MARKS AND CHANNELS

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Contents

Why Marks and Channels?

- Learning to reason about marks and channels gives you the building blocks for analyzing visual encodings.
- The core of the design space of visual encodings can be described as an orthogonal combination of two aspects: graphical elements called marks, and visual channels to control their appearance.
- Even complex visual encodings can be broken down into components that can be analyzed in terms of their marks and channel structure.

Defining Marks and Channels

- Channel Types
- Mark Types

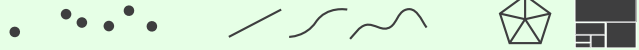
Marks and channels

Concept 1

Marks are basic *geometric elements* that depict *items* or *links*

Marks as Items/Nodes

- Points
- Lines
- Areas



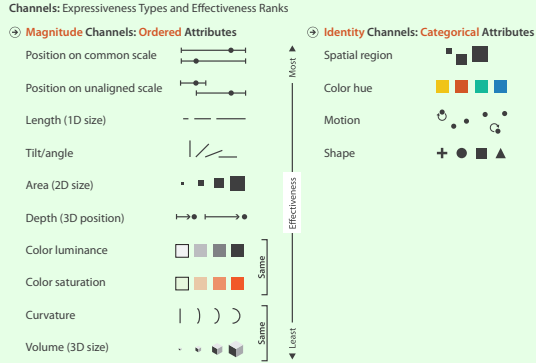
Marks as Links

- Containment
- Connection

Marks and channels (cont.)

Concept 2

Channels control appearance of *marks*



Using marks and channels

(a) Bar charts encode two attributes using a line mark with the vertical spatial position channel for the quantitative attribute, and the horizontal spatial position channel for the categorical attribute.

(b) Scatterplots encode two quantitative attributes using point marks and both vertical and horizontal spatial position.

(c) A third categorical attribute is encoded by adding color to the scatterplot.

(d) Adding the visual channel of size encodes a fourth quantitative attribute as well.

(a) (b) (c) (d)

Channel Types

The human perceptual system has two fundamentally different kinds of sensory modalities.

- The **identity** channels tell us information about what something is or where it is.
- In contrast, the **magnitude** channels tell us how much of something there is.

Mark Types

- A mark always represents an *item*
- A **connection** mark shows a pairwise relationship between two items, using a line
- A **containment** mark shows hierarchical relationships using areas, and to do so connection marks can be nested within each other at multiple levels.

Using Marks and Channels

- Expressiveness and Effectiveness
- Channel Rankings

Expressiveness and Effectiveness

Two principles guide the use of visual channels in visual encoding: **expressiveness** and **effectiveness**

- *Expressiveness* principle dictates that the visual encoding should express all of, and only, the information in the dataset attributes.
  - match channel and data characteristics
- *Effectiveness* principle dictates that the importance of the attribute should match the **salience** of the channel; that is, its noticeability.
  - encode most important attributes with highest ranked channels

Channel Rankings

Effectiveness rankings for the visual channels are broken down according to the two expressiveness types of *ordered* and *categorical* data

- *Ordered* attributes should be shown with the magnitude channels
  - The most effective is **aligned spatial position**, followed by **unaligned spatial position**
  - **Length**, **angle**, **area**
  - **Depth**
  - **Luminance** and **saturation**.
  - **Curvature** and **volume**
- *Categorical* attributes should be shown with the identity channels
  - The most effective channel for categorical data is spatial **region**
  - **Hue**
  - **Motion**
  - **Shape**

Channel Effectiveness

- Accuracy
- Discriminability
- Separability
- Popout
- Grouping

Fundamental Theory

- The obvious way to quantify effectiveness is **accuracy**: how close is human perceptual judgement to some objective measurement of the stimulus?
- We perceive different visual channels with different levels of accuracy; they are not all equally distinguishable.

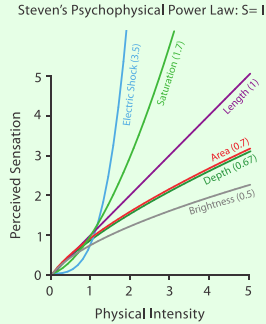
Fundamental Theory (cont.)

Concept 3 (The psychophysical power law of Stevens)

The apparent magnitude of all sensory channels follows a power function based on the stimulus intensity:

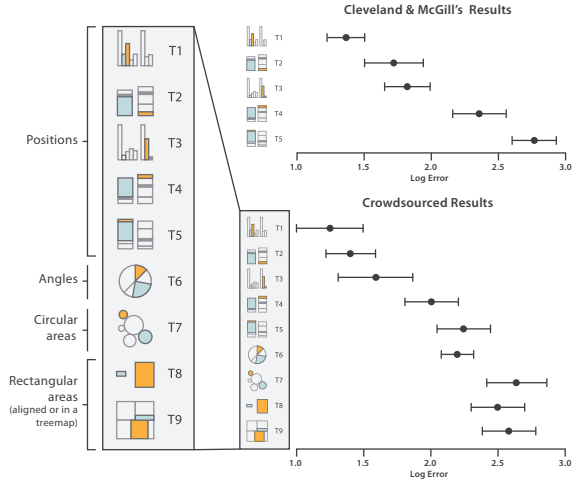
$$S = I^n \tag{1}$$

where S is the perceived sensation and I is the physical intensity.



Accuracy: Vis experiments

Error rates across visual channels, with recent crowdsourced results replicating and extending seminal work from Cleveland and McGill

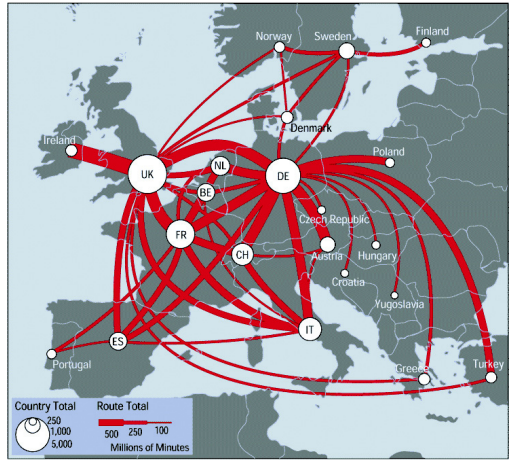


Discriminability: How many usable steps?

- The question of **discriminability** is: if you encode data using a particular visual channel, are the differences between items perceptible to the human as intended?
- The characterization of visual channel thus should quantify the number of **bins** that are available for use within a visual channel, where each *bin* is a distinguishable step or level from the other

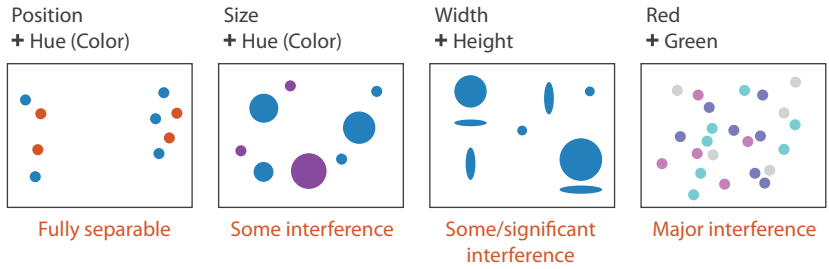
Example

- Linewidth has a limited number of discriminable bins.



Separability vs. Integrality

- We cannot treat all visual channels as *completely independent* from each other, because some have *dependencies* and *interactions* with others
- We must consider a continuum of potential interactions between channels for each pair, ranging from the orthogonal and independent **separable** channels to the inextricably combined **integral** channels



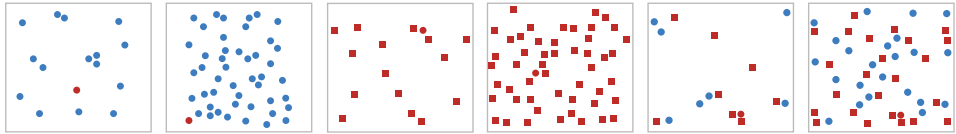
Popout

Many visual channels provide visual **popout**, where a distinct item stands out from many others immediately

- Task: Find the red dot
- Question: how long does it take?
- *Parallel processing* on many individual channels
  - speed independent of distractor count
  - speed depends on channel and amount of difference from distractors
- *Serial search* for (almost all) combinations
  - speed depends on number of distractors

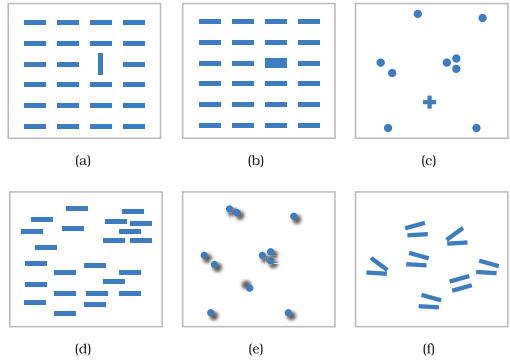
Popout (cont.)

- Visual popout. (a) The red circle pops out from a small set of blue circles. (b) The red circle pops out from a large set of blue circles just as quickly. (c) The red circle also pops out from a small set of square shapes, although a bit slower than with color. (d) The red circle also pops out of a large set of red squares. (e) The red circle does not take long to find from a small set of mixed shapes and colors. (f) The red circle does not pop out from a large set of red squares and blue circles, and it can only be found by searching one by one through all the objects



Popout (cont.)

- Many channels support visual popout, including (a) tilt, (b) size, (c) shape, (d) proximity, and (e) shadow direction. (f) However, parallel line pairs do not pop out from a sea of slightly tilted distractor object pairs and can only be detected through serial search



Grouping

- The effect of perceptual **grouping** can arises from either the use of link marks or from the use of identity channels to encode categorical attributes
- Encoding link marks using areas of **containment** or lines of **connection** conveys the information that the linked objects form a group with a very strong perceptual cue
- **Proximity** $\rightarrow$ same spatial region
- **Similarity** $\rightarrow$ same values as other categorical channels

Relative vs. Absolute Judgements

Relative vs. absolute judgements

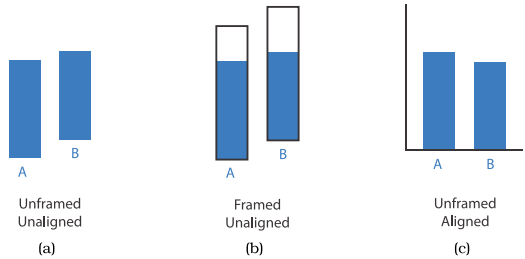
The human perceptual system is fundamentally based on relative judgements, not absolute ones. This principle is known as **Weber's Law**

Corollary 1

- *The amount of length difference we can detect is a percentage of the object's length*
- *Ratio of increment to background is constant*
- *Accuracy increases with common frame/scale and alignment*
- *Filled rectangles differ in length by 1:9, difficult judgement*
- *White rectangles differ in length by 1:2, easy judgement*

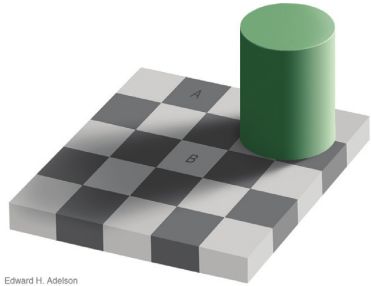
Example

- Weber's Law states that we judge based on relative, not absolute differences. (a) The lengths of unframed, unaligned rectangles of slightly different sizes are hard to compare. (b) Adding a frame allows us to compare the very different sizes of the unfilled rectangles between the bar and frame tops. (c) Aligning the bars also makes the judgement easy

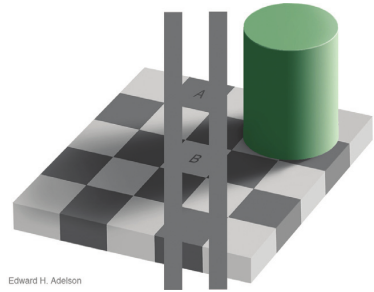


Relative luminance judgements

- Perception of luminance is contextual based on contrast with surroundings
- Luminance perception is based on relative, not absolute, judgements. (a) The two squares A and B appear quite different. (b) Superimposing a gray mask on the image shows that they are in fact identical.



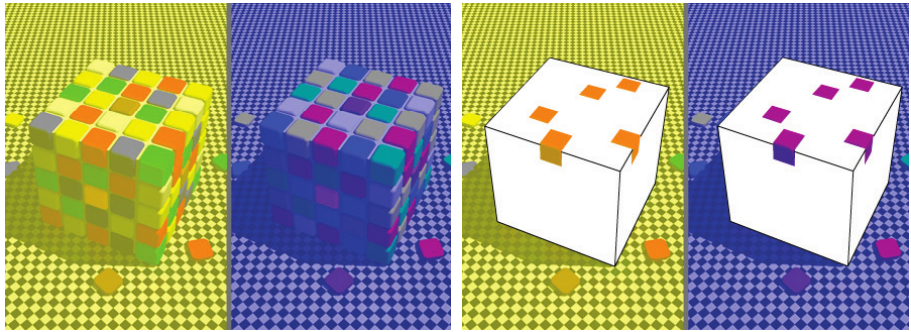
(a)



(b)

Relative color judgements

- Color perception is also relative to surrounding colors and depends on context. (a) Both cubes have tiles that appear to be red. (b) Masking the intervening context shows that the colors are very different: with yellow apparent lighting, they are orange; with blue apparent lighting, they are purple.



(a) (b)

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