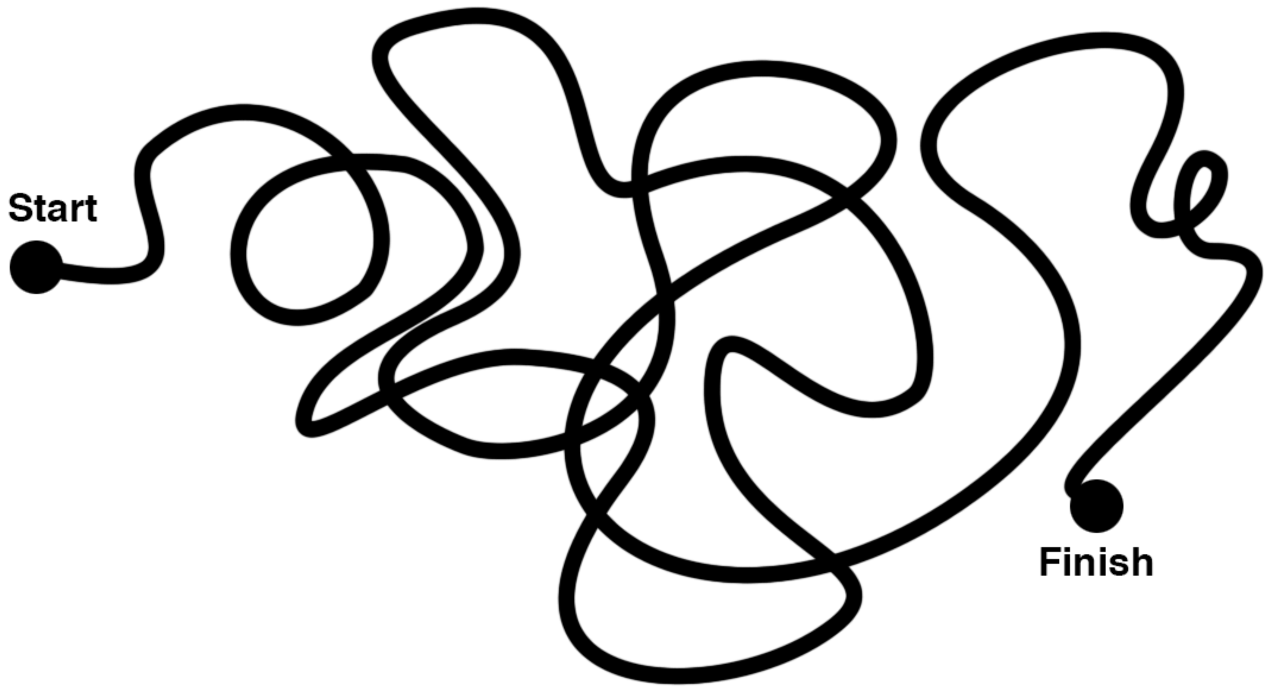
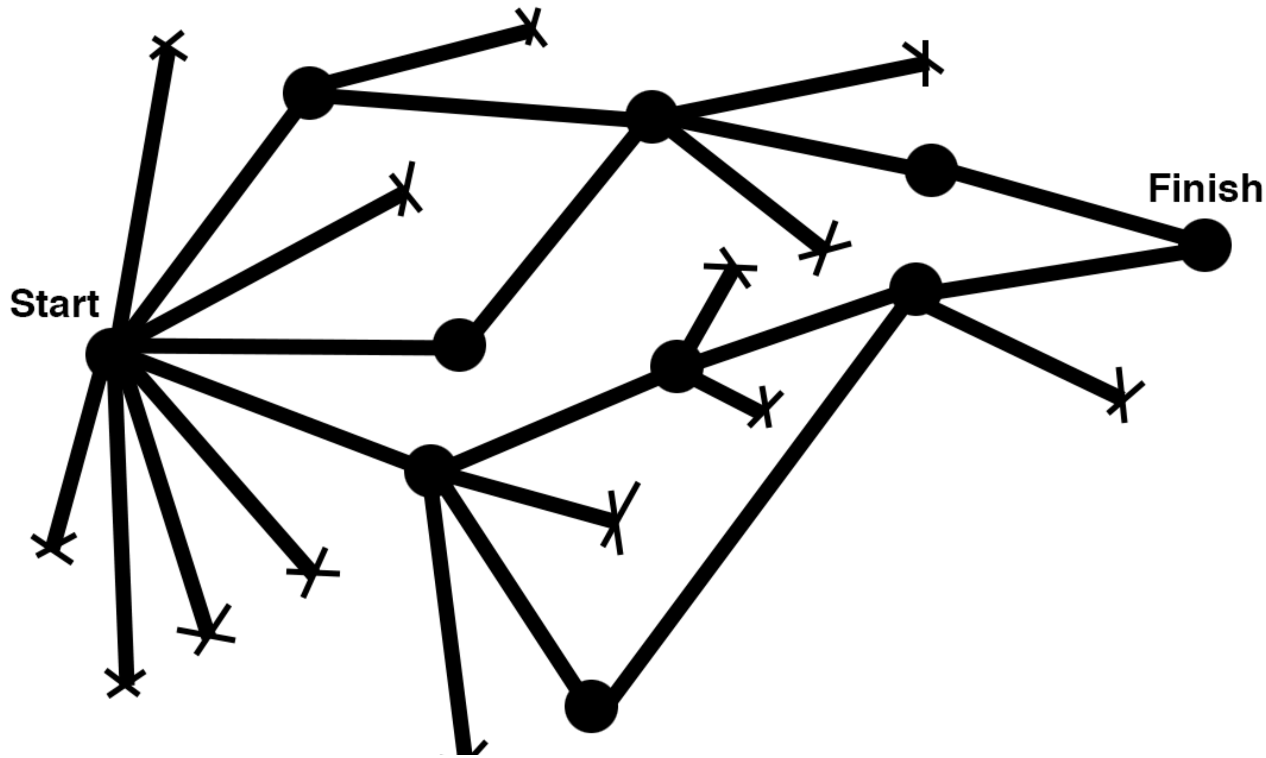
For some fun……

The process of a junior designer



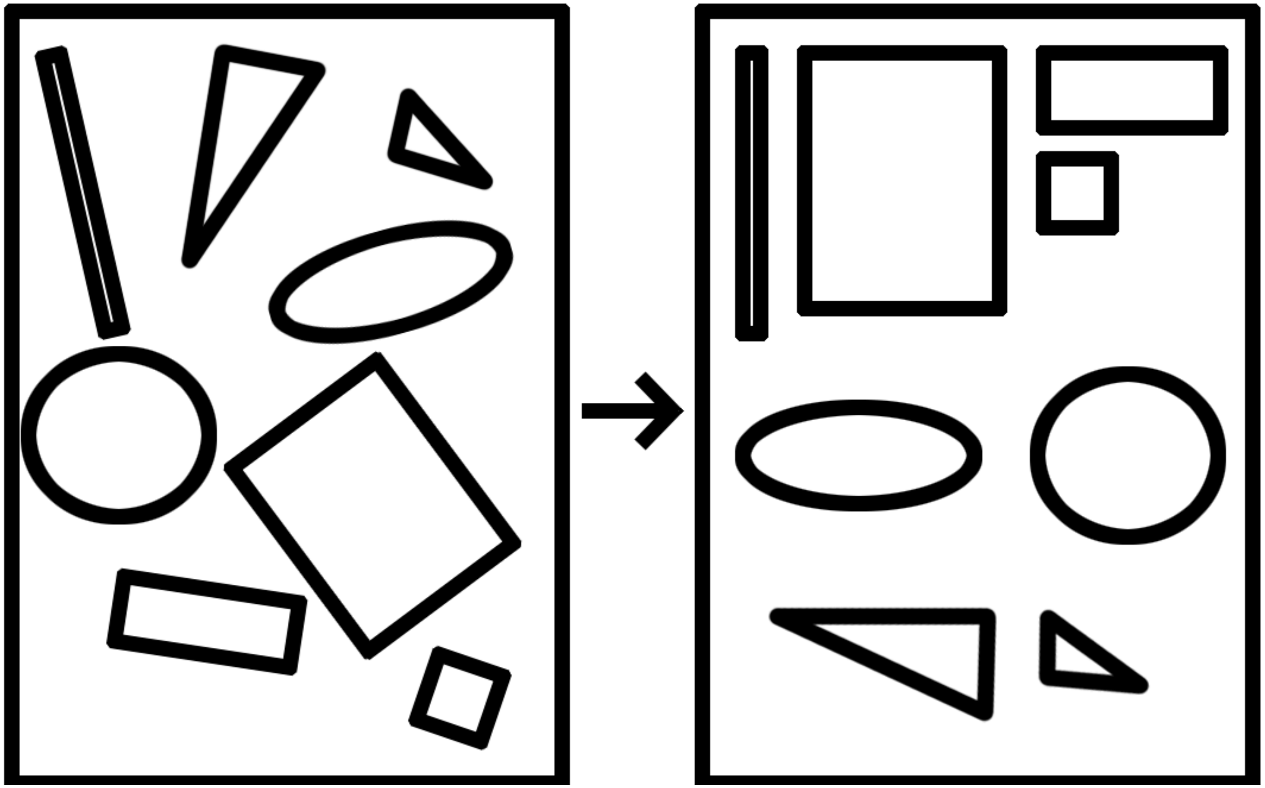
https://medium.com/the-year-of-the-looking-glass/junior-designers-vs-senior-designers-fbe483d3b51e

The process of a senior designer



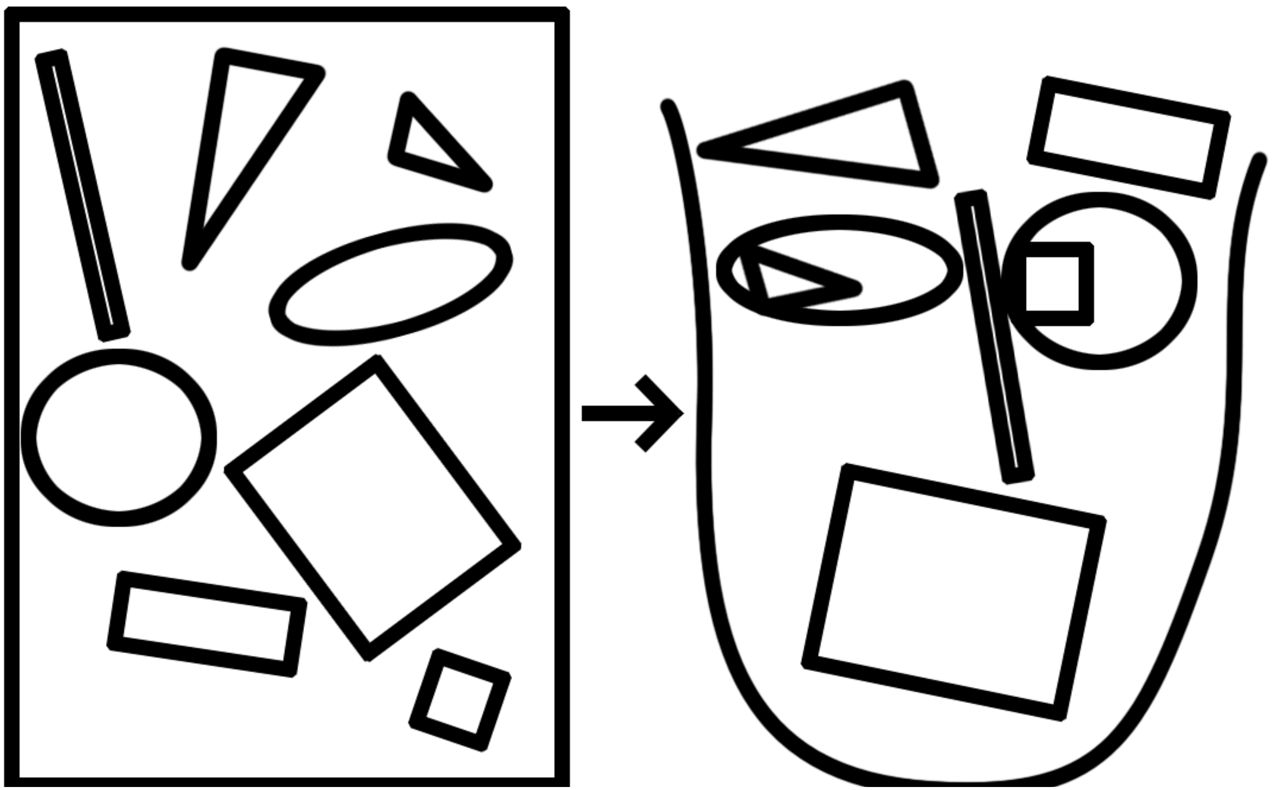
https://medium.com/the-year-of-the-looking-glass/junior-designers-vs-senior-designers-fbe483d3b51e

Junior ambitions: make it look good



https://medium.com/the-year-of-the-looking-glass/junior-designers-vs-senior-designers-fbe483d3b51e

Senior ambitions: add some value



https://medium.com/the-year-of-the-looking-glass/junior-designers-vs-senior-designers-fbe483d3b51e

IAT 814
Perception 1

Or

What You See is Maybe Not What You Were Supposed to Get

SFU

SCHOOL OF INTERACTIVE
ARTS + TECHNOLOGY

Why we need to understand perception

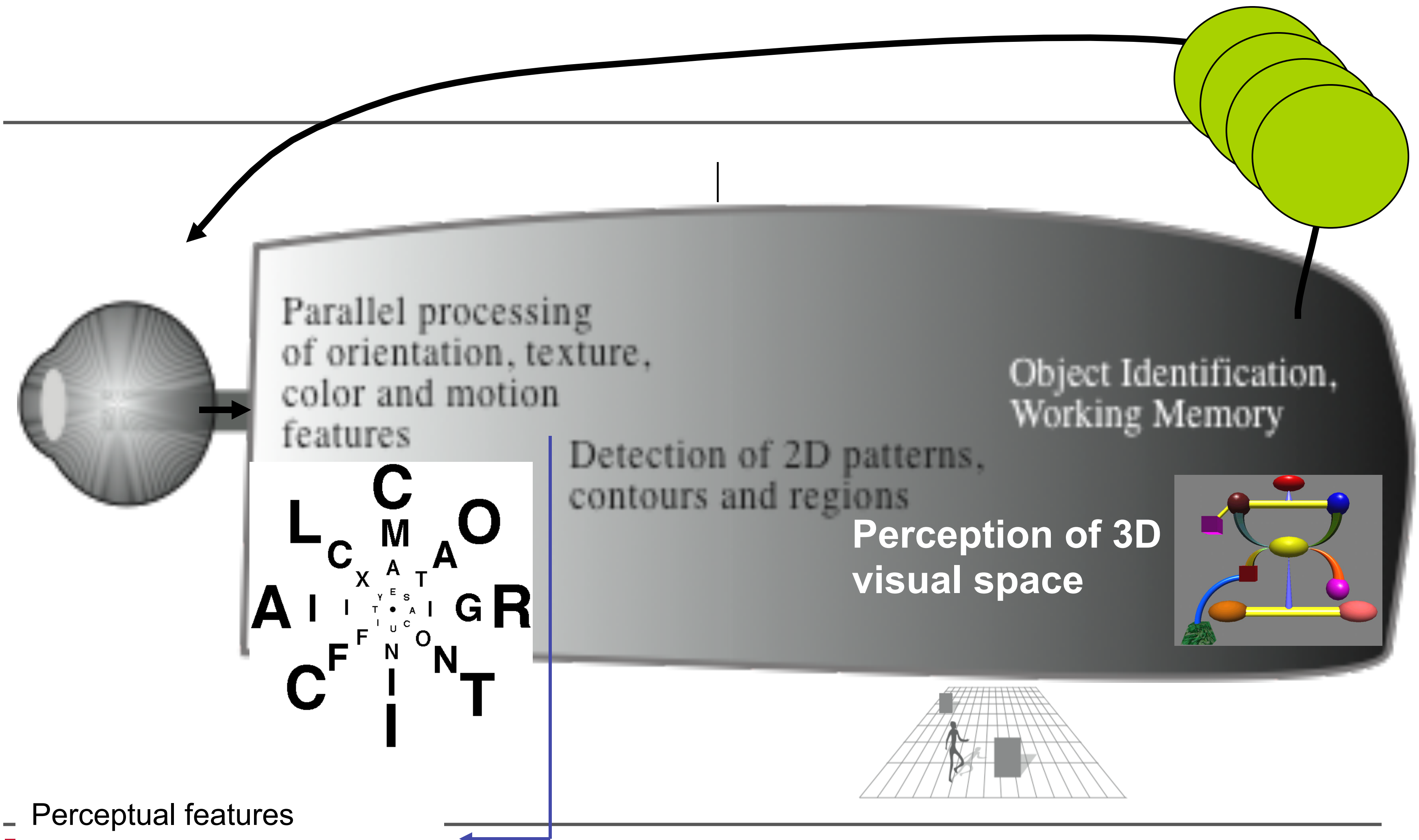
- The ability of viewers to interpret visual (graphical) encodings of information and thereby decode information in graphs.

A Simple Model of how we see

- Two stage process
  - Parallel extraction of low-level properties of scene
  - Sequential goal-directed processing

Eye → Stage 1: Early, parallel detection of color, texture, shape, spatial attributes → Stage 2: Serial processing of object identification (using memory) and spatial layout, action

The machinery



- Perceptual features

Stage 1 - Low-level, Parallel

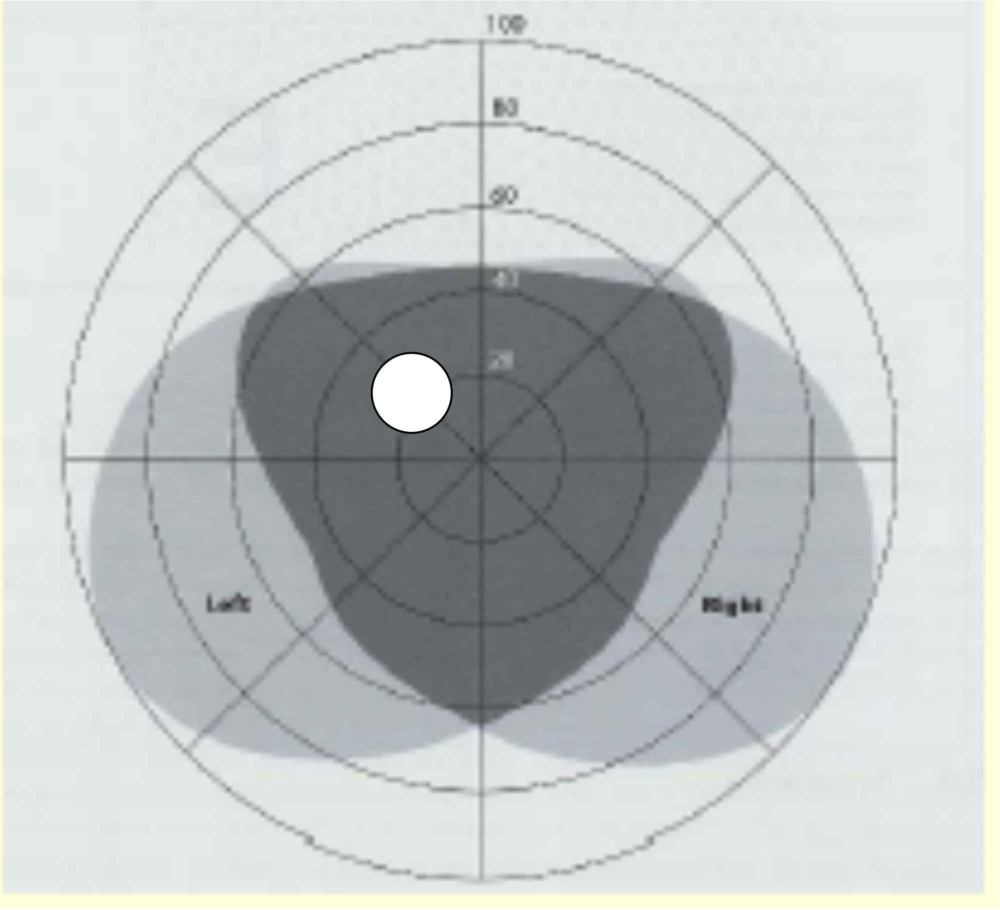
- Neurons in eye & brain responsible for different kinds of information
  - Orientation, color, texture, movement, etc.
  - Arrays of neurons work in parallel
  - Occurs “automatically”
  - Rapid
  - Information is transitory, briefly held in iconic store
  - Bottom-up data-driven model of processing
  - Often called “pre-attentive” processing

Visual acuity

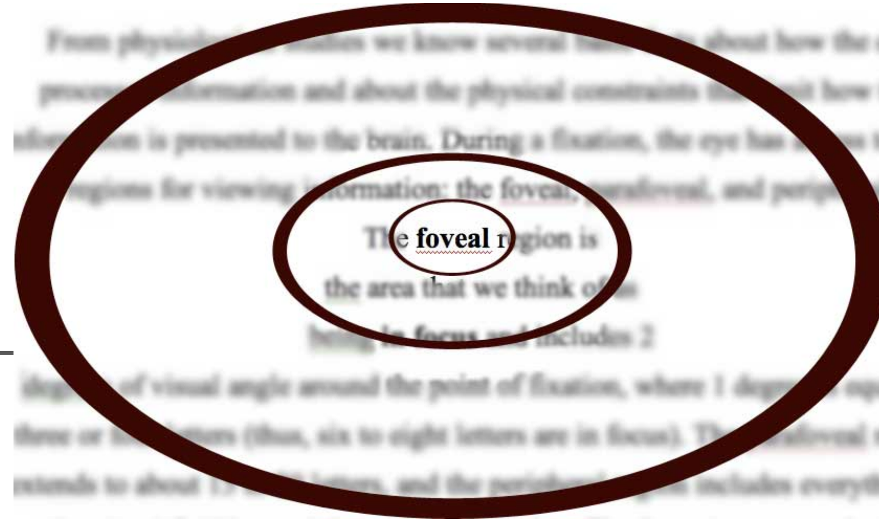
- How accurately we can distinguish/separate objects and form
  - Measured in angles : degrees, minutes and seconds (360, 60, 60)
- An object subtends a visual angle of 10° means
  - The object covers a 10° extent in your ***field of view***
- We only see acutely in the *fovea/parafovea*
  - The thumb test

Visual field of view

- How accurately we can distinguish/ separate objects and form
- We only see acutely in the *fovea/ parafovea*
  - The thumb test



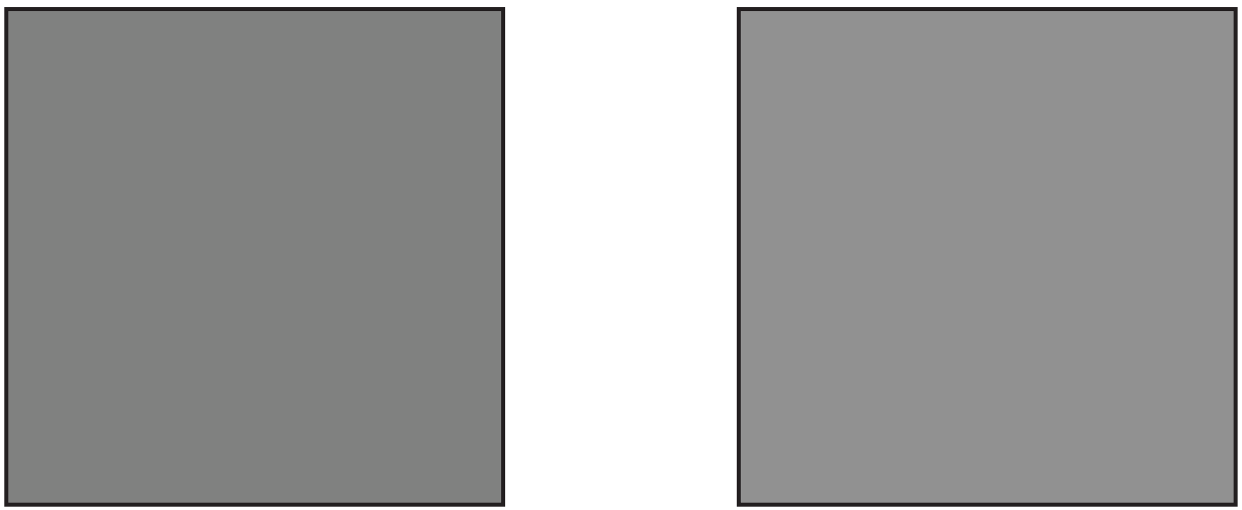
Useful field of view



- Experiments using displays densely populated with targets reveal small UFOVs, from 1 to 4 degrees of visual angle
- For low character densities (less than one per degree of visual angle), the useful visual field can be as large as 15 degrees.
- With greater target density, the UFOV becomes smaller and attention is more narrowly focused; with a low target density, a larger area can be attended.

Detecting differences

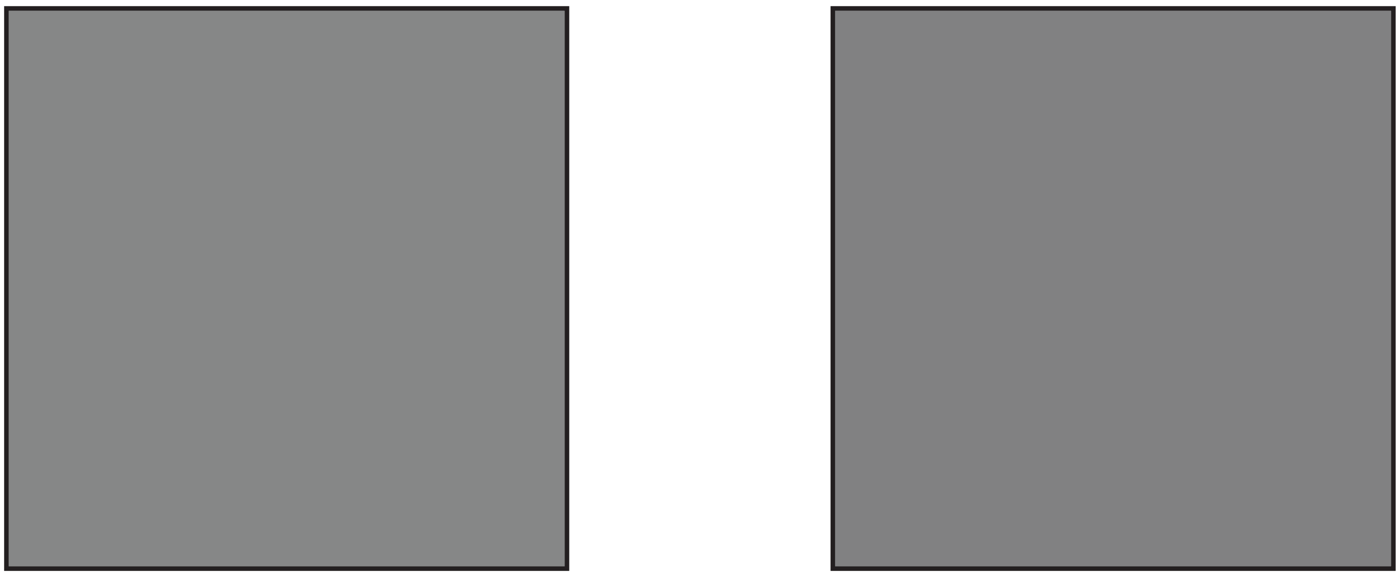
- Which is brighter?



128, 128, 128 | 144, 144, 144

Detecting differences

- Which is brighter?



134, 134, 134 128, 128, 128

Just Noticeable Difference

- JND (Weber's Law)
- The smallest detectable difference between equally spaced levels of a stimulus
- Ratios are more important than magnitude
- Most continuous variation perceived in distinct steps

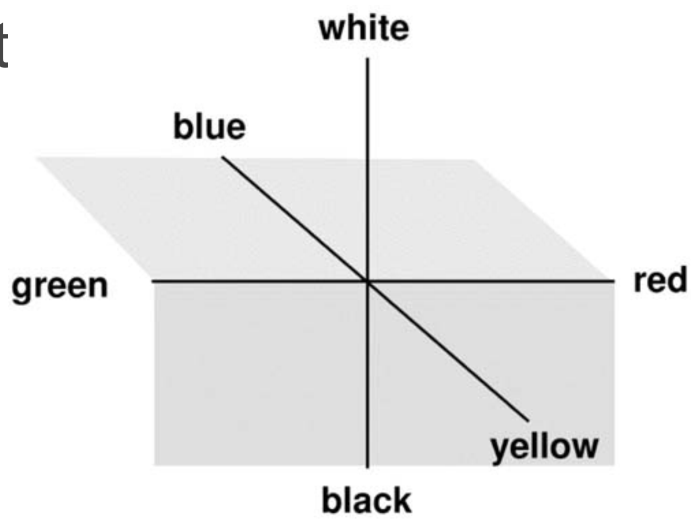
What we see is not always what is “there”

- Contrast and luminance illusions
- Colour effects
- Spatial frequency processing

Light comes in 3 channels

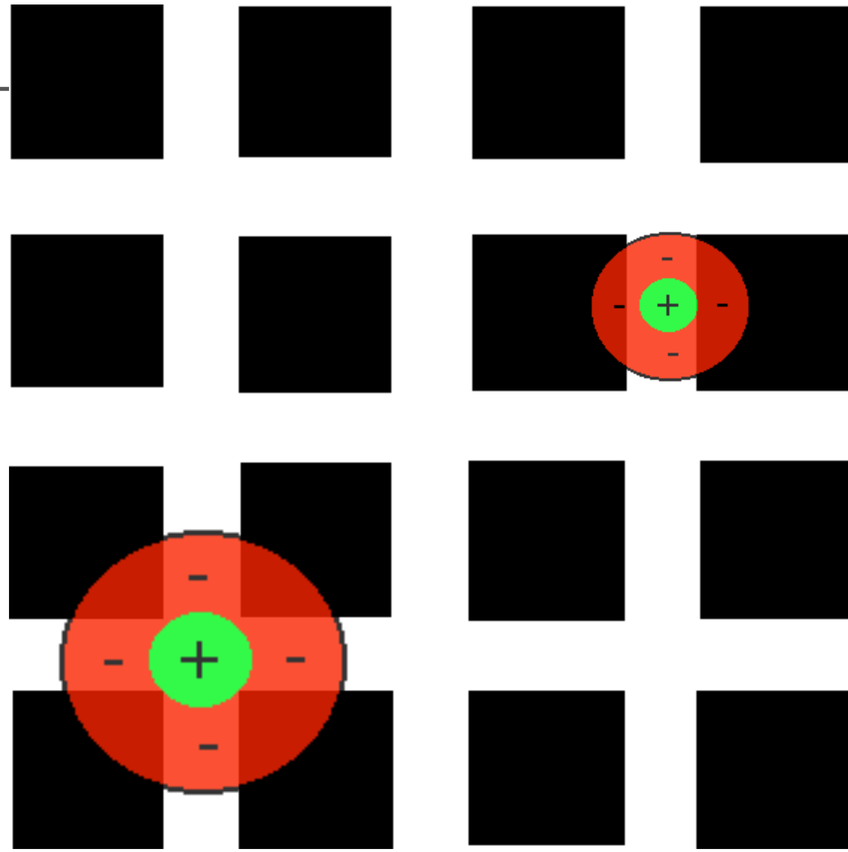
- The receptive field of a cell is the visual area over which a cell responds to light.
- Excitation explains many contrast

- *Luminance*: the physical stimulus
- *Brightness*: what we "see"

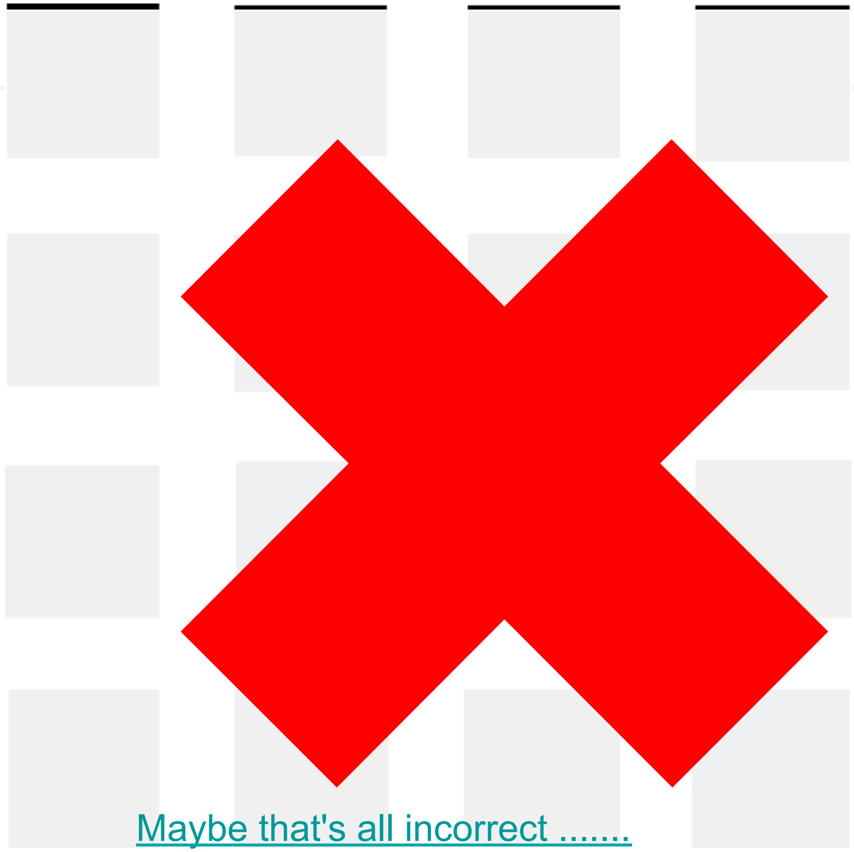


Brightness illusions: Hermann Grid

•



Brightness illusions: Hermann Grid

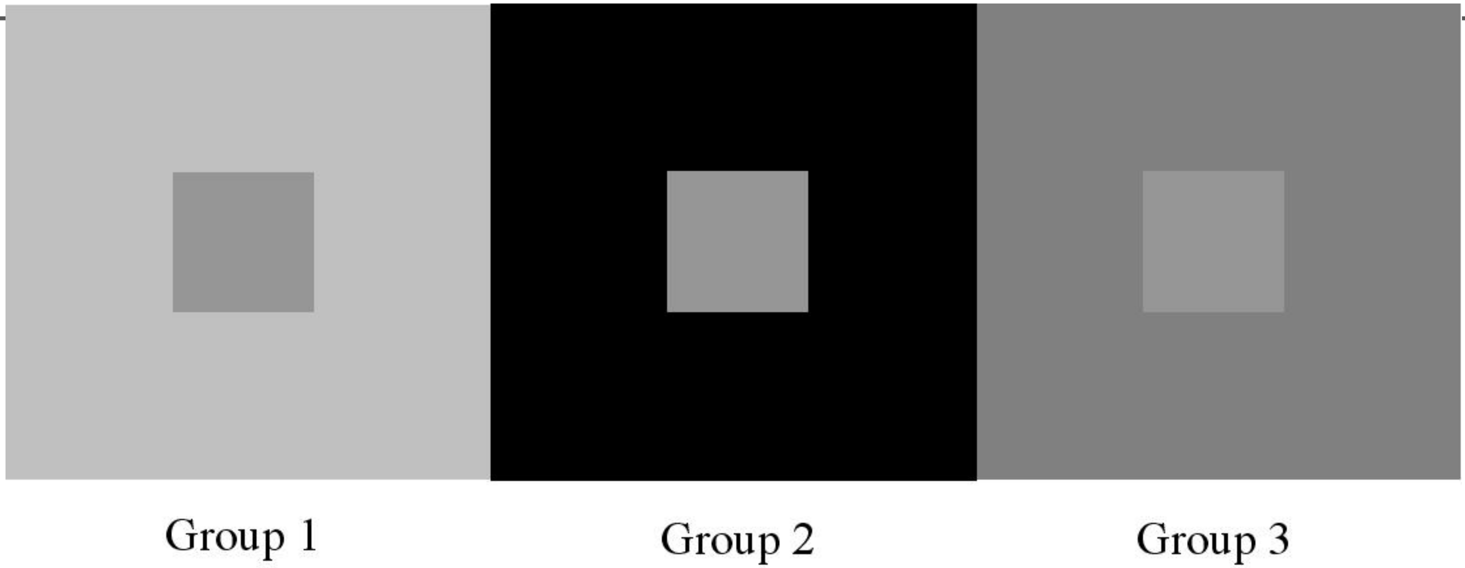


[Maybe that's all incorrect ....]

Other brightness illusions

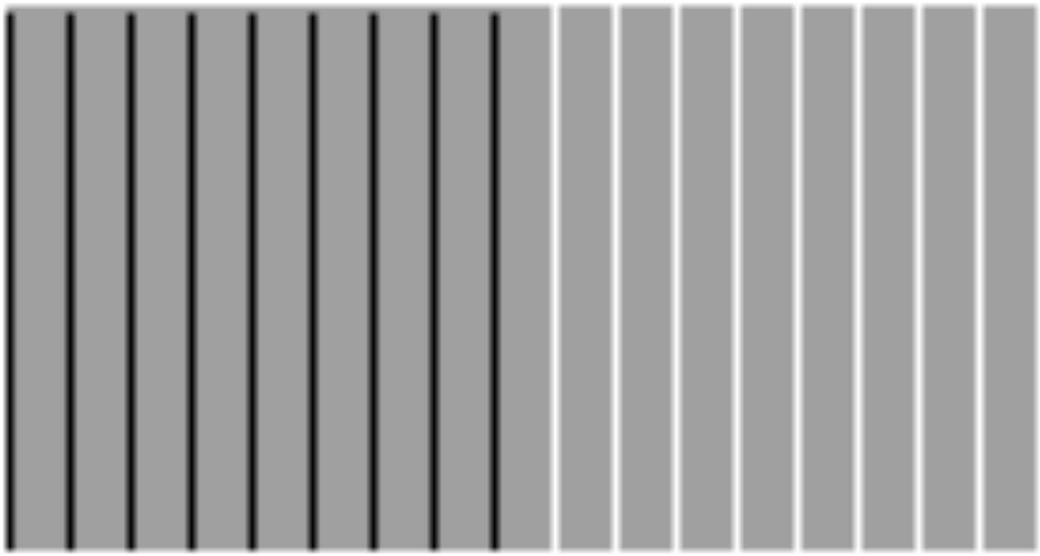
- The scintillating Grid
- Misperceived Luminance gradients

Simultaneous contrast effects



- a gray patch on a dark background looks lighter than the same gray patch on a light background.
- http://www.michaelbach.de/ot/lum_dynsimcontrast/index.html

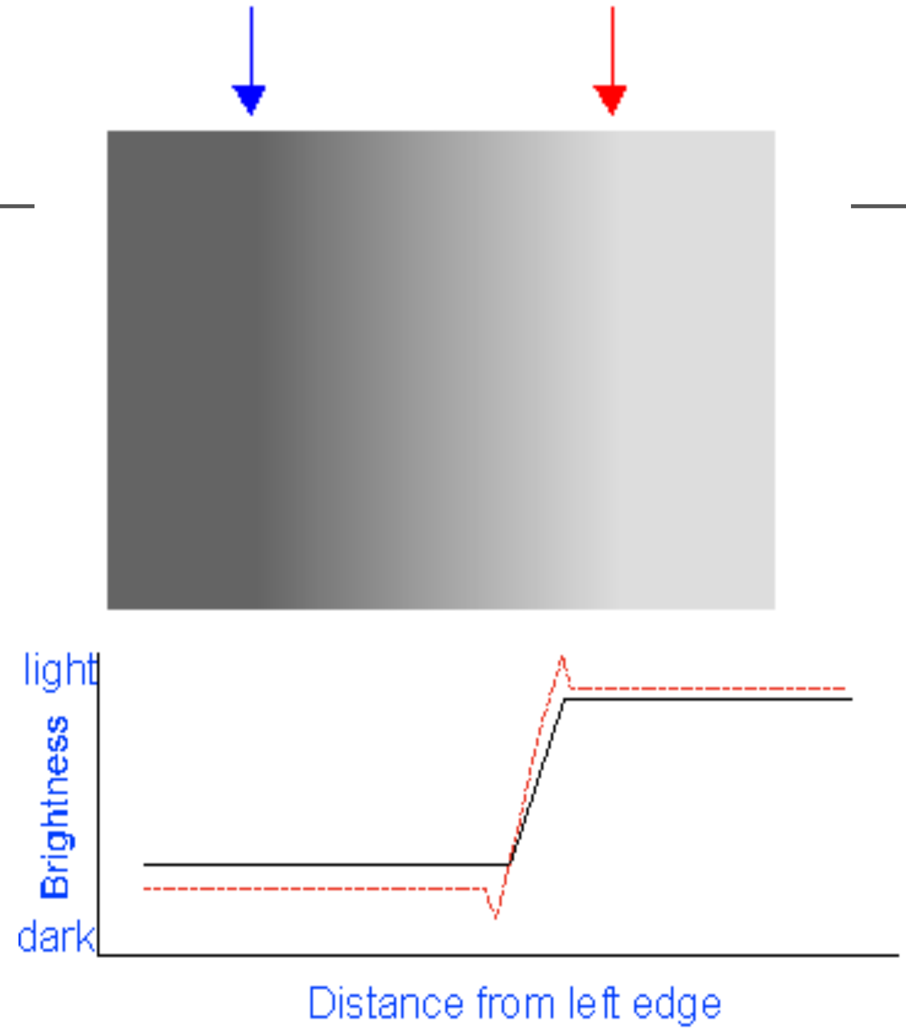
Assimilation of lightness



- The gray background with black lines appears to be darker while the gray background with white lines appears to be lighter.

Mach bands

- Illusory Mach bands appear when gradients from darker to lighter shades are created



Mach bands

- The effect is robust with different shapes and numbers of gradients

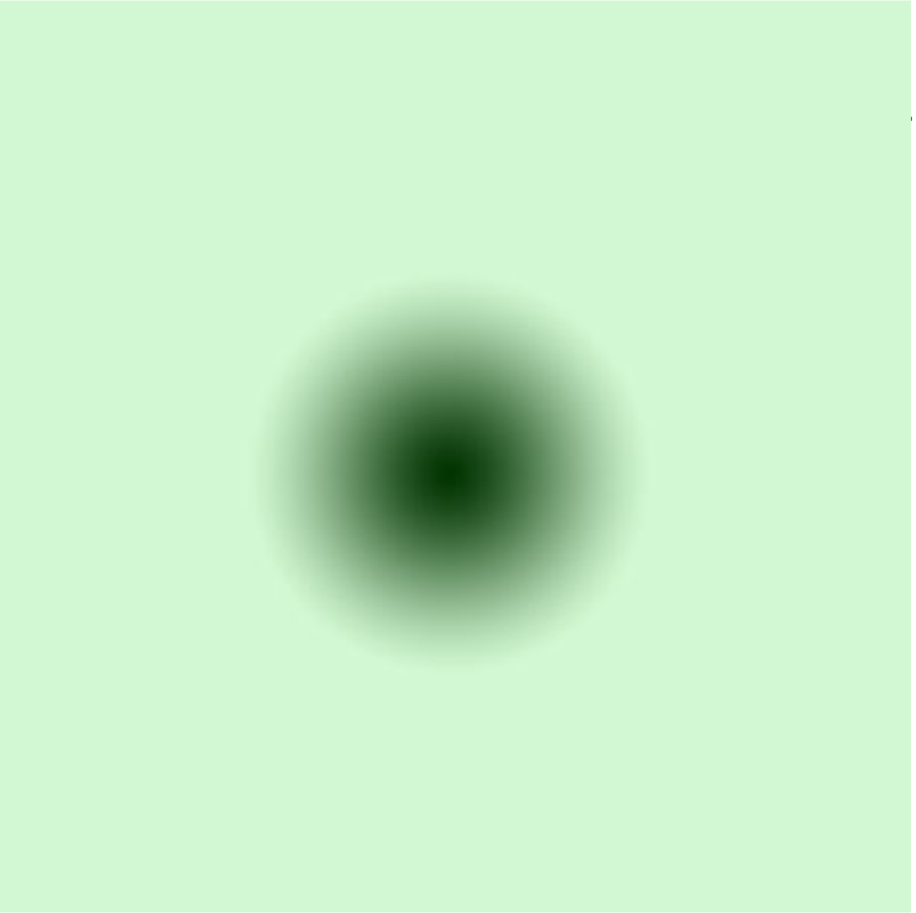


Image from perceptualstuff.org

Mach bands

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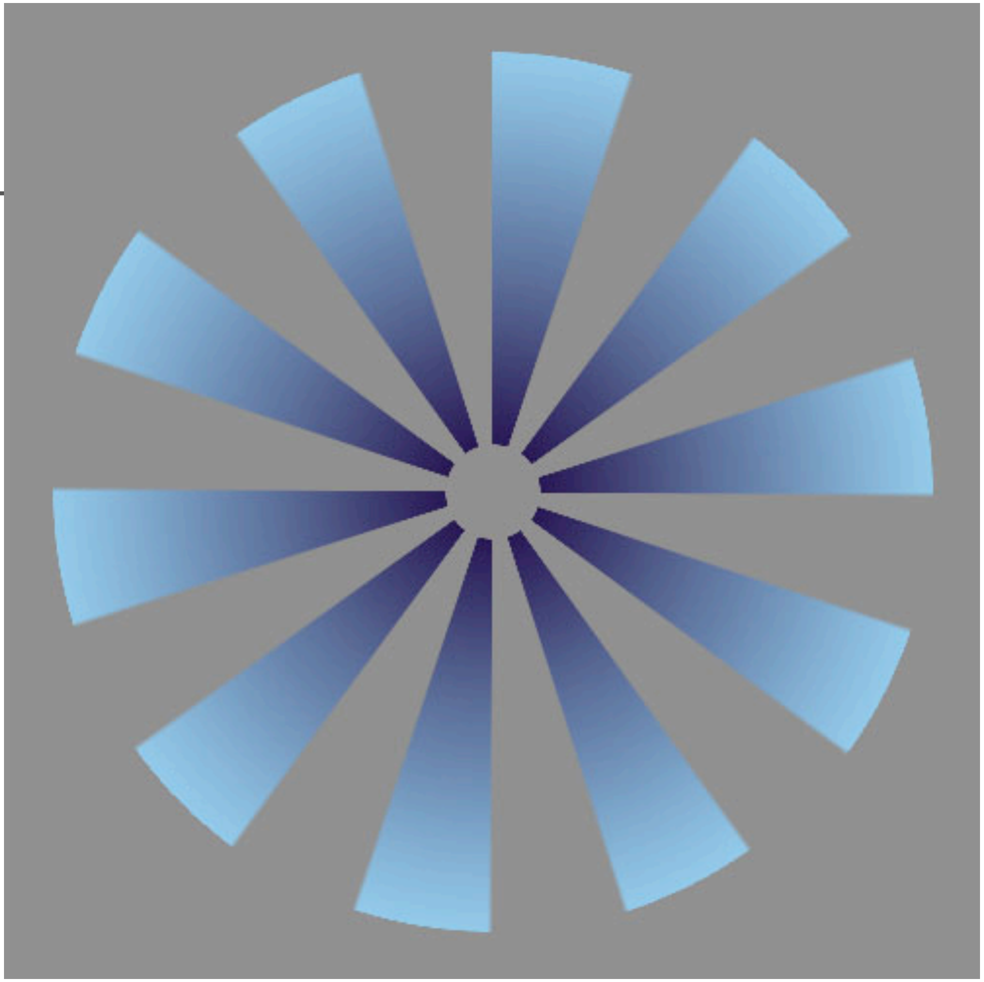

Image from perceptualstuff.org

Mach bands

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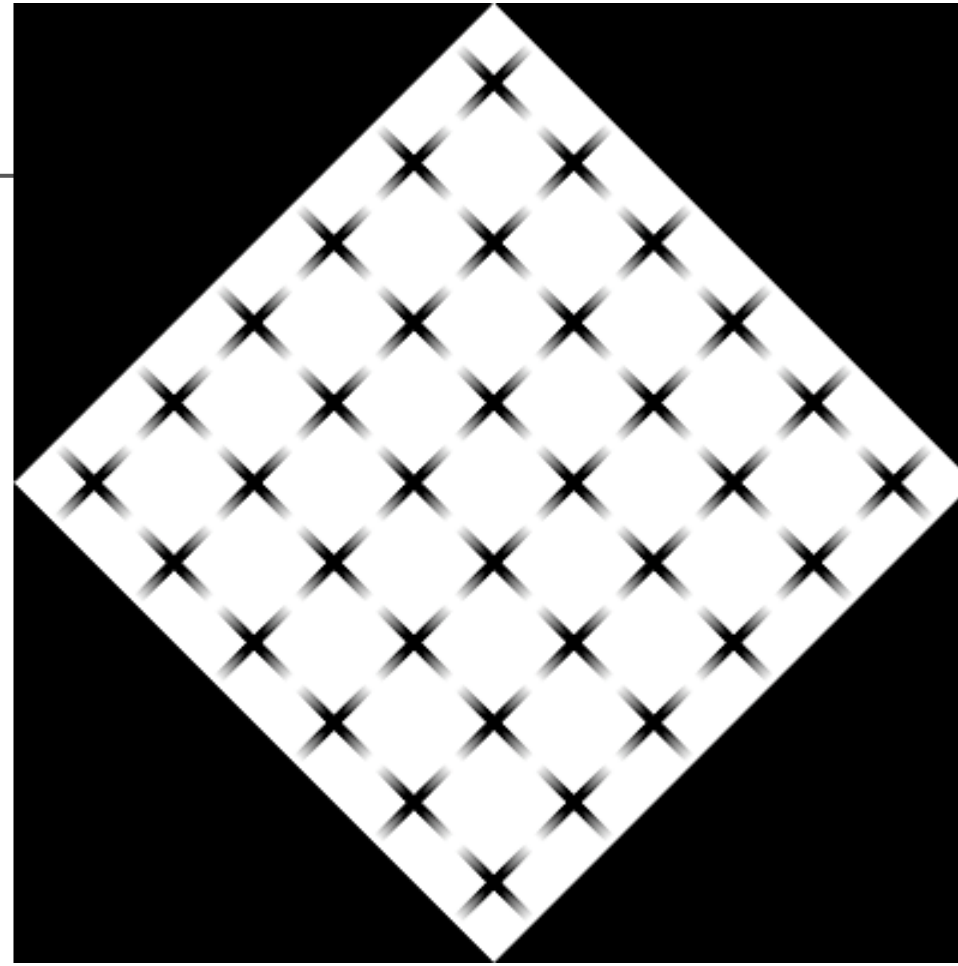
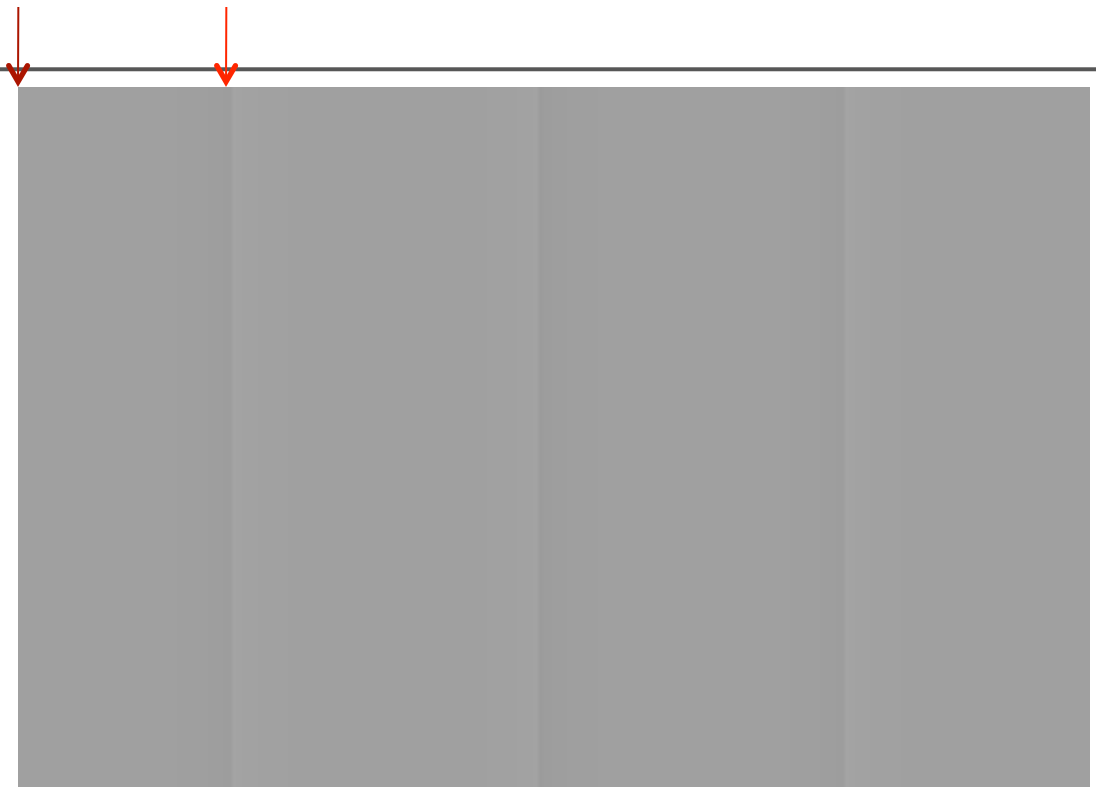


Image from perceptualstuff.org

Chevreuil Illusion



- When a sequence of gray bands is generated , the bands appear darker at one edge than at the other, even though they are uniform

Chevreuil Illusion

- Again, this also works in colour and with irregular borders.
- Note we are not talking about hue change but luminance change

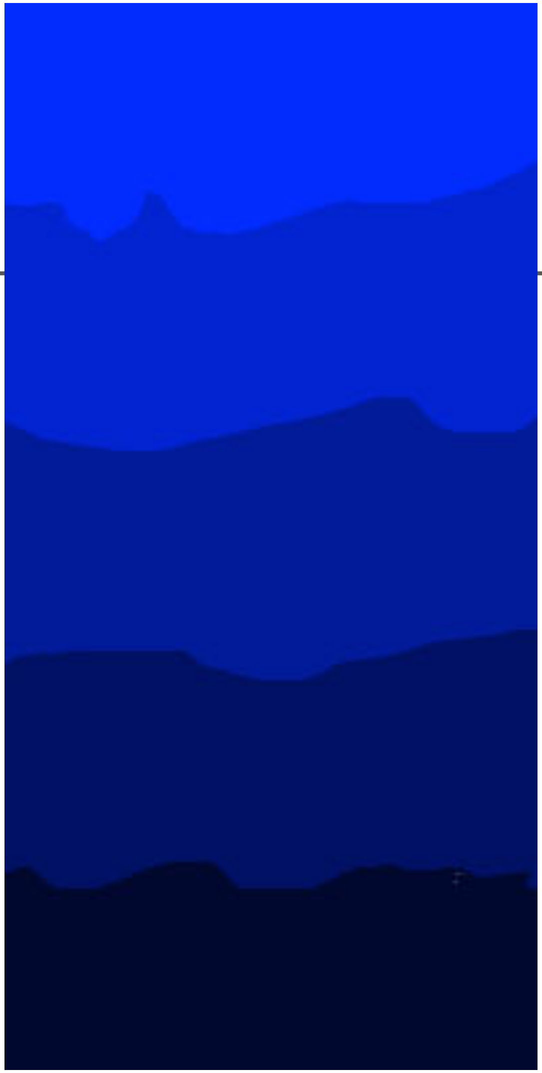


Image from perceptualstuff.org

Dynamic Luminance

- Changes in apparent brightness with quick changes in viewing distance

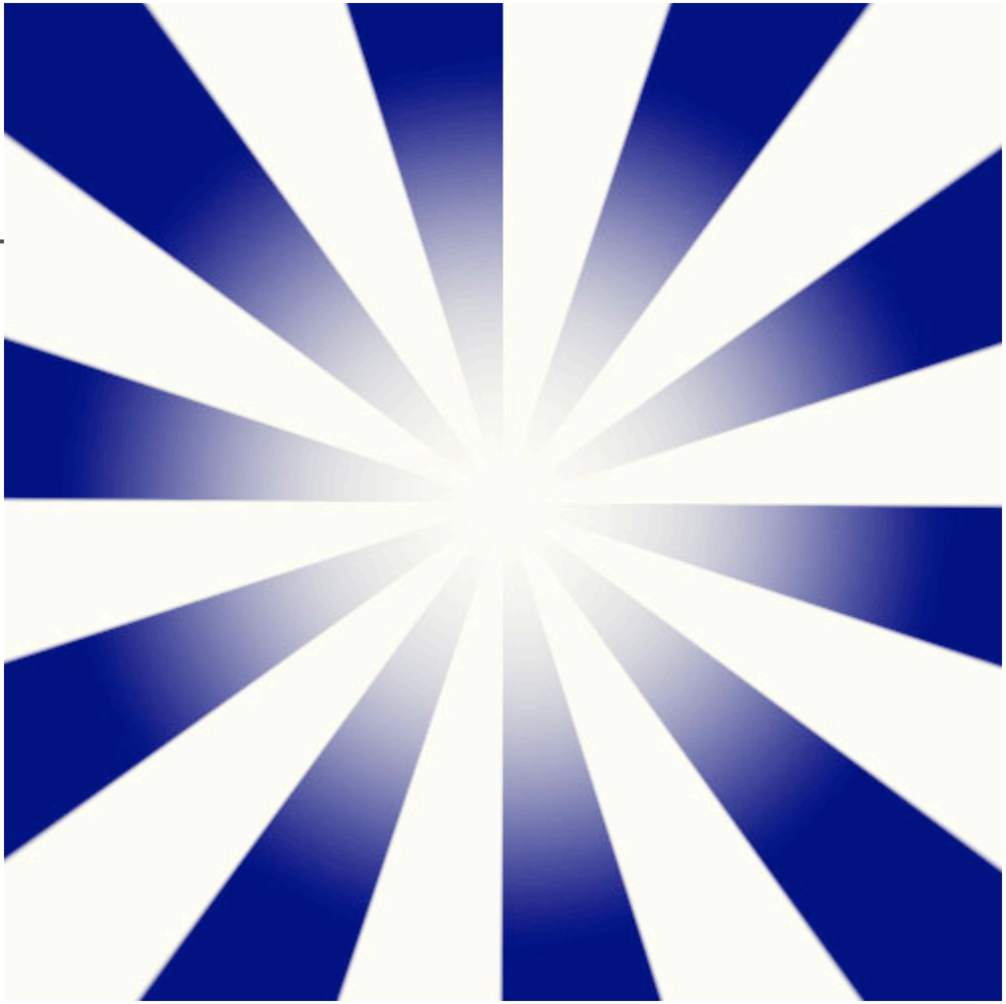


Image from perceptualstuff.org

The Breathing Light Illusion

- Change in apparent brightness as you move closer in and farther away quickly

- Gori, S. & Stubbs, D. A. (2006). A new set of illusions - The Dynamic Luminance-Gradient Illusion and the Breathing Light Illusion. Perception. 35, 1573-15771.

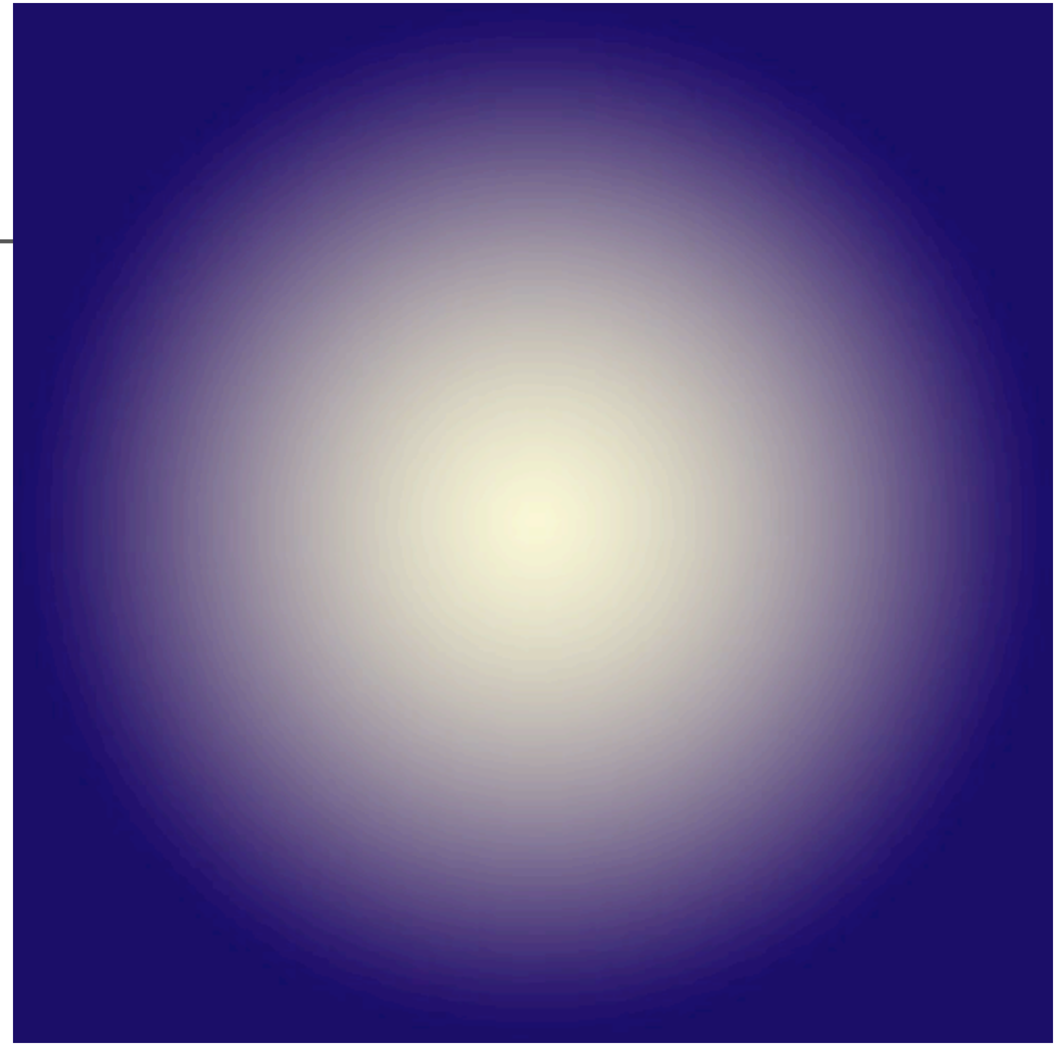
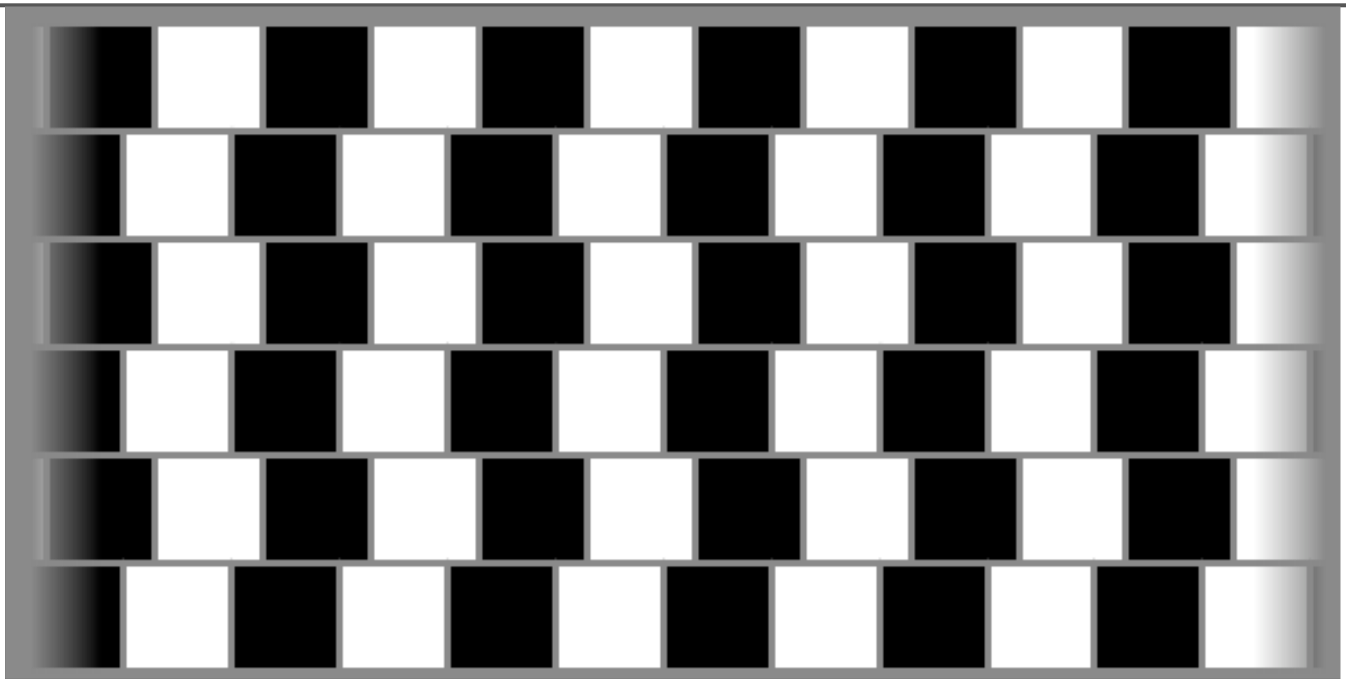


Image from perceptualstuff.org

The Café Wall Illusion

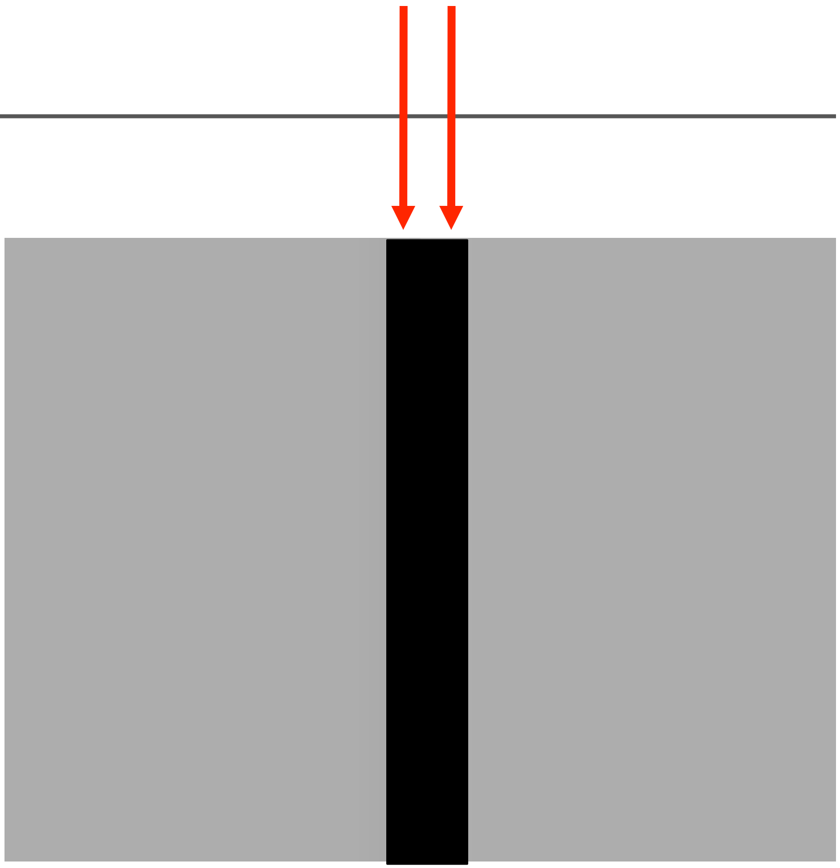


- The tiles are actually evenly rectangular

Cornsweet effect

- Which area is lighter than the other?

- These areas appear different in lightness, but are in fact the same



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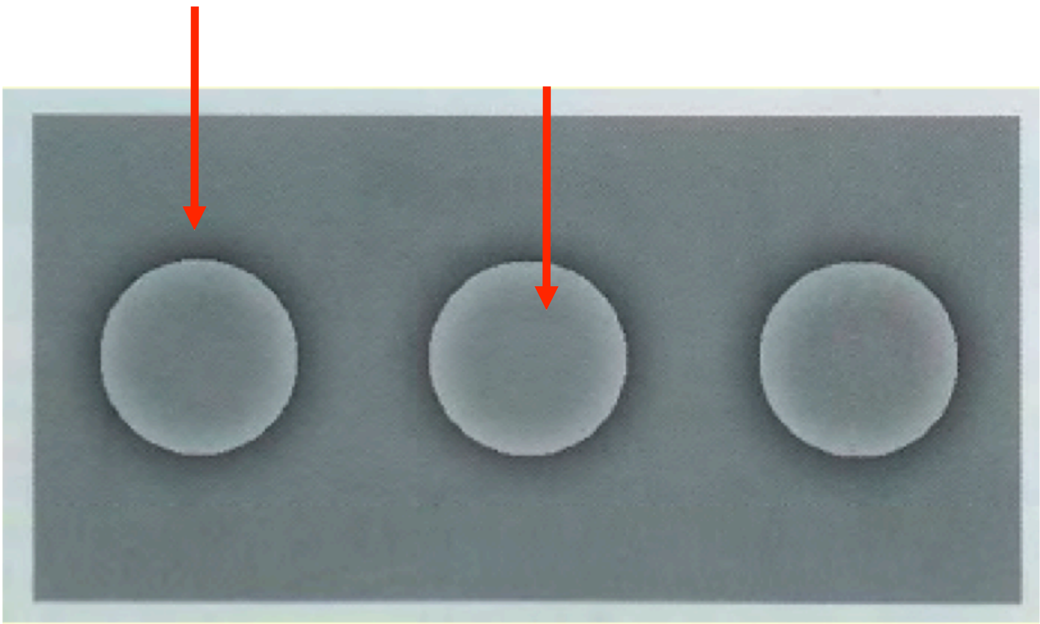
- These areas appear different in lightness, but are in fact the same



Effects cause error!

- Simultaneous contrast effects can result in large errors of judgment when reading quantitative (value) information displayed using a gray scale.
- average error **of 20%** of the entire gray scale in a map encoding gravity fields using 16 levels of gray.

Effects cause error!

- highlight the deficiencies in the common shading algorithms used in computer graphics.
- Smooth surfaces are often displayed using polygons,
  - visual artifacts because of the way the visual system enhances the boundaries at the edges of polygons.
- Need to use more interpolated approaches, such as Phong shading, to avoid Chevreuil or Mach illusions

Edge enhancement

- edge detection signals the positions and contrasts of edges in the environment.
- *pseudo-edges* : two areas that physically have the same lightness can be made to look different by having an edge between them that shades off gradually to the two sides
- The brain does *perceptual interpolation* so that the entire central region appears lighter than surrounding regions.

- The enhancement of edges is also an important part of some artists' techniques

- Seurat deliberately enhanced edge contrast to make his figures stand out.

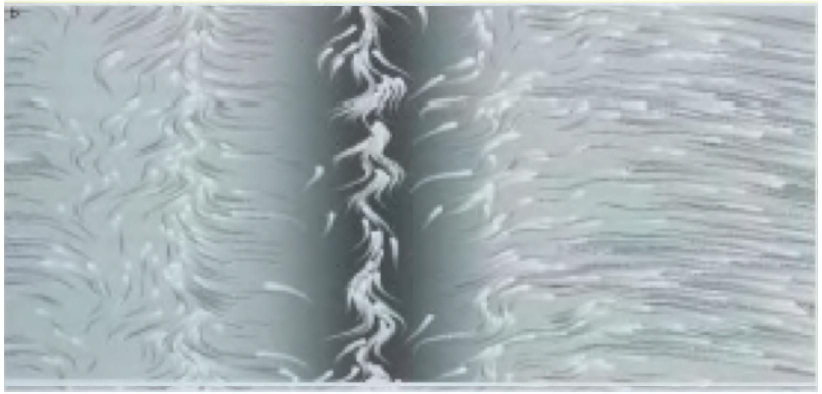
Spatial Frequency modulation

- Edge enhancement involves adjusting or amplifying the higher frequency information in the spatial domain
  - **High-pass filtering** techniques from image processing

- We can also adjust the low spatial frequency of the background luminance
  - **Low pass filters**

- Remember the Clinton/Frist example

Low spatial frequency modulation



Humans are multiscale perceivers

Hybrid images

Oliva, Torralba and Schyns. Hybrid images. Siggraph 2006.

Light does not equal bright!

- Contrast effects are an example of a mismatch between how our contrast perception mechanisms work and the impoverished nature of the graphical displays
- We know the “perceived brightness” of something has little to do with the amount of light that actually comes from it

How do we tell light from dark?

- What defines white, black,gray?
- Receptor signals do not tell us **absolute** values
  - amount of light on the retina - the light meter
- They tell us **relative** values
  - change of amounts of light
  - Change meter
- Contrast illusions
- Non-linear perception

- GRAY
  SCALES
  CAN
  BE
  MISLEADING

Brightness, Lightness and **Luminance**

- Luminance refers to the measured amount of light coming from some region of space.
  - Physical measure, not perceptual quantity
  - Main measure for monitor calibration

- luminance refers to something that can be **physically measured**.

- The other two terms refer to psychological variables.

Brightness and lightness

Brightness refers to the perceived amount of light coming from a self-luminous **source**.

- particularly important in the design of critical displays where ambient light may be highly variable

Lightness generally refers to the perceived reflectance of a **surface**.

- A white surface is light.
- A black surface is dark

Luminance, Contrast and Constancy

- Luminance is completely unrelated to perceived brightness or lightness
- Luminance is completely unrelated to perceived brightness or lightness
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- Luminance is completely unrelated to perceived brightness or lightness
- Luminance is completely unrelated to perceived brightness or lightness

Adaptation, Contrast and Sensitivity

- So how do we tell “lightness”?
- A major task of the visual system is to extract information about the lightness and color and of objects despite a great variation in illumination and viewing conditions.

Constancy

- Luminance is completely unrelated to perceived lightness or brightness
- Under some situations a white object will emit less light than a dark object
- We can still distinguish black from white (lightness constancy)

Adaptation, Contrast and Constancy

- The first-stage mechanism of lightness constancy is **adaptation**.
- The second stage of level invariance is **lateral inhibition**.
- Both mechanisms help the visual system to factor out the effects of the amount and color of the illumination

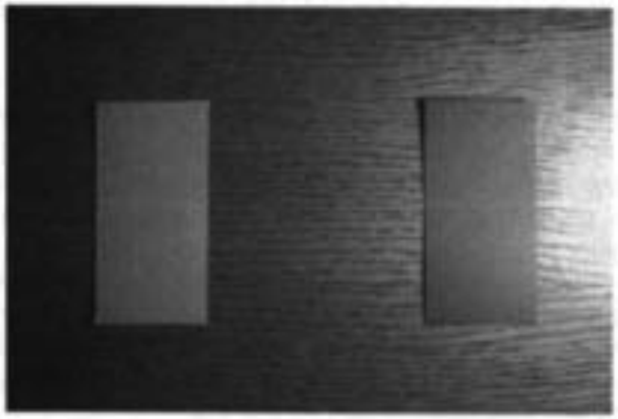
Contrast and constancy

- Contrast mechanisms help us achieve constancy by signaling differences in light boundaries
  - Edges of objects
- Can tell which piece of paper is gray or white regardless of surface reflectance
- White paper is brighter relative to its background than the dark paper
  - **Simultaneous contrast** mechanism
- Not relative brightness but surface lightness

Contrast and constancy

- Concentric opponent receptive fields react most strongly to differences in light levels
  - Edges of objects

- Simultaneous contrast mechanism: item relative to surround



- Corrects for background intensity differences

Perception of Surface Lightness

- Adaptation and contrast are not sufficient
- Three additional factors

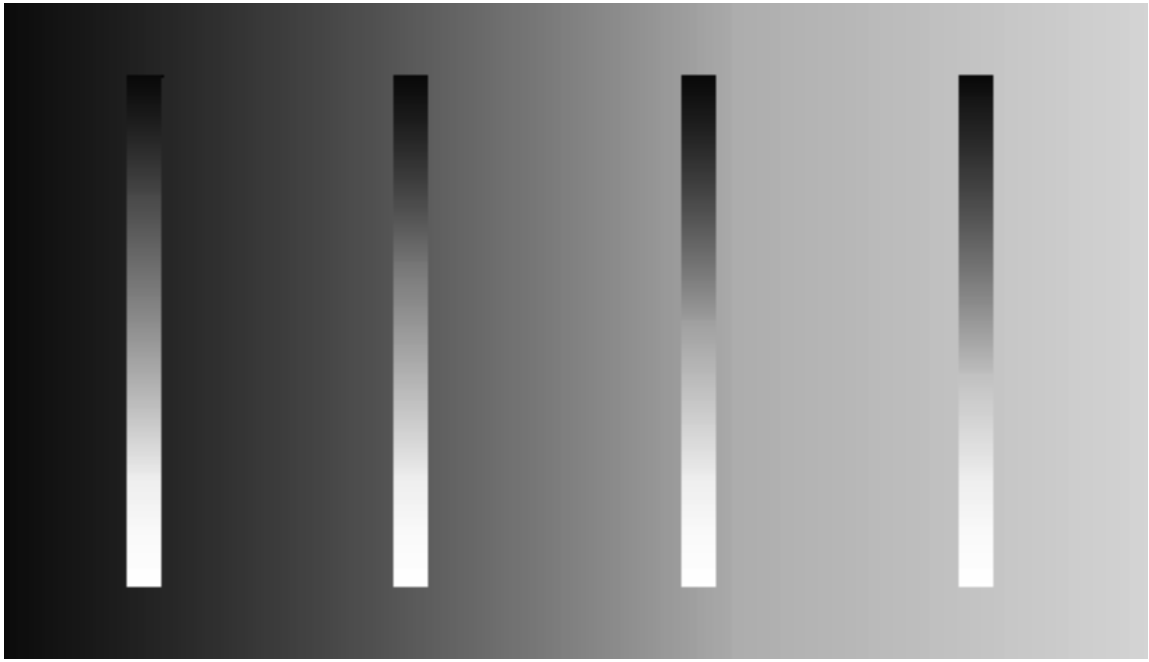
1. Illumination direction and surface orientation;
   - A surface turned away from the light will reflect less light than one facing it, but we can still judge it accurately
2. Reference white:
   - We judge by the lightest object in the scene ***
3. Ratio of specular and non-specular reflection

Lightness differences and perceptual gray scales

- Ideal gray scale would show equal differences in data values as perceptually equally spaced gray steps
  -
- Size of difference affects perception of brightness differences
  - Smallest difference between 2 grays - JND (just noticeable difference)

- **Contrast crispening:**
  - Differences are perceived as larger when samples are similar to the background colour

Crispening




tripe
stripe

Higher-level:Sequential, Goal-Directed

- Splits into subsystems for object recognition and for interacting with environment
- Increasing evidence supports independence of systems for symbolic object manipulation and for locomotion & action
- First subsystem then interfaces to verbal linguistic portion of brain, second interfaces to motor systems that control muscle movements

High level vision processes

- Slow serial processing
- Involves working and long-term memory
- Top-down processing

- Limited resources

Preattentive Processing

- How does human visual system analyze images?
  - Some things seem to be done preattentively, without the need for focused attention
  - Generally less than 200-250 msecs (eye movements take 200 msecs)
  - Seems to be done in parallel by low-level vision system

Preattentive processing

- A limited set of visual properties are processed preattentively (without need for focusing attention).
  - **Visual features**

- This is important for the design of visualizations
  - what can be perceived immediately
  - what properties are good discriminators
  - what can mislead viewers
  - Differentiate items “at a glance”

Some examples from Chris Healey:

http://www.csc.ncsu.edu/faculty/healey/PP/PP.html

How Many 3's?

1281768756138976546984506985604982826762
9809858458224509856458945098450980943585
9091030209905959595772564675050678904567
8845789809821677654876364908560912949686

How Many 3's?

12817687561389765469845069856049828267 62
98098584582245098564589450984509809435 85
90910302099059595957725646750506789045 67
88457898098216776548763649085609129496 86

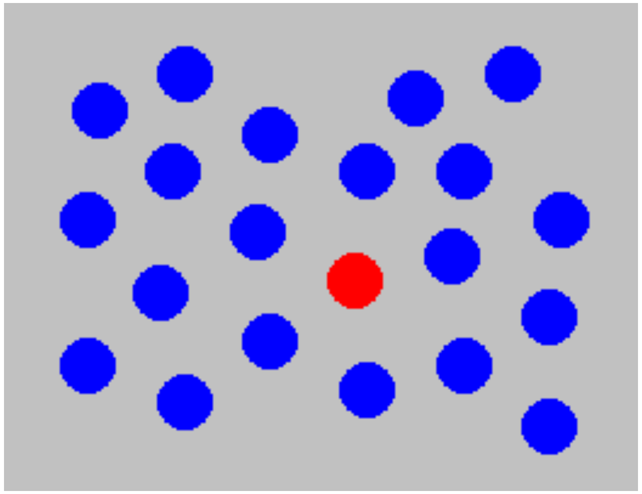
What Kinds of Tasks?

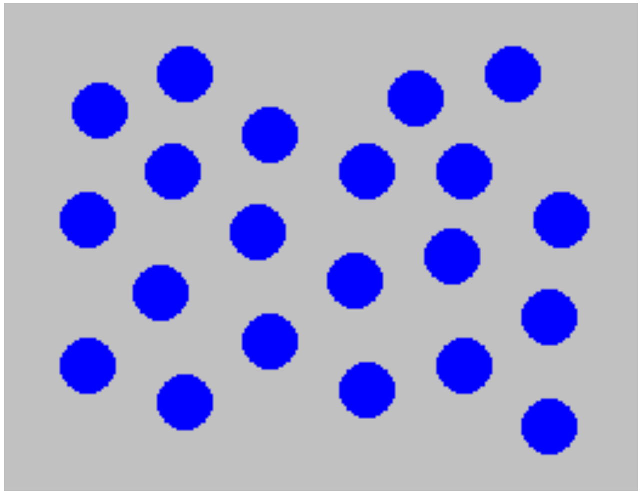
- Target detection
  - Is something there?
- Boundary detection
  - Can the elements be grouped?
  - What associates them?
- Counting
  - How many elements of a certain type are present?

Examples:

- Where is the red circle? Left or right?
- Put your hand up as soon as you see it.

Example: Colour selection



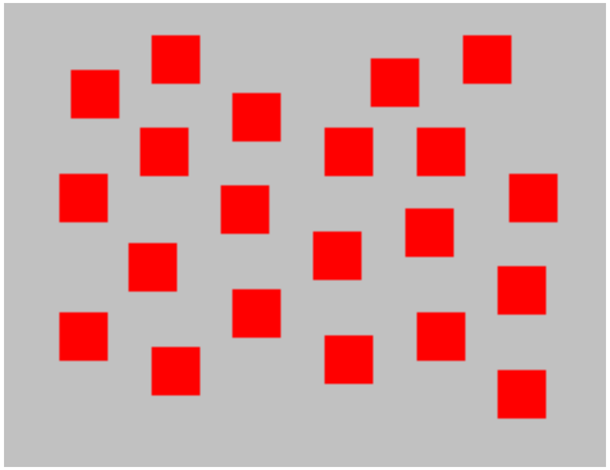


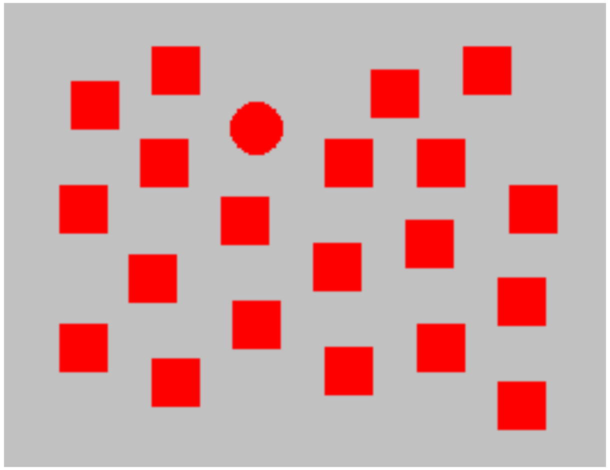
Viewer can rapidly and accurately determine whether the target (red circle) is present or absent. Difference detected in **color**.

Examples:

- Where is the red circle? Left or right?
- Put your hand up as soon as you see it.

Example: shape selection



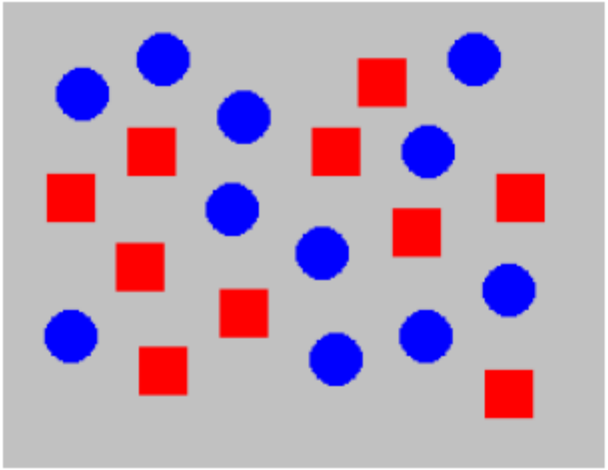
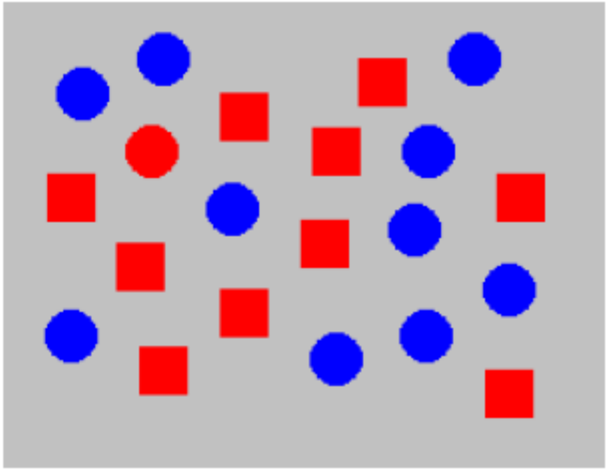


Viewer can rapidly and accurately determine whether the target (red circle) is present or absent. Difference detected in **form** (curvature)

Examples:

- Where is the red circle? Left or right?
- Put your hand up as soon as you see it.

Hue and Shape

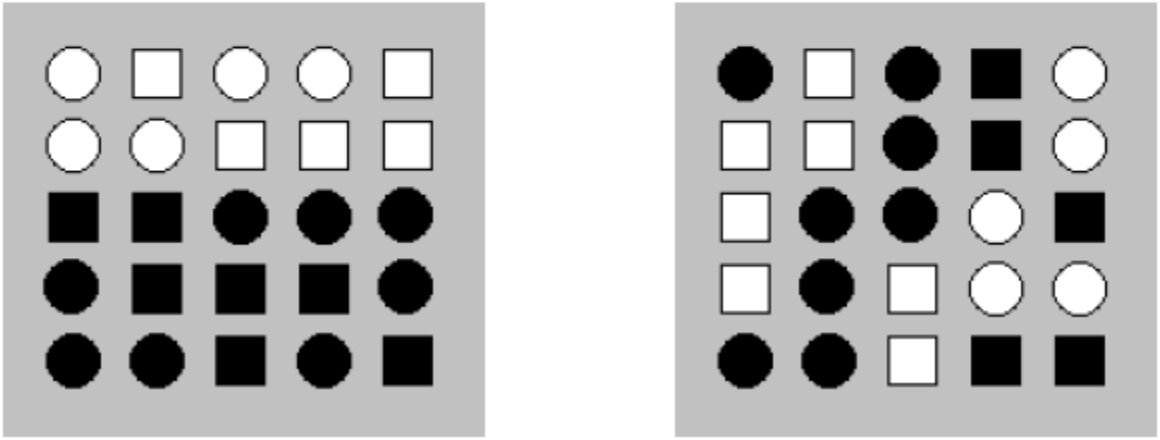
- Cannot be done preattentively
- Must perform a sequential search
- Conjunction of features (shape and hue) causes it

Examples

- Boundaries matter

- Where is /are the white circles?
- Put your hand up as soon as you see it.

Fill and Shape

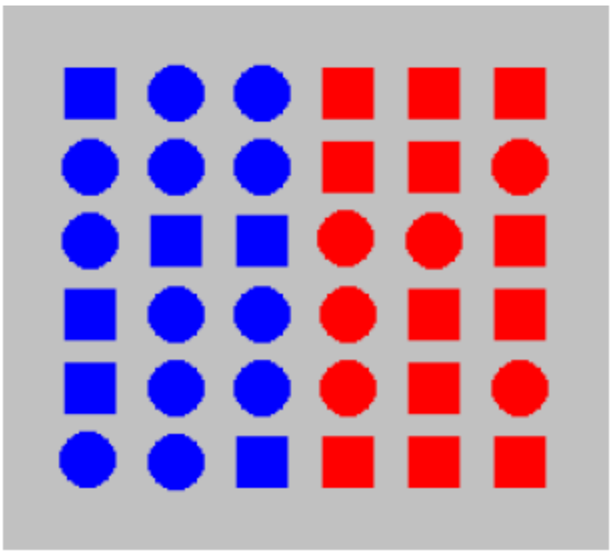


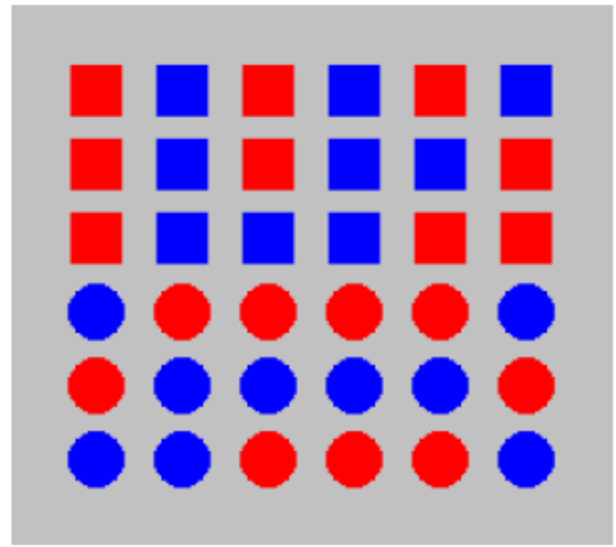
- Left can be done preattentively since each group contains one unique feature
- Right cannot since the two features are mixed (fill and shape)

Examples

- Is there a boundary?

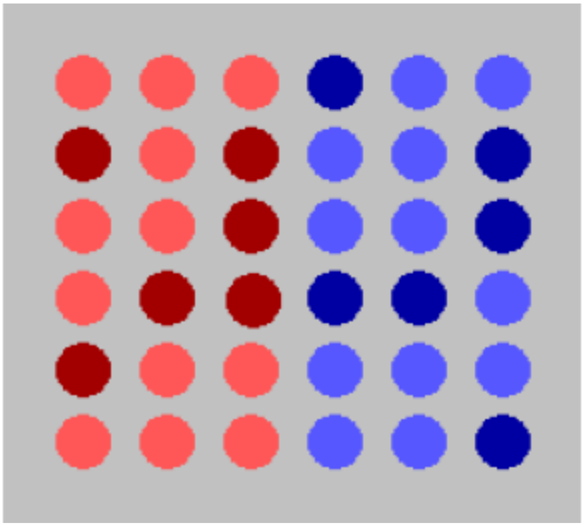
Hue versus Shape

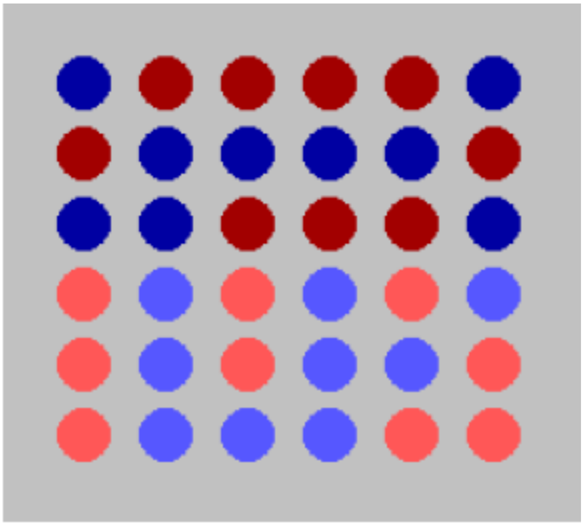




- Left: Boundary detected preattentively based on hue regardless of shape
- Right: Cannot do mixed color shapes preattentively

Hue vs. Brightness





- Left: Varying brightness seems to interfere
- Right: Boundary based on brightness can be done preattentively

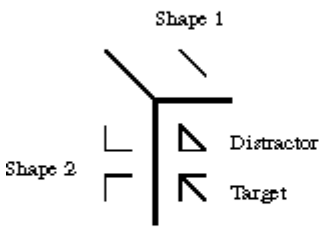
Try for yourself

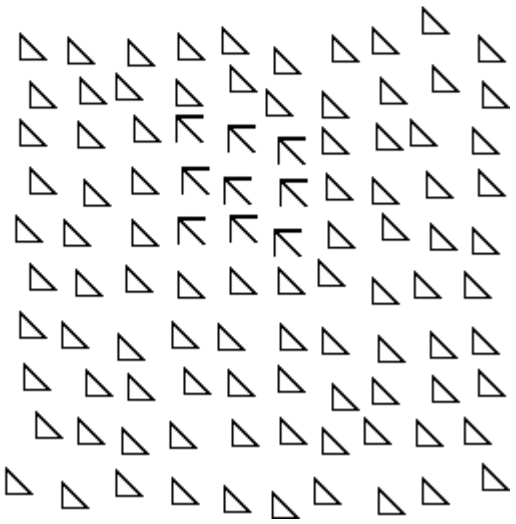
- Healey's applet

Preattentive Features

- Certain visual forms lend themselves to preattentive processing
- Variety of forms seem to work

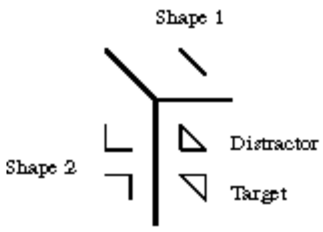
Example: emergent features

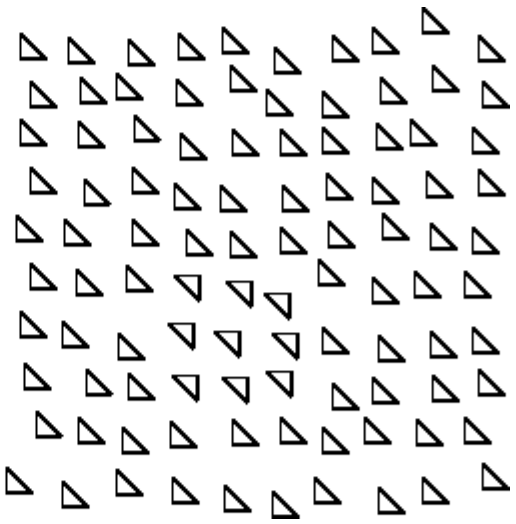




Target has a unique feature with respect to distractors (open sides) and so the group can be detected preattentively.

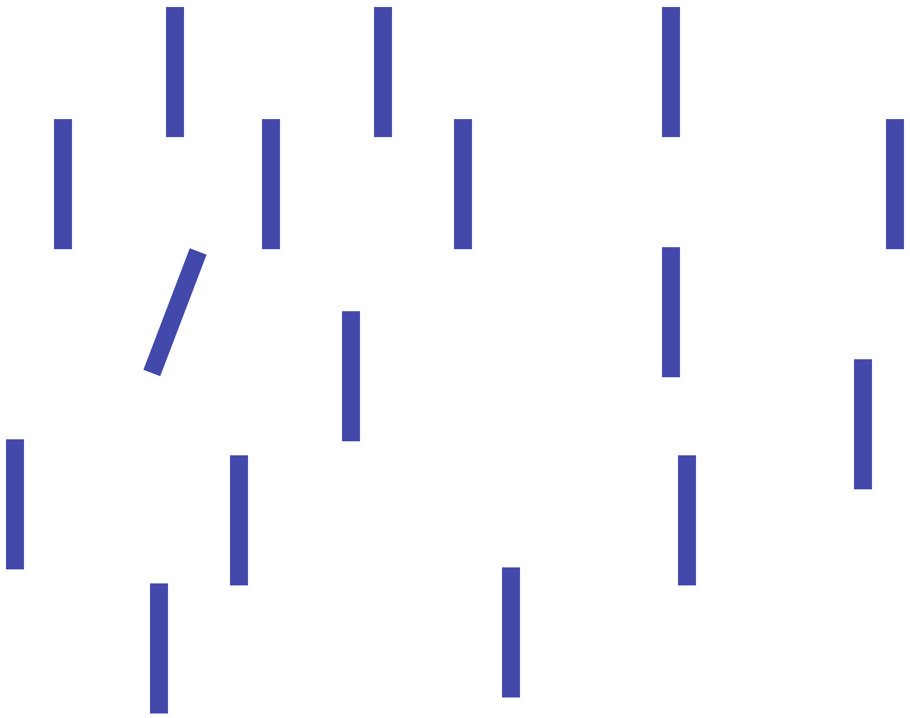
Example: emergent features



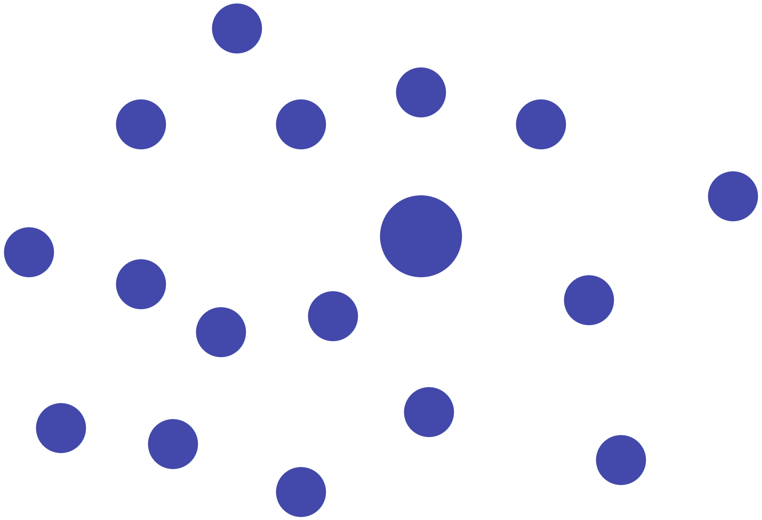


Target does not have a unique feature with respect to distractors and so the group cannot be detected preattentively.

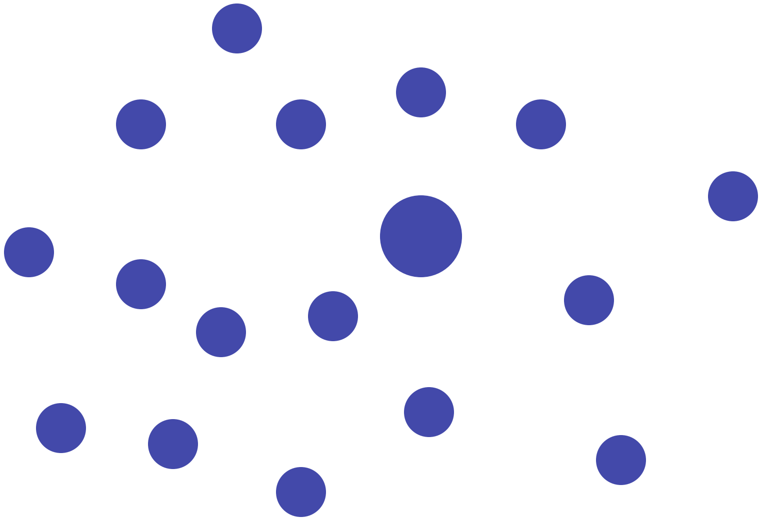
Example: orientation



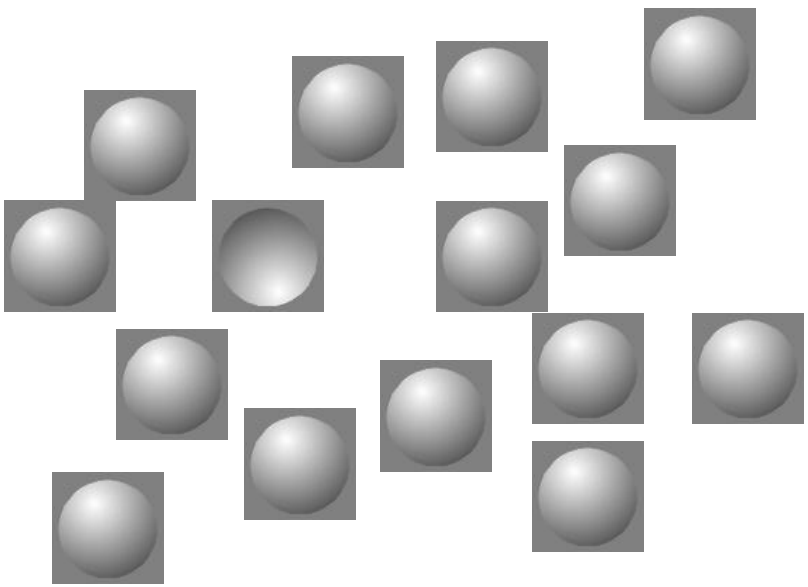
Example: size



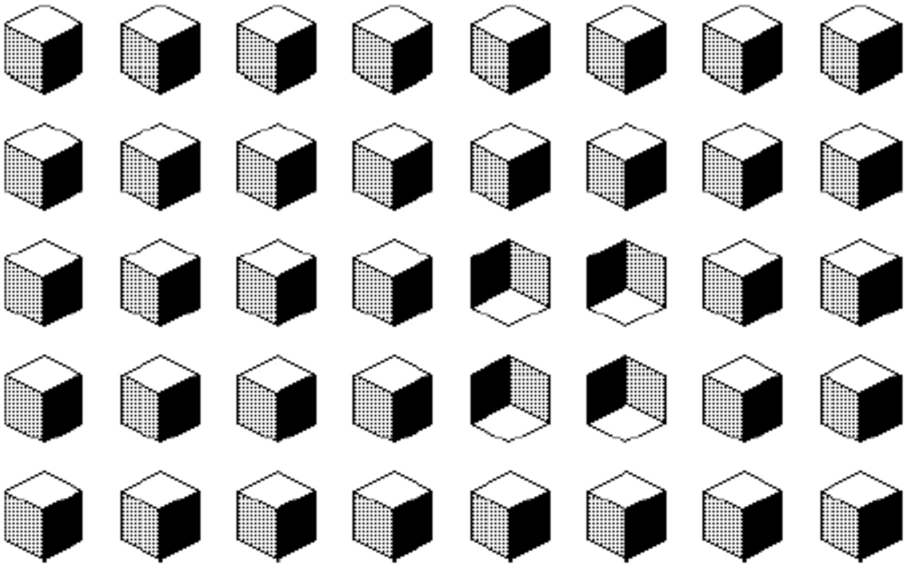
Example: motion



Example: simple shading



3-D Figures



Preattentive processing features

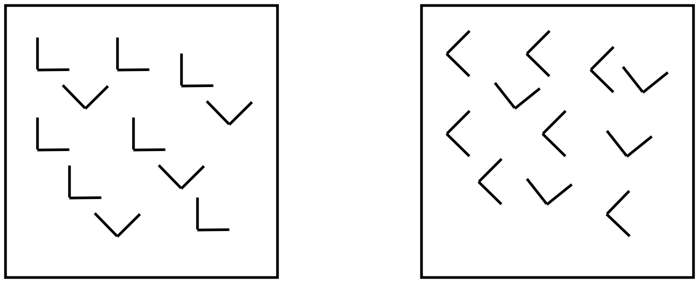
- Form
  - Line orientation
  - Line length
  - line width
  - Size
  - Curvature
  - Spatial grouping
  - Blur
  - numerosity
- Colour
  - Hue
  - Intensity
- Motion
  - Flicker
  - Direction of motion
- Spatial position
  - 2D position
  - Stereo depth
  - Concavity/convexity shape from shading

For more examples, check

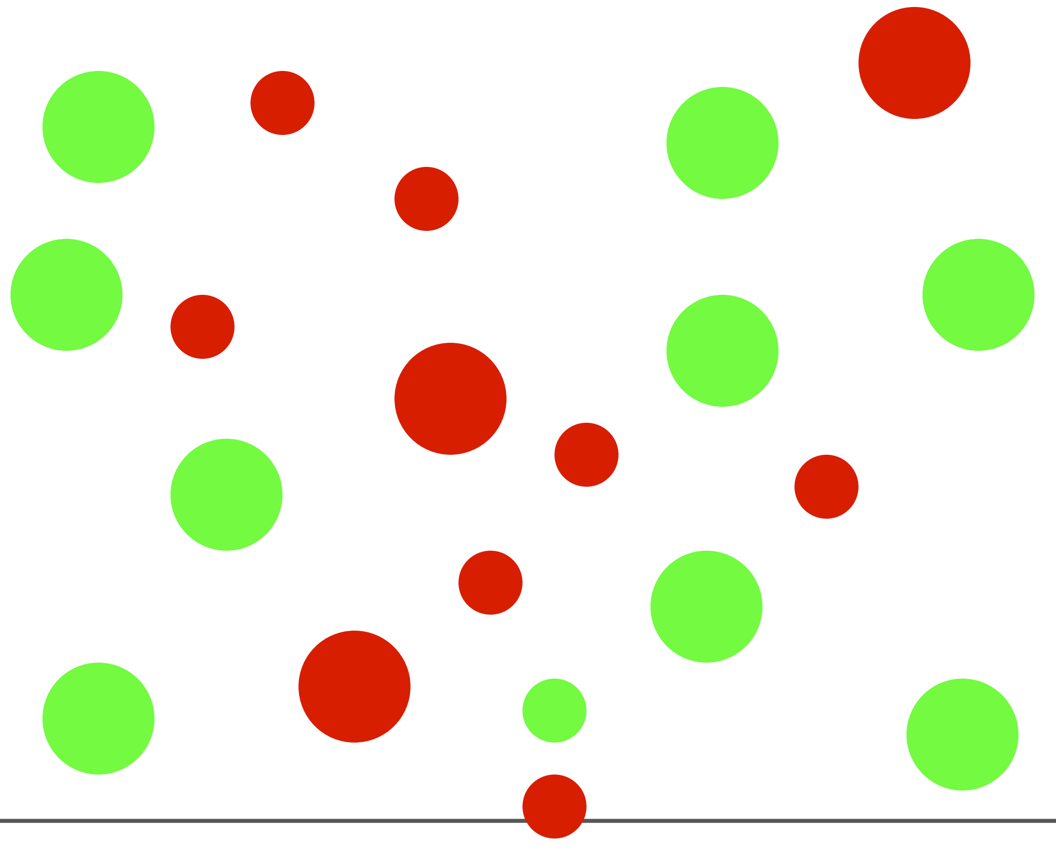
- Chris Healey's table of visual features shown to be preattentively processed

Asymmetric and graded preattentive properties

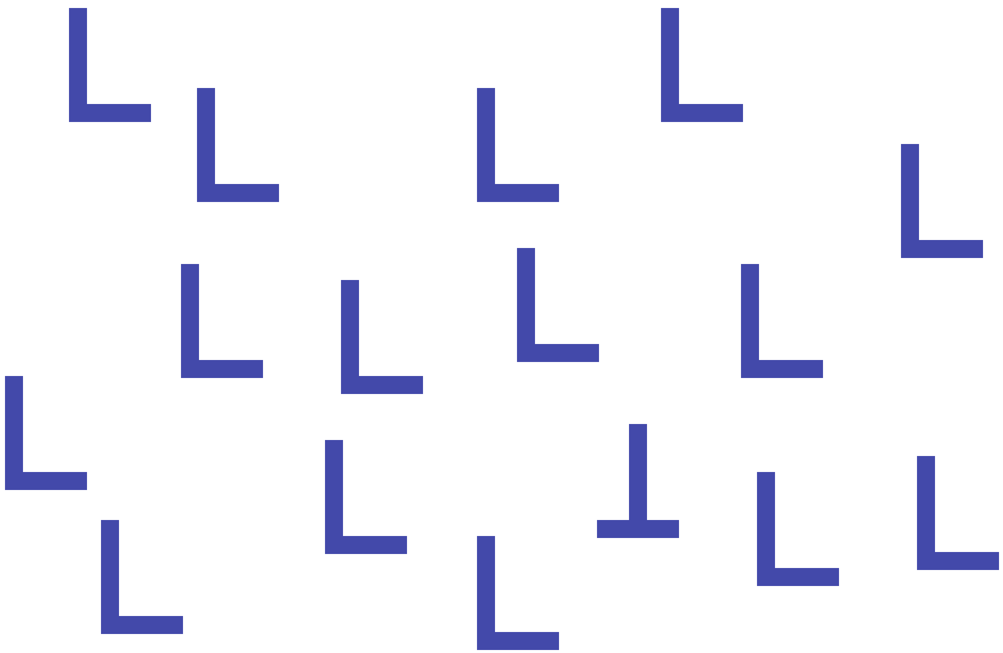
- Some properties are asymmetric
  - a sloped line among vertical lines is preattentive
  - a vertical line among sloped ones is not
- Some properties have a gradation
  - some more easily discriminated among than others



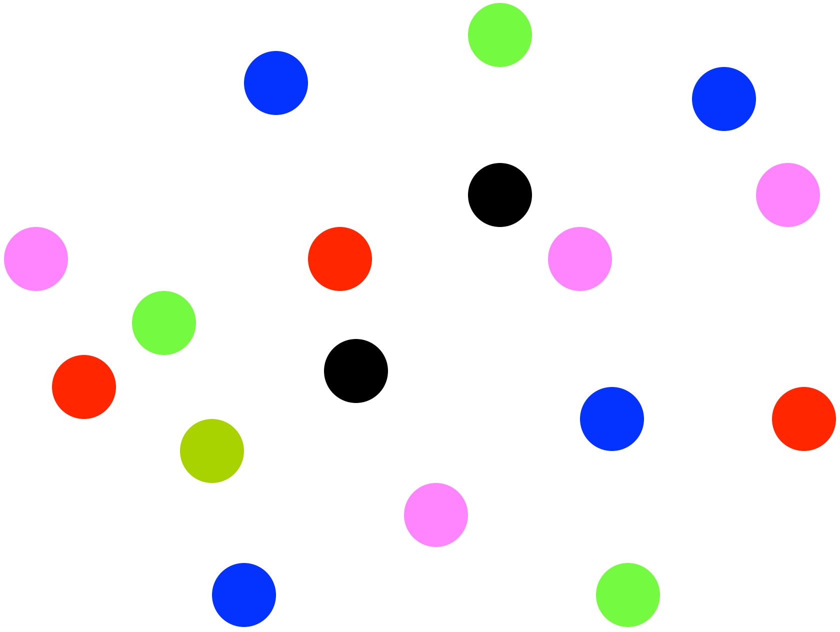
Conjunction does not pop out



Compound features do not pop out



Surrounded colours do not pop out



Distraction and clutter explained (a bit)

- pre-attentive symbols become less distinctive as the variety of **distractors** increases.

- Studies have shown that two factors are important in determining whether something stands out preattentively:
  - the **degree of difference** of the **target** from the **non-targets** (distractors), and
  - the **degree of difference** of the **non-targets** from **each other**.

Preattentive processing

- For example, yellow highlighting of text works well if yellow is the only color in the display besides black and white, but if there are many colors the highlighting will be less effective.
- So which visual dimensions are pre-attentively stronger and therefore more **salient** (get attention better)?

Potential PA Features

- length
- width
- size
- curvature
- number
- terminators
- intersection
- closure
- hue
- intensity
- flicker
- direction of motion
- stereoscopic depth
- 3-D depth cues
- lighting direction

Perceptually Based Visualization

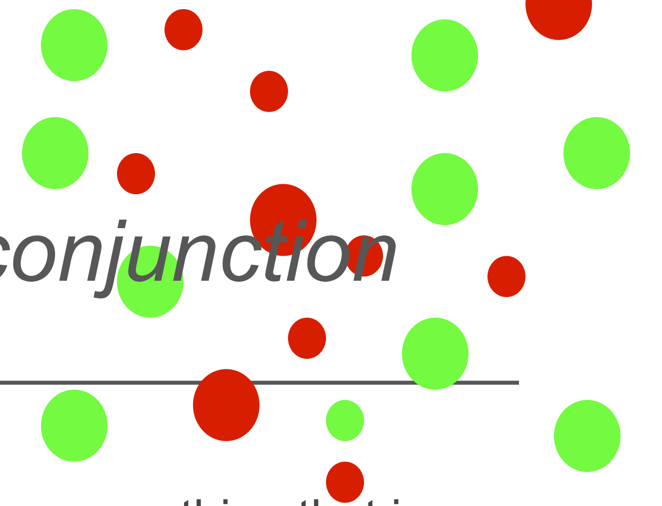
Key Perceptual Features

- Brightness
- Hue
- Texture
- Shape
- Fill

Preattentive channels

- Form (orientation/size)
- Colour
- Simple motion/blinking
- Addition/numerosity (up to 3)
- Spatial, stereo depth, shading, position

Coding with several features: *conjunction*



What happens with more complex patterns ?

- a large red circle, not just something that is red or something that is large?

- slow if the surrounding objects are large (but not red ones) and other red sizes.
  - a serial search of either the red or the large circles.

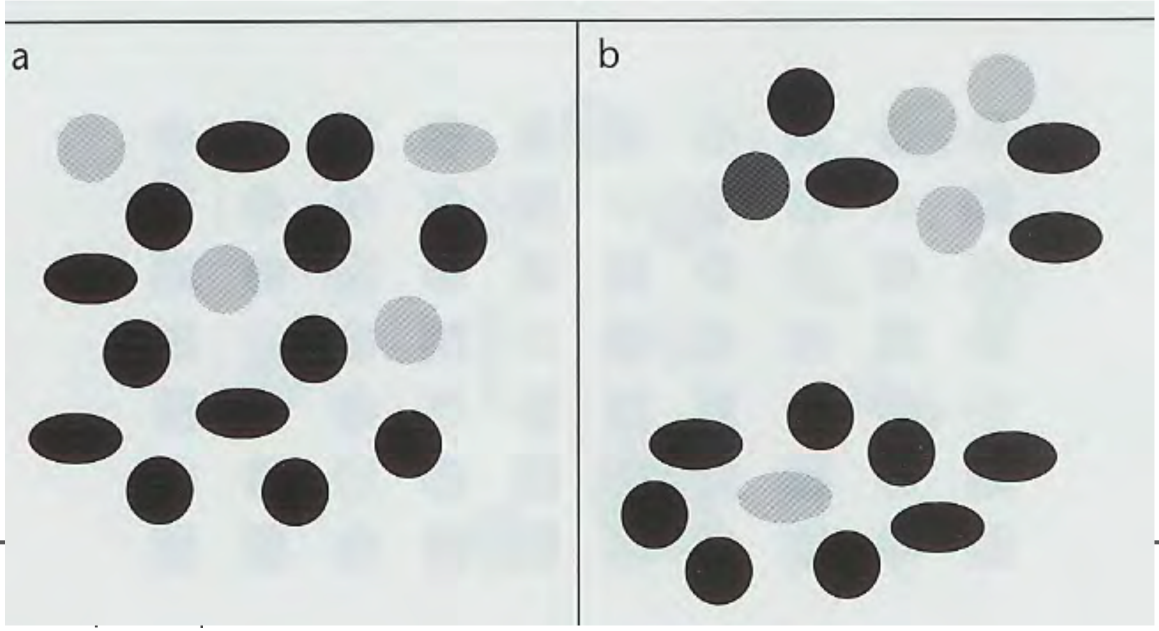
- *conjunction search* - searching for the specific conjunction of colour and size attributes.
  - generally not pre-attentive, although there are a few very interesting exceptions.

Conjunctions with spatial dimensions

- There are a number of preattentive dimension pairs that do appear to allow conjunctive search
- Spatial grouping on the XY plane

Spatial conjunction

- To find the gray ellipses, either the gray things or the elliptical things must be searched. However, the search can be speeded up by **spatial grouping**. If attention is directed to the lower cluster, perceiving the gray ellipse is pre-attentive.



SFU

Ware, C. Information Visualization: Perception for Design. Elsevier, 2004..

Conjunction with spatial dimensions

Stereoscopic depth

- Depth and colour
- Depth and movement
- Useful for highlighting techniques allowing for preattentive search within the set of highlighted items
- Decreses as depth layers increase

- Convexity, concavity and colour
- Motion and shape, motion and colour
    - Can find a red circle in a set of moving targets

Glyph Construction

- Suppose that we use two different visual properties to encode two different variables in a discrete data set
  - color, size, shape, lightness
- Will the two different properties interact so that they are more/less difficult to untangle?
  - Integral - two properties are viewed holistically
  - Separable - Judge each dimension independently

Integral-Separable

- Not one or other, but along an axis

Integral ↕ Separable

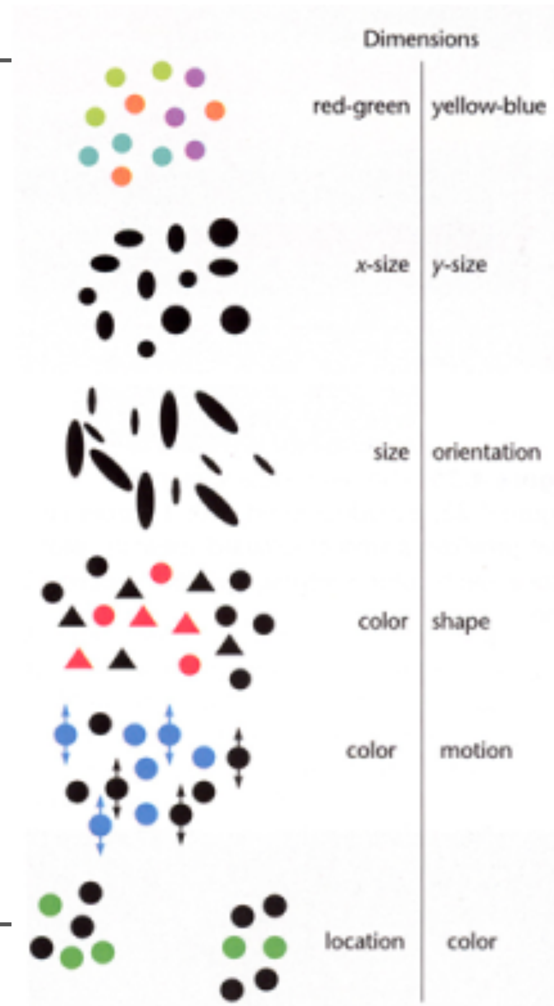
red-green	yellow-blue
red-green	black-white
shape height	shape width
shape	size
color	size
direction motion	shape
color	shape
color	direction motion
x,y position	size, shape, color

Integral vs. Separable Dimensions

Integral

↓

Separable

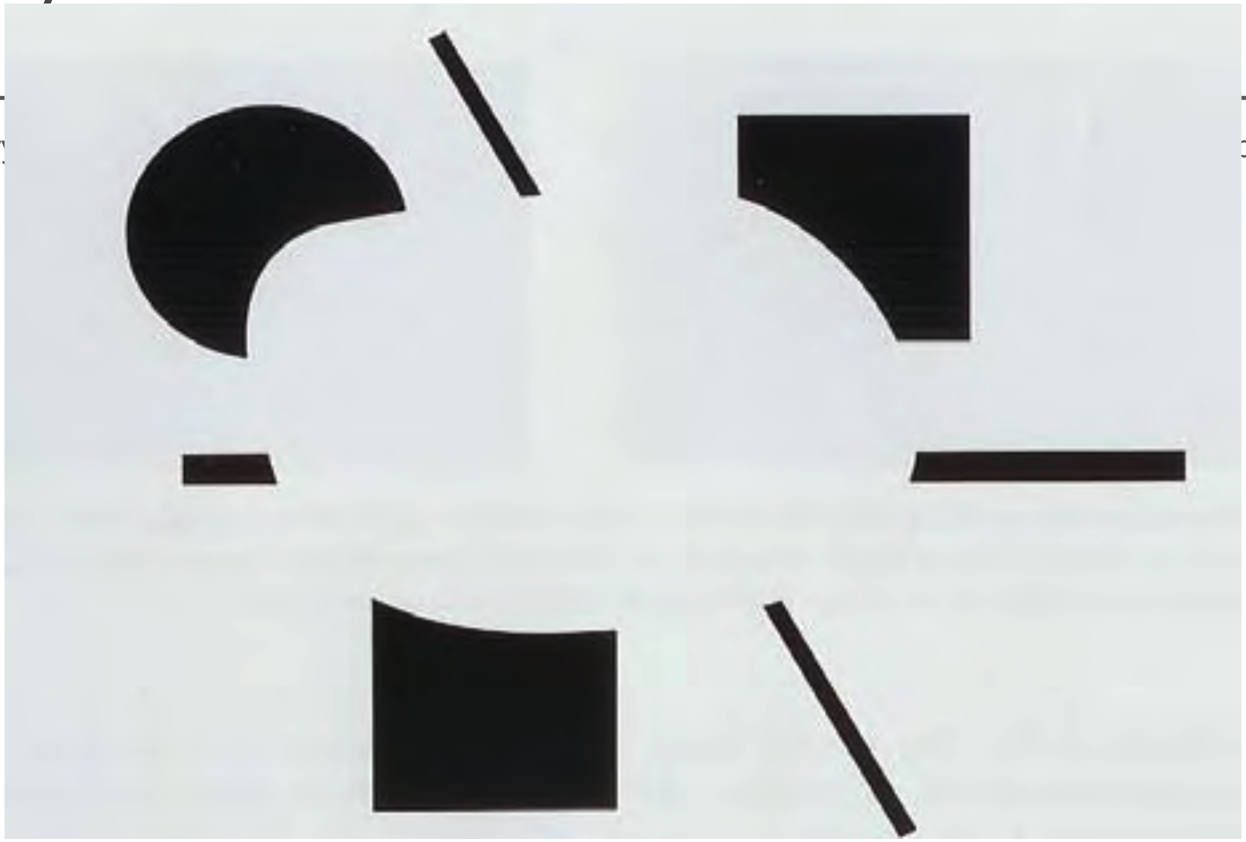


[Ware 2000]

More on Contours

- A contour is a continuous perceived boundary between regions of a visual image.
- A contour can be defined by a line, by a boundary between regions of different color, by stereoscopic depth, by motion patterns, or by texture.
- Contours can even be perceived where there are none.

Illusory Contours



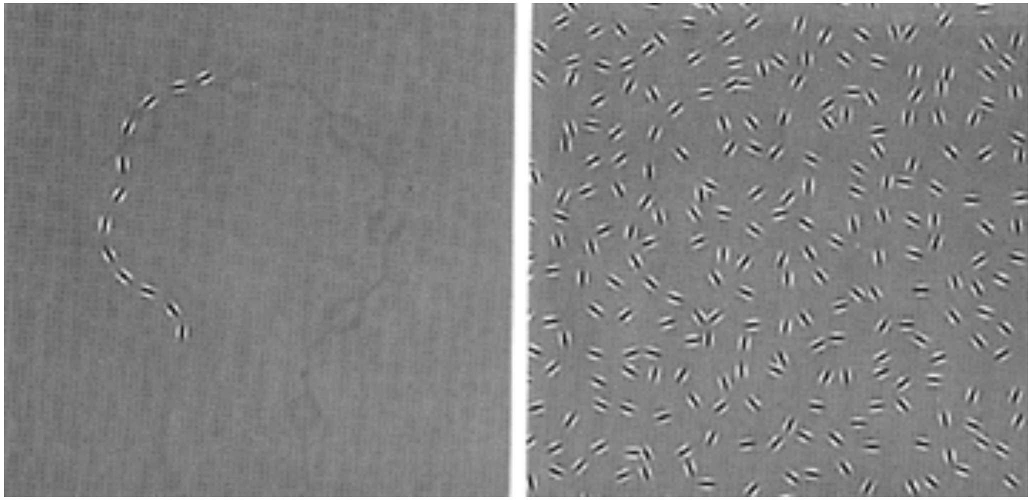
- an illusory ... present.

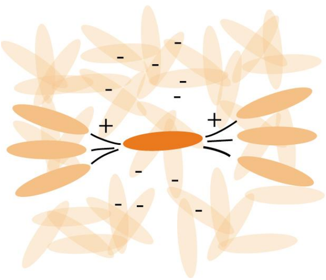
Contour perception

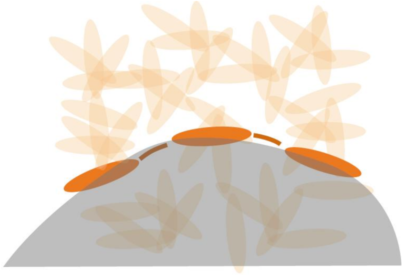
- We don’t understand contour perception very well
- Suggestion that our receptors fire all together and that is how we”hold” contours in mind
- Circumstances of contour perception and good continuity empirically validated

Field, Hayes and Hess

Contour finding mechanisms

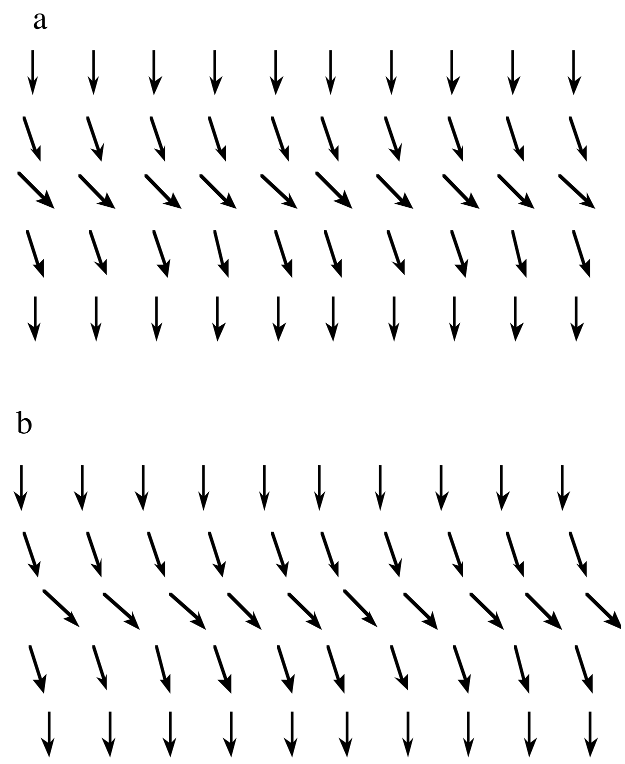






More Contours

- Direct application to vector field display
- Should be easier to perceive if smooth (i.e. **continuous**) lines can be drawn through the arrows
- b is more effective than a



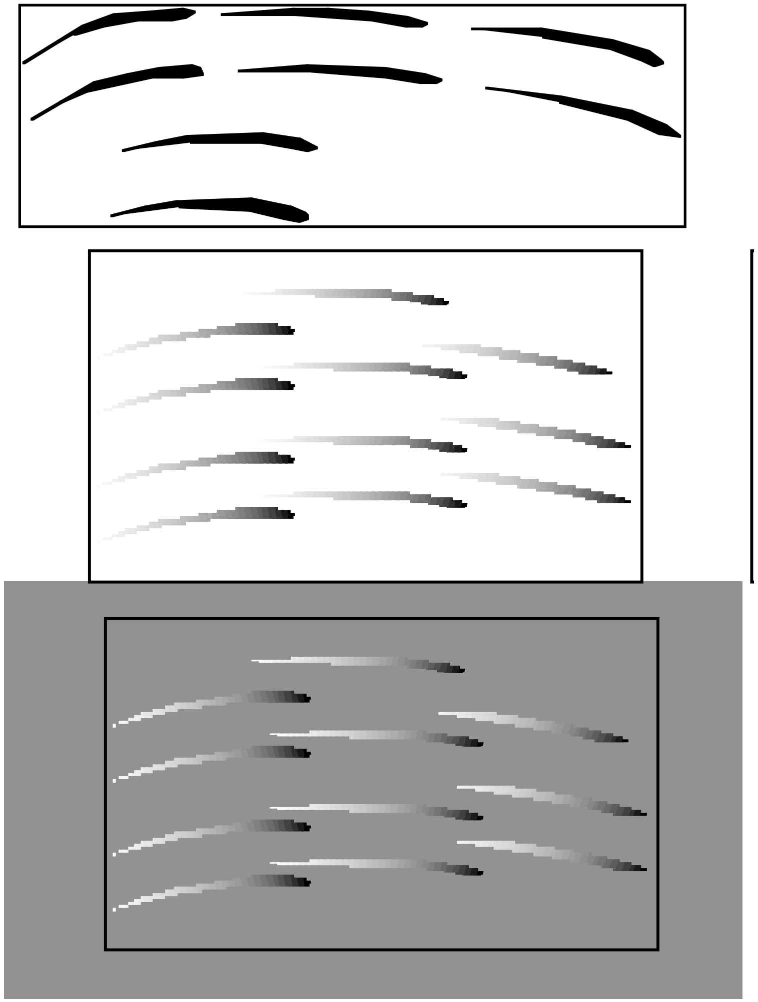
Ware, *Information Visualization: Perception for Design*

Perceiving Direction: representing vector fields

- The perception of contour leads us naturally to the perceptual problem of representing vector fields.
  - Vector fields used to show flow
  - Currents, winds, fluid
- This problem can be broken down into two components: the representation of orientation and the representation of magnitude.
- Some techniques display one component but not both

Vector fields

- Contours and pen strokes, 3D, shading
- Interaction between direction of colour change and background colour
- Away from bg colour
- In Ware's exps, colour change direction dominated shape



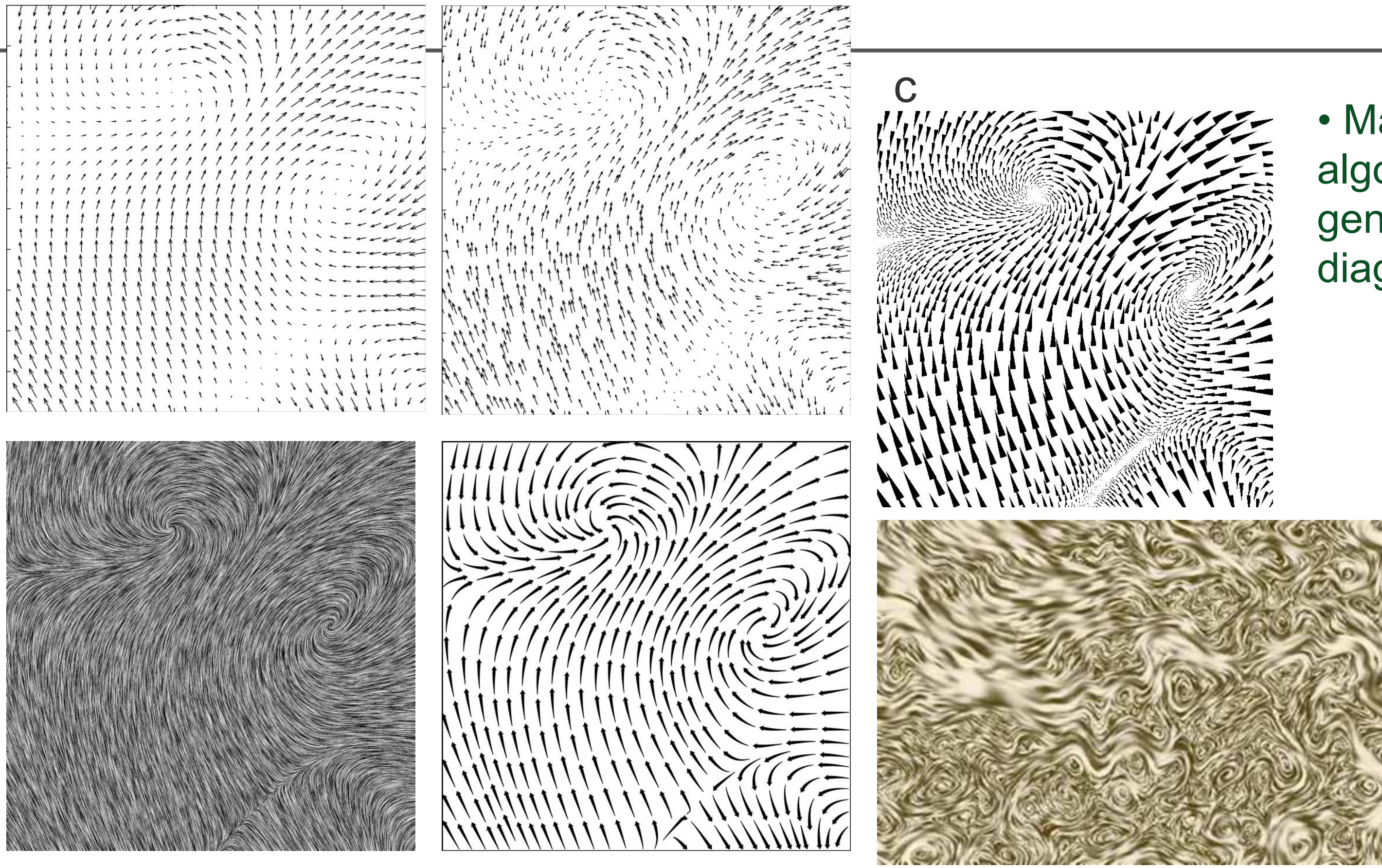
Flow field visualisation

- Identify location and nature of critical points
- Judge *advection* trajectory
  - Path taken by a dropped particle
- Patterns of high and low velocity
- Patterns of high and low vorticity
- Patterns of high and low turbulence

Data dimensions and critical factors

- Direction
- Magnitude
- Advection
- Global pattern
- Local pattern
- Nodal points

Vector Field Visualization



- Many different algorithms to generate flow diagrams

Best for advection

Laidlaw

Transparency and layering

- In many visualization problems, it is desirable to present data in a layered form.
- This is especially common in geographic information systems (GISs).
- Sometimes, a useful technique is to present one layer of data as if it were a transparent layer over another.

Transparency and layering

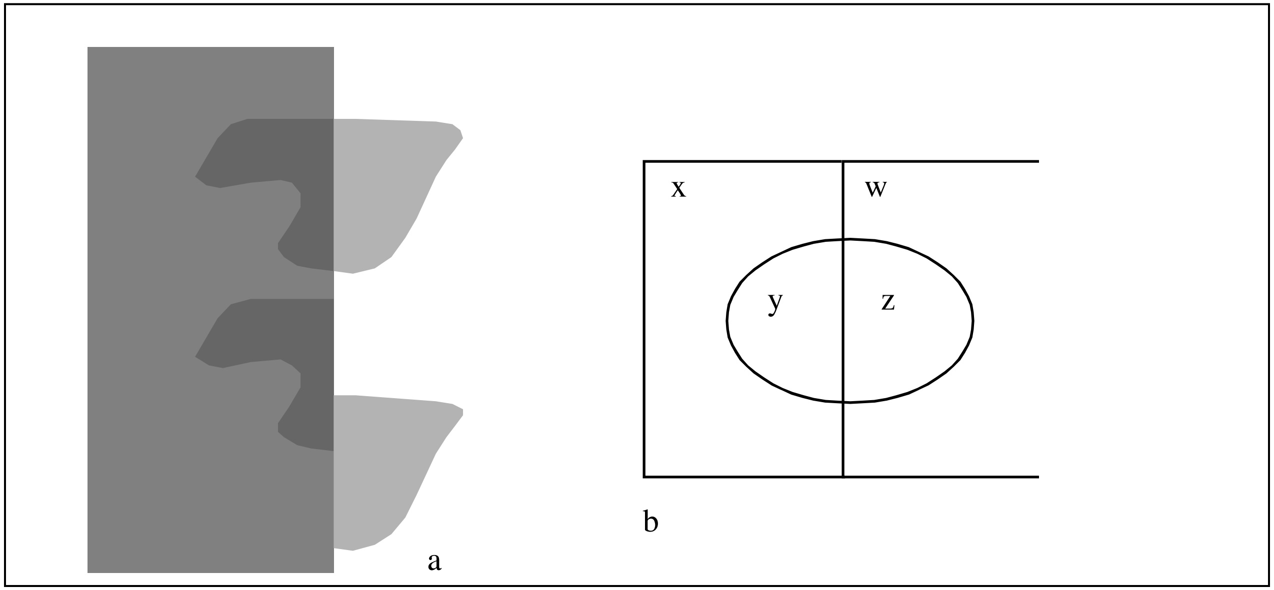
- However, there are many perceptual pitfalls in doing this.

- The contents of the different layers will always interfere with each other to some extent, and sometimes the two layers will fuse perceptually so that it is not possible to determine to which layer a given object belongs.

Transparency

- Ratio of colour or grey
  - x < y < z or x > y > z
  - y < z < w or y > z > w

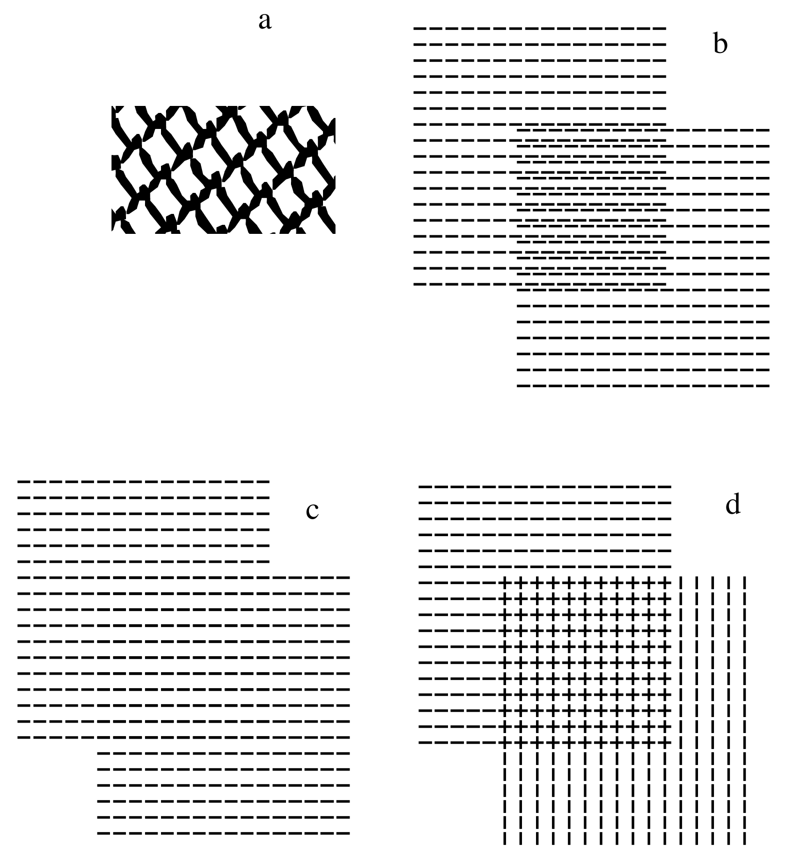
Continuity is important in transparency



Laciness (Cavanaugh)

- Layered data: be careful with composites of textures
- Similar patterns perceptually interfere (last lecture)
- Overlay menus and images need perceptually strongly distinct channels

b is a distinct patch



c is one,

d is "bistable"