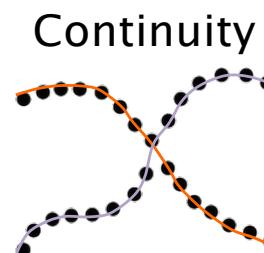
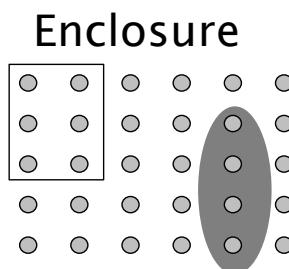
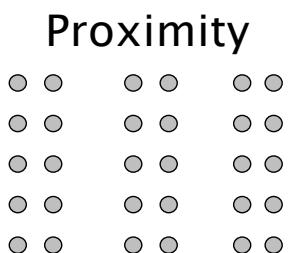
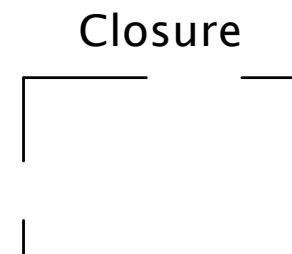
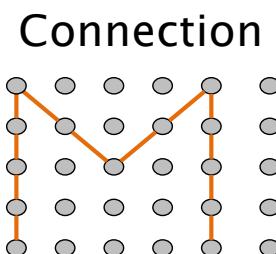
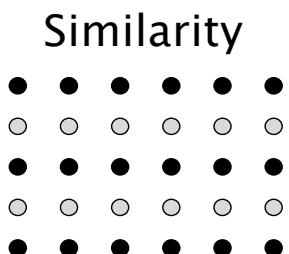
---

64

# Gestalt principles

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- Visual features that lead the viewer to group visual objects together



---

# Gestalt principles

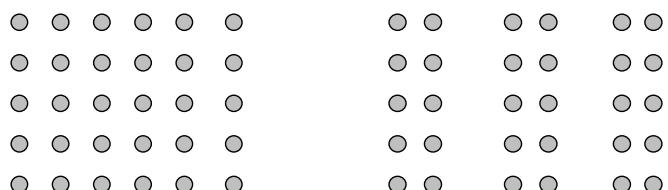
---

- Visual patterns that lead observers to perceive objects together or separate
  - ◆ Proximity
  - ◆ Similarity
  - ◆ Enclosure
  - ◆ Closure
  - ◆ Continuity
  - ◆ Connection

# Gestalt principles

---

- Visual patterns that lead observers to perceive objects together or separate
  - ◆ **Proximity**
  - ◆ Similarity
  - ◆ Enclosure
  - ◆ Closure
  - ◆ Continuity
  - ◆ Connection



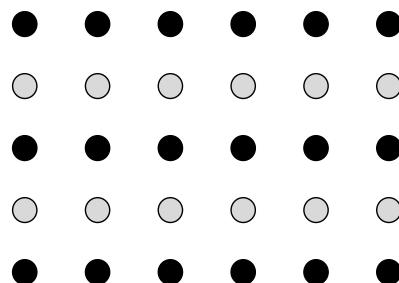
---

67

# Gestalt principles

---

- Visual patterns that lead observers to perceive objects together or separate
  - ◆ Proximity
  - ◆ **Similarity**
  - ◆ Enclosure
  - ◆ Closure
  - ◆ Continuity
  - ◆ Connection



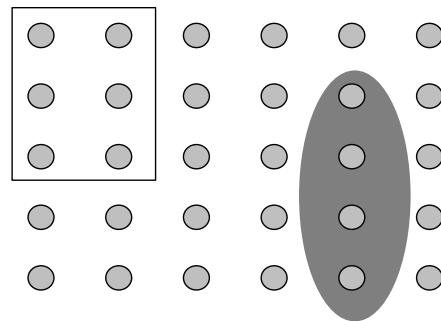
---

68

# Gestalt principles

---

- Visual patterns that lead observers to perceive objects together or separate
  - ◆ Proximity
  - ◆ Similarity
  - ◆ **Enclosure**
  - ◆ Closure
  - ◆ Continuity
  - ◆ Connection



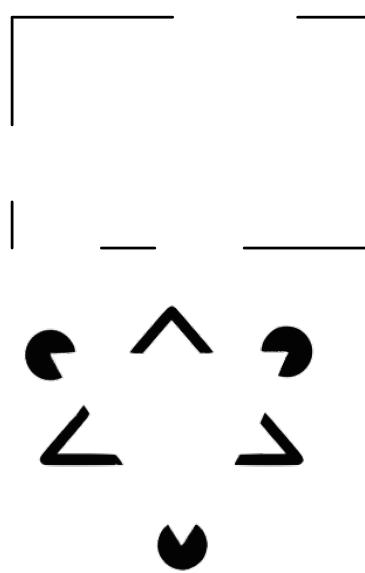
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69

# Gestalt principles

---

- Visual patterns that lead observers to perceive objects together or separate
  - ◆ Proximity
  - ◆ Similarity
  - ◆ Enclosure
  - ◆ **Closure**
  - ◆ Continuity
  - ◆ Connection



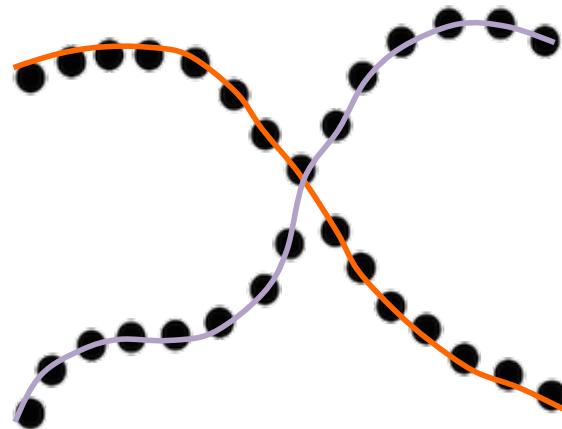
---

70

# Gestalt principles

---

- Visual patterns that lead observers to perceive objects together or separate
  - ◆ Proximity
  - ◆ Similarity
  - ◆ Enclosure
  - ◆ Closure
  - ◆ **Continuity**
  - ◆ Connection



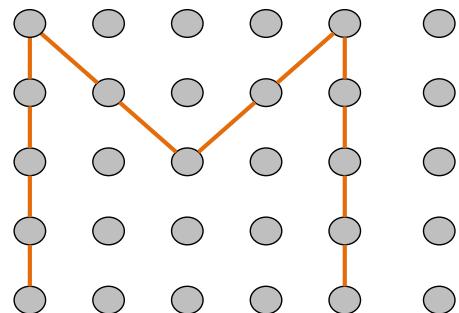
---

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# Gestalt principles

---

- Visual patterns that lead observers to perceive objects together or separate
  - ◆ Proximity
  - ◆ Similarity
  - ◆ Enclosure
  - ◆ Closure
  - ◆ Continuity
  - ◆ **Connection**



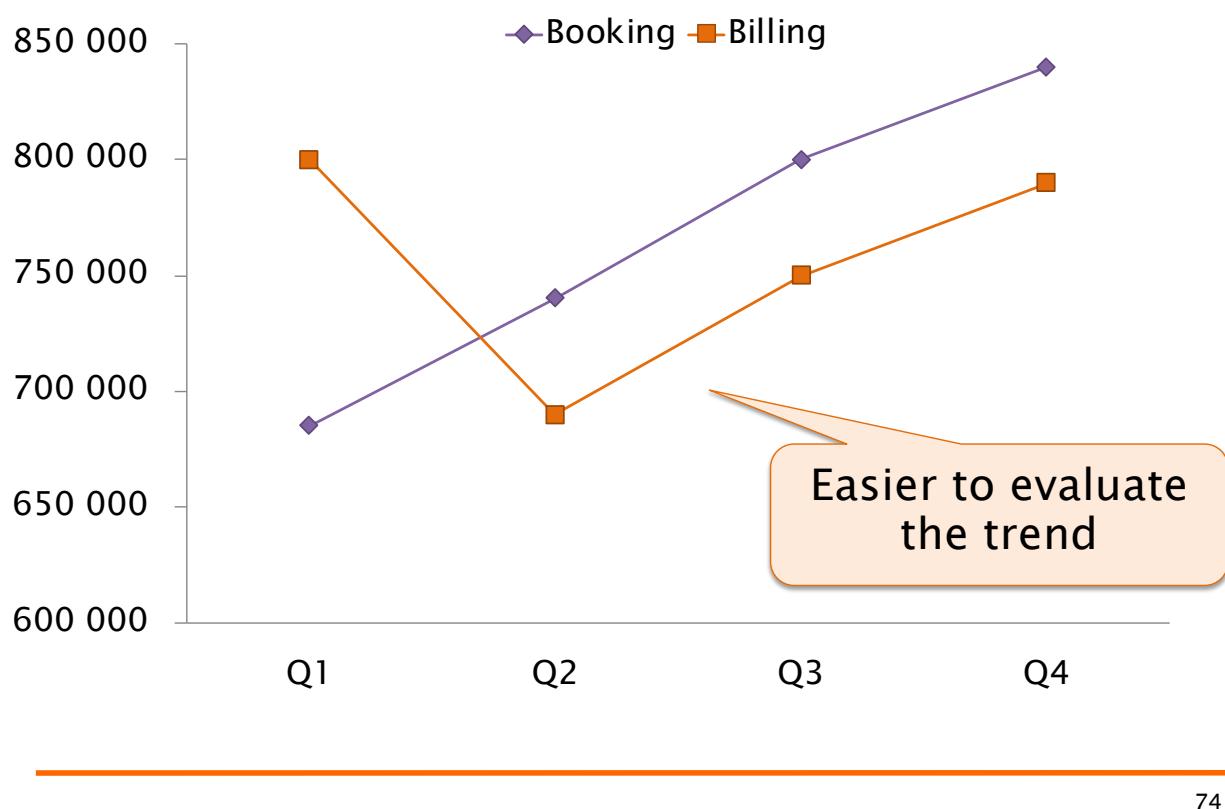
---

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# Similarity in Shape & Color

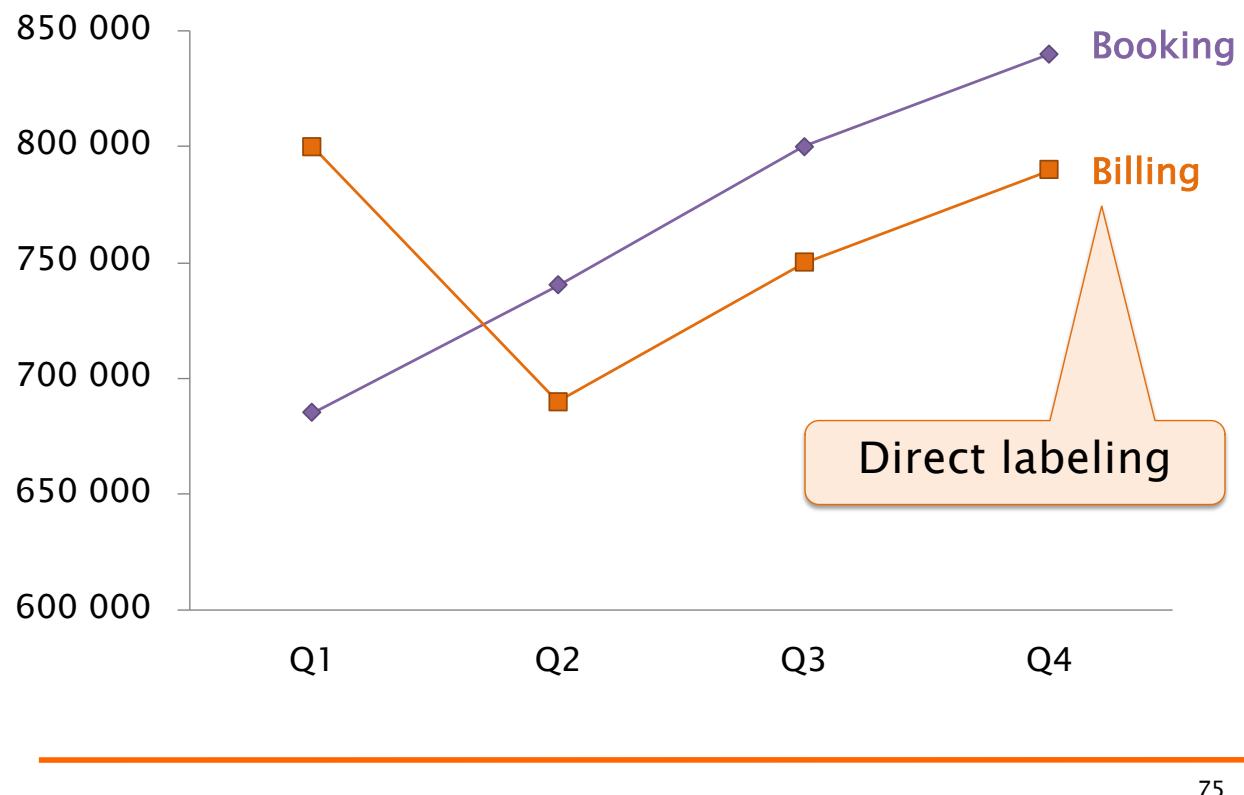


# Similarity+Connection



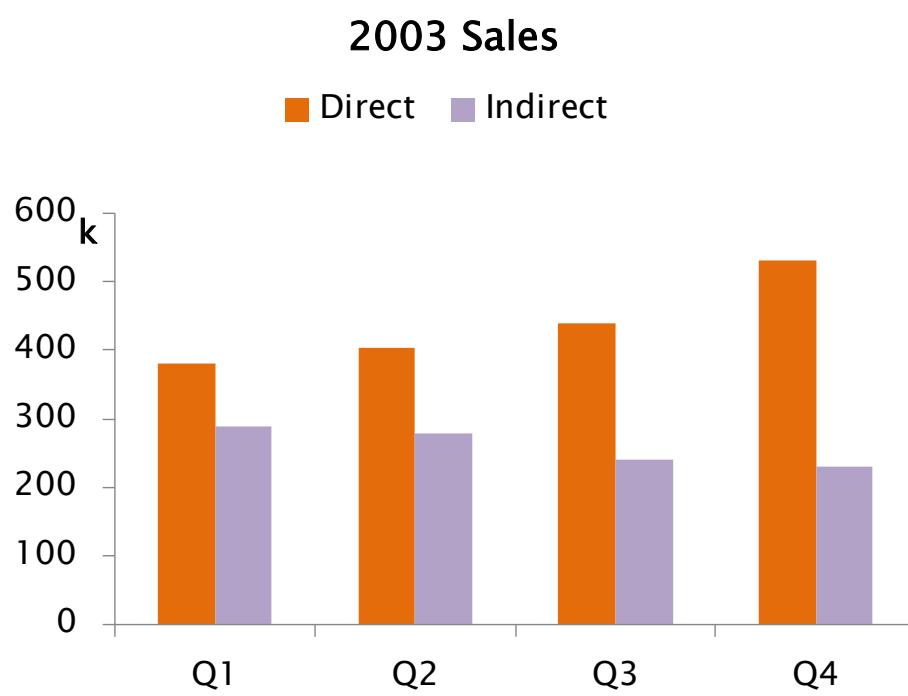
# Similarity+Connection+Proximity

---



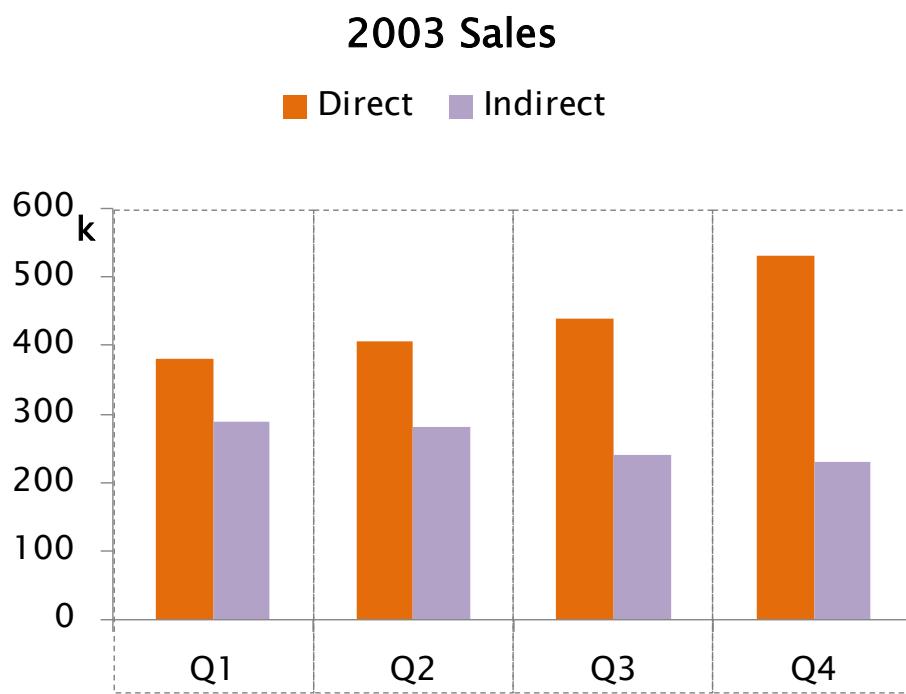
# Similarity × Proximity

---



# Similarity × Proximity & Enclosure

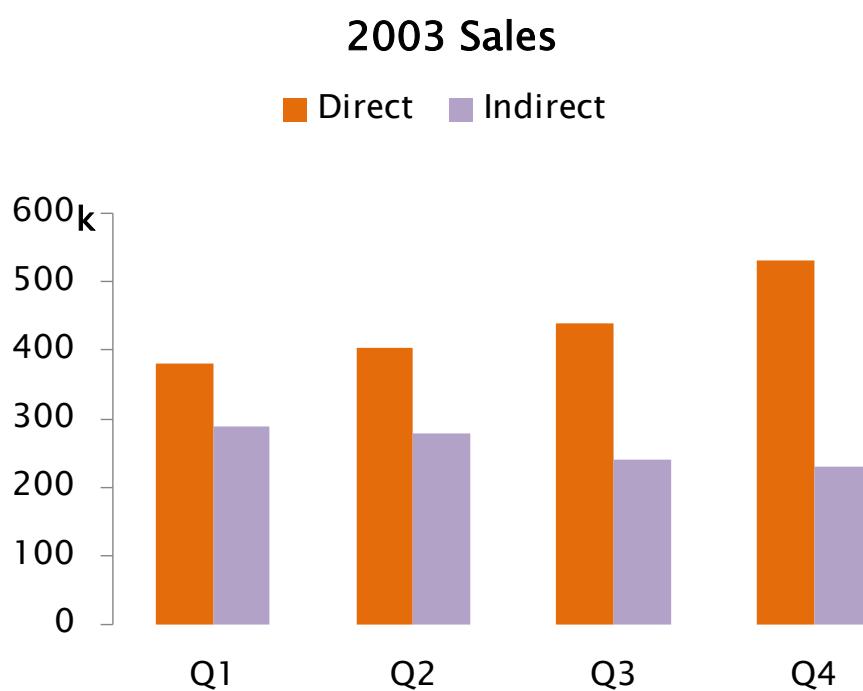
---



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# Continuity replaces axis

---



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# Distinct perceptions

---

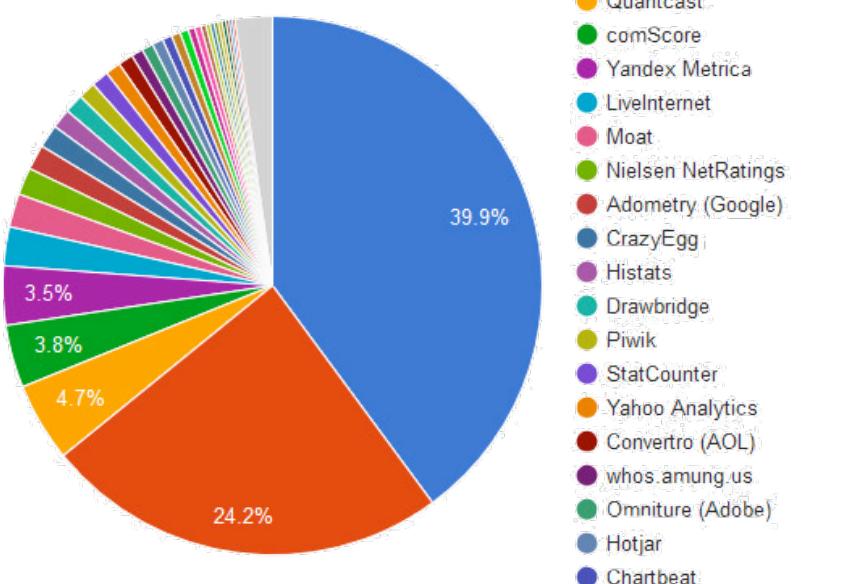
- The immediacy of any pre-attentive cue declines as the variety of alternative patterns increases
  - ◆ Even if all the distracting patterns are individually distinct from the target
  - ◆ For each single attribute no more than **four** distinct levels are immediately discernible
  - ◆ This limit affects the similarity principle

---

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# Rainbow Pies

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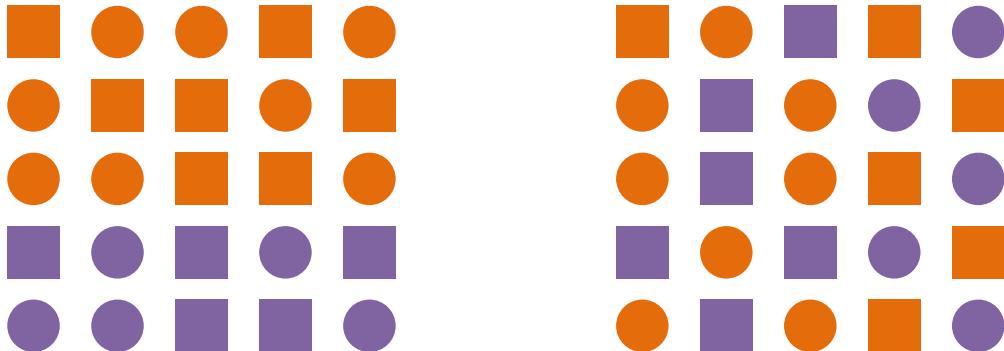


---

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# Attribute Interference

---

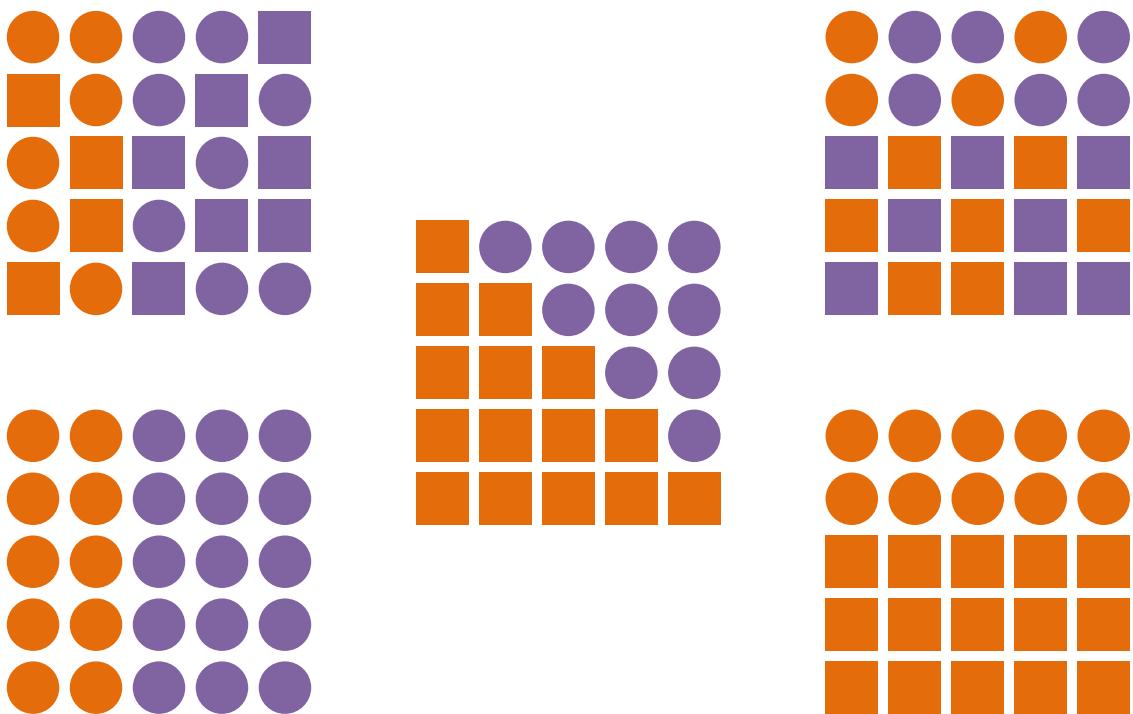


---

81

# Attribute Interference

---



---

82

# Cultural conventions

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- Reading proceed from left to right and from top to bottom
    - ◆ At least in western culture
  - What is at the top (on the left) precedes what is at the bottom (on the right) in terms of
    - ◆ Importance
    - ◆ Ordering
    - ◆ Time
- 

83

## Emphasis

---

| Attribute       | Tables                        | Graphs  |
|-----------------|-------------------------------|---|
| Line width      | Boldface text                 | Thicker lines   |
| Size            | Bigger tables<br>Larger fonts | Bigger graphs<br>Wider bars<br>Bigger symbols                               |
| Color intensity |                               | Darker or brighter colors   |
| 2-D position    |                               | Positioned at the top<br>Positioned at the left<br>Positioned in the center |

---

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## VISUAL INTEGRITY

## Principles of integrity

PUC

- **Proportionality**
  - ◆ Representation as physical quantities should be proportional to the represented numbers
- **Utility**
  - ◆ Graphical element should convey useful information
- **Clarity**
  - ◆ Labeling should counter graphical distortion and ambiguity

# Proportionality

---

PUC

- The magnitude of visual attributes should represent faithfully the magnitude of measures
- They should allow
  - ◆ Discrimination: are they different?
  - ◆ Comparison: which is larger?
  - ◆ Magnitude Assessment: how much larger?

---

87

# Lie Factor

---

PUC

$$LF = \frac{\text{size of effect shown in graphic}}{\text{size of effect in data}}$$

- Overstating
  - ◆  $LF > 1 \Leftrightarrow \log(LF) > 0$
- Understating
  - ◆  $LF < 1 \Leftrightarrow \log(LF) < 0$
- Fair
  - $LF = 1 \Leftrightarrow \log(LF) = 0$

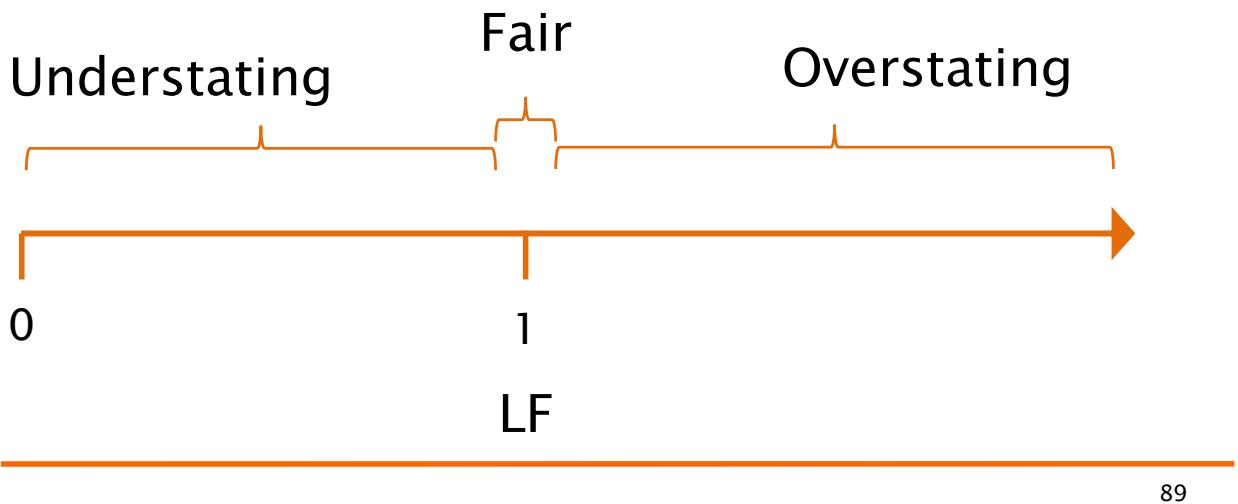
---

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# Lie Factor

PUC

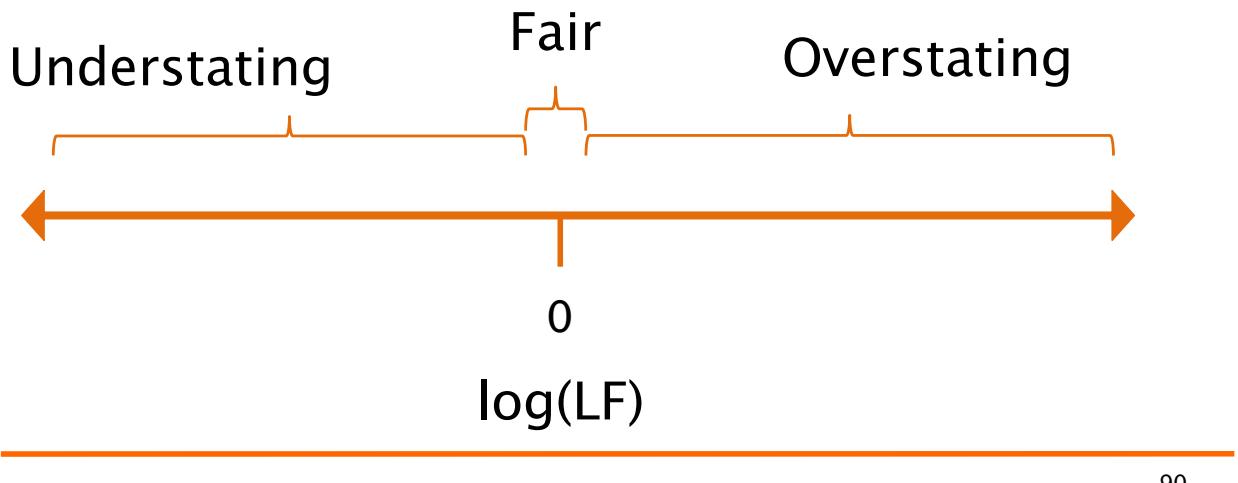
$$LF = \frac{\text{size of effect shown in graphic}}{\text{size of effect in data}}$$



89

# Lie Factor

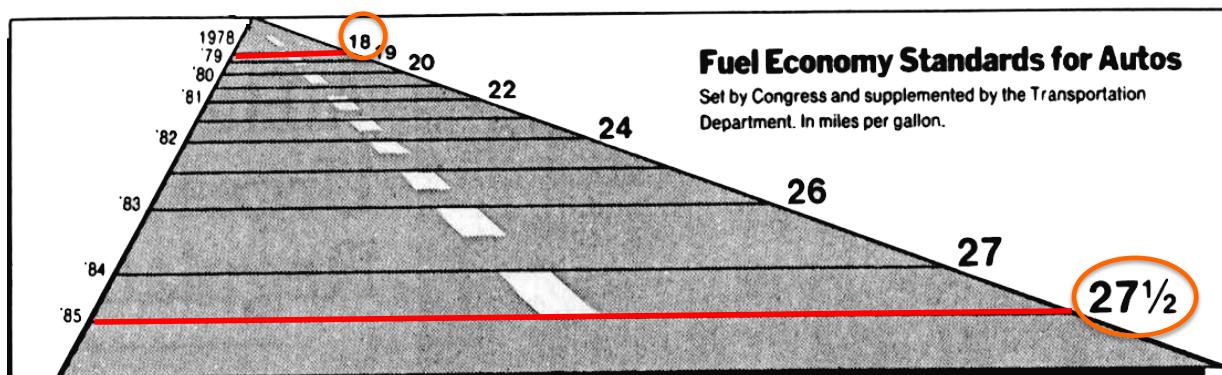
$$LF = \frac{\text{size of effect shown in graphic}}{\text{size of effect in data}}$$



90

# Lie Factor – Example

PUC



$$\frac{18.7}{2.2} = 8.5 \text{ on graphic}$$

$$\frac{27.5}{18} = 1.52 \text{ in data}$$

$$LF = 8.5 / 1.52 = 5.59$$

91

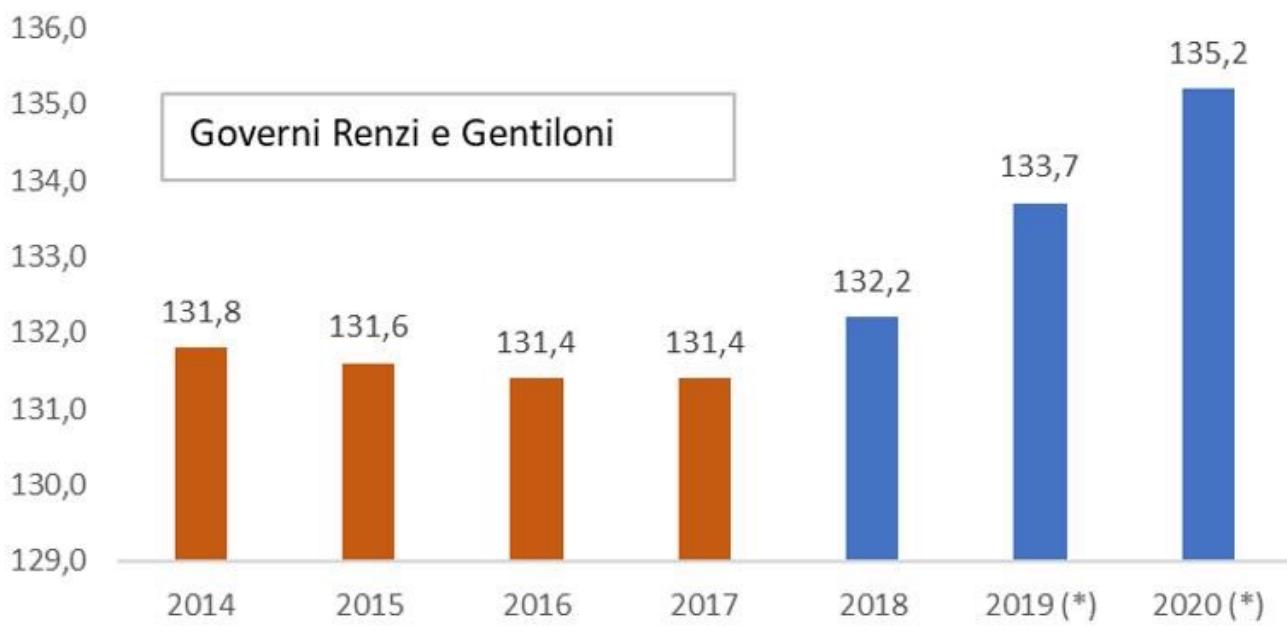
# Lie Factor – Example

PUC

## Debito pubblico (% PIL)

(\*) previsioni Commissione UE

Governo Conte



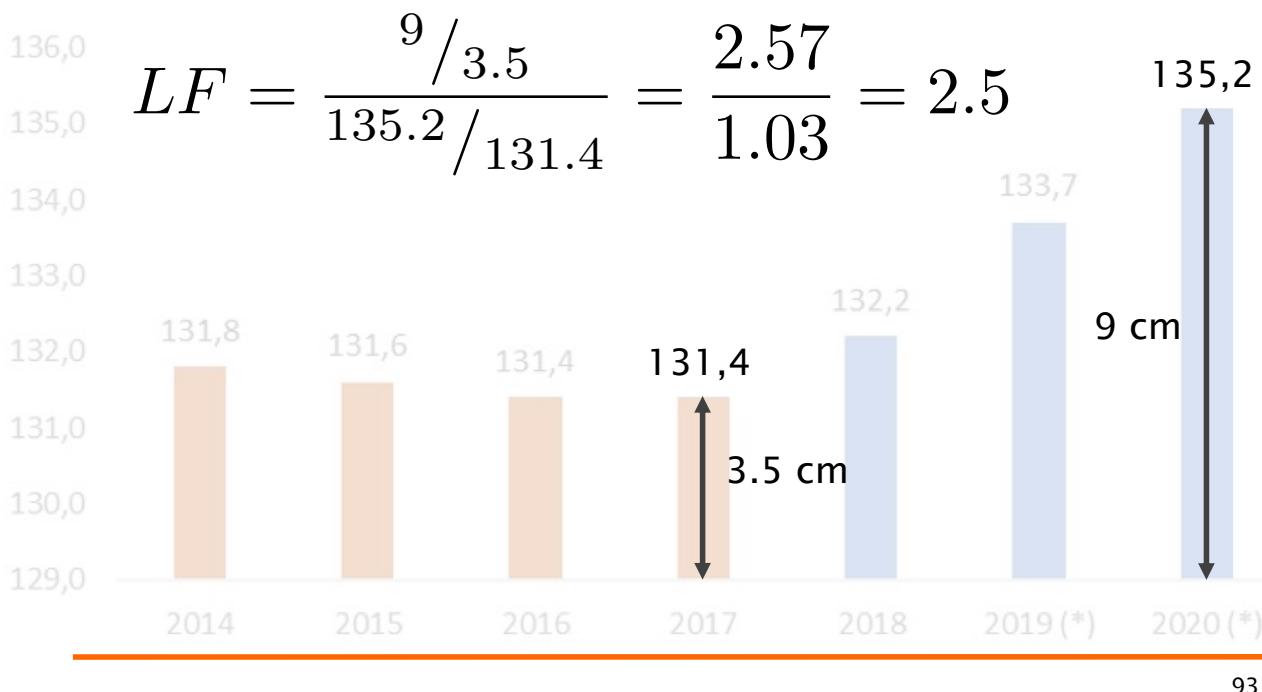
92

# Lie Factor – Example

PUC

Debito pubblico (% PIL)

(\*) previsioni Commissione UE



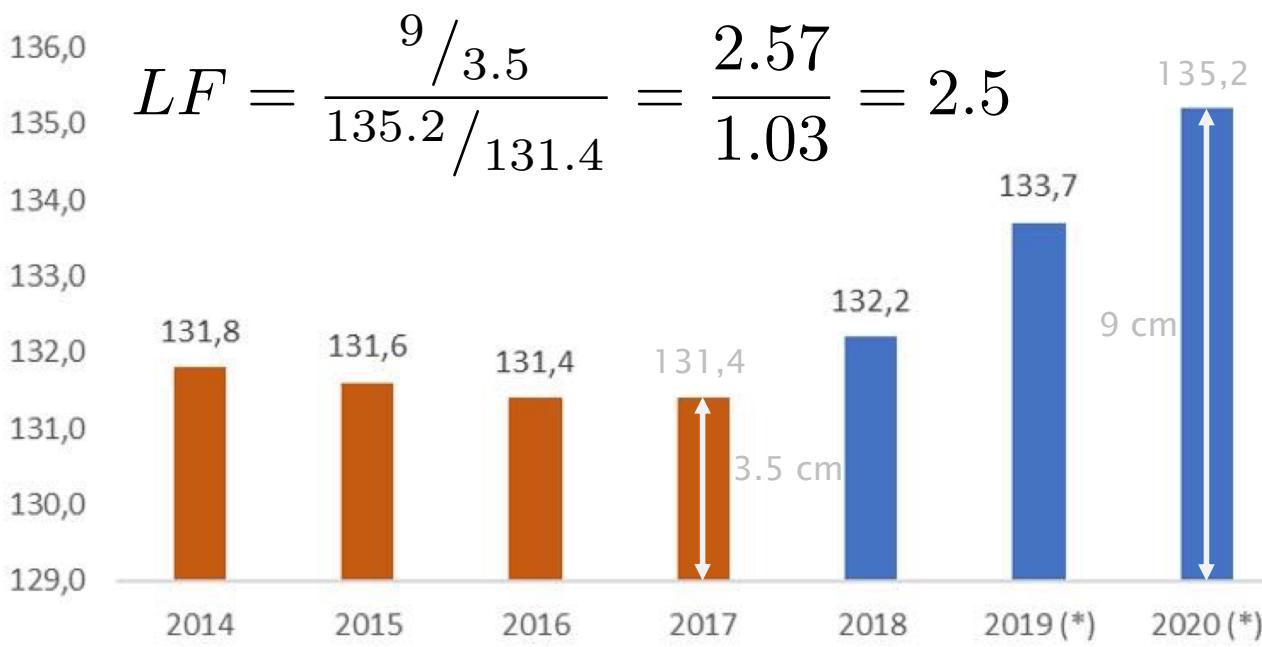
93

# Lie Factor – Example

PUC

Debito pubblico (% PIL)

(\*) previsioni Commissione UE

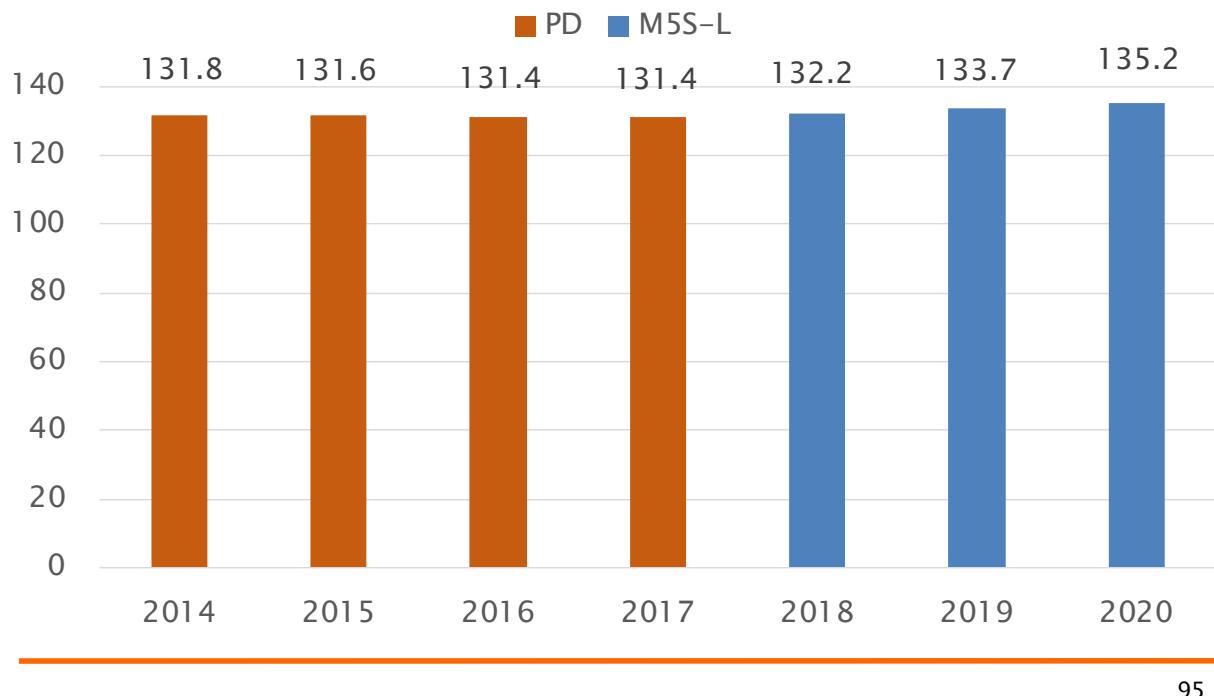


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# Lie Factor –Redesign

PUC

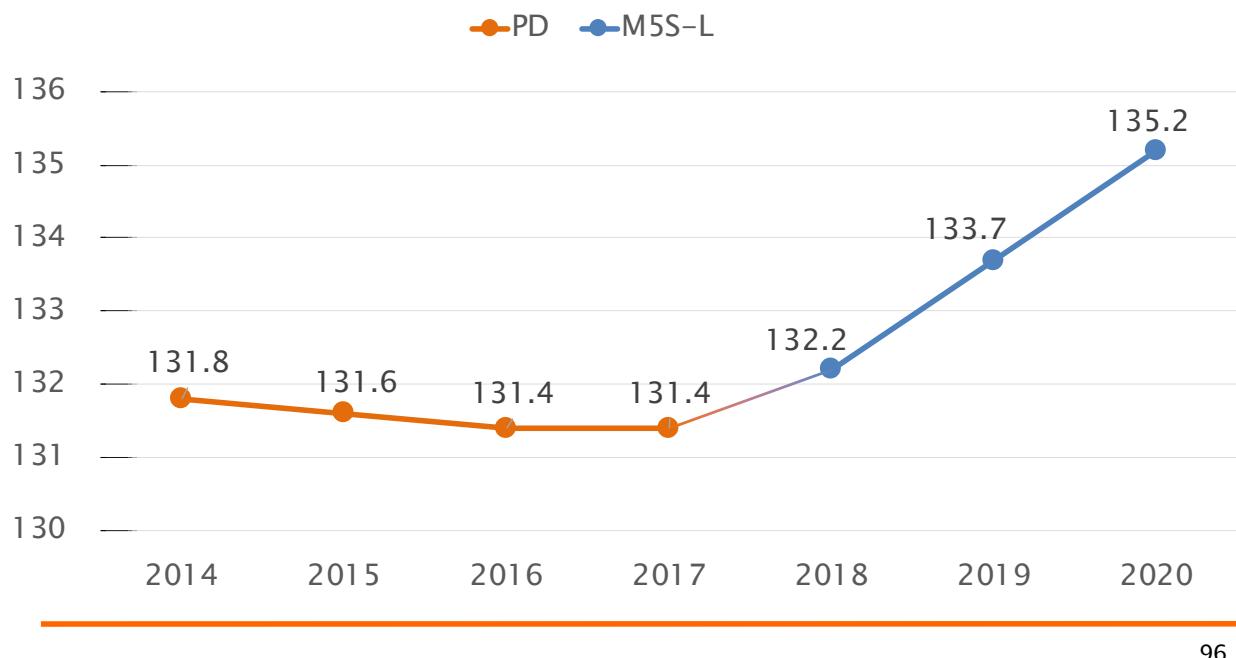
## Debito Pubblico (% PIL)



# Lie Factor – Redesign

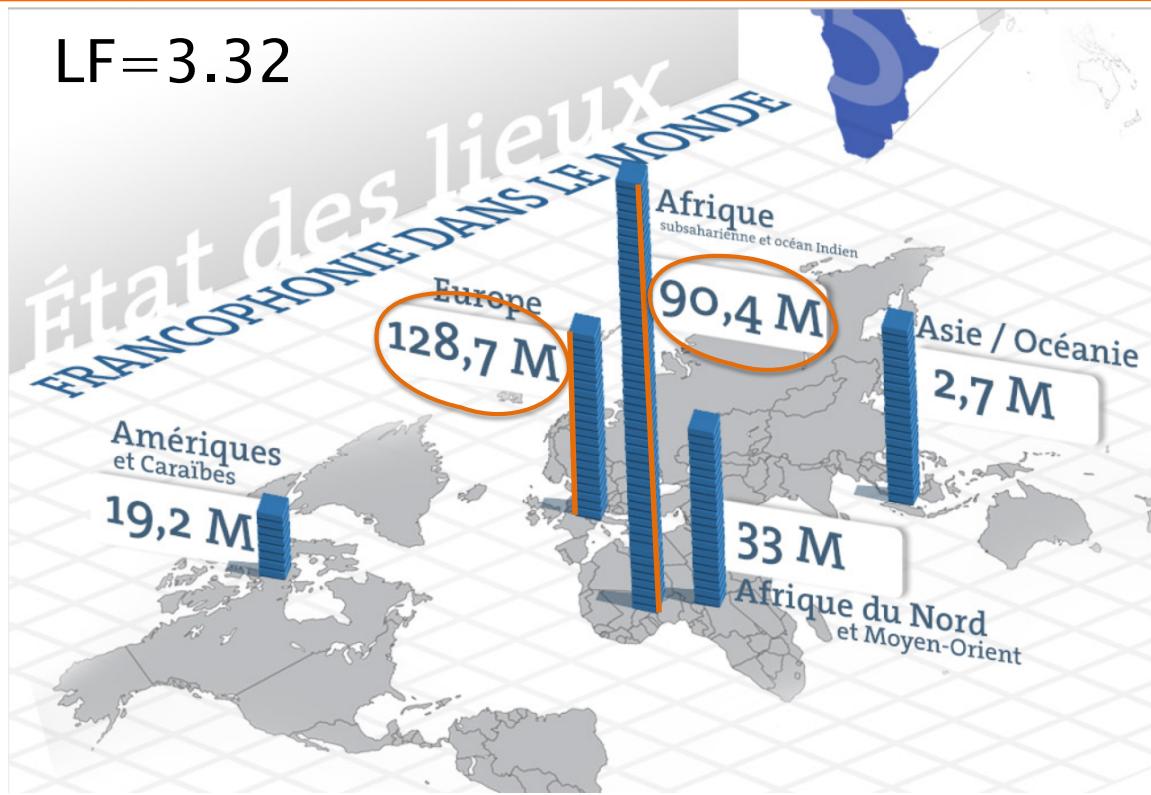
PUC

## Debito Pubblico (% PIL)



# Lie Factor

LF=3.32



@prrgutierrez #WTFViz

97

# Lie Factor

## Air France, des chiffres qui parlent

Salaire annuel brut  
d'un commandant en fin de carrière  
sur Boeing 777



Nombre d'heures de vol  
en long-courrier pour un commandant



LF=2.49



Le Point @LePoint · Oct 23

#AirFrance : les chiffres qui parlent [ow.ly/TKN13](http://ow.ly/TKN13)

# Guidelines for design

---

- Keep the physical Lie Factor = 1
- Limit the perceptual Lie Factor as much as possible
  - ◆ Per Steven's law, avoid area comparisons

---

99

# Utility

---

PUC

- Every element should convey useful information
- Unnecessary visual objects or attributes distract from the message
  - ◆ Different attributes trigger a search for a rationale (e.g. random colors)

---

100

Data-ink ratio =  $\frac{\text{data ink}}{\text{total ink used to print the graphic}}$

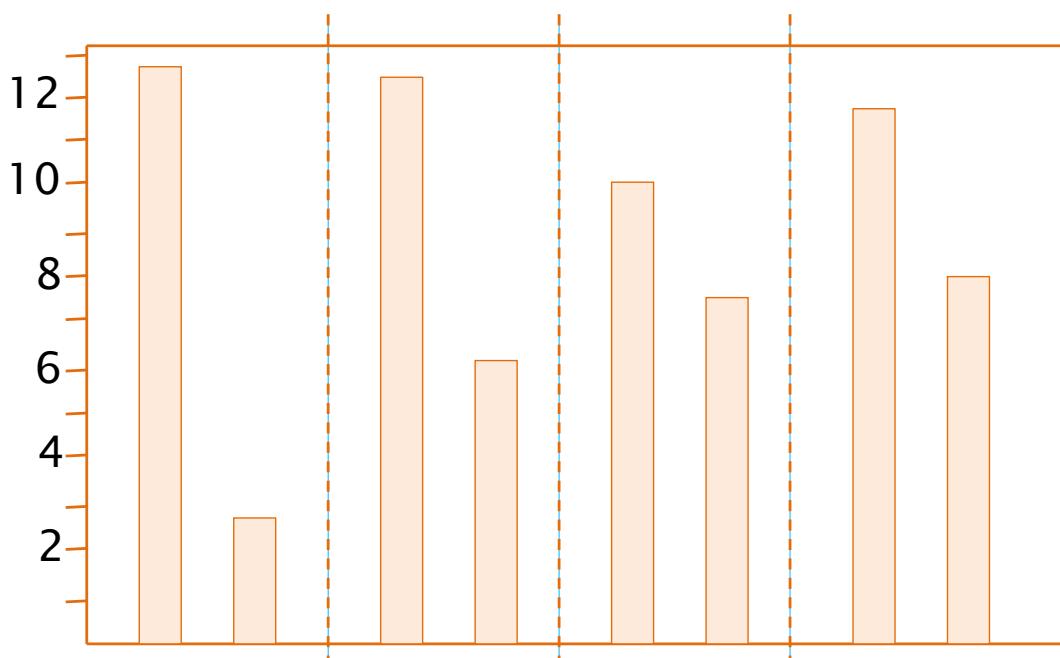
- Proportion of a graphic's ink devoted to the non-redundant display of data information

- ◆ Or:

$$1 - \frac{\text{ink that can be erased without loss of information}}{\text{total ink used to print the graphic}}$$

---

101



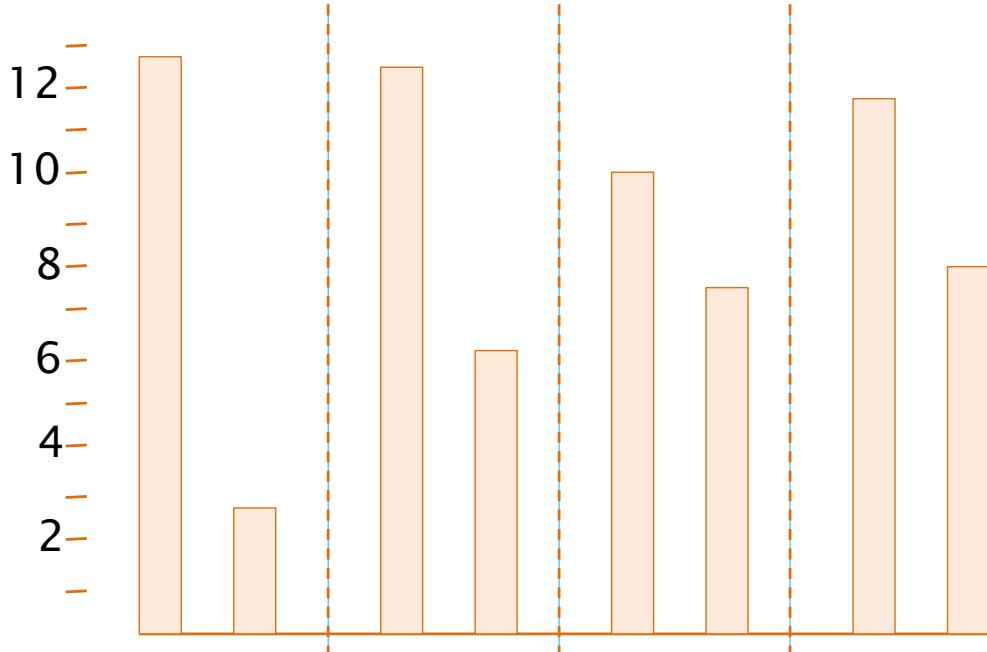
---

102

# Data-ink

---

PUC



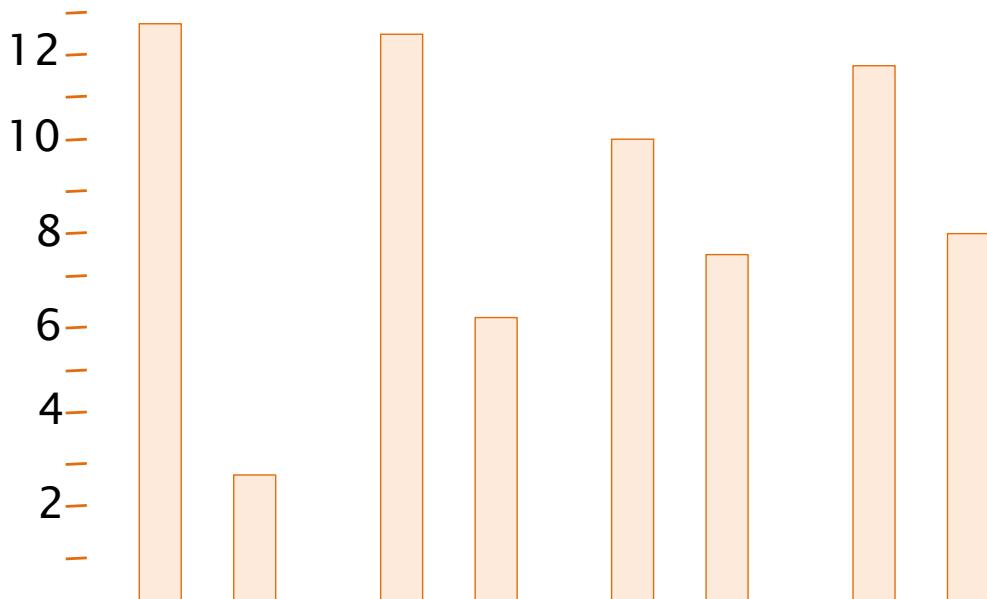
---

103

# Data-ink

---

PUC



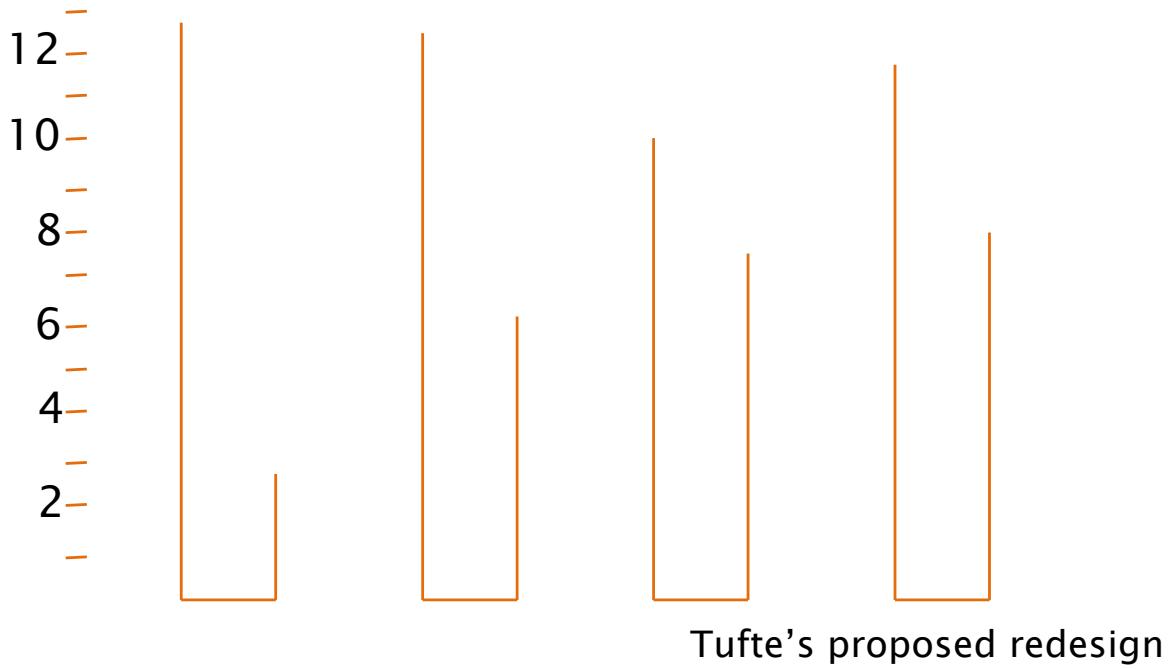
---

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# Data-ink

---

PUC



105

## Guidelines for design

---

PUC

- Maximize data-ink ratio
  - ◆ Erase non-data-ink
  - ◆ Erase redundant data-ink
- “Within reason”

*Above all else show the data*

*E.Tufte*

106

# Use of contrast

---

PUC

- Include differences corresponding to actual differences
- Effective when one item is different in a context of other items that are the same
  - ◆ Bright saturated color among mid colors

---

107

# Chartjunk

---

PUC

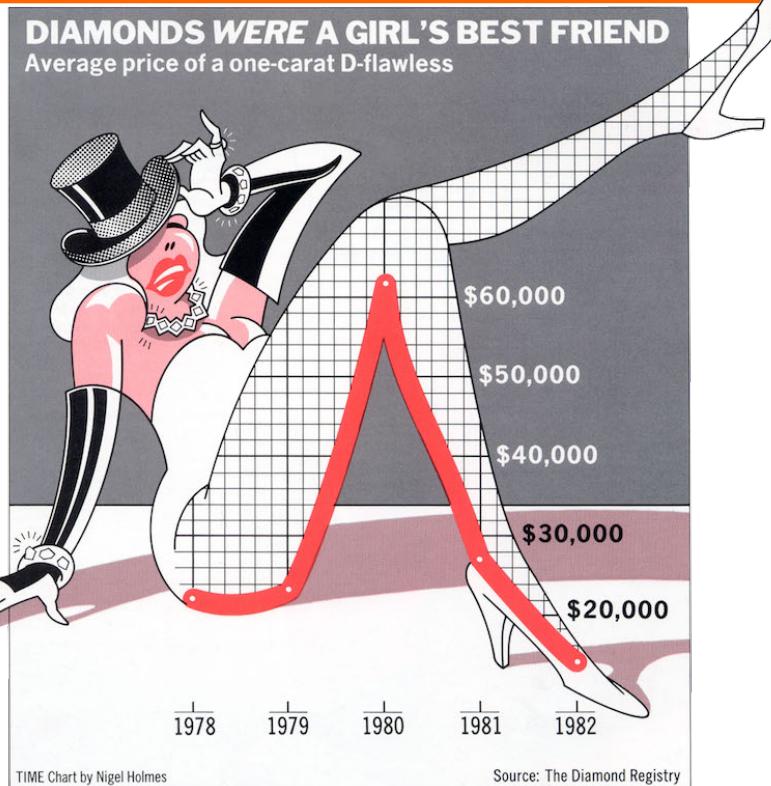
- The presence of unnecessary elements that distract or hide the message conveyed by the diagram

---

108

# Chartjunk

PUC



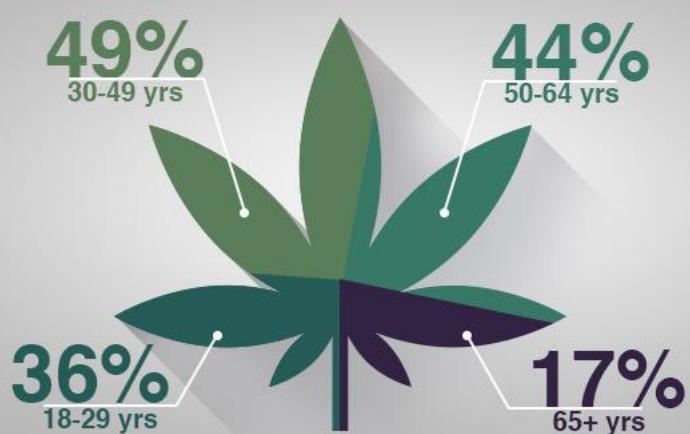
Nigel Holmes:  
<http://nigelholmes.com>

109

# Chartjunk

PUC

## AMERICANS WHO HAVE TRIED WEED



#highprofits

CNN SUNDAYS  
10P ET/PT

110

# Clarity

---

- Visual encoding and layout should make perception tasks easy and effortless
  - Textual and support elements should provide effective support to understanding the information
  - Any variation in the graph should represent useful information otherwise it is noise obfuscating the message
- 

111

# Clarity

---

- **Textual** elements should provide effective support to understanding
    - ◆ Hierarchical
      - Size and position reflects importance
    - ◆ Readable
      - Large enough
    - ◆ Horizontal
    - ◆ Close to data (avoid legends)
  - Always label the axes
- 

112

- Get it right in black and white
- Use medium hues or pastels
  - ◆ Bright colors distract and tire out
- Use color only when needed to serve a particular communication goal

---

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## Cognitive Dissonance

---

ROSSO

BLU

VERDE

GIALLO

---

114

# Detection and Separation

PUC

Efficiency and efficacy of perception tasks is affected by:

- **Detection**

The capability to visually identify the objects that represent the data to be compared

- **Separation**

The distance between the objects to be compared

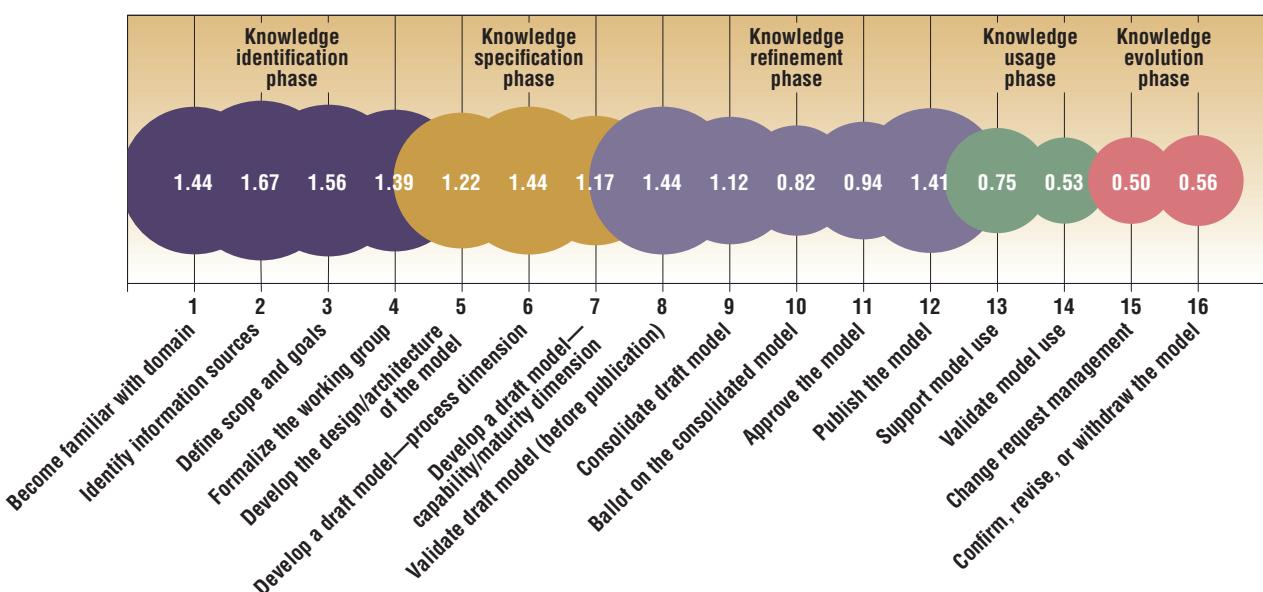
- affects negatively the accuracy

---

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# Clarity

PUC

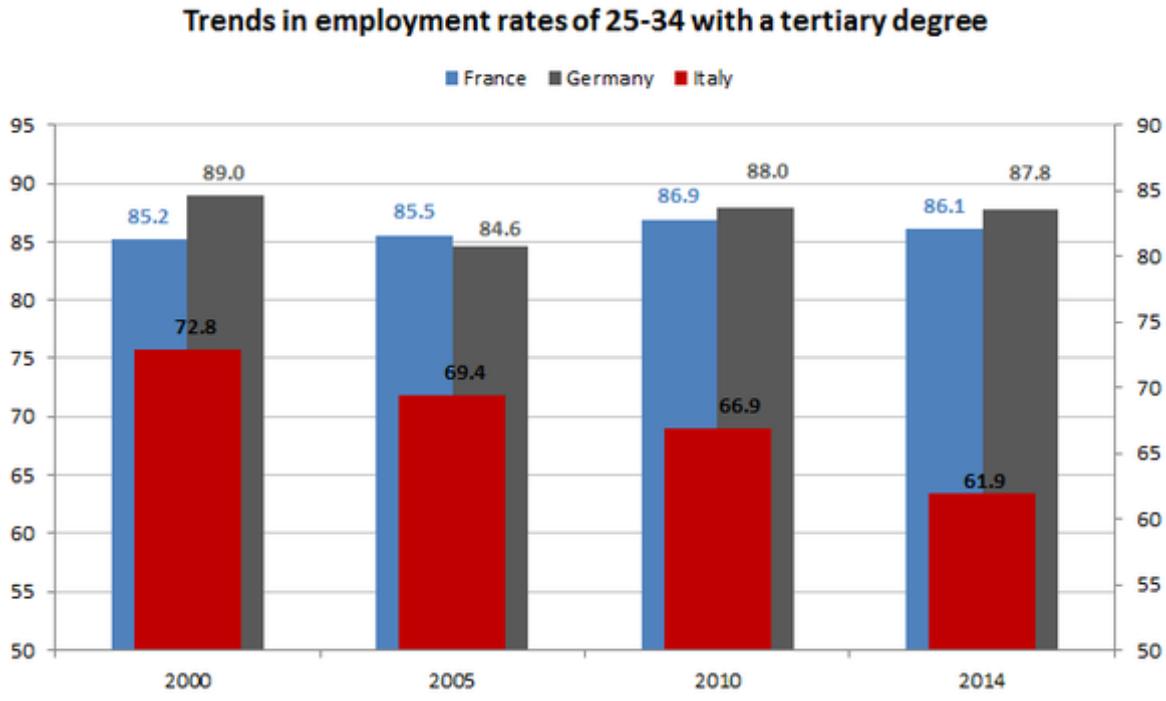


---

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# Example

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## Analysis

---

- Proportionality
  - ◆ Due to non-zero base bars, it has a large lie factor (2.2):
    - ratio of real values: 87.8 : 61.9
    - ratio on graph: 37.8 : 11.9
- Utility
  - ◆ Most elements appear useful
  - ◆ X-axis ticks can be removed
  - ◆ Y grid could be made less prominent

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# Analysis

---

- Clarity
  - ◆ It uses a **dual scale** that confuses and makes very hard a visual comparison of the values and further distorting the compared values.
  - ◆ The dual scale is not mentioned anywhere and it is not clear which values refer to which scale.
  - ◆ In general the usage of bars is not the most appropriate visual representation if the goal is to show a trend or evolution in time.

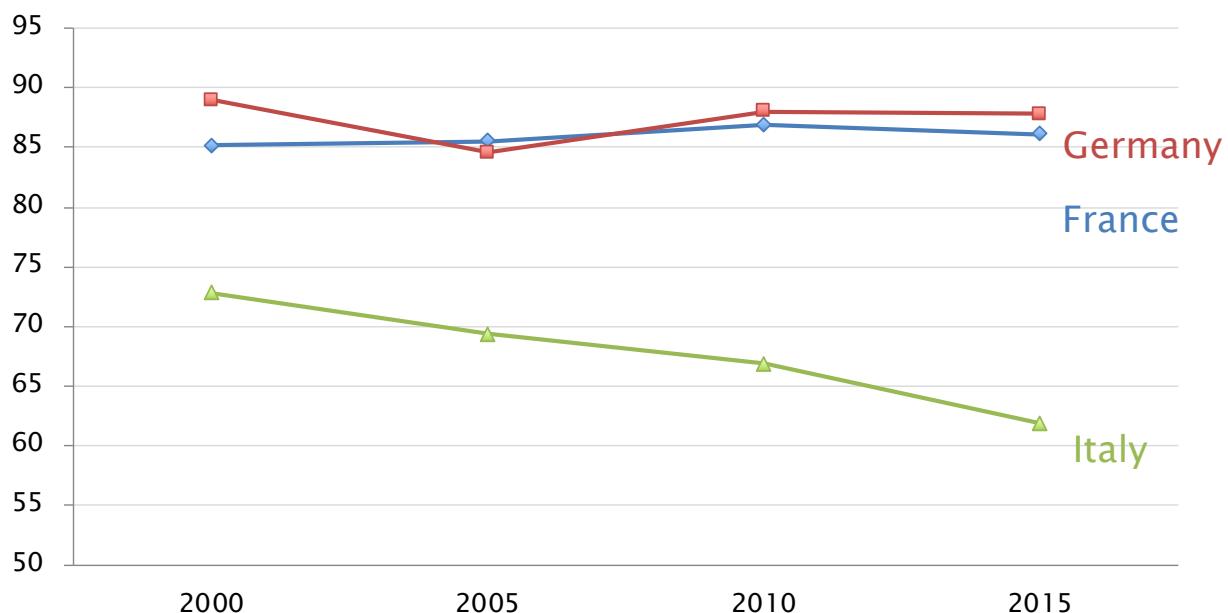
---

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# Redesign

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Trends in employment rates of 25–34 with a tertiary degree



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# References

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- <http://www.color-blindness.com>
- <http://www.csc.ncsu.edu/faculty/healey/PP/index.html>

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