Lecture: Visual encoding

Ines Arana

i.arana@rgu.ac.uk

Ref: T. Munzner, Visualisation Analysis and Design, CRC Press, 2014.

Statement for Audio and Video Learning Resources

Video and audio content at the University uses closed captions generated by automatic speech recognition (ASR). The ASR process is based on machine learning algorithms which automatically transcribe voice to text. According to our technology providers, this process is approximately 70-90% accurate depending on the quality of the audio, and consequently video and audio closed captions may include some transcription errors. It is therefore important to recognise that the original recording is the most accurate reflection of the content, and not the captions.

If you require accurate captions as part of your reasonable adjustments, please contact the Inclusion Centre to discuss your requirements.

Content

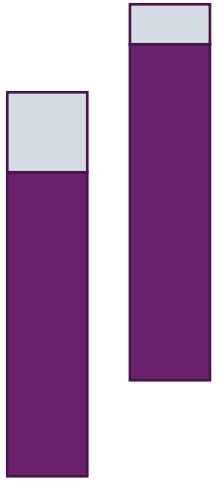
- Visual encodings
- Relative vs. absolute judgements
- Marks
- Channels
  - Rankings
  - Effectiveness
  - Separability
  - Expressiveness

Weber's law

- Judge based on relative, not absolute positions

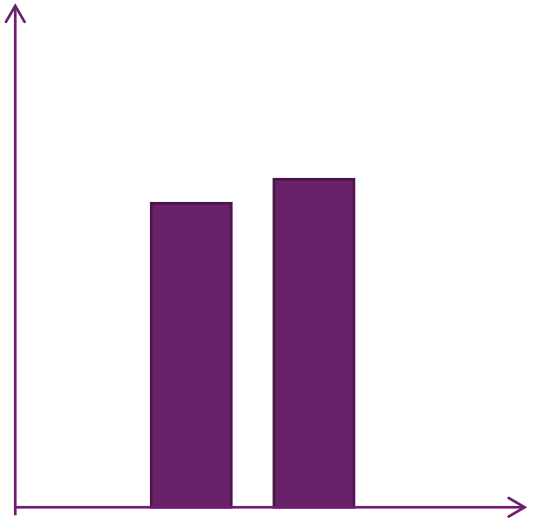
A B

Unframed, unaligned



A B

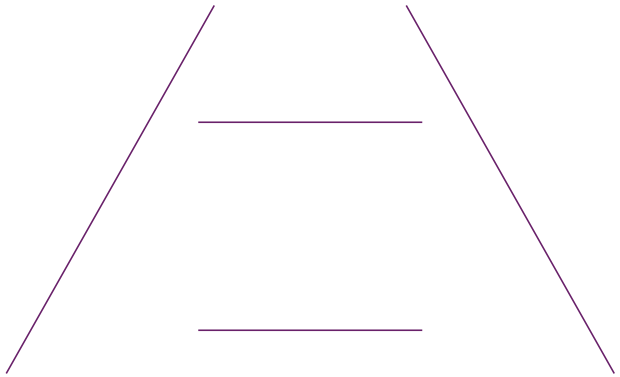
Framed, unaligned



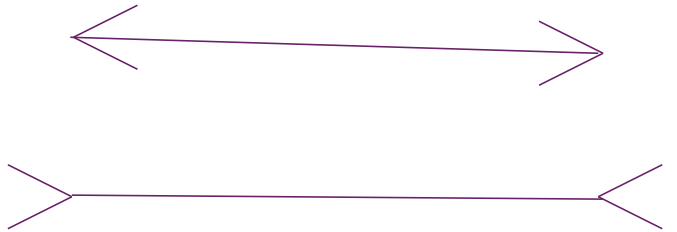
A B

Unframed, aligned

Illusions

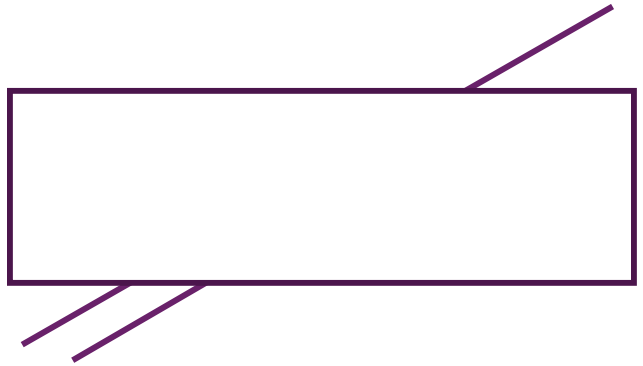


The Ponzo illusion



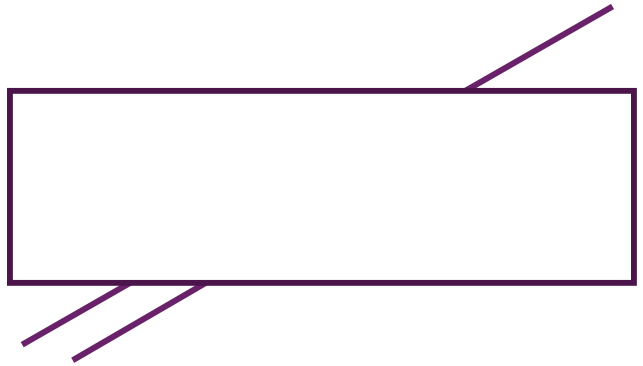
The Muller-Lyer illusion

… illusions - Poggendorf



Poggendorf illusion. The line at the top appears to be a continuation of the line on the bottom right.

… illusions



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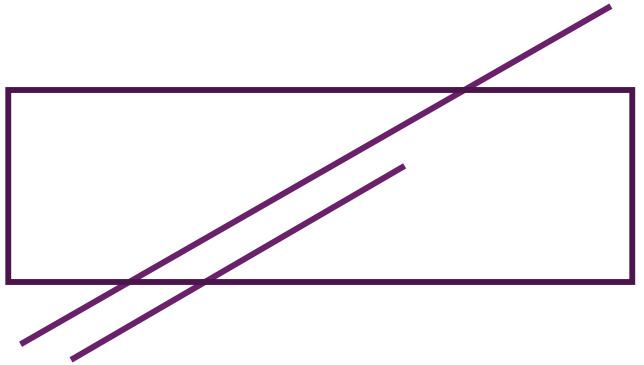
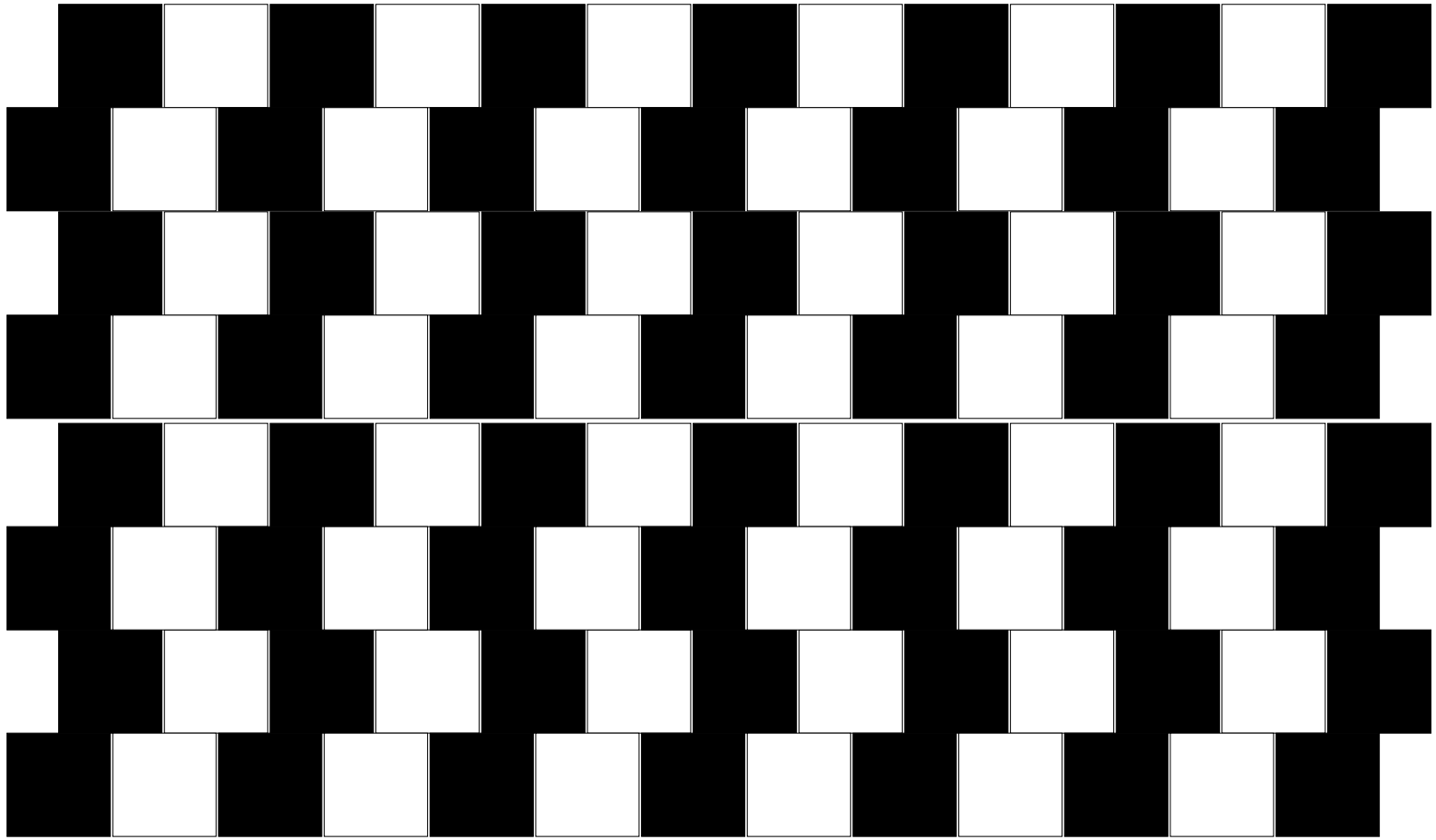


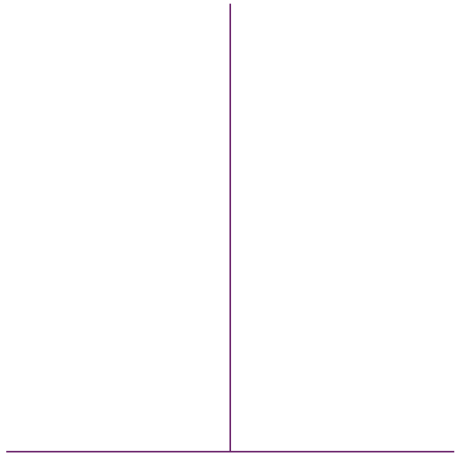
Humans tend to overestimate the size of sharp angles.

… illusions – Café wall

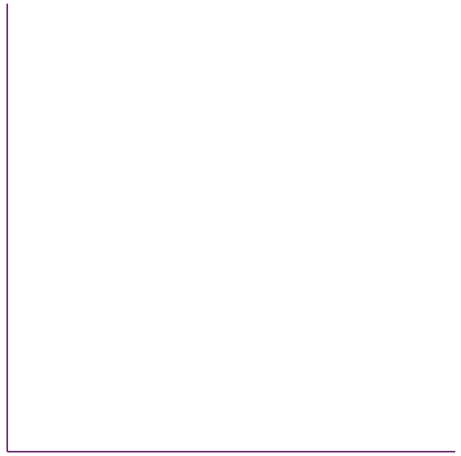


All lines are straight and cross at right angles. It is made of black and white squares

… illusions – horizontal/vertical



Which line is longer?

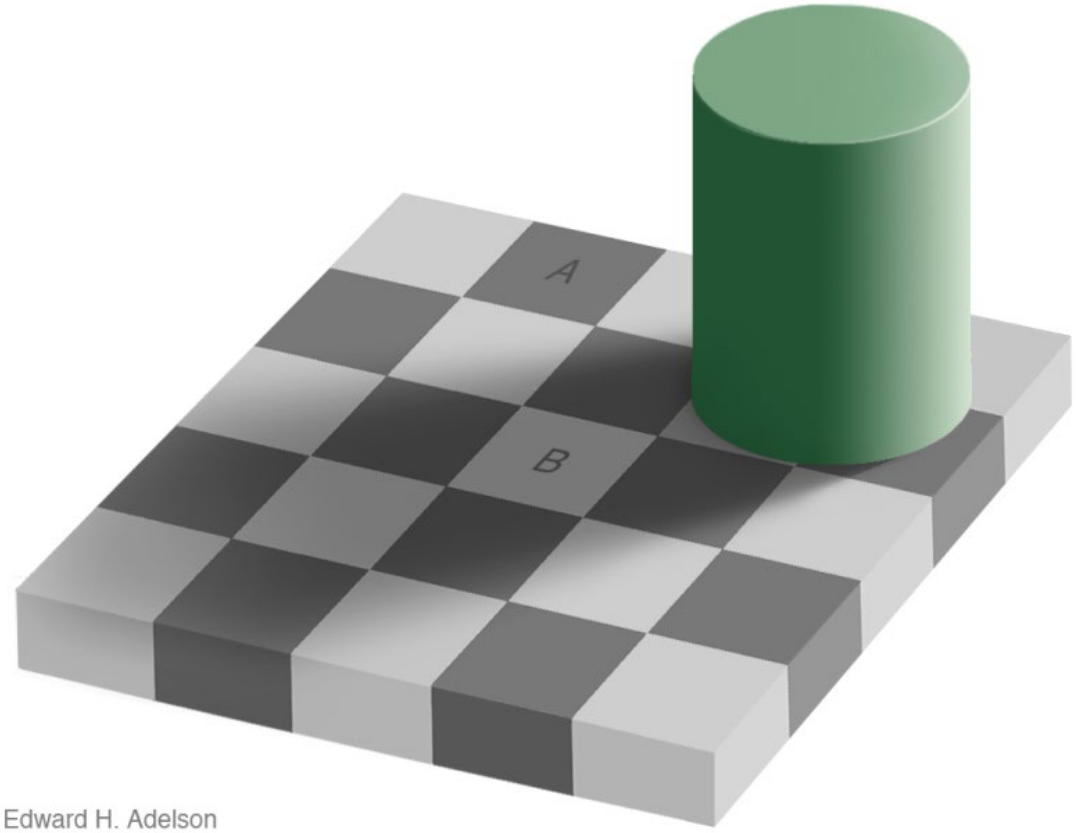


Both lines are of equal length in both drawings

Relative vs. absolute judgements

- Weber's law illustrates judgement based on relative ***position***
- Other relative judgements:
  - Lightness
  - Colour

Lightness perception

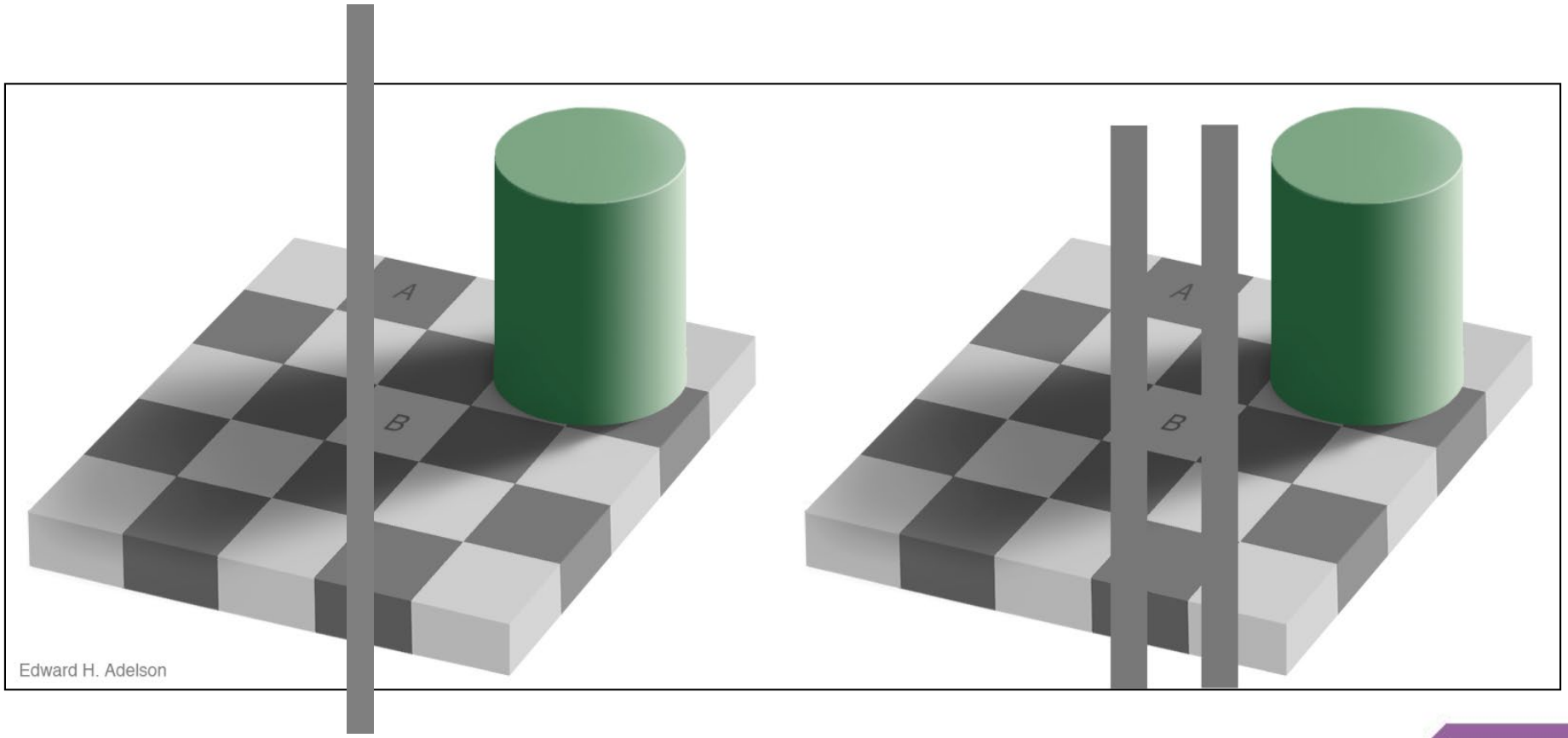


Edward H. Adelson

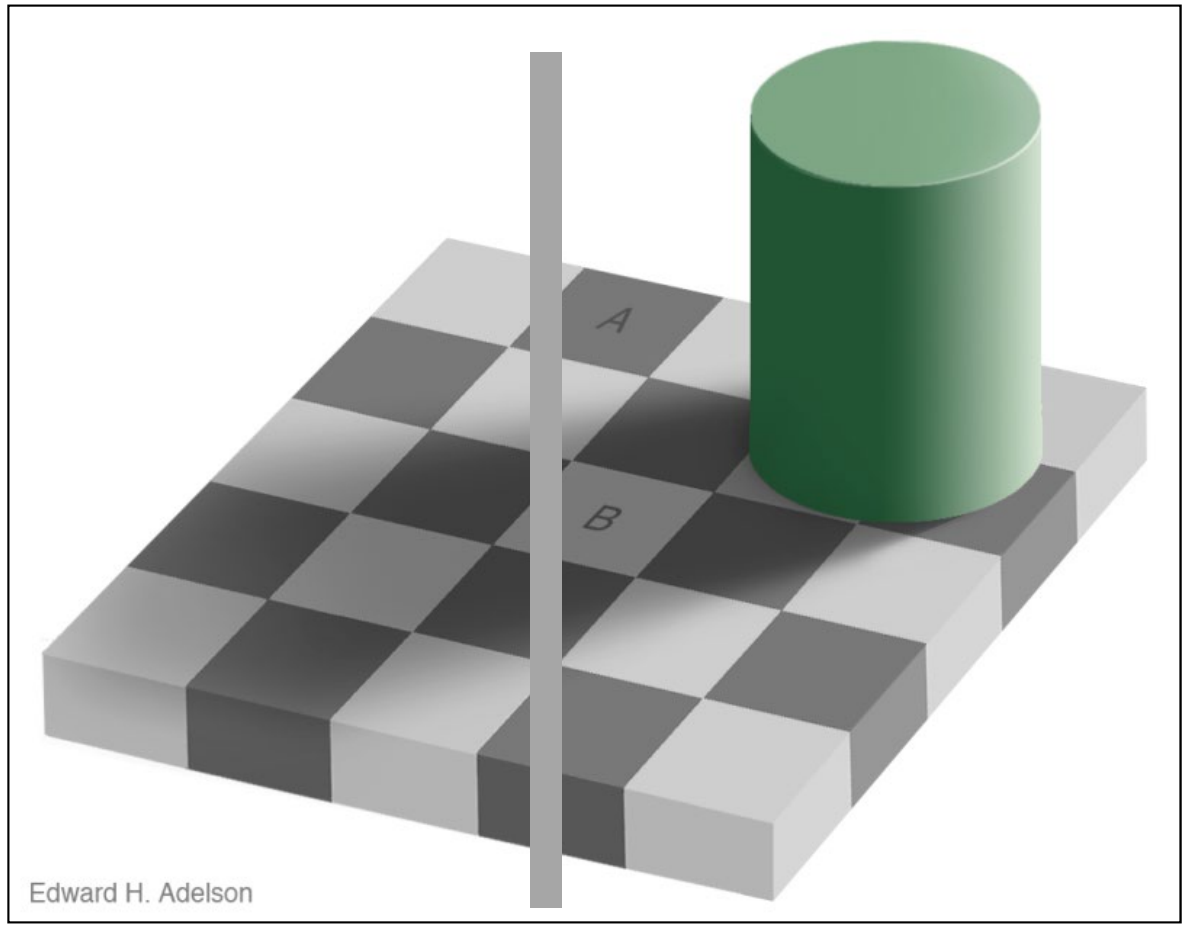
Is square A lighter, equal or darker than square B?

http://persci.mit.edu/_media/gallery/checkershadow_double_full.jpg [accessed 29/01/2023]

… or is it?

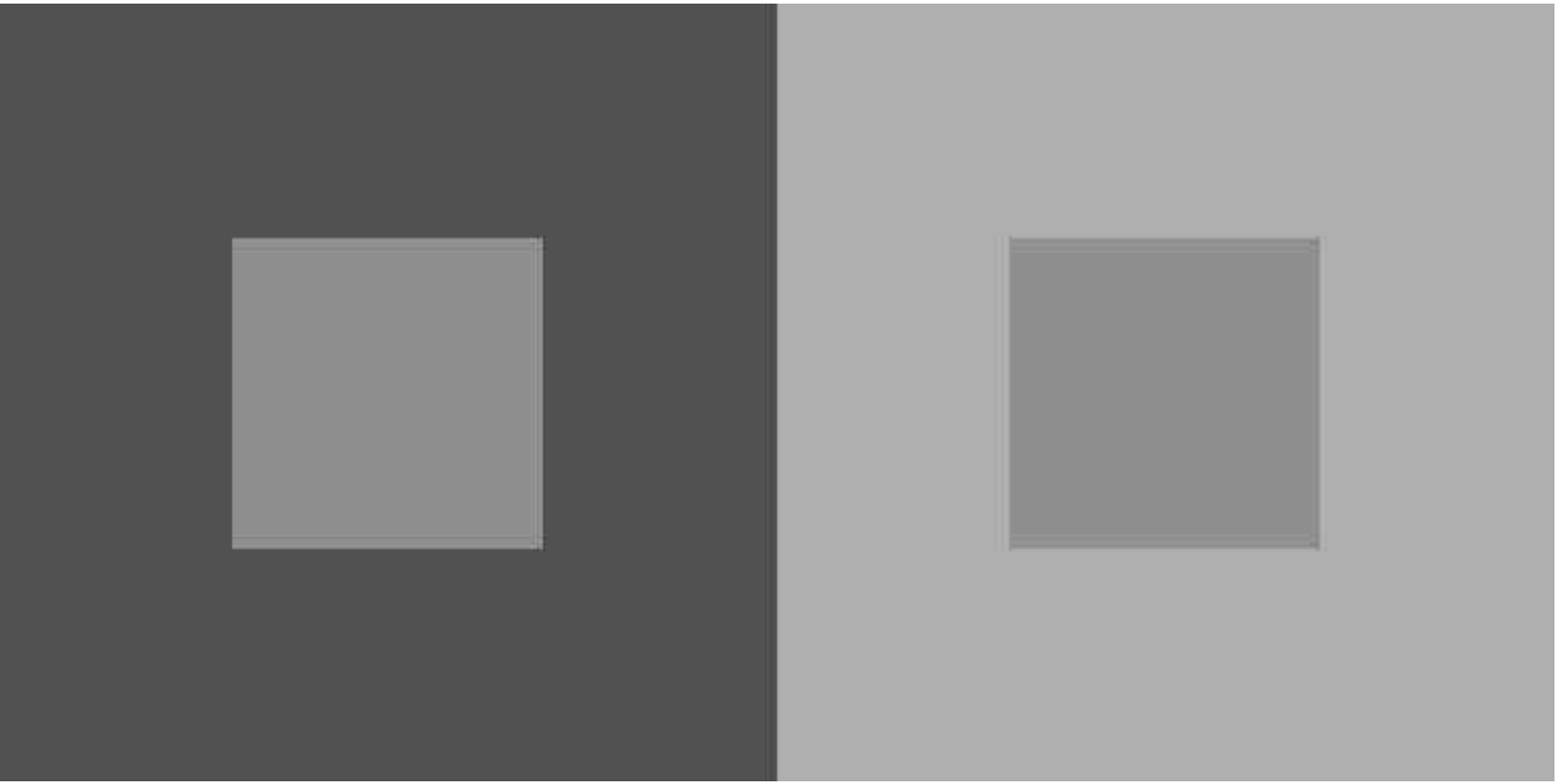


What if we lighten the colour of the new line?



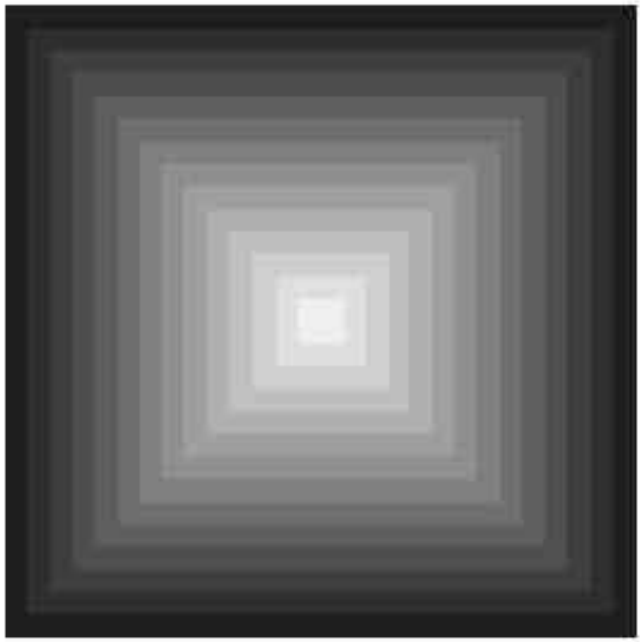
It is clear that the new line is lighter than both squares A and B.

Simultaneous contrast effect

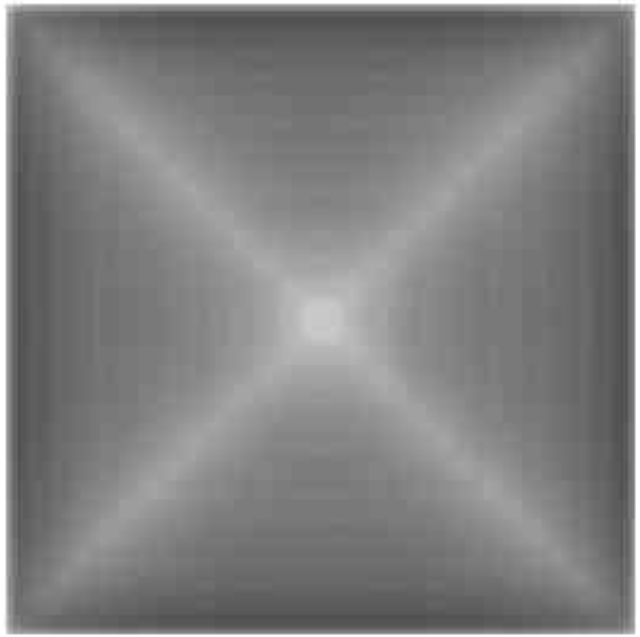


Adelson, E.H. Lightness Perception and Lightness Illusions. In The New Cognitive Neurosciences, 2nd ed., M. Gazzaniga, ed. Cambridge, MA: MIT Press, pp. 339-351, (2000).http://persci.mit.edu/pub_pdfs/gazzan.pdf

An illusion by Vasarely (a) and a bandpass filtered version (b)



a

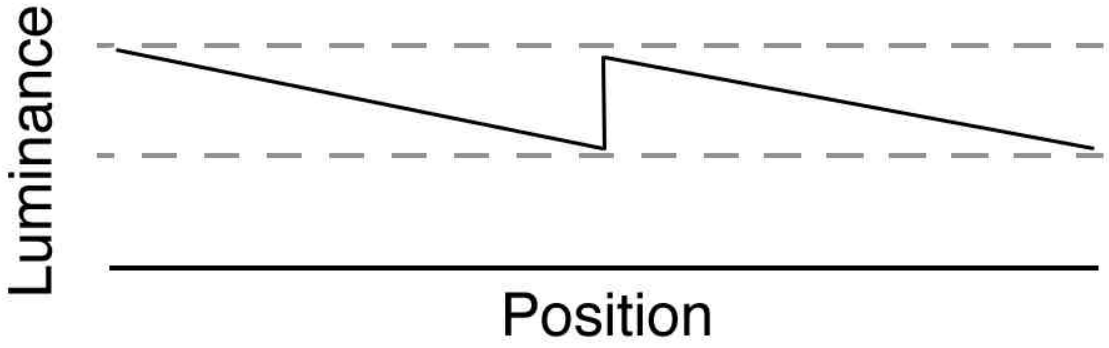


b

Adelson, E.H. Lightness Perception and Lightness Illusions. In The New Cognitive Neurosciences, 2nd ed., M. Gazzaniga, ed. Cambridge, MA: MIT Press, pp. 339-351, (2000).http://persci.mit.edu/pub_pdfs/gazzan.pdf

Filtered version enhances diagonals

Craik-O'Brien-Cornsweet Effect



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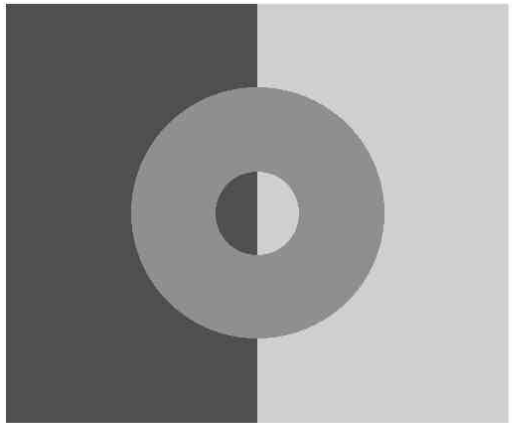
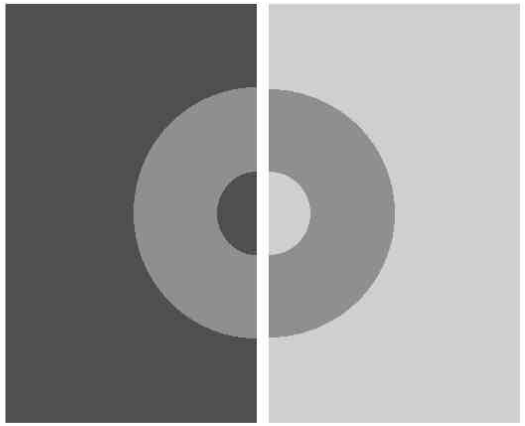
Koffa Ring



a



b

The Koffa ring is all the same colour/shade even if the surroundings are different. As soon as the ring is split, the right hand side appears darker than the left.

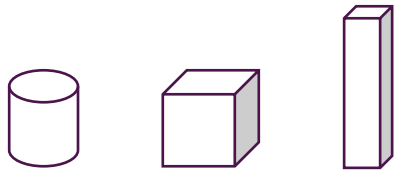
Adelson, E.H. Lightness Perception and Lightness Illusions. In The New Cognitive Neurosciences, 2nd ed., M. Gazzaniga, ed. Cambridge, MA: MIT Press, pp. 339-351, (2000).http://persci.mit.edu/pub_pdfs/gazzan.pdf

Marks and channels

- Design space can be largely described using:
  - ***Marks:*** graphical elements
  - ***Channels:*** visual ways of altering the appearance of a mark.

Marks

- Geometric primitives
  - 0D – point
  - 1D – line
  - 2D – area
  - 3D - volume

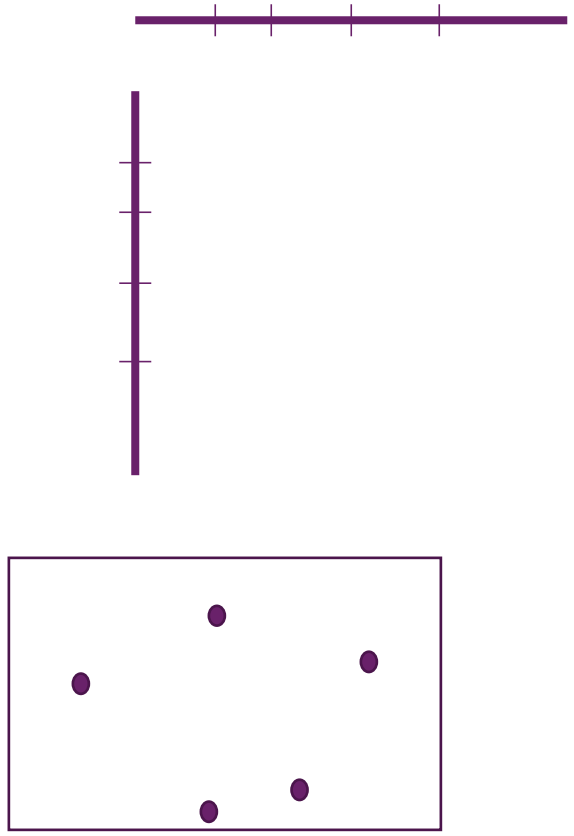


Channels

- Channels are visual parameters which change the appearance of a mark
  - Independent of mark's dimensionality
- Channels include:
  - Position
    - Along common scale
    - Along identical, non aligned scales
  - Size
  - Shape
  - Orientation - tilt
  - Hue (colour)
  - Saturation
  - Lightness

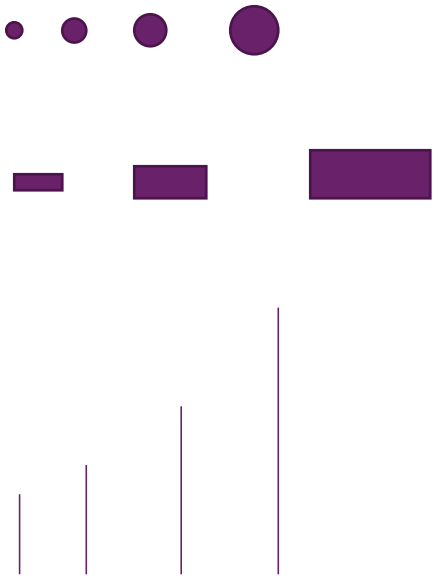
… channels

- Position
  - Horizontal
  - Vertical
  - Both



… channels - size

- Size



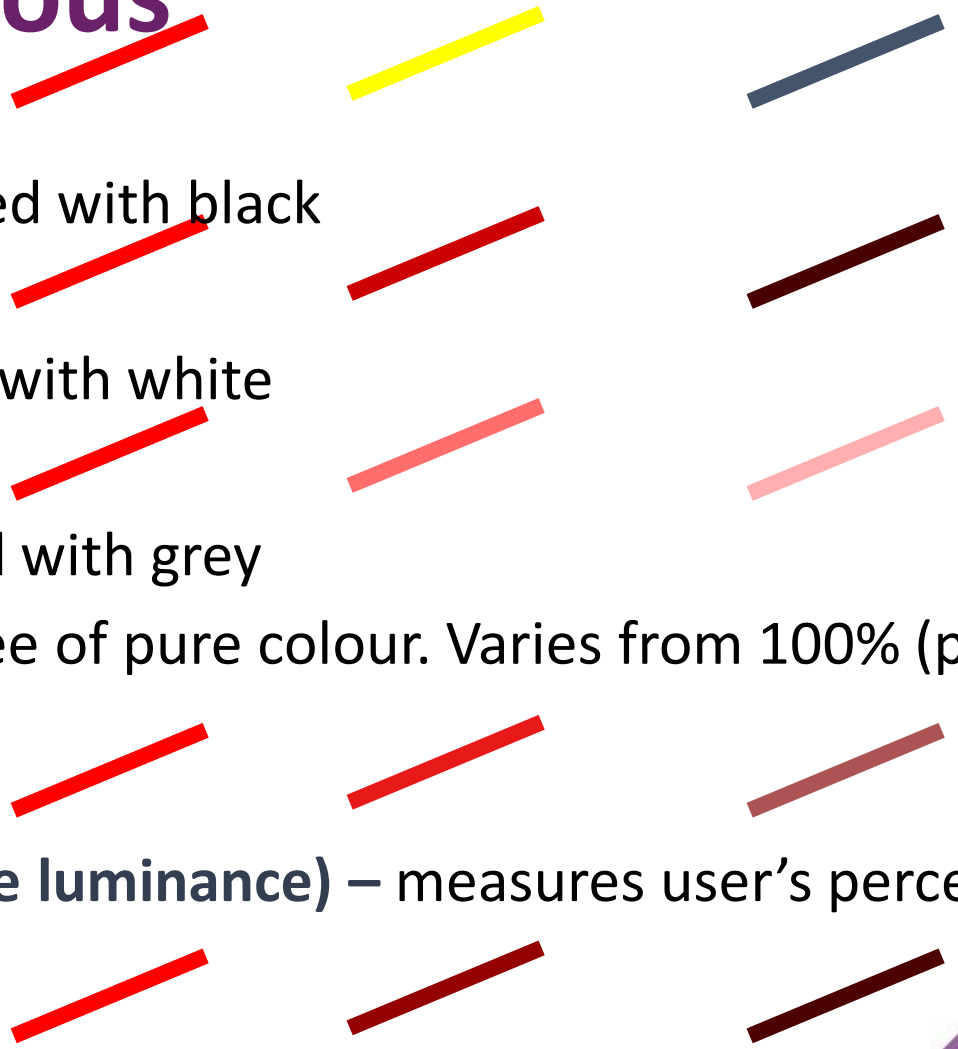
… channels - shape

- Shape

… channels - orientation

- Orientation – tilt

… channels - various



- **Hue** – colour
- **Shade** – primitive colour mixed with black
- **Tint** – primitive colour mixed with white
- **Tone** – primitive colour mixed with grey
- **Saturation (intensity)** – degree of pure colour. Varies from 100% (pure colour) to 0% (grey)
- **Lightness (brightness/relative luminance)** – measures user's perception of light

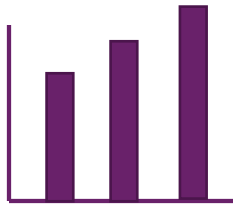
Combining marks and channels

- In previous examples
  - Each attribute encoded using ONE channel

- Multiple channels can be used to encode same attribute
  - **Aids perception**
  - But **limits number of attributes** that can be shown

Using marks and channels

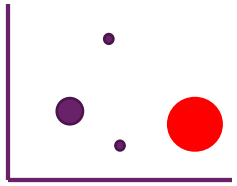
- Bar charts
  - Encode one attribute
  - Line mark + vertical spatial position (channel)



- Scatterplots (2D)
  - Encode 2 attributes
  - Point marks and vertical and horizontal positions (channels)

- Scatterplot + colour
  - Encode 3 attributes

- Scatterplot + colour + size
  - Encode 4 attributes

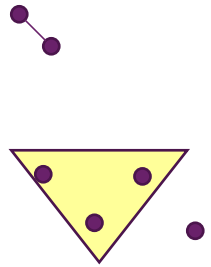


Channel types

- **What** – identity and location
  - Shape
  - Colour
  - Spatial region
- **How much**:
  - Length
  - Area
  - Volume
  - Tilt

Mark types

- For tables
  - A mark represents an item
- For graphs/networks
  - A mark can represent
    - An item
      - Can use points, lines or areas
    - A link (relationship between items)
      - Connection: pairwise relationship – use lines
      - Containment; hierarchical relationship – use areas



Expressiveness principle

- **The visual encoding should**
  - **contain all of the information in the dataset attributes**
  - **and only that information**

- E.g.
  - Ordered data should be visualised in a way that is perceived as being ordered
  - Unordered data should not be visualised in a way that shows an order

Effectiveness principle

- **The importance of an attribute must match the salience of the channel used to describe it.**
  - Most important attribute shown using most effective channel
  - Less important attribute shown using less effective channel.
- How do we rank the effectiveness of a channel?

Channel uses

- Ordered data
  - Shown with “how much” channels
- Categorical data
  - Shown with “what” channels.

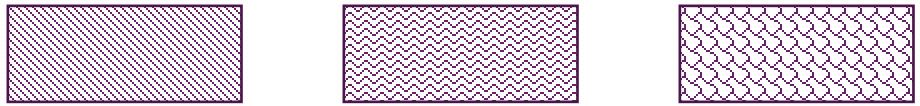
Channel rankings – how much

Effectiveness

- Position on common scale
- Position on unaligned scale
- Length
- Tilt / angle
- Area
- Curvature
- Volume
- Lightness
- Saturation
- Stipple density

Channel rankings - what

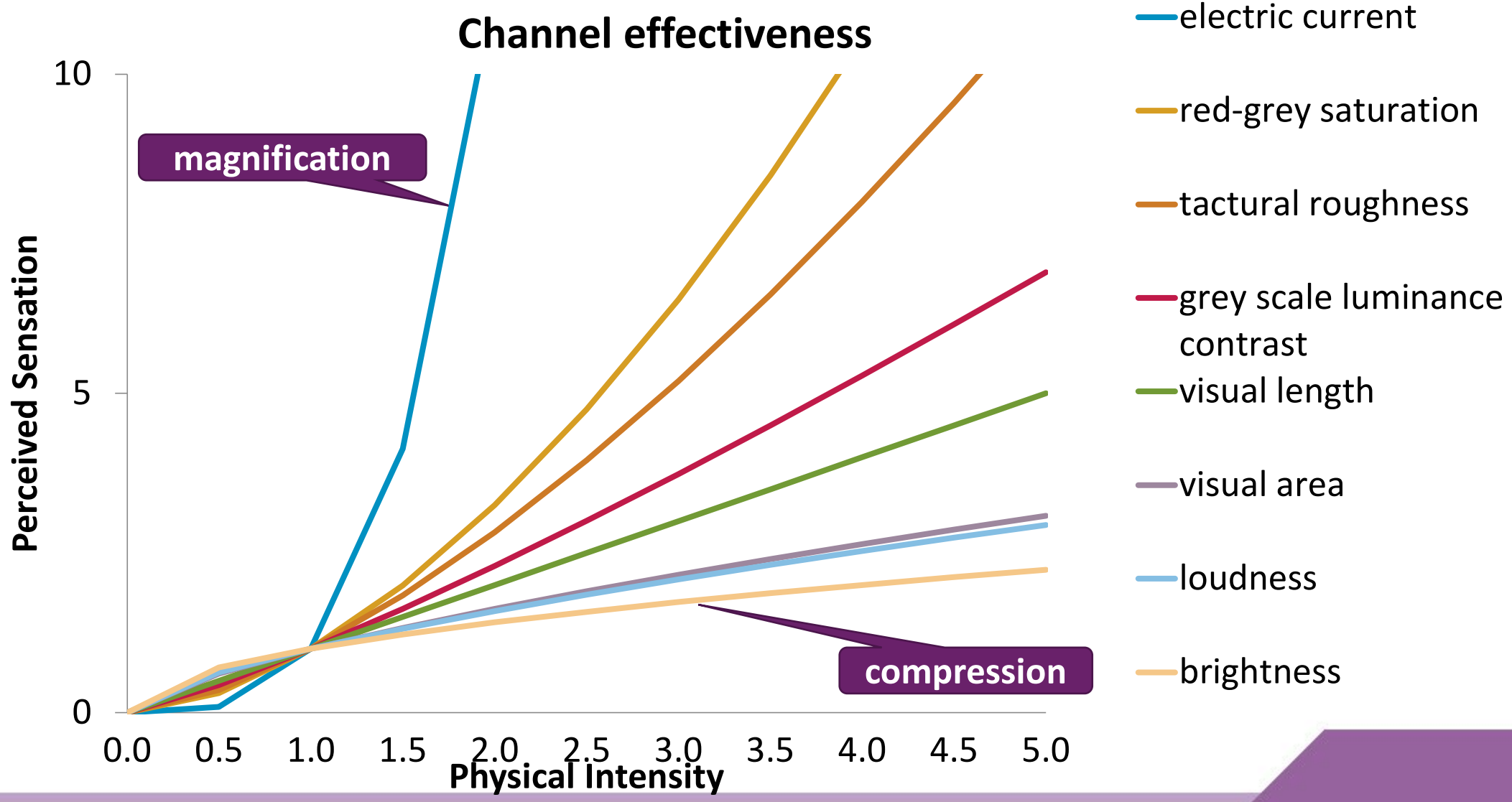
Effectiveness

- Region
- Colour hue
- Shape
- Stipple pattern 

Effectiveness - accuracy

- How close is perceptual judgement to reality?
- Different visual channels have different degrees of accuracy
  - Stimuli are generally magnified or compressed
- Perceived sensation
  - $S = I^n$
  - Where S is the perceived sensation
  - I is the physical intensity
  - n ranges from 0.5 for brightness to 3.5 for electrical current
    - n < 1 – sublinear, i.e. sensation is **compressed.**
    - n > 1 – superlinear, i.e. sensation is **magnified.**

… effectiveness - accuracy



Which perception channels are accurate?

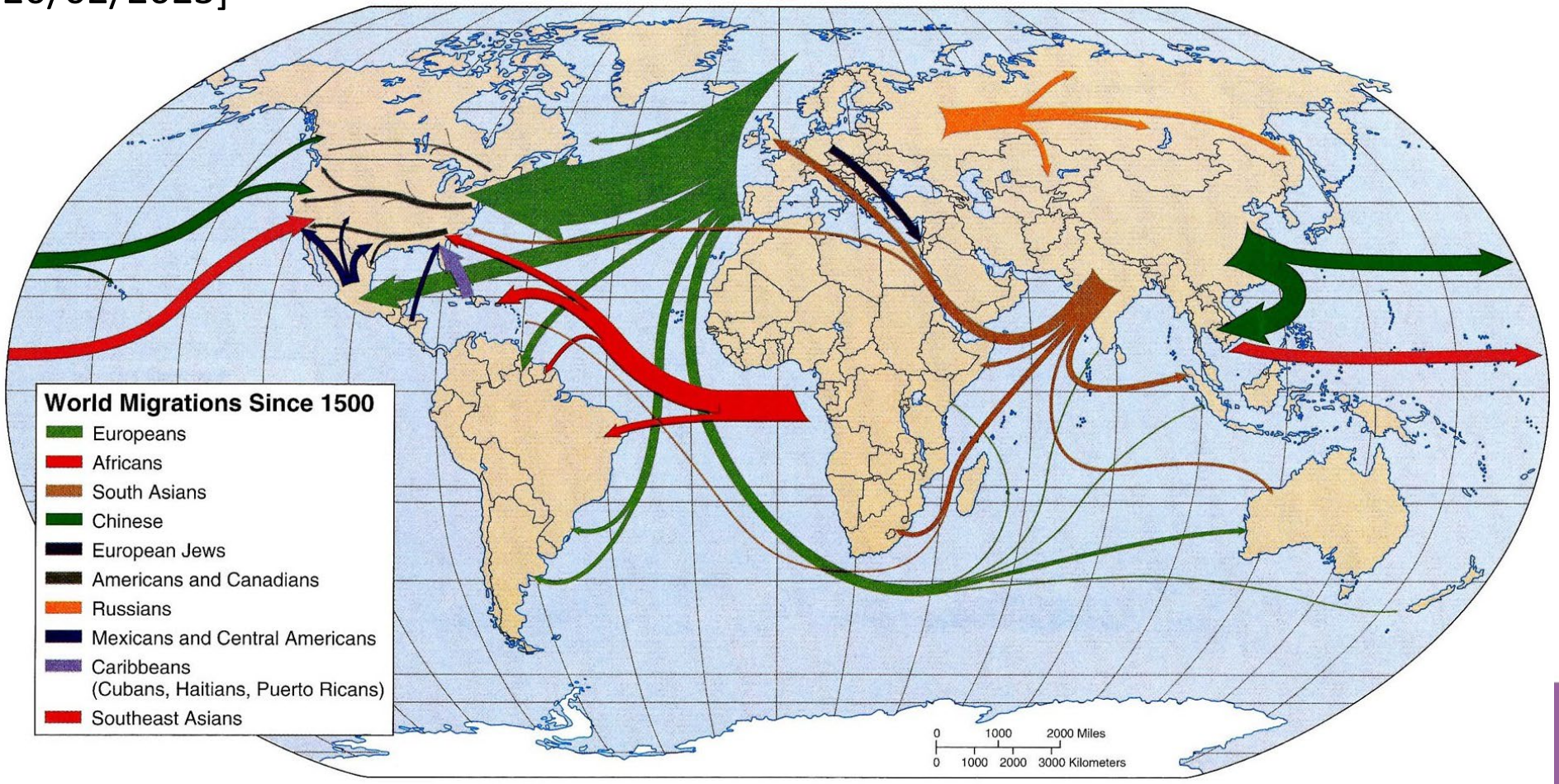
- **Accurate channels**
  - Length
  - Position along common scale
  - Position (non aligned scales)
  - Length (no scale)
  - Direction and angle (no scale)
- Other channels
  - Compressed sensation
    - E.g. double brightness does not lead to double the sensation
  - Magnified sensation
    - E.g. double the red-grey saturation leads to more than double the sensation.
- Area not so good
- Volume and curvature even worse!

Discriminability

- Quantify number of bins for use with a visual channel
  - Bin – a distinguishable step
- Line width
  - Very few bins
  - Can only increase line width up to a point
    - It then becomes a polygon
  - But it is good to show 3 or 4 data attribute values
- Must match number of different attribute values to number of bins in visual channel.

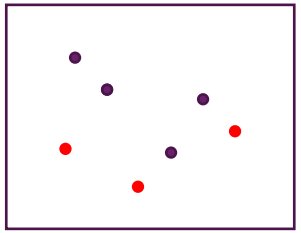
Effective line channels

- From http://www.holtz.org/Library/Images/Slideshows/Gallery/Maps/1500-2000%20migrations.jpg [accessed 20/02/2023]



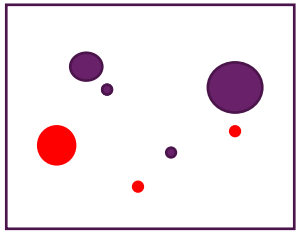
Separability

- Channels interact
- Potential interactions between pairs of channels must be considered
  - Independent channels – **separable**
  - Inextricably combined channels – **integral**



Position
Hue

Fully separable

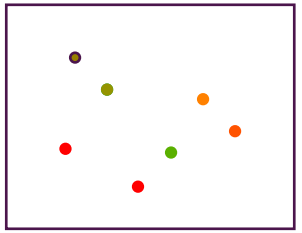


Size
Hue

Some interference

Size: width
Size: height

Significant interference

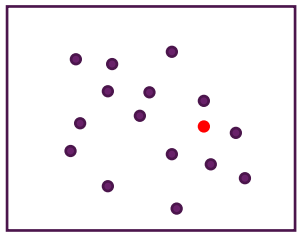


Red
Green

Major interference

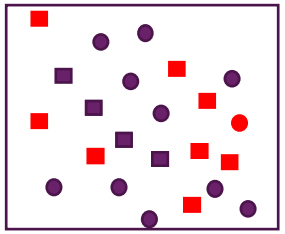
Popout

- A distinct item stands out from items around it.
- Happens for colour hue, shape, tilt, size, shape, proximity.



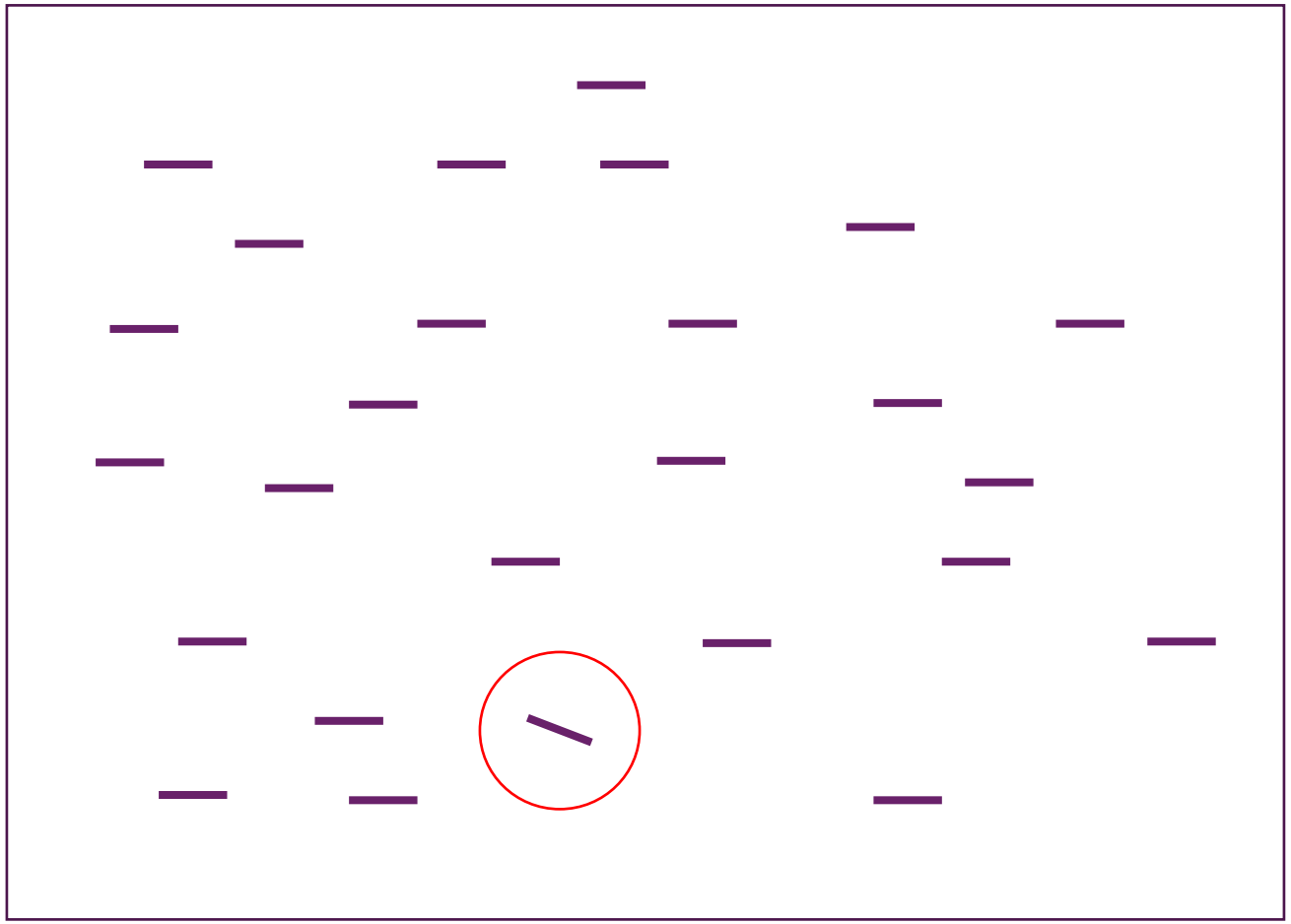
Red dot pops out from a sea of blue dots

Blue dot pops out from a sea of blue squares

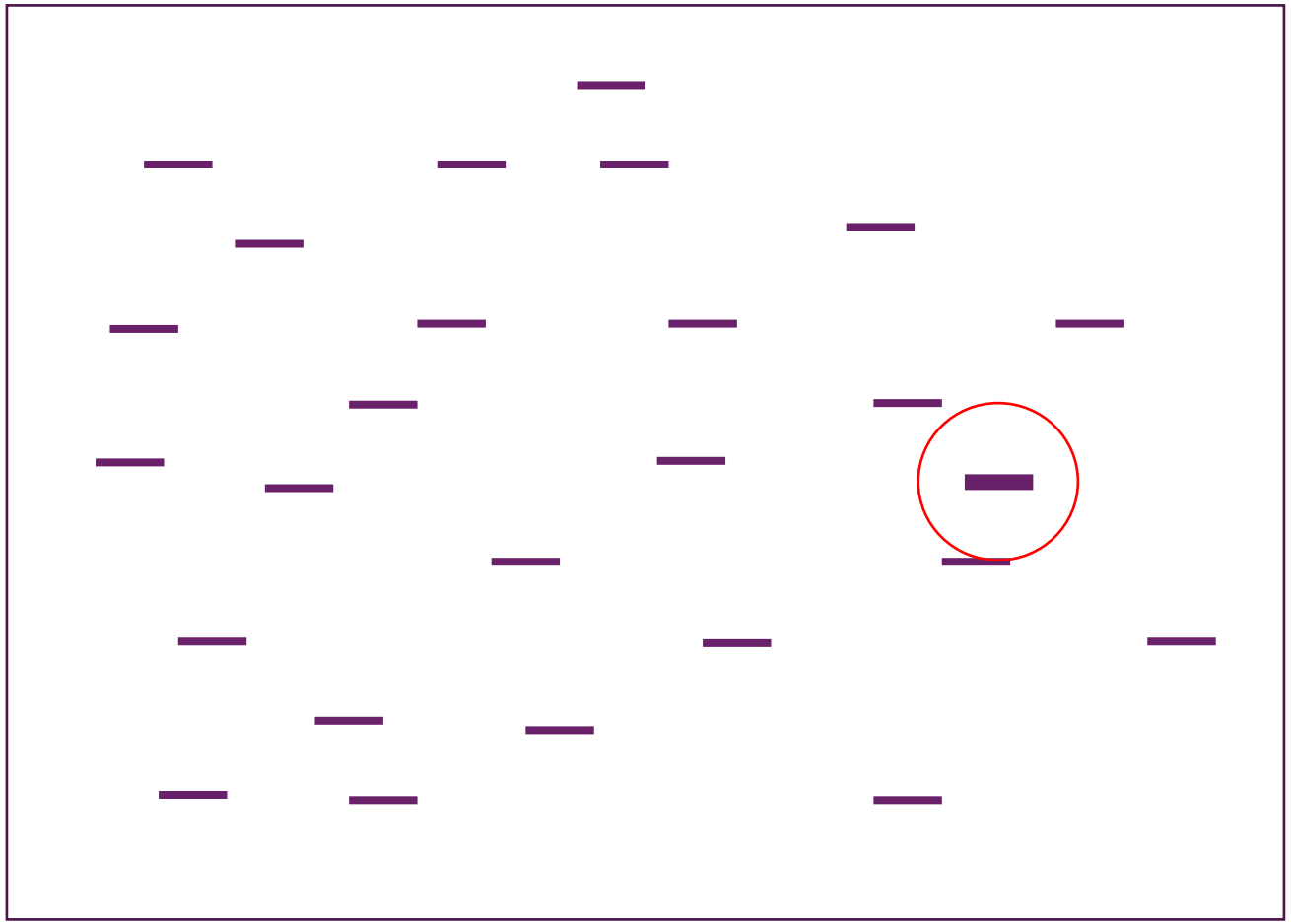


Red dot does not pop out from a sea of blue dots and red and blue squares

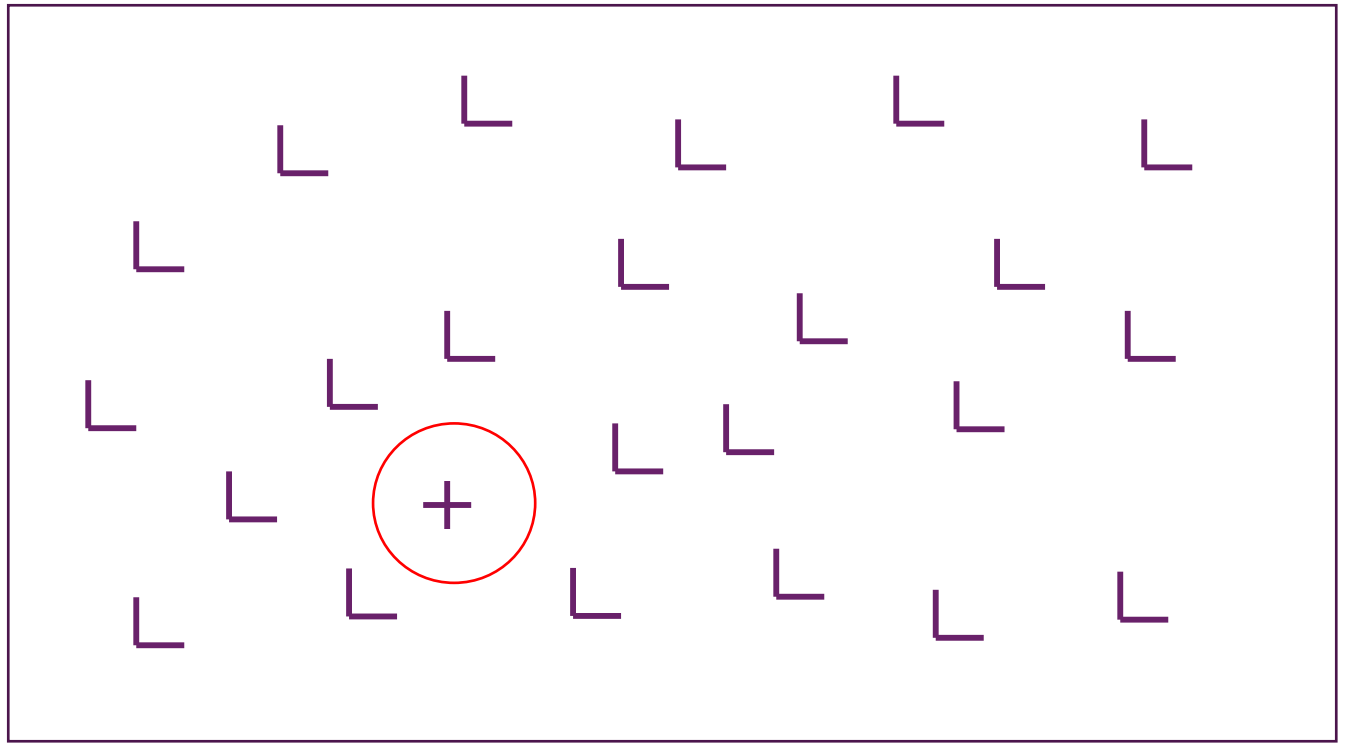
Pop out?



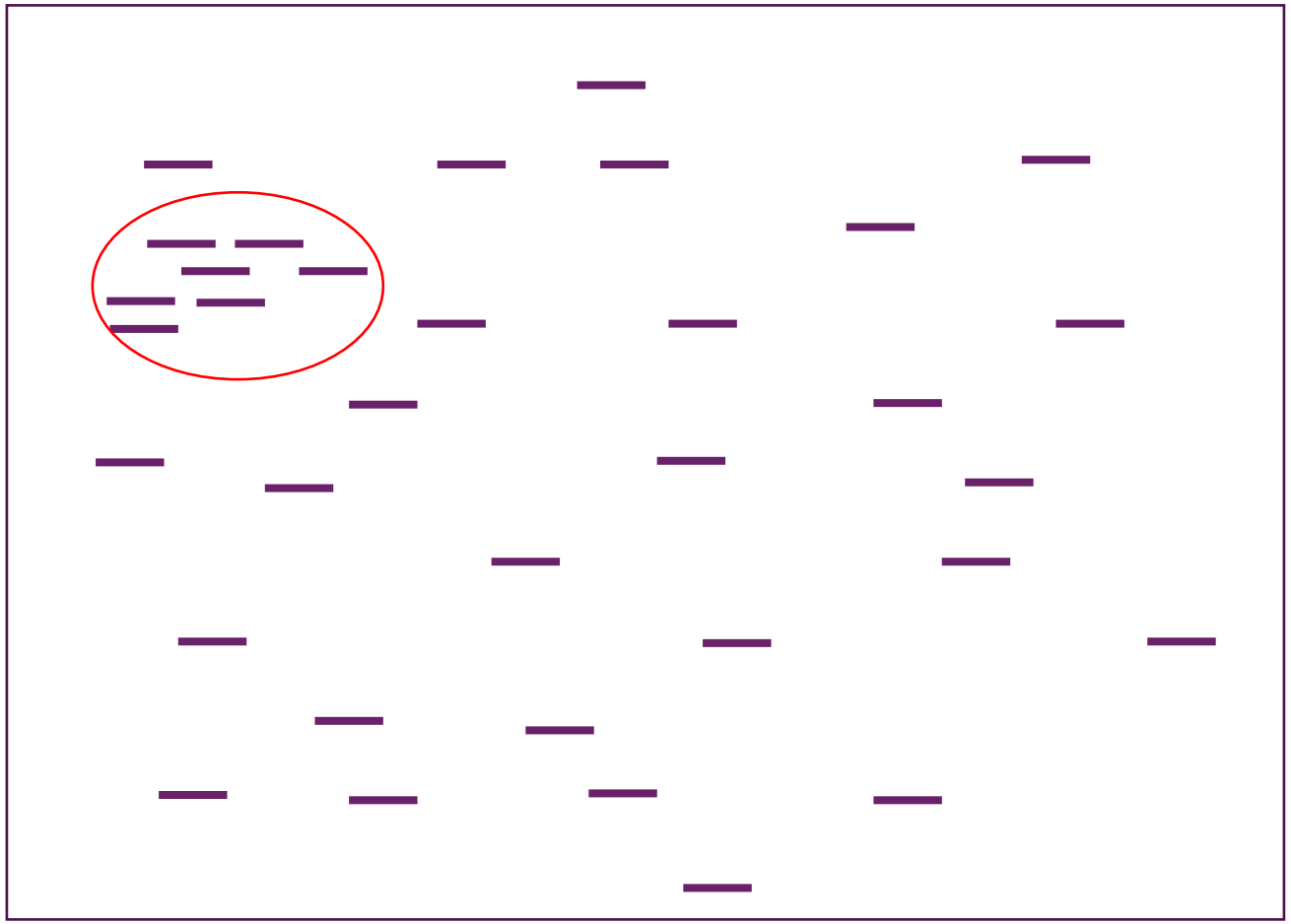
Pop out? Thickness



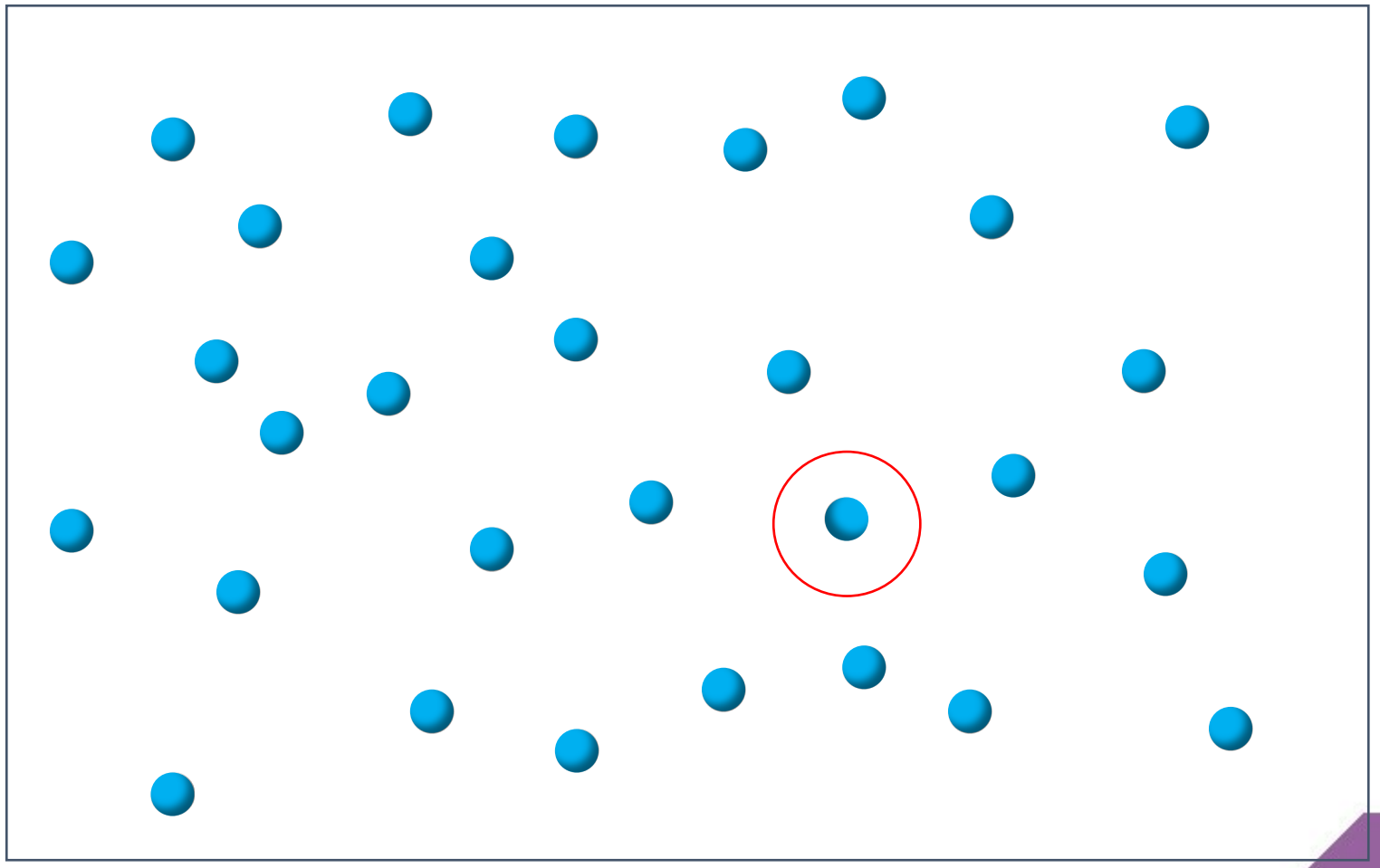
Pop out? Position of lines meeting



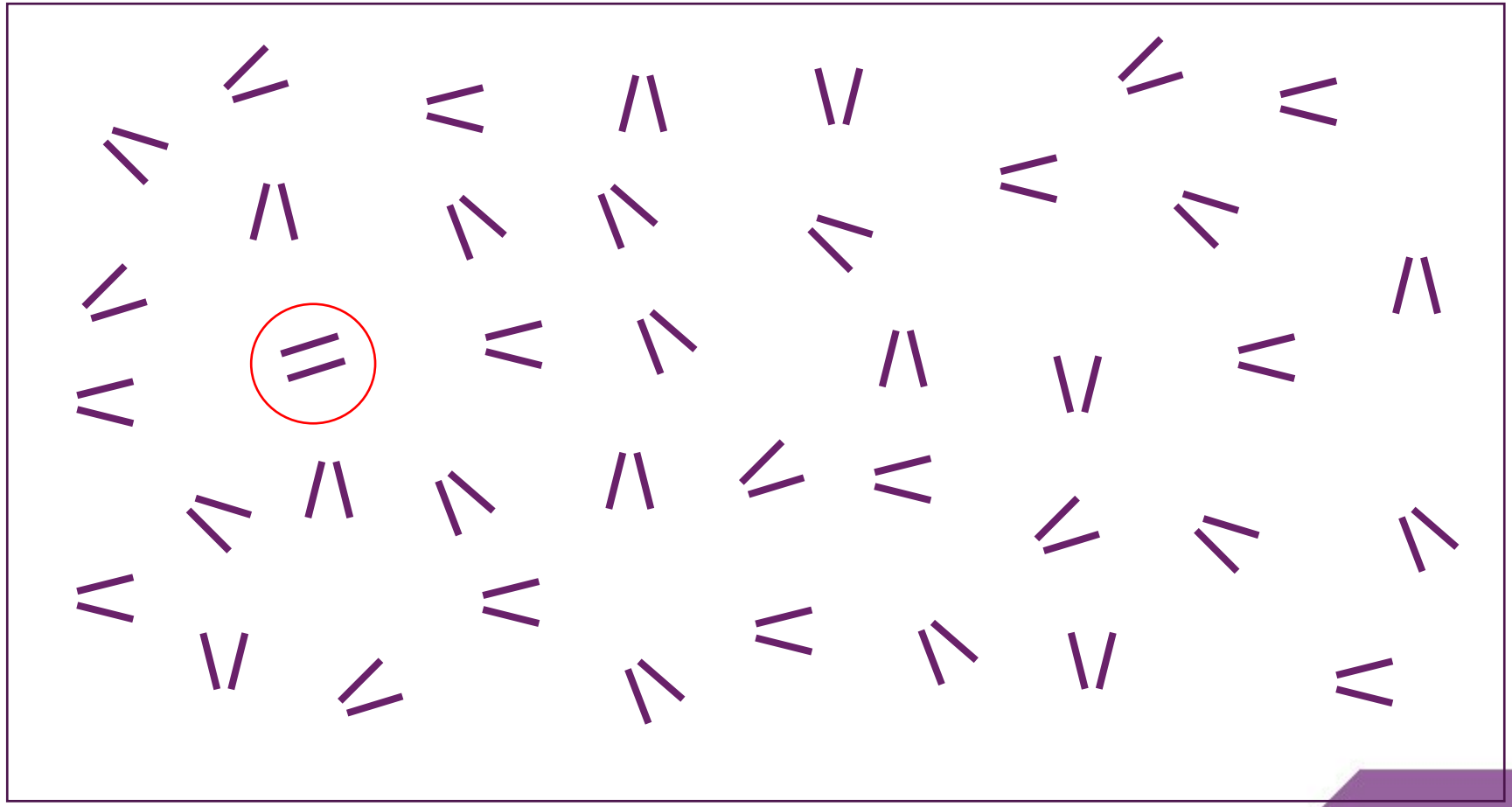
Pop out? Density



Pop out? Shadow



Pop out? Angle



… spot the popouts

- Tilt
- Size
- Shape
- Proximity
- Shadow direction (more difficult?)
- Parallel lines amongst slightly tilted ones – do NOT pop out at all!

Popouts

- Depend on lots of things including
  - Channel
  - Difference between target and surroundings
- Combination of channels may prevent popouts

Channel features

- Planar position
  - Excellent for both:
    - Ordered channels
    - Unordered channels
- Vertical and horizontal position combined into planar position
  - Height more important than horizontal length
  - But ratio of standard displays gives more space to horizontal axis.

Channel features 2

- Colour channels
  - Red to green
  - Blue to yellow
  - Black to white (luminance)
- Luminance channel – high resolution edge information
- Colour deficiency
  - Generally inability to differentiate the red to green channel

… channel features 3

- Colour
  - Luminance – how much channel for ordered data
  - Saturation – how much for ordinal data
  - Hue – what channel
    - Very effective for categorical data

- Unlike luminance and saturation, hue does not have perceptual ordering

Channel features 4

- Size
  - A how much channel for ordered data
  - Interacts with most other channels
- Length, area, volume
  - Higher dimensionality channels subsume lower dimensionality ones
    - E.g. area subsumes length
- Length is easy to judge
- Area and volume are more difficult.

Channel features 5

- Orientation
  - Tilt
  - Angle
    - Precise perception when near horizontal, vertical or diagonal
      - Distinguish
        - 89 degrees from 90 - yes
        - 44 from 45 - yes
        - 0 from 1 - yes
        - 37 from 38 – that's a problem

2 degrees difference between the two angles above

Unless the two are superimposed it is difficult to detect the difference

Channel features 6

- Shape
  - Includes lots of features
    - Curvature
    - Closure
    - Termination
    - Intersection
- Not with area marks or line marks
- Lots of bins if size of shape is big enough
  - But this may not be possible depending on size of display.

Channel features 7

- Stippling – filling regions with short lines, dots, etc
  - Still used for line marks
  - Not so much for area marks as colour visualisation is available.

Summary

- Judgements based on relative information
- Marks and channels used for visualisation
- Characteristics of marks and channels
  - Rankings – which channels are best?
  - Measured according to
    - Effectiveness
    - Separability
    - Expressiveness