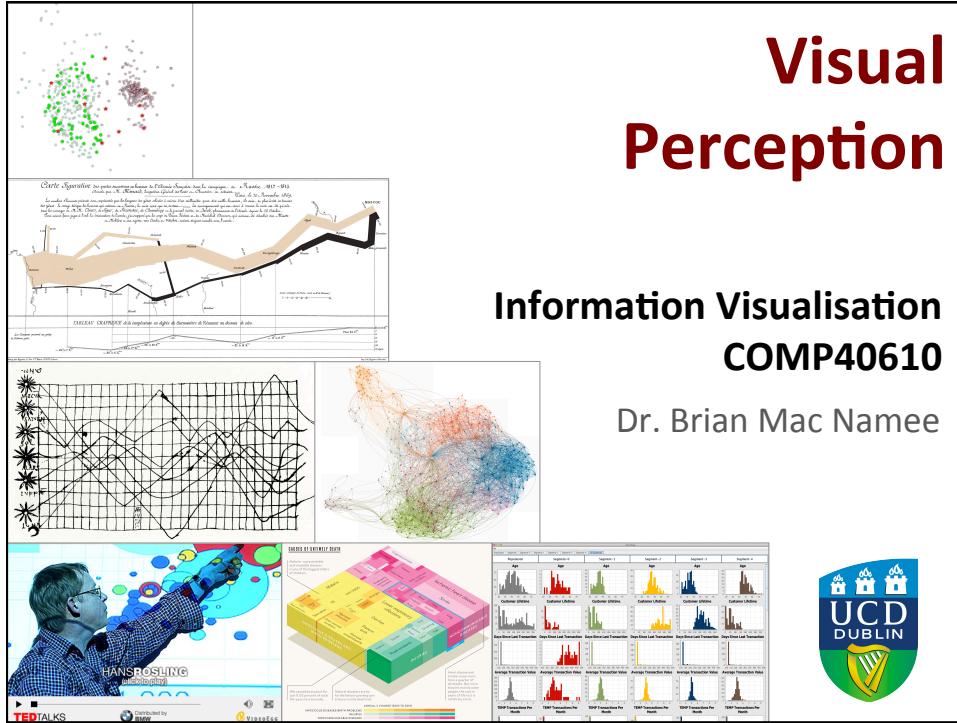


Visual Perception

Information Visualisation COMP40610

Dr. Brian Mac Namee



Origins

This course curates material from multiple online and published sources

When this is the case full citations will be given

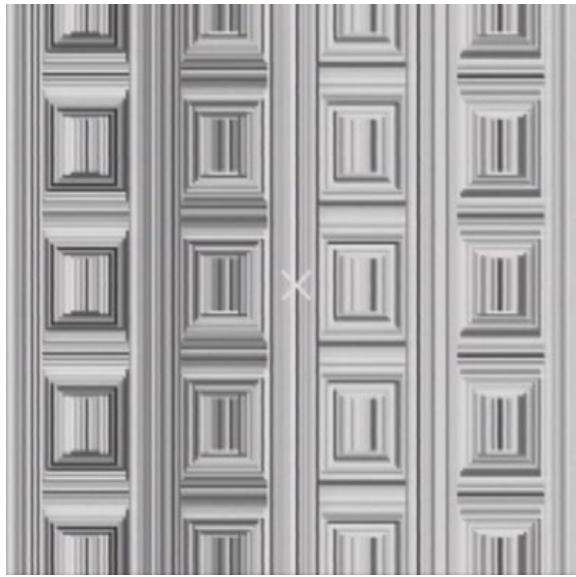
Agenda

Understanding how we visually perceive information is fascinating

We will look at

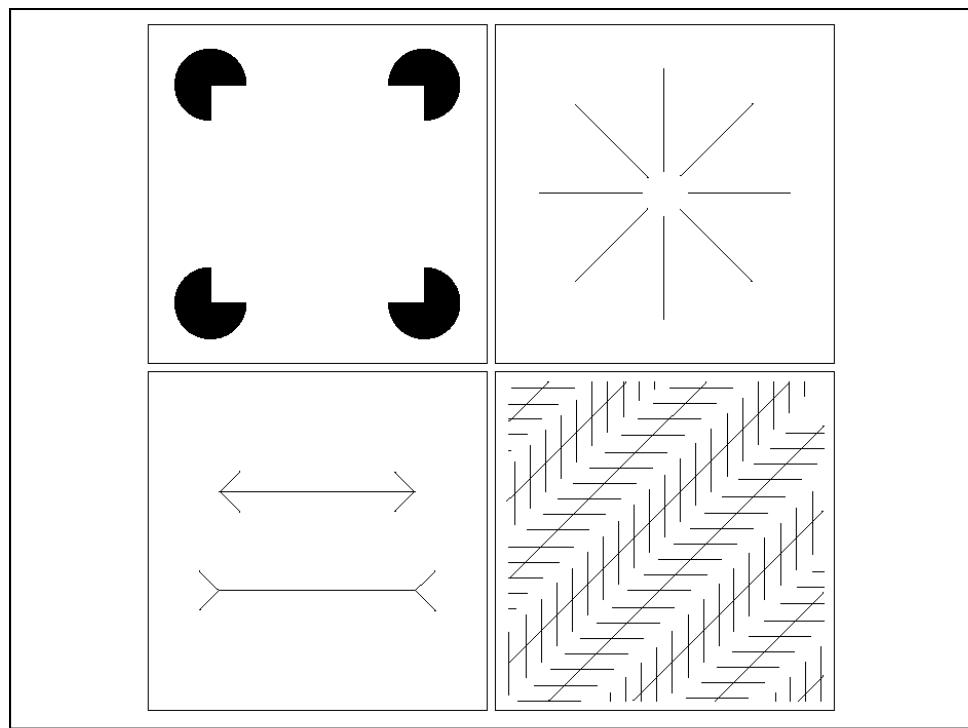
- Seeing is believing?
- What is perception?
- Visual attention
- Gestalt principles
- Semiotics

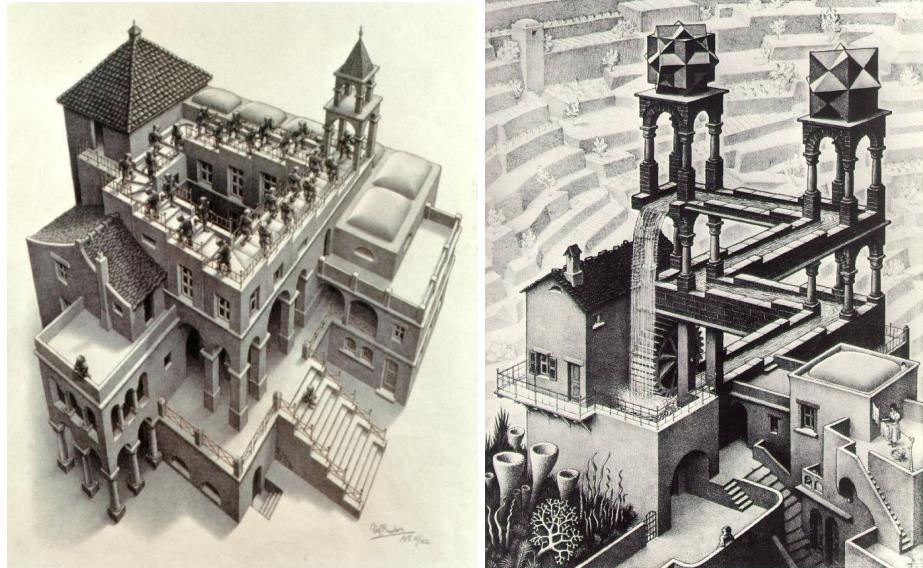
SEEING IS BELIEVING?



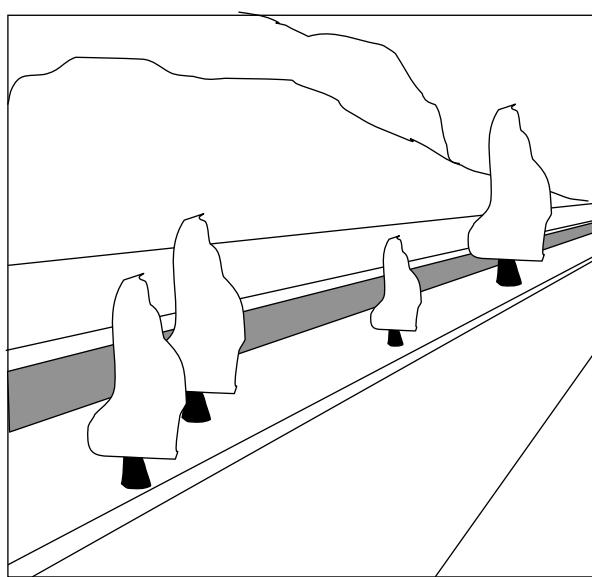
Stare at the cross in the middle of the image
and think about circles



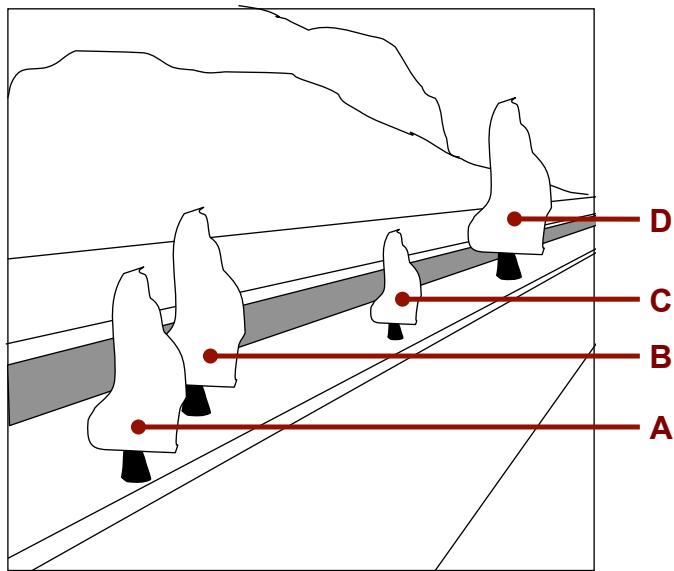




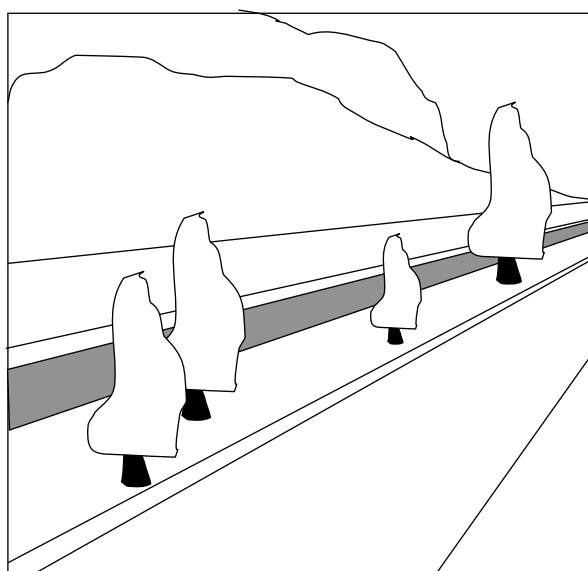
Which Tree Is Biggest On The Slide?



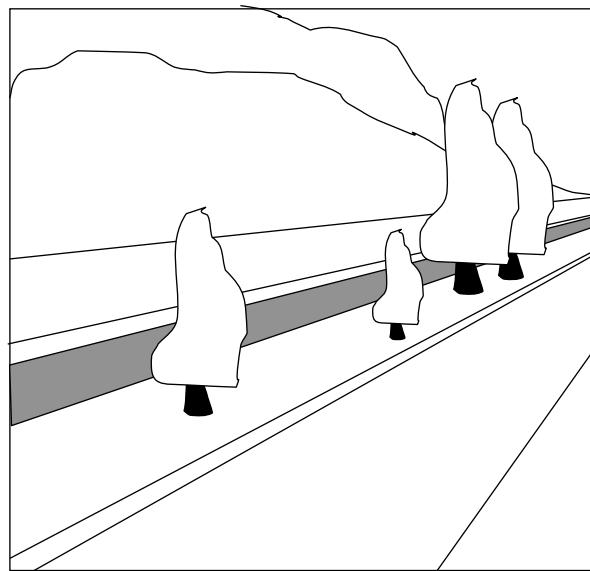
Which Tree Is Biggest On The Slide?



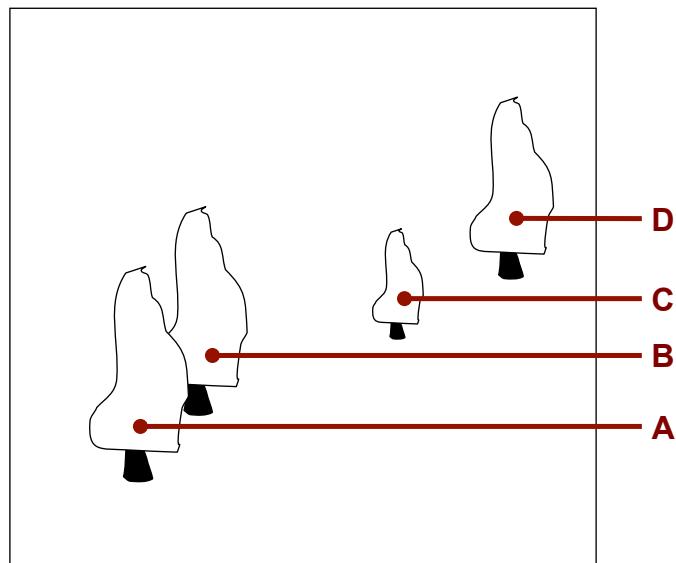
Which Tree Is Biggest On The Slide?



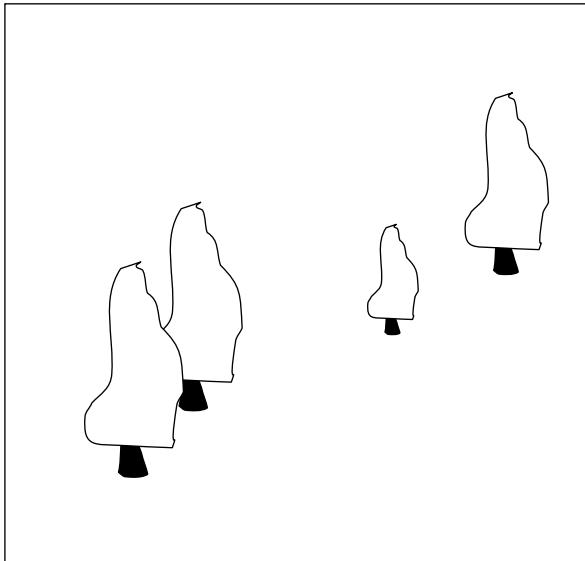
Which Tree Is Biggest On The Slide?



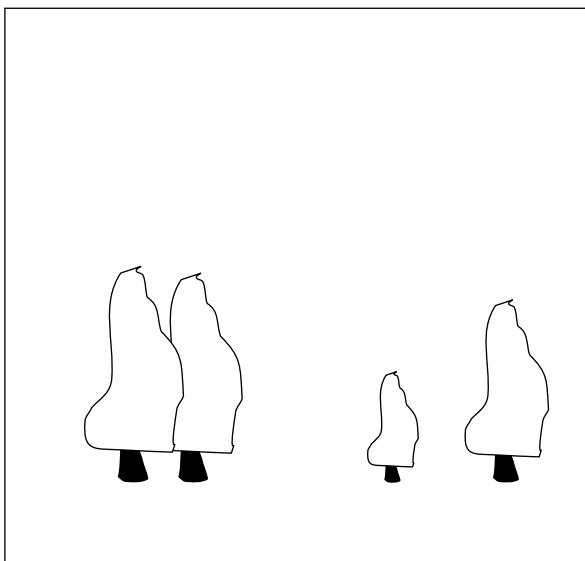
Which Tree Is Biggest On The Slide?



Which Tree Is Biggest On The Slide?



Which Tree Is Biggest On The Slide?

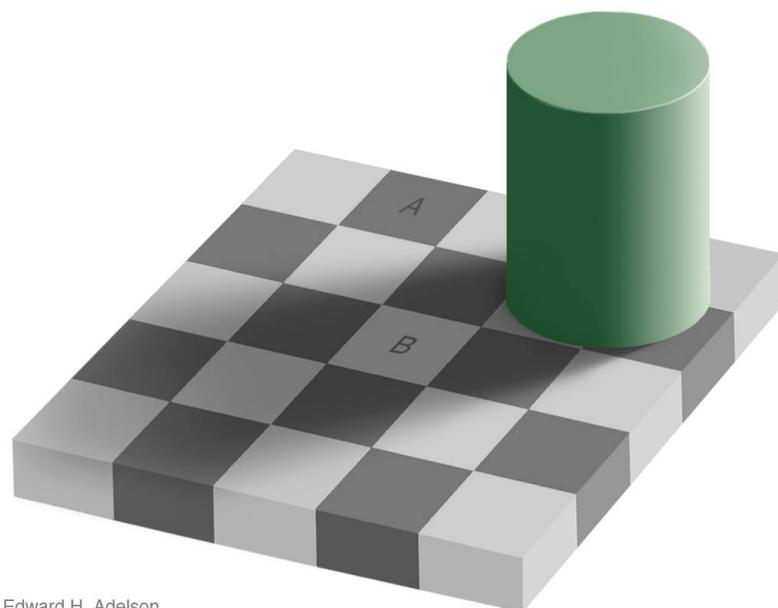




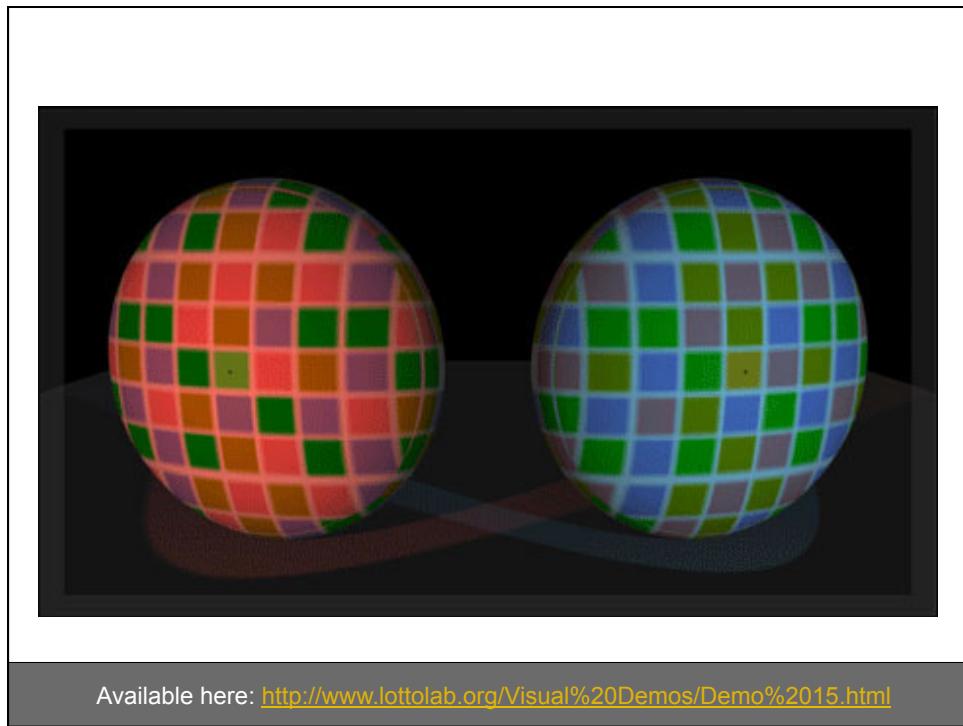
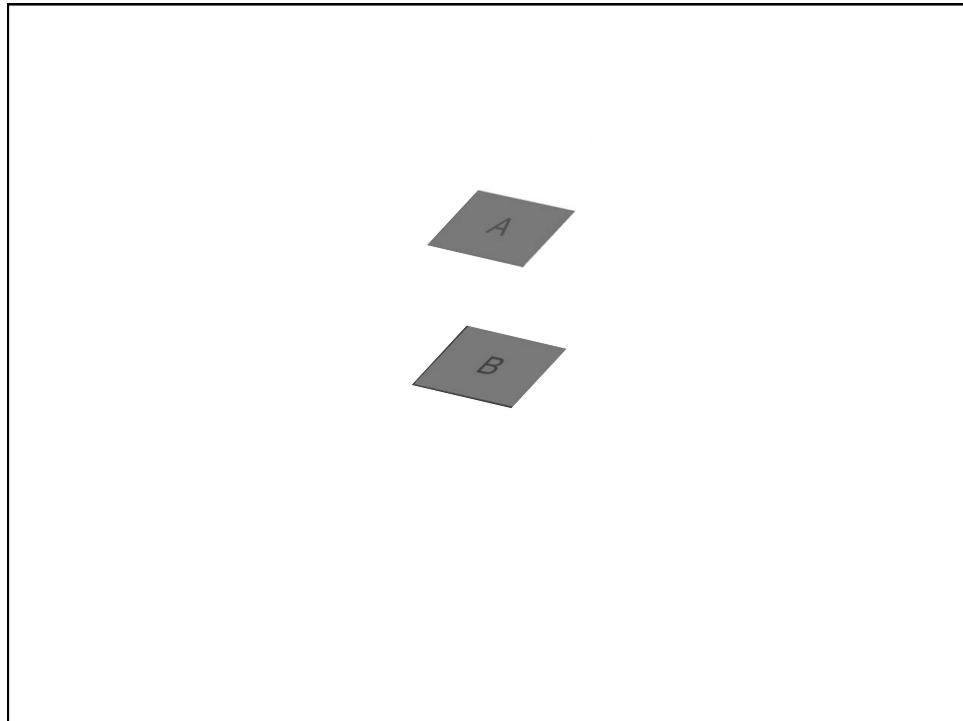
Ames Room (www.richannel.org/tales-from-the-prep-room-the-ames-room)
Photo Credit: Ian Stannard, Flickr (www.flickr.com/photos/silly_little_man/5132242358)

Aoccdrnig to rscheearch at Cmabrigde
Uinervtisy, it deosn't mttaer in waht
oredr the ltteers in a wrod are, the
olny iprmoetnt tihng is taht the frist
and lsat ltteer be at the rghit pclae.
The rset can be a toatl mses and you
can sitll raed it wouthit a porbelm.
Tihs is bcuseae the huamn mnid deos
not raed ervey lteter by istlef, but the
wrod as a wlohe.

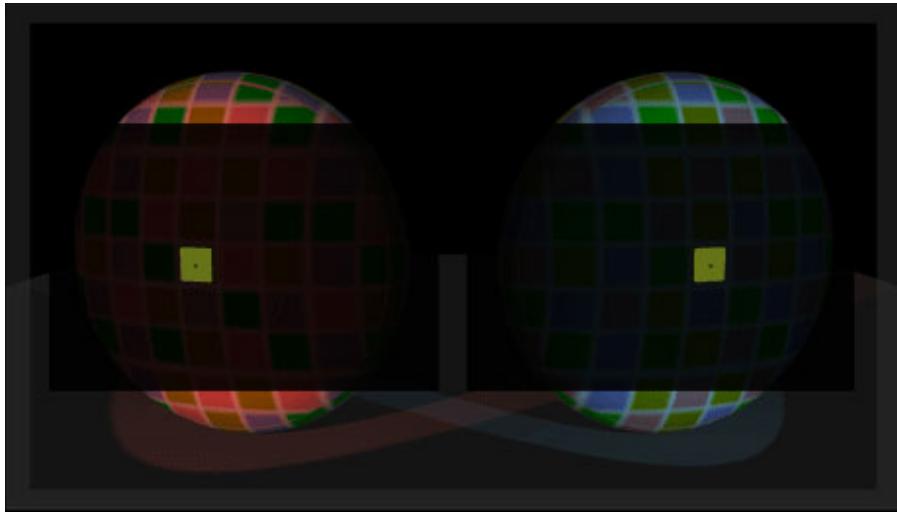
FINISHED FILES ARE THE RESULT OF
YEARS OF SCIENTIFIC STUDY COMBINED
WITH THE EXPERIENCE OF YEARS.



For more great illusion examples take a look at: <http://web.mit.edu/persci/gaz/>



Available here: <http://www.lottolab.org/Visual%20Demos/Demo%202015.html>



Available here: <http://www.lottolab.org/Visual%20Demos/Demo%202015.html>

WHAT IS PERCEPTION?

Perception

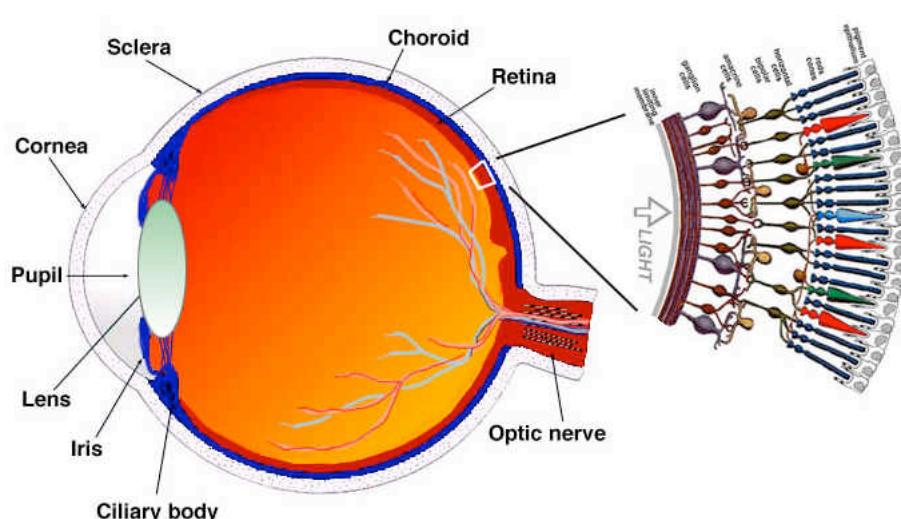
Our five senses (sight, hearing, taste, smell & touch) provide us with the raw material with which to be aware of and understand the world around us

Stimuli are features of the environment which are sensed by our sense organs

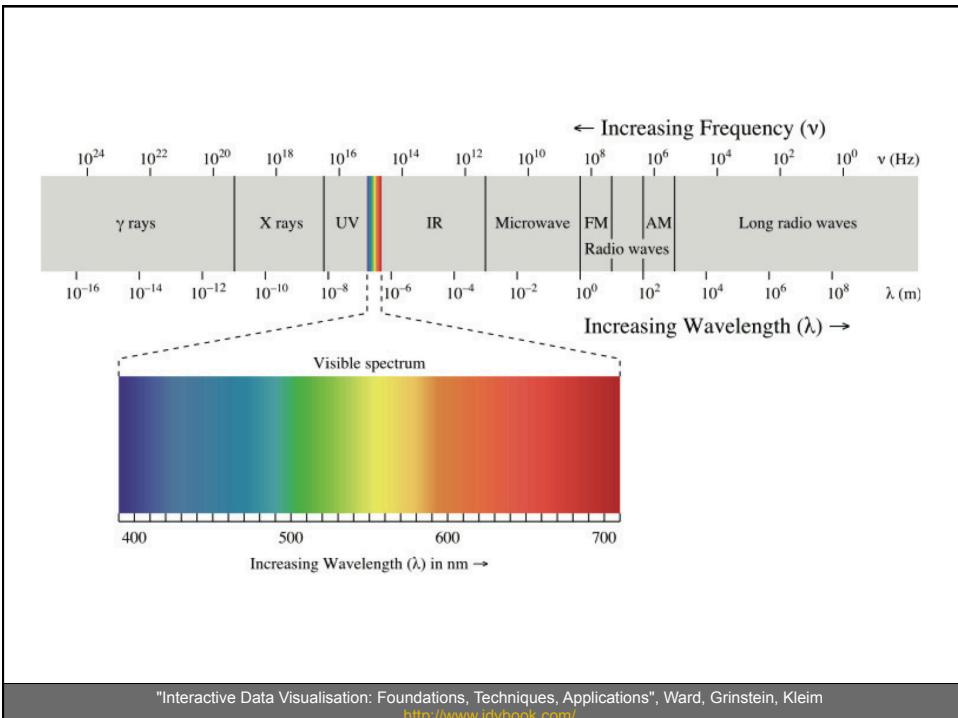
Each sense organ responds to different stimuli

A **sensation** is a physical response of a sense organ to a stimulus

An Introduction to Behavioural Science, Martin O'Grady, Gill & Macmillan, 2001



<http://www.biologymad.com/nervoussystem/evenotes.htm>



"Interactive Data Visualisation: Foundations, Techniques, Applications", Ward, Grinstein, Kleim
<http://www.idvbook.com/>

Perception

Our senses respond only to a small range of the possible stimuli in the world

- Our ears respond to a narrow range of frequencies
- Our eyes respond to only a narrow band of the electromagnetic spectrum

Broadly, our senses allow us all to experience the world in the same way

Our sense organs are **passive** and **biologically understandable**

Perception

Perception is the psychological process of actively selecting and organising stimulus information detected by the sensory organs so as to create conscious awareness

Perception is an **active** process that is only somewhat **psychologically understandable**

Perception

Not all of the stimulus information detected by our sense organs is used to create conscious awareness

Rather a small subset of stimulus information is **selected** and **organised** to create conscious awareness

VISUAL ATTENTION

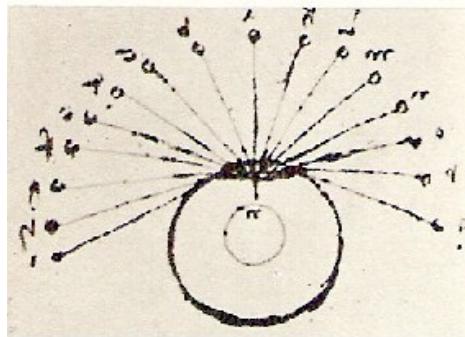
Visual Attention

Visual attention refers to the various mechanisms that help determine which regions of an image are selected for detailed analysis by our vision system

At any instant detailed information of shape and colour is only possible in a small portion of our visual field - about the size of your thumbnail viewed at arm's length

Healey, Christopher and Enns, James, Attention and Visual Memory in Visualization and Computer Graphics, IEEE Transactions on Visualization and Computer Graphics, vol 18 (7), pp 1170–1188, 2012
www.csc.ncsu.edu/faculty/healey/download/tvcg_11.pdf

Visual Attention



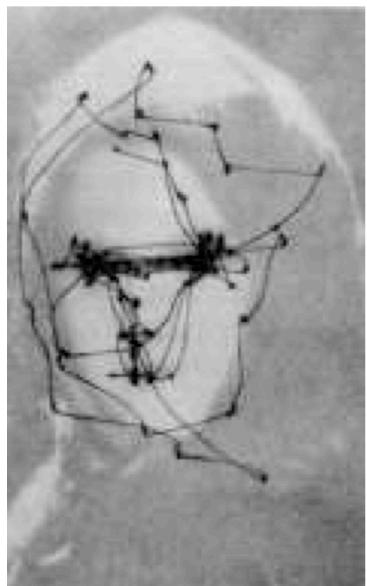
Leonardo Da Vinci completed some of the earliest studies of visual attention and may have been the first to propose the distinction between **foveal** and **peripheral** vision

The Fixation-Saccade Cycle

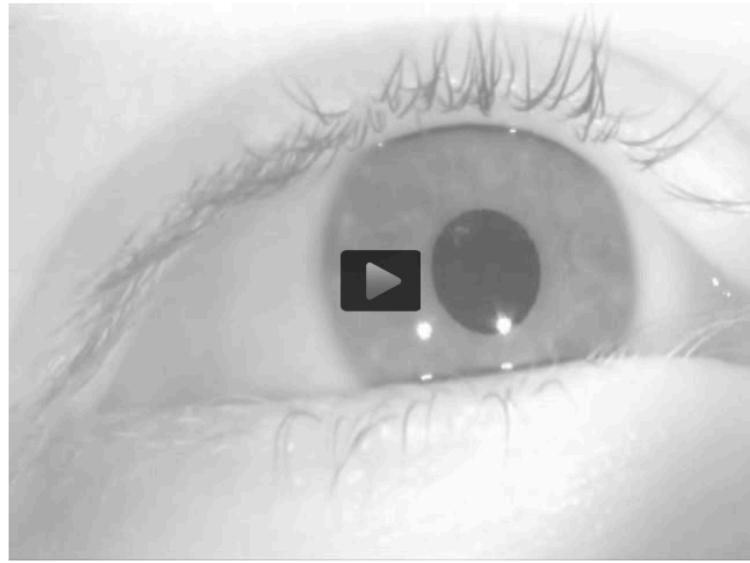
To overcome this limitation our eyes move rapidly alternating between:

- **Fixations:** during which detailed information from a small region is visible
- **Saccades:** a brief during which eyes flick to a new location (**saccadic masking** makes things fuzzy at this point)

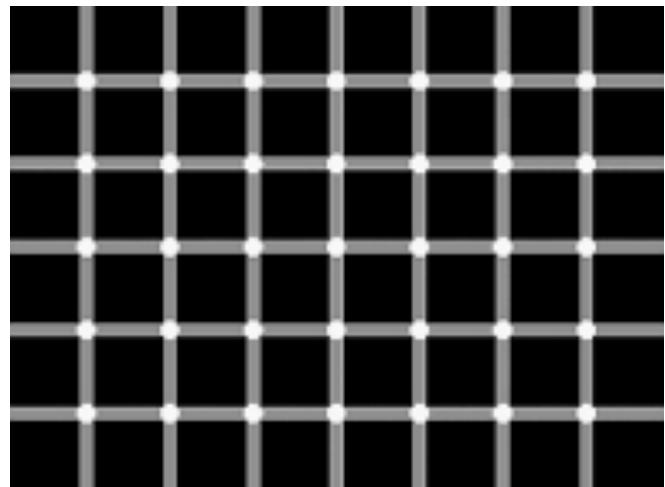
The **fixation-saccade cycle** repeats 3-4 times each second



"Interactive Data Visualisation: Foundations, Techniques, Applications", Ward, Grinstein, Kleim
<http://www.idvbook.com/>

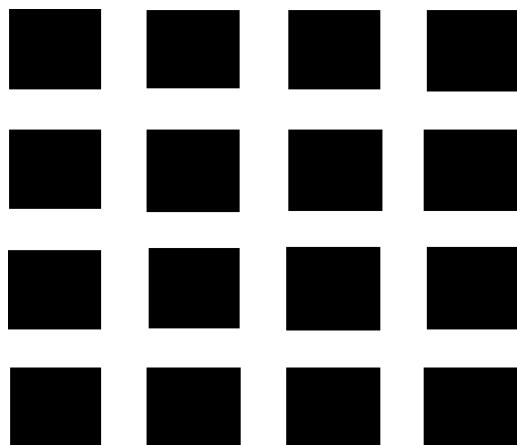


<https://en.wikipedia.org/wiki/>
File:This shows a recording of the eye movements of a participant looking freely at a picture.webm



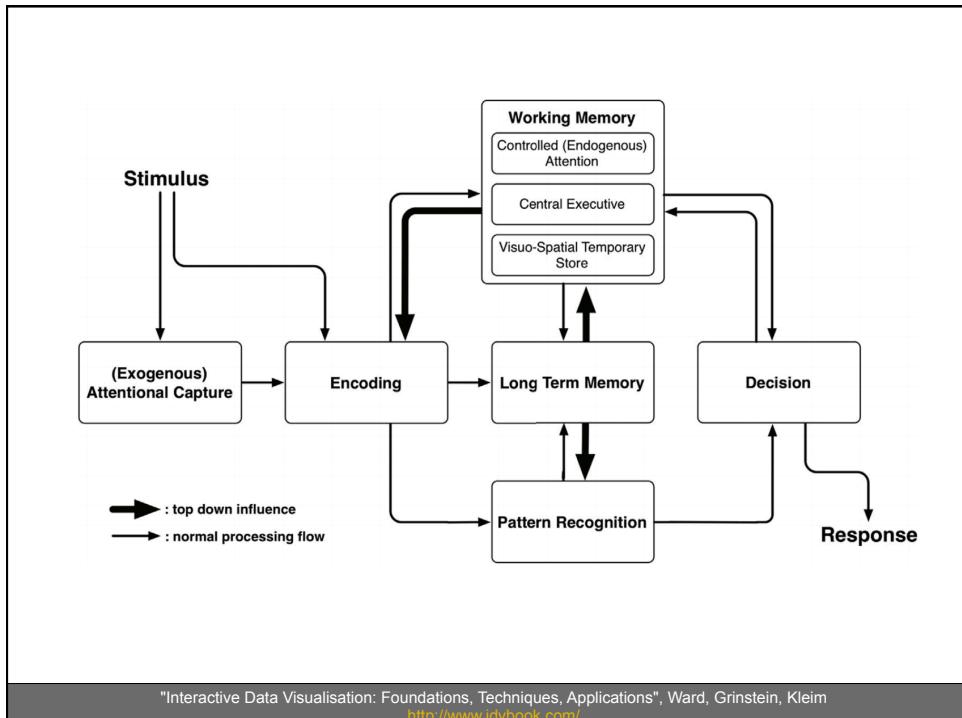
The Hermann grid illusion

"Interactive Data Visualisation: Foundations, Techniques, Applications", Ward, Grinstein, Kleim
<http://www.idvbook.com/>



The Hermann grid illusion

"Interactive Data Visualisation: Foundations, Techniques, Applications", Ward, Grinstein, Kleim
<http://www.idvbook.com/>



Visual Attention

We will look at a few properties of visual attention that arise:

- Pre-attentive properties
- Change blindness
- Attention blindness

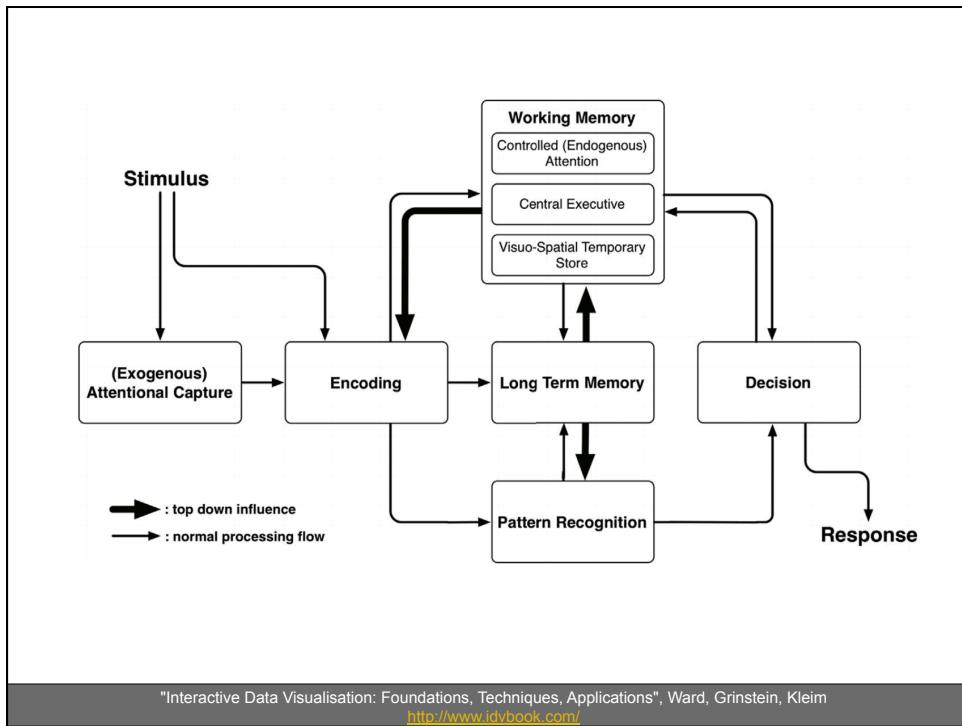
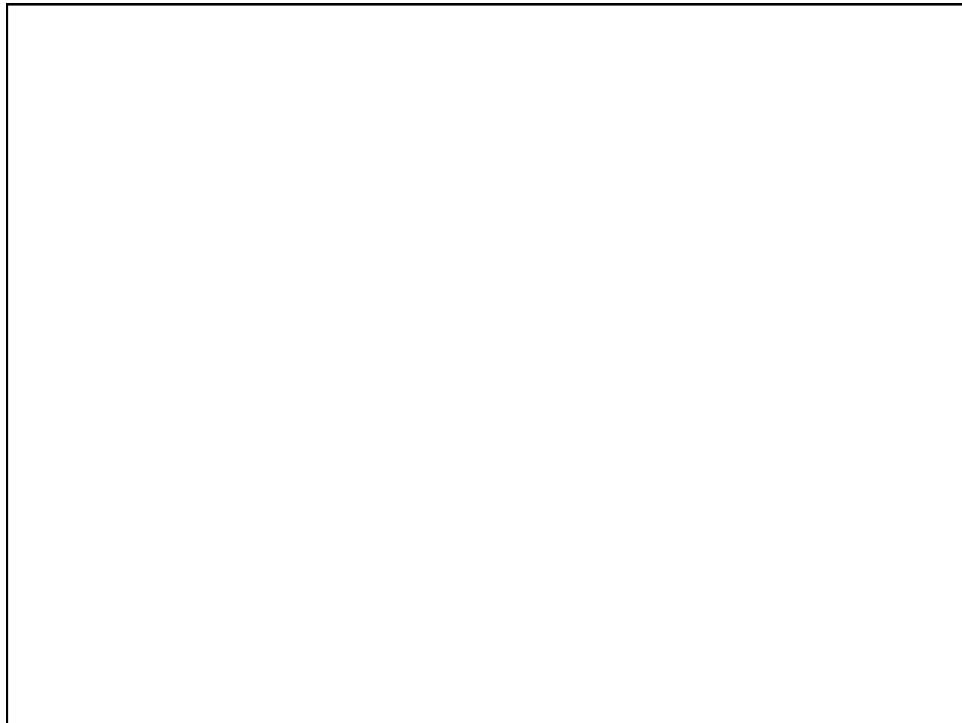
PRE-ATTENTIVE PROPERTIES

How many of the letter b are present?

a j g n t b f y d k e i f h t
d t n j f o s e w b h t w u i
y b a s g r c h y i j n g f s
y v f d s p l b n h g h n j n

How many of the letter b are present?

a j g n t **b** f y d k e i f h t
d t n j f o s e w **b** h t w u i
y **b** a s g r c h y i j n g f s
y v f d s p l **b** n h g h n j n



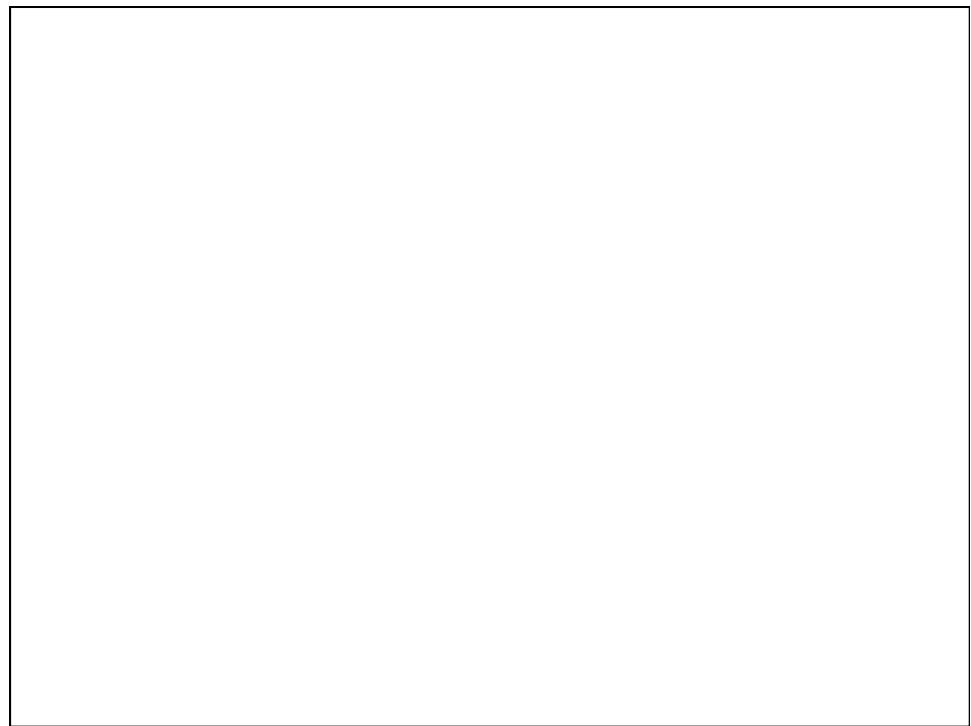
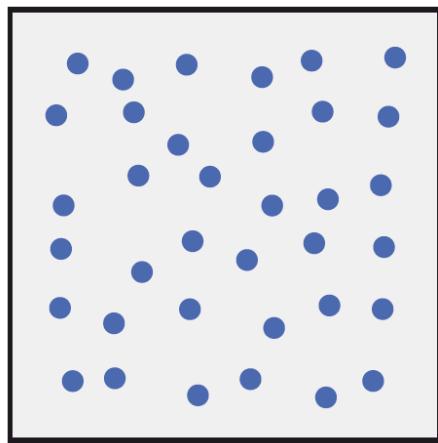
Pre-attentive Properties

There are a limited set of visual features that are detected by low-level, fast-acting visual processes within the period of a single fixation

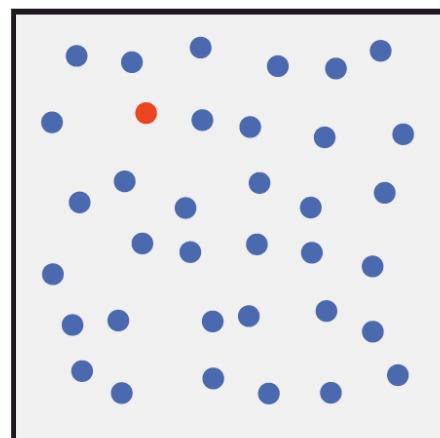
These are known as **pre-attentive properties**

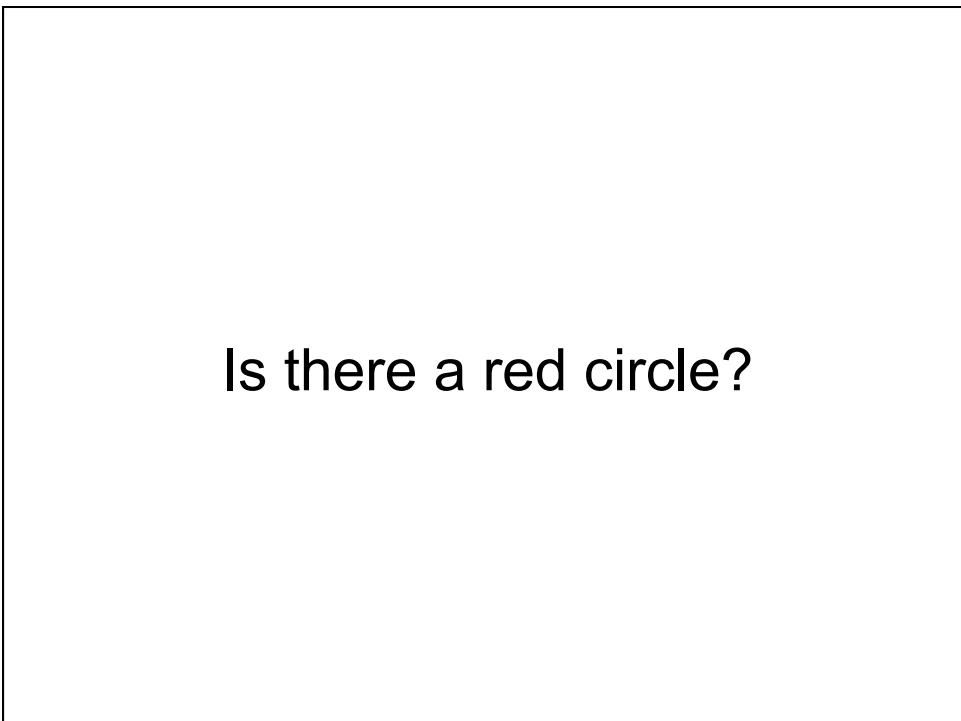
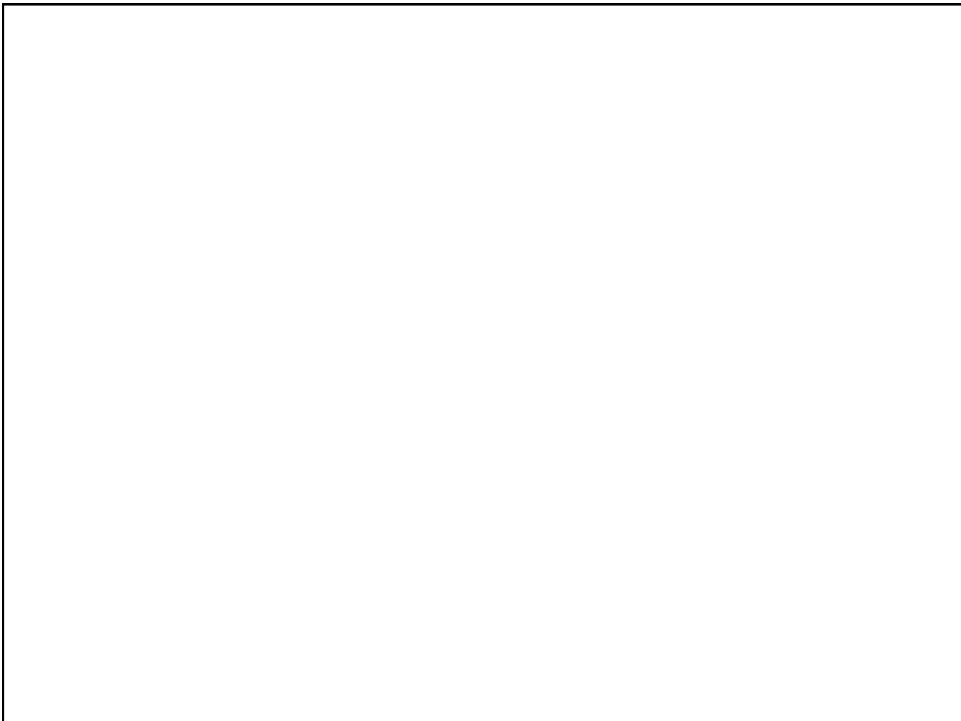
These are some of the most effective properties we can use in visualisations as they allow elements to *pop out* of a display

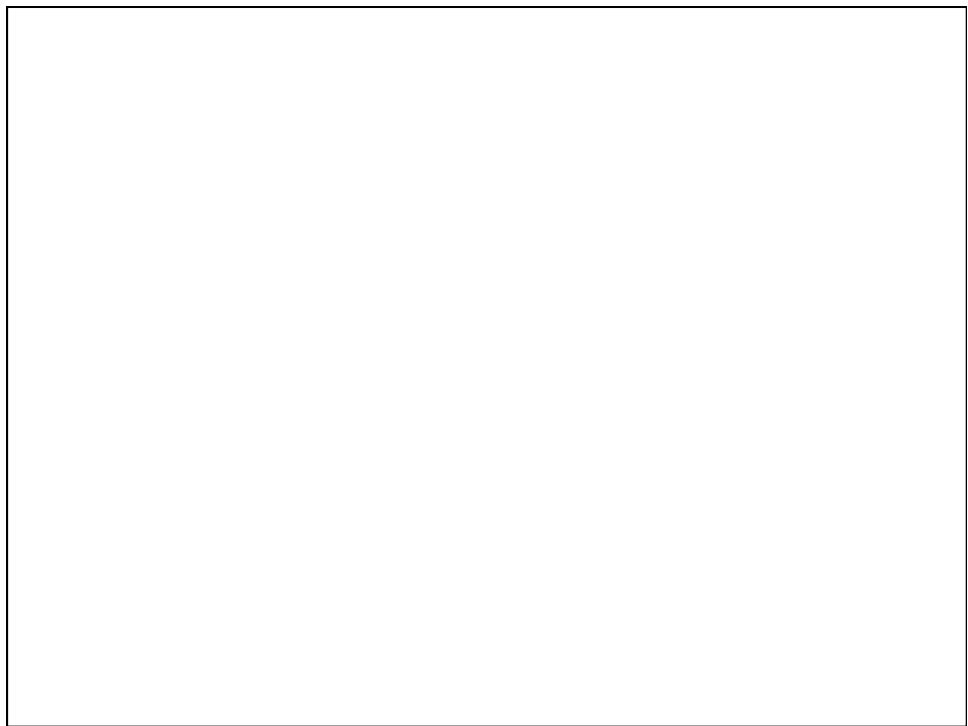
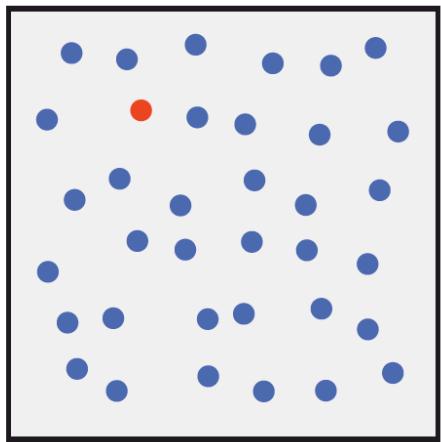
Is there a red circle?



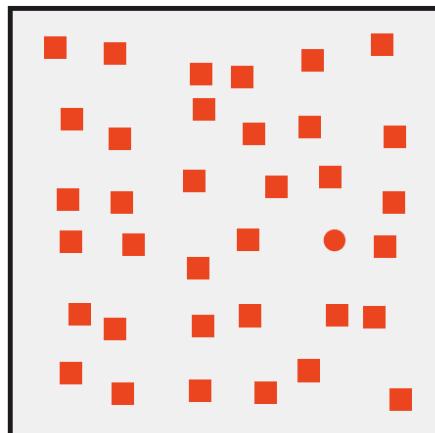
Is there a red circle?

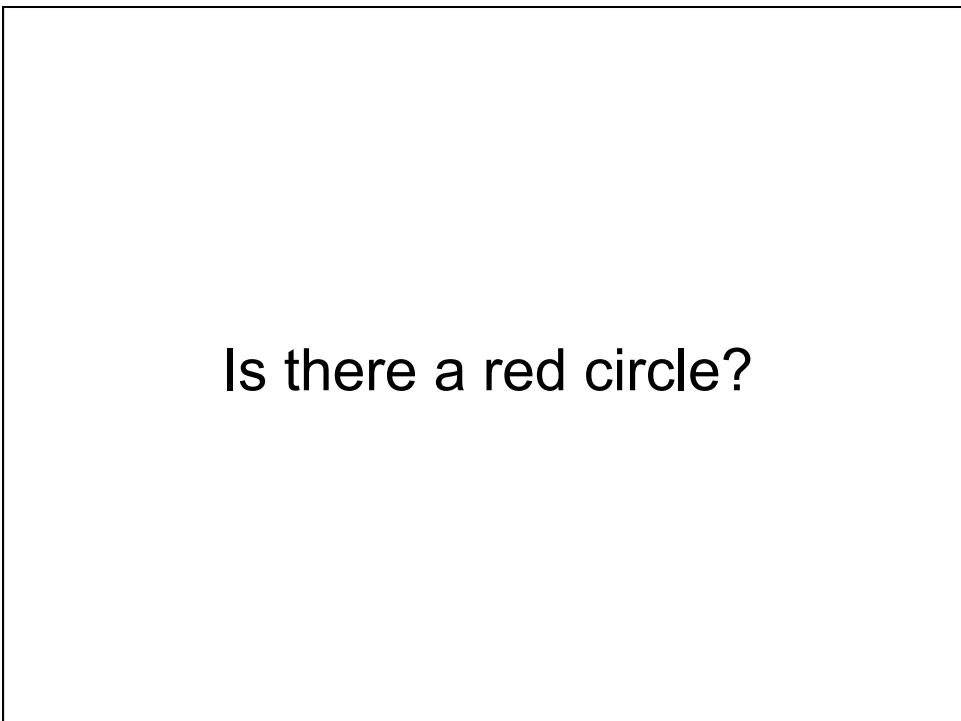
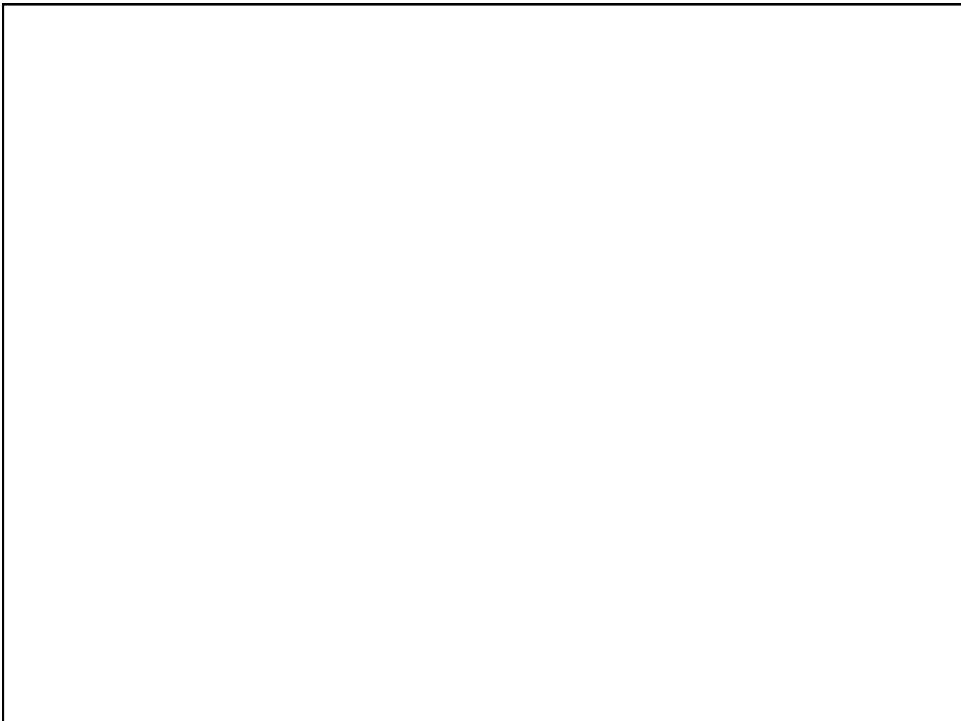


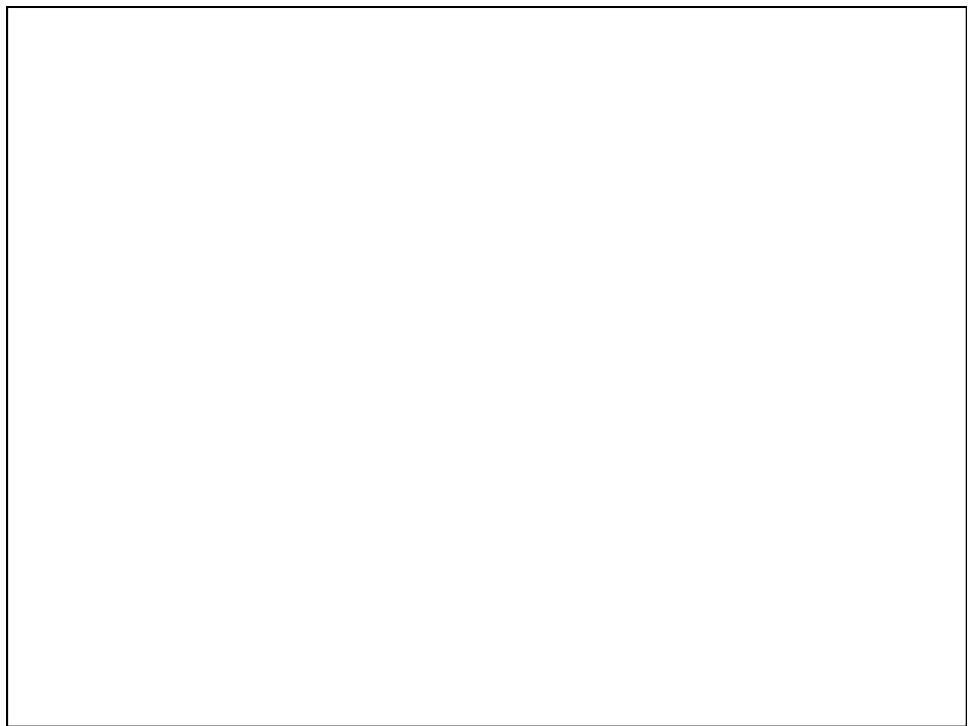
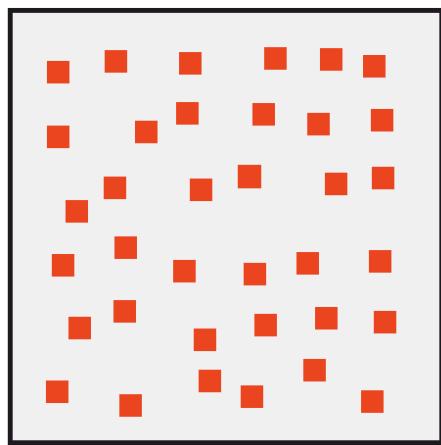




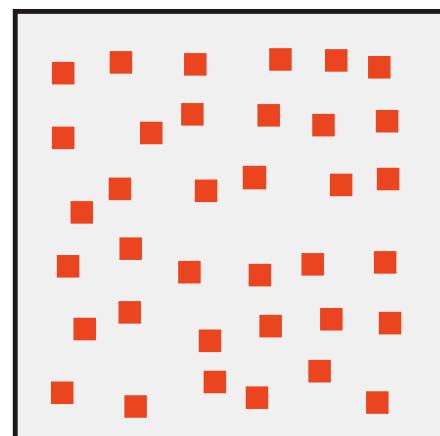
Is there a red circle?

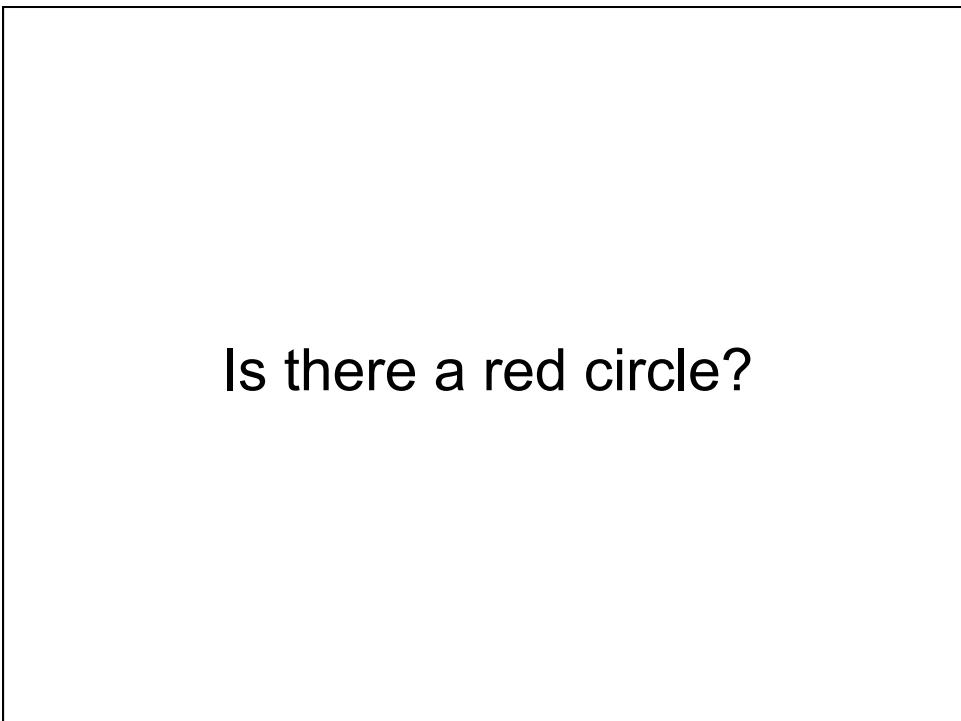
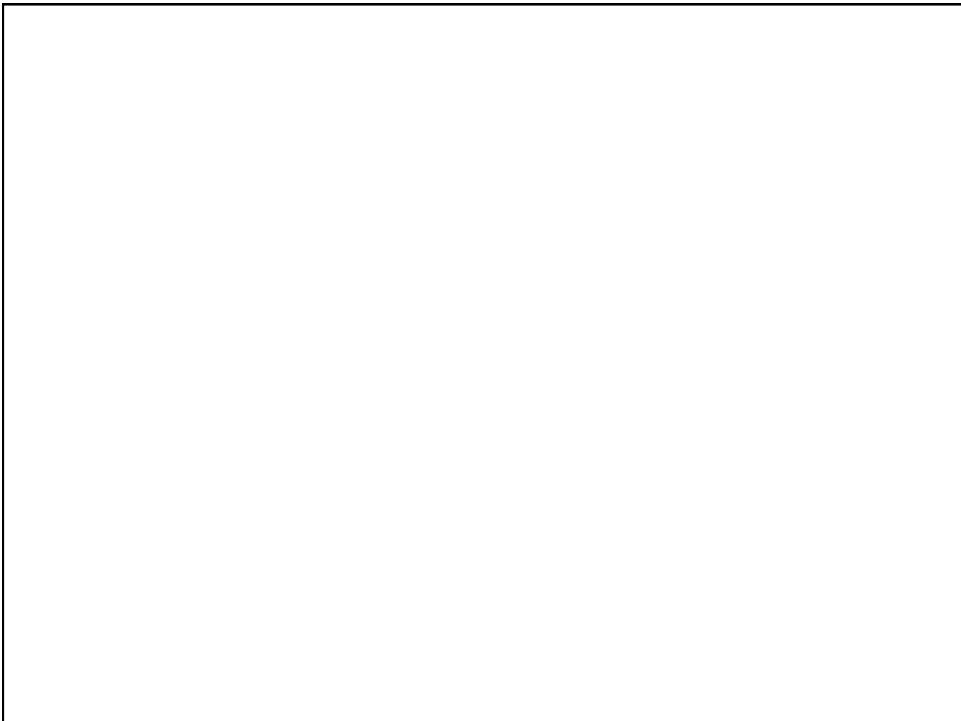


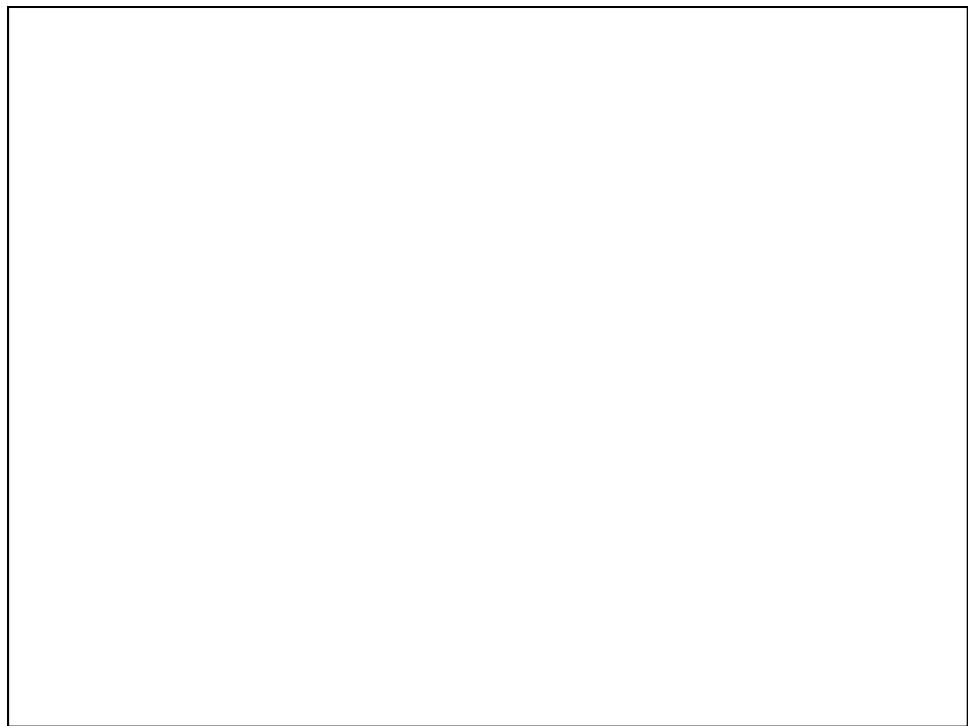
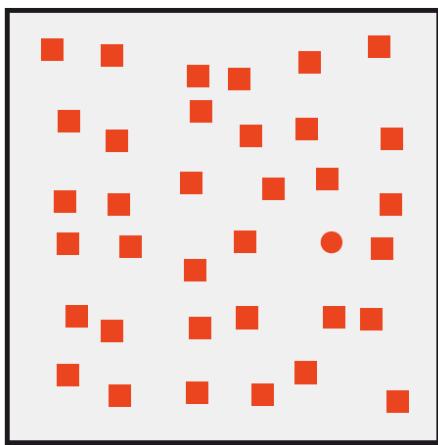




Is there a red circle?







Pre-attentive Visual Properties

length	Triesman & Gormican [1988]
width	Julesz [1985]
size	Triesman & Gelade [1980]
curvature	Triesman & Gormican [1988]
number	Julesz [1985]; Trick & Pylyshyn [1994]
terminators	Julesz & Bergen [1983]
intersection	Julesz & Bergen [1983]
colour (hue)	Nagy & Sanchez [1990, 1992]; D'Zmura [1991] Kawai et al. [1995]; Bauer et al. [1996]

Healey, Christopher and Enns, James, Attention and Visual Memory in Visualization and Computer Graphics, IEEE Transactions on Visualization and Computer Graphics, vol 18 (7), pp 1170–1188, 2012
www.csc.ncsu.edu/faculty/healey/download/tvcg_11.pdf

Pre-attentive Visual Properties

intensity	Beck et al. [1983]; Triesman & Gormican [1988]
flicker	Julesz [1971]
direction of motion	Nakayama & Silverman [1986]; Driver & McLeod [1992]
binocular lustre	Wolfe & Franzel [1988]
stereoscopic depth	Nakayama & Silverman [1986]
3-D depth cues	Enns [1990]
lighting direction	Enns [1990]

Healey, Christopher and Enns, James, Attention and Visual Memory in Visualization and Computer Graphics, IEEE Transactions on Visualization and Computer Graphics, vol 18 (7), pp 1170–1188, 2012
www.csc.ncsu.edu/faculty/healey/download/tvcg_11.pdf

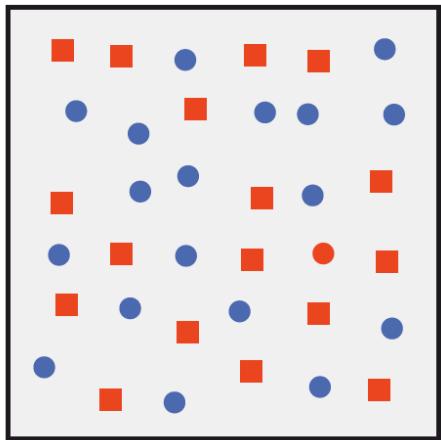
Conjunction Targets

When a target is defined by the joint presence of two or more visual properties it becomes more difficult

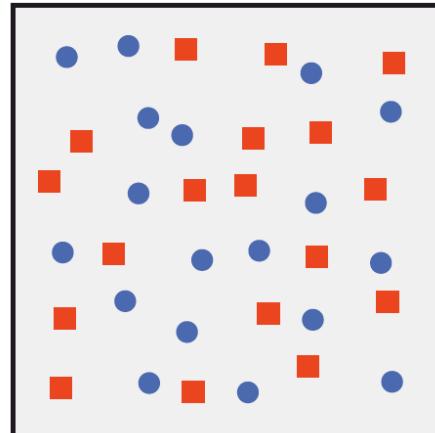
Numerous studies have shown that most conjunction targets cannot be detected pre-attentively

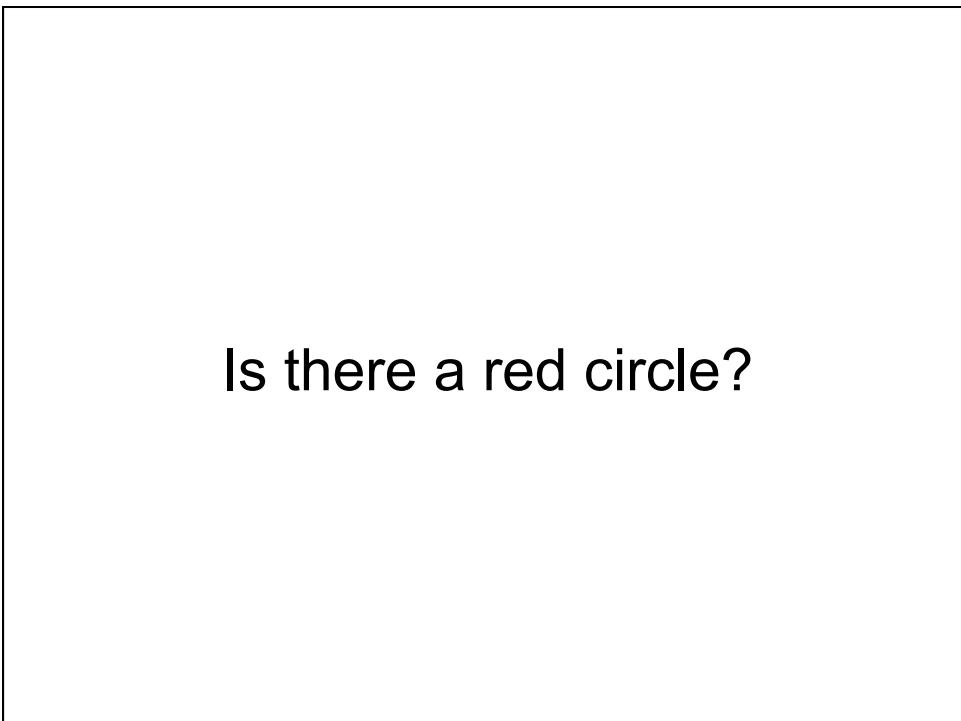
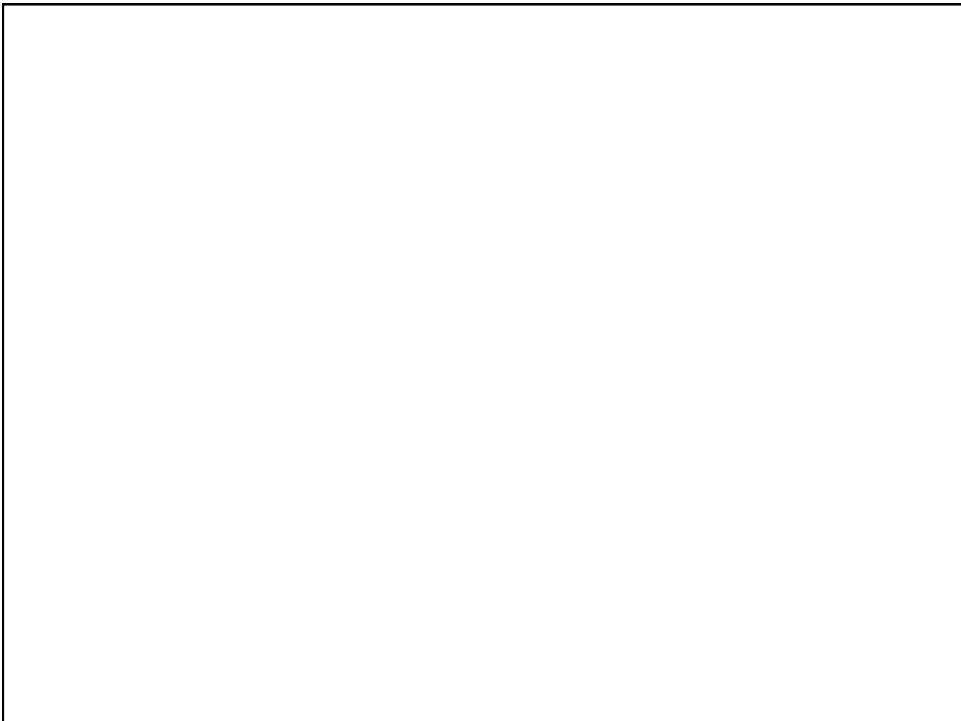
Viewers must perform a time consuming serial search through the display to confirm presence or absence

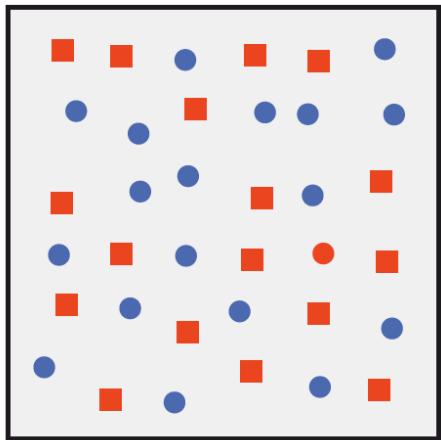
Is there a red circle?



Is there a red circle?







Theories Of Pre-attention

A number of theories attempt to explain how pre-attentive processing occurs within the visual system

These include:

- Feature integration [Treisman, 1985]
- Textons [Julész & Bergen, 1983]
- Similarity theory [Quinlan & Humphreys, 1987]
- Guided search [Wolfe, 1994]
- Boolean maps [Huang & Pashler, 2007]
- Ensemble coding [Ariely, 2001]

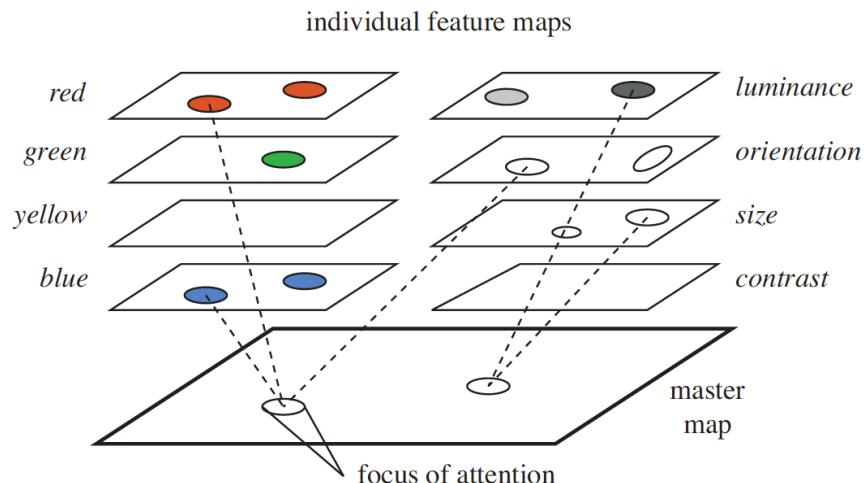
Healey, Christopher and Enns, James, Attention and Visual Memory in Visualization and Computer Graphics, IEEE Transactions on Visualization and Computer Graphics, vol 18 (7), pp 1170–1188, 2012
www.csc.ncsu.edu/faculty/healey/download/tvcg-11.pdf

Feature Integration

Treisman [1985] proposed a model of low-level human vision made up of a set of feature maps and a master map of locations

- Each feature map registers activity for a specific visual feature
- If a target has a unique feature, one can simply access the given feature map to see if any activity is occurring
- A conjunction target can only be detected by accessing two or more feature maps through a serial search

Feature Integration

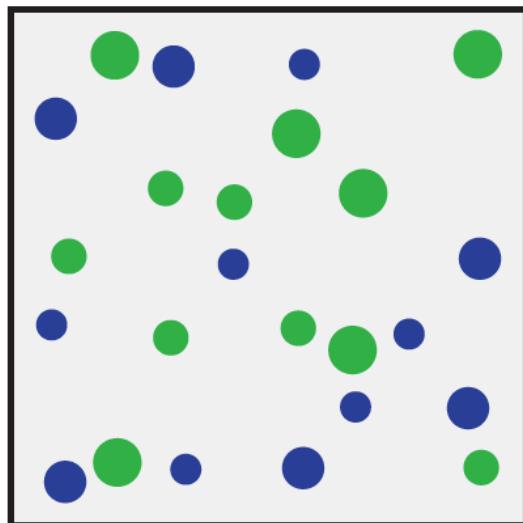


Ensemble Coding

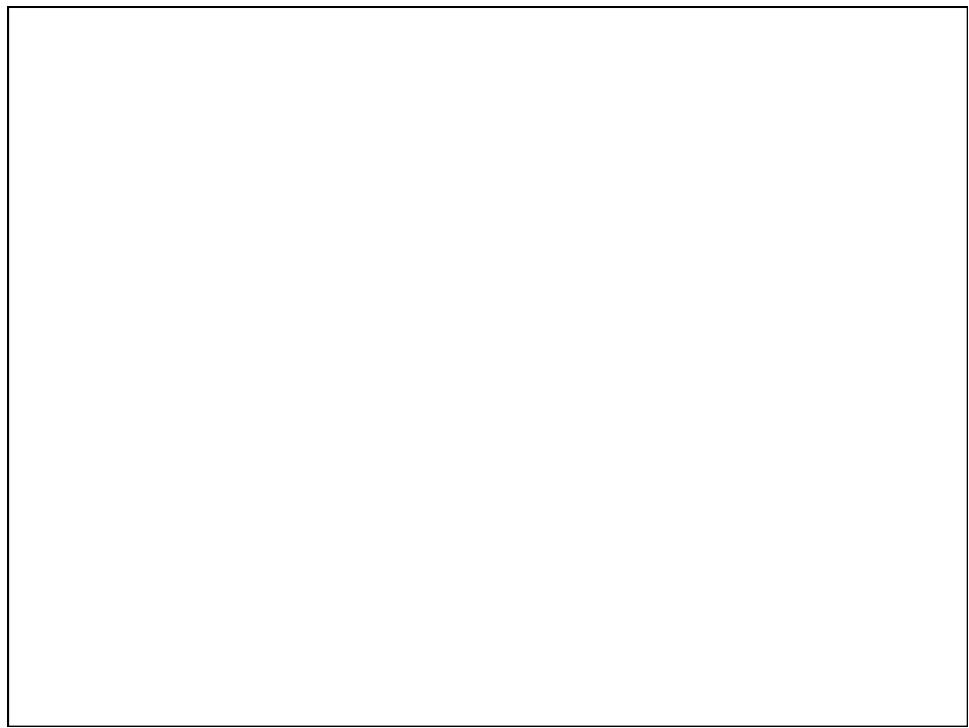
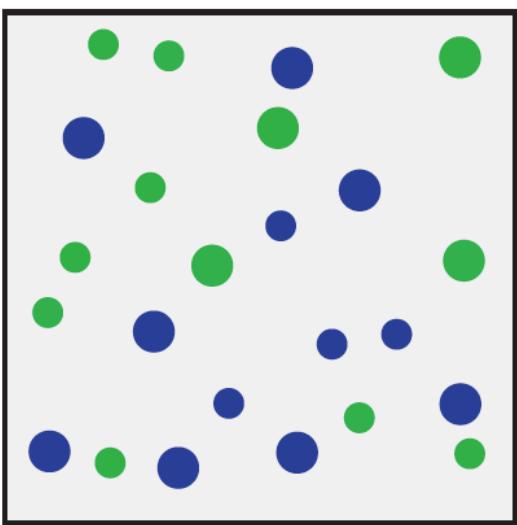
As well as being able to guide attention our low-level vision systems have a remarkable ability to generate a quick summary of how simple visual features are distributed across the field of view

Research suggests that there is a pre-attentive mechanism that records summary statistics of visual features without retaining information about the constituent elements that generated the summary

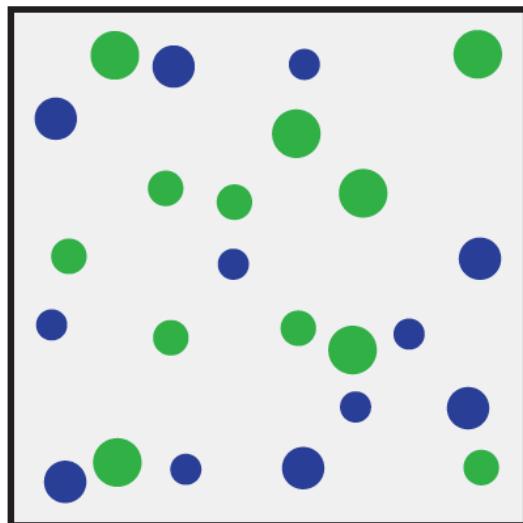
Which group is bigger on average, green or blue?

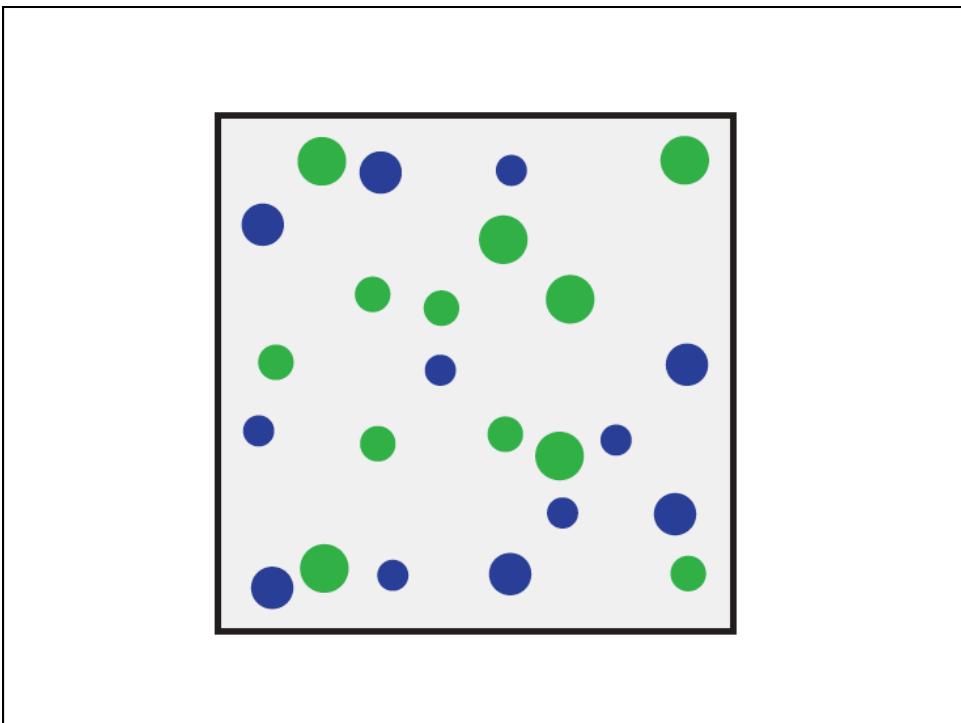
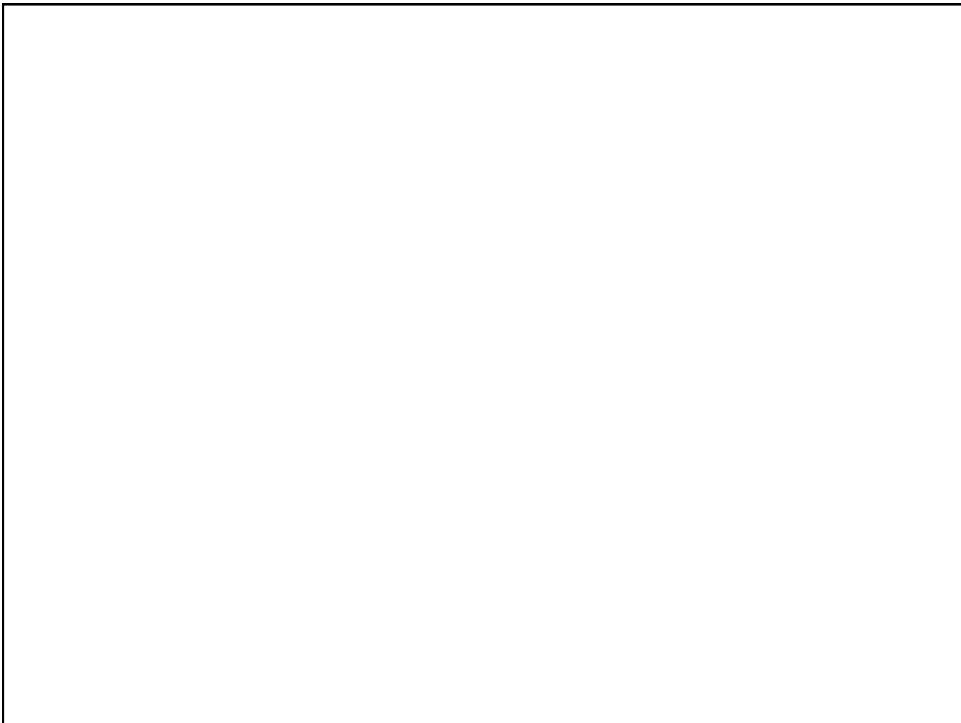


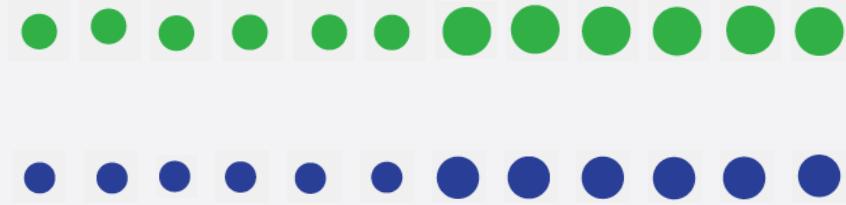
Which group is bigger on average, green or blue?



Which group is bigger on average, green or blue?





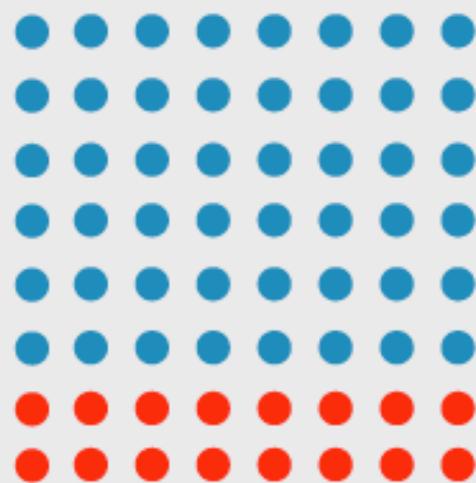


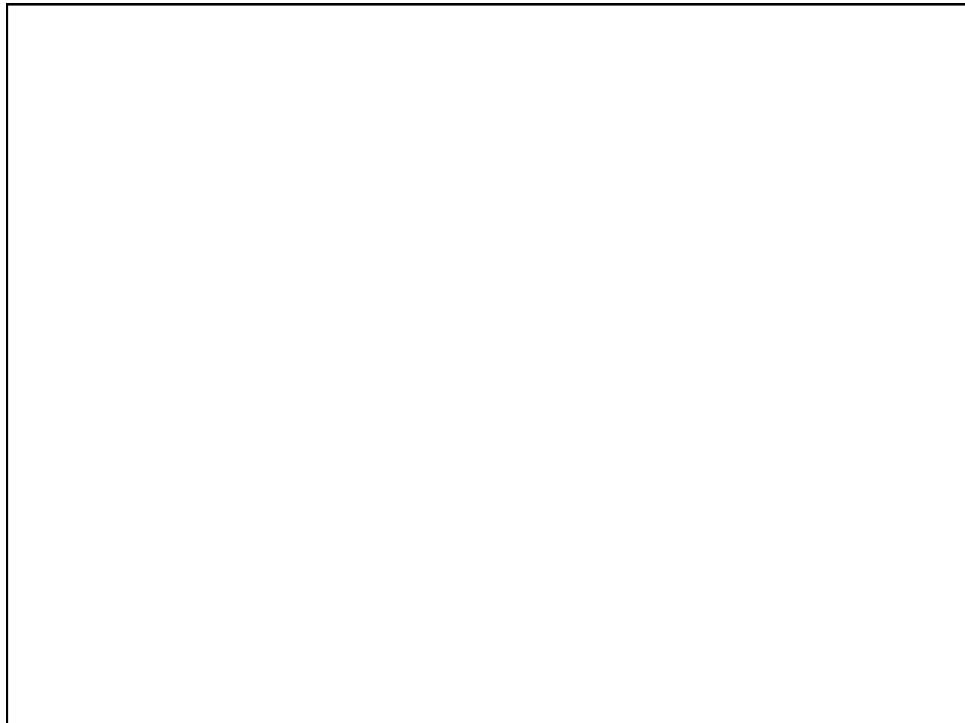
Feature Hierarchies

One of our most important considerations is deciding how to present information in a display without producing visual confusion

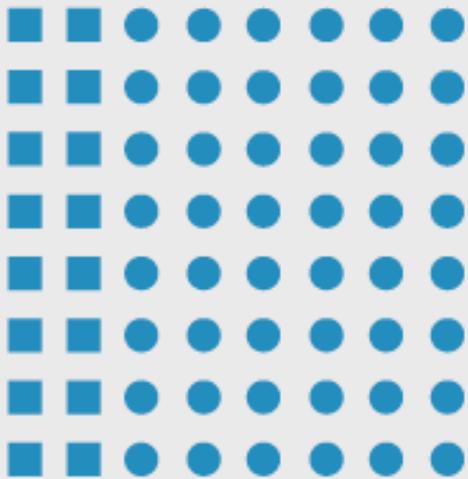
A feature hierarchy appears to exist in the visual system: for certain tasks one visual feature may be **more salient** than another

Find the boundary

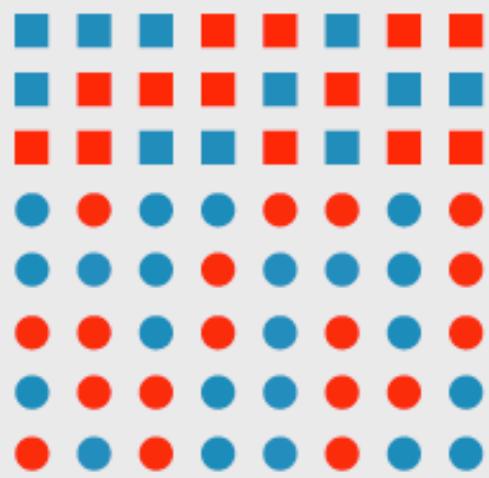


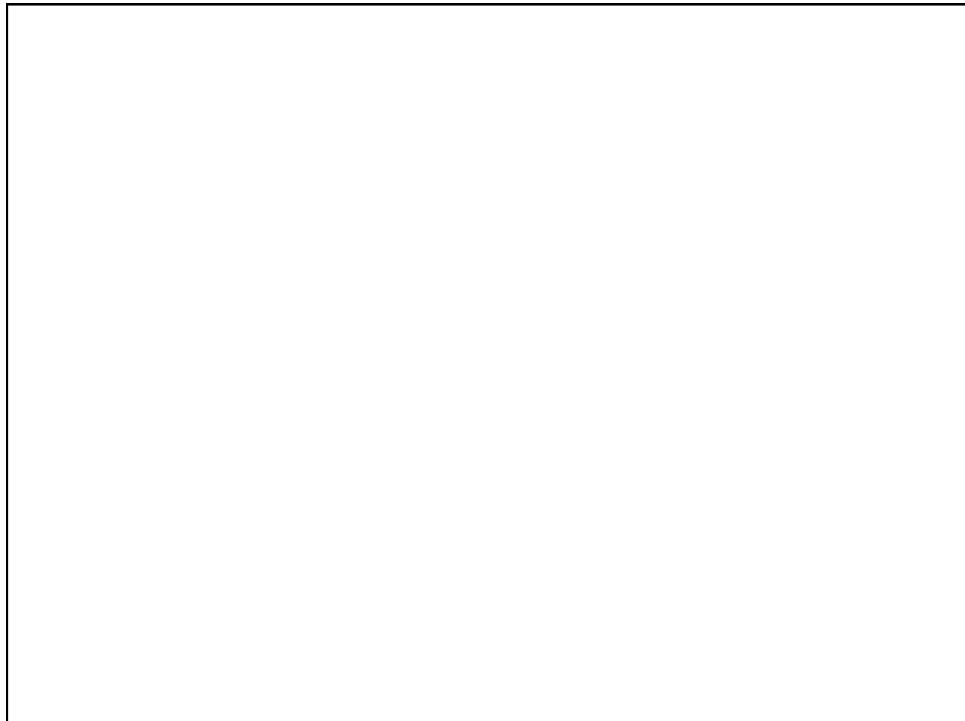


Find the boundary

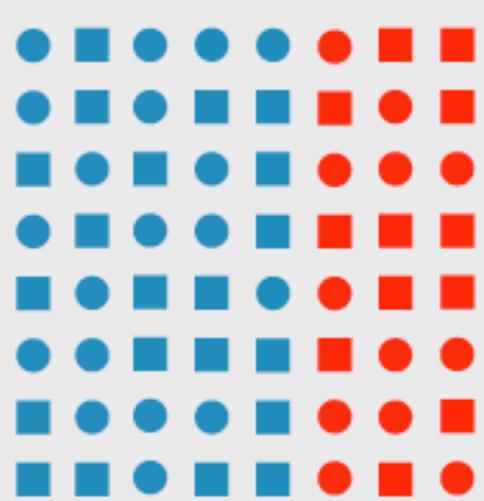


Find the boundary

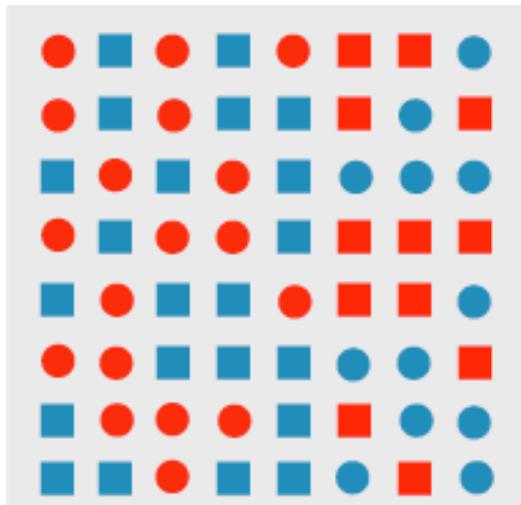




Find the boundary



Find the boundary



Lessons

If low-level visual processes can be harnessed during visualization, they can draw attention to areas of potential interest in a display

The visual features assigned to different data attributes must

- Take advantage of the strengths of our visual system
- Be well-suited to the viewer's analysis needs not produce visual interference effects (e.g., conjunction search) that mask information

CHANGE BLINDNESS

Consequences

Out of the theories of attention some interesting features arise in relation to visual expectation & memory:

- Postattentive amnesia
- Attention guided by memory
- **Change blindness**
- **Inattentional blindness**

Spot the difference

Interactive Data Visualization: Foundations, Techniques, and Applications, Matthew O. Ward, Georges Grinstein and Daniel Keim
CRC Press, 2010
<http://www.idvbook.com/teaching-aid/videos/>









INATTENTION BLINDESS



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<http://www.youtube.com/watch?v=vJG698U2Mvo>

GESTALT PRINCIPLES



Gestalt Principles

Forms or patterns transcend the stimuli used to create them

- Why do patterns emerge?
- Under what circumstances?

Principles of how we organise the disparate elements of sensory experience into a sensible whole

- Principles developed by psychologists from the German Gestalt School
- *Gestalt* is the German word for *whole*

Gestalt Principles

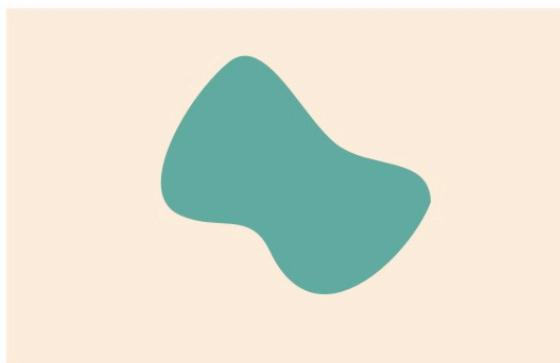
There is no definitive list of Gestalt principles, but some of the key features are:

- Figure-ground articulation
- Proximity principle
- Similarity principle
- Continuity principle
- Closure principle
- Past experience principle
- Connectedness principle

Gestalt principles, Dejan Todorovic (2008), Scholarpedia, 3(12):5345.
http://www.scholarpedia.org/article/Gestalt_principles

Figure-Ground Articulation

“Inhomogeneous visual fields are perceived as being articulated into two components, the figure on the ground”



Gestalt principles, Dejan Todorovic (2008), Scholarpedia, 3(12):5345.
http://www.scholarpedia.org/article/Gestalt_principles

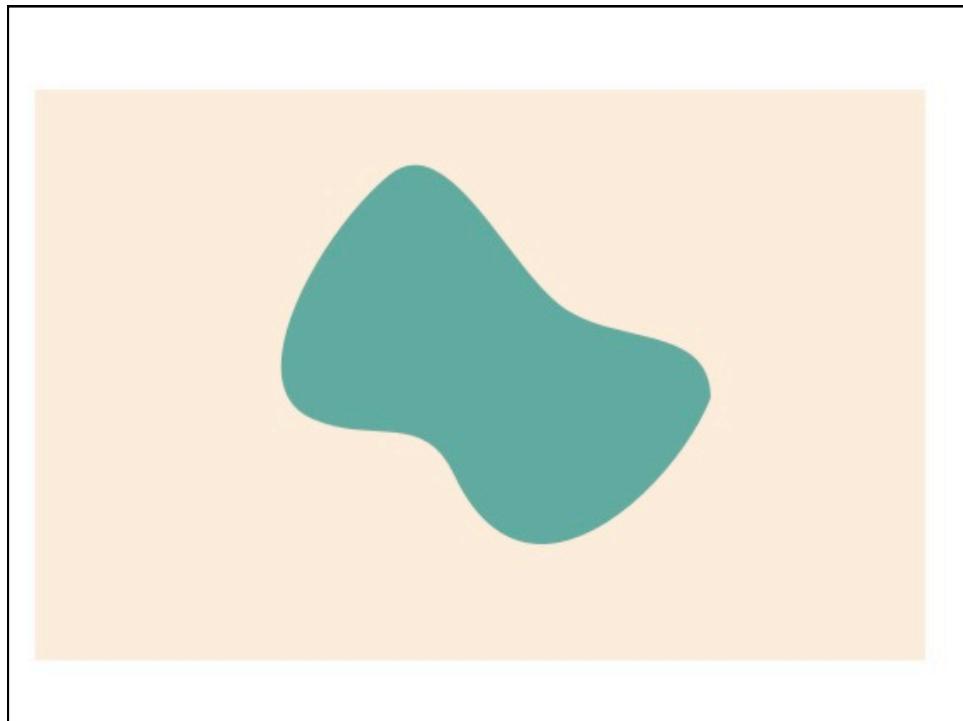
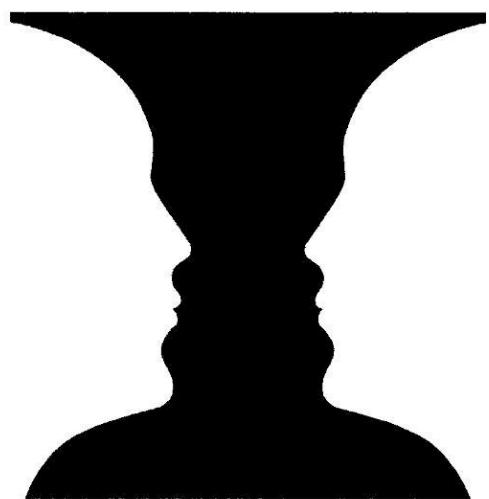
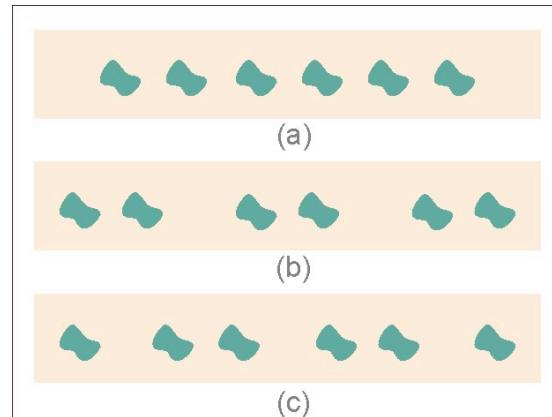


Figure-Ground Articulation

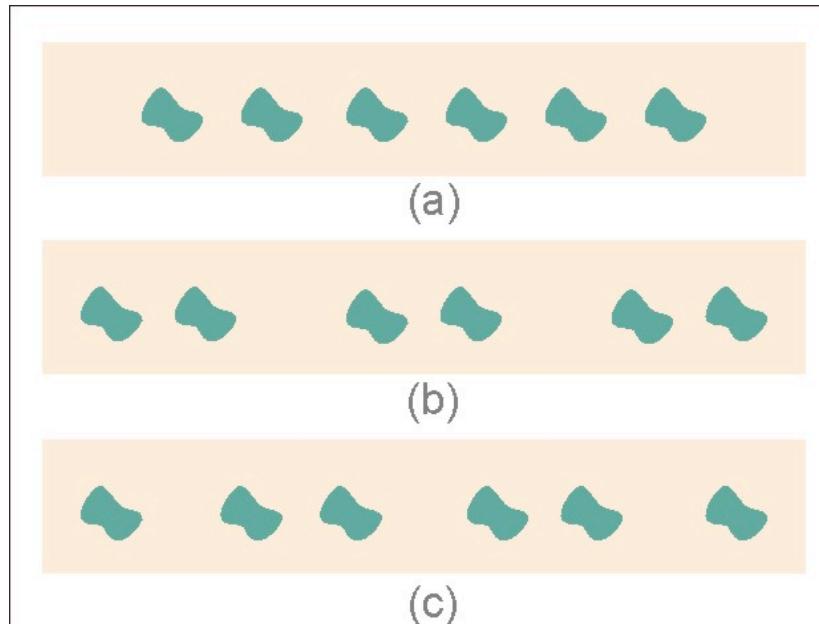


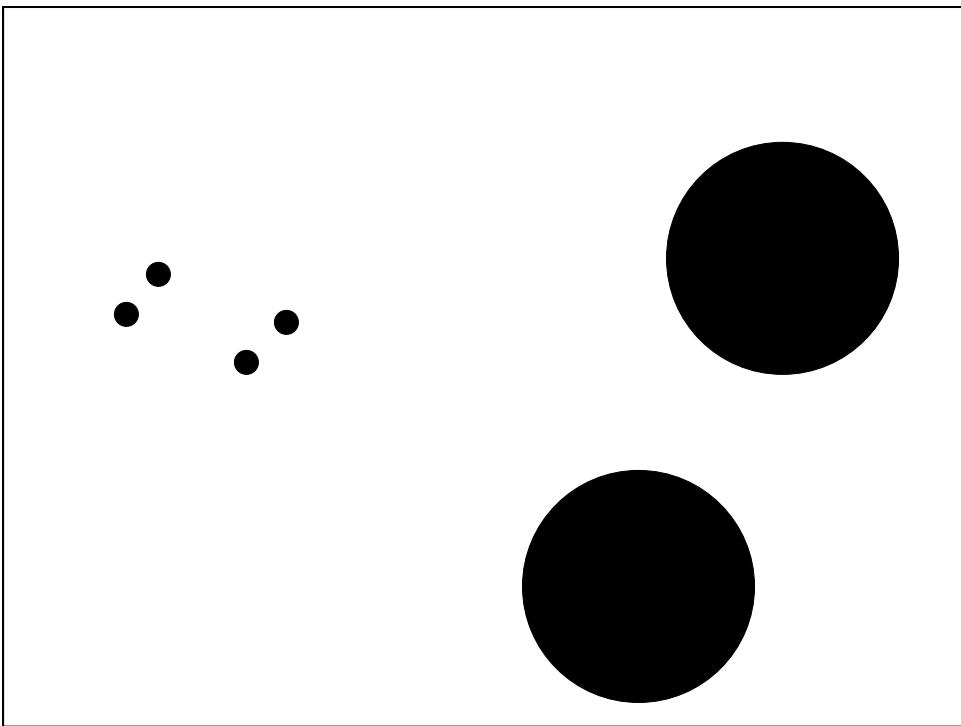
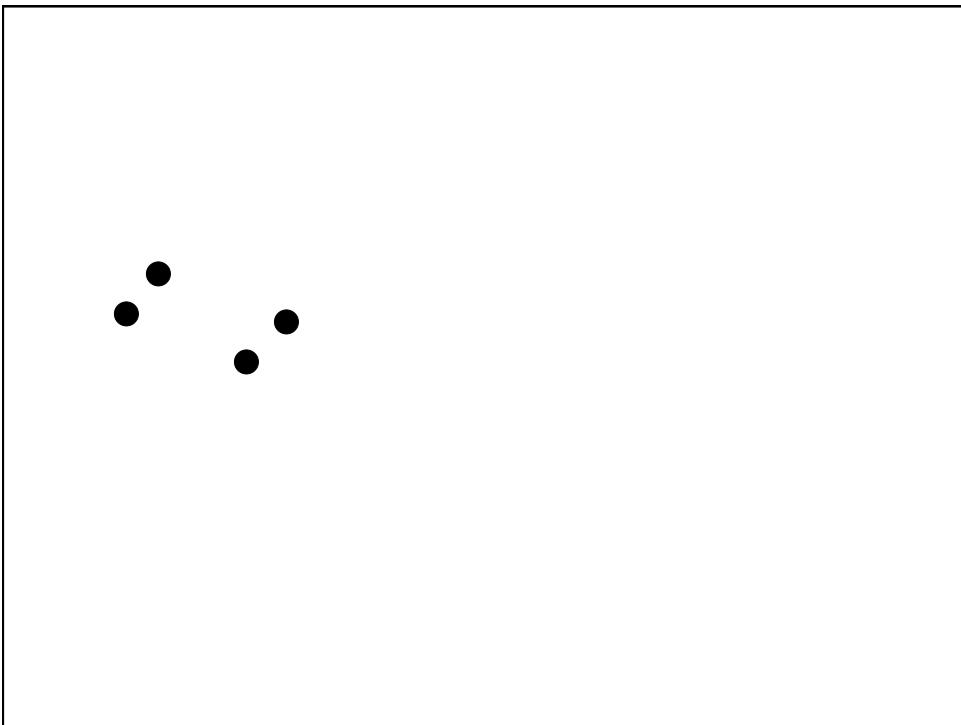
Proximity Principle

“elements tend to be perceived as aggregated into groups if they are near each other”



Gestalt principles, Dejan Todorovic (2008), Scholarpedia, 3(12):5345.
http://www.scholarpedia.org/article/Gestalt_principles





Similarity Principle

“elements tend to be integrated into groups if they are similar to each other”



(a)



(b)

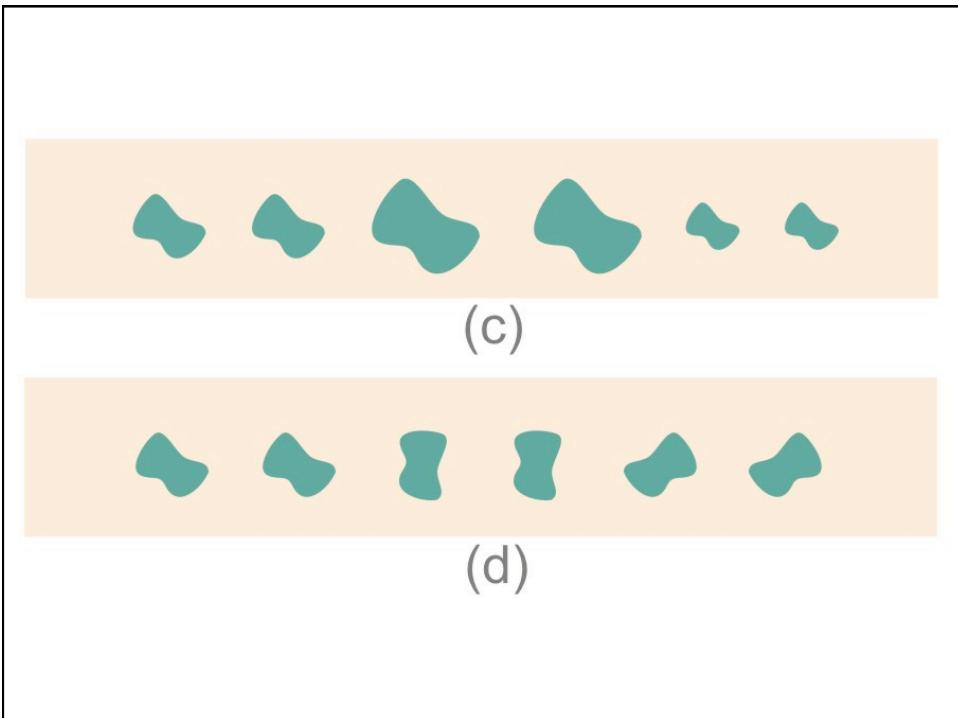
Gestalt principles, Dejan Todorovic (2008), Scholarpedia, 3(12):5345.
http://www.scholarpedia.org/article/Gestalt_principles



(a)

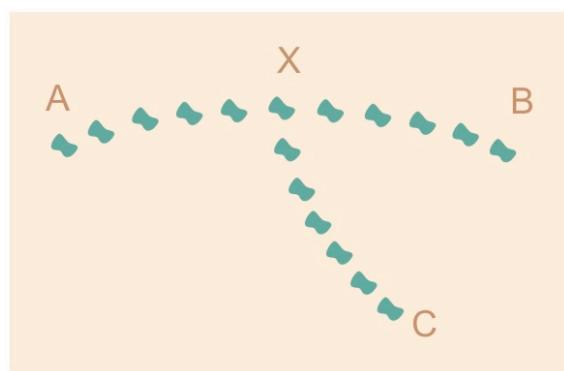


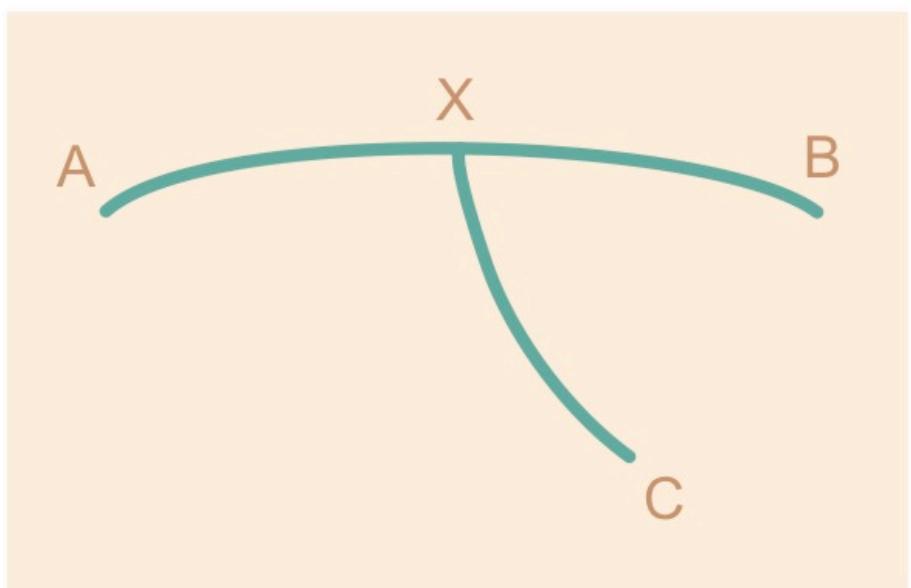
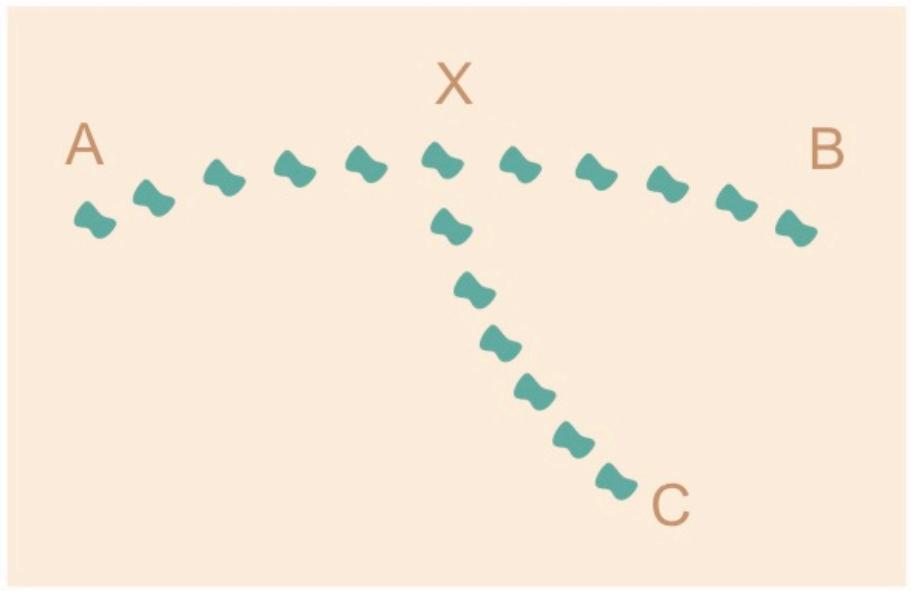
(b)



Continuity Principle

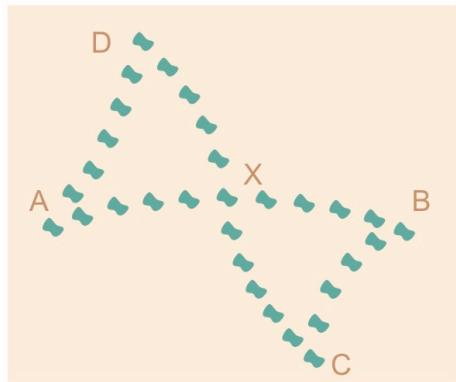
“oriented units tend to be integrated into perceptual wholes if they are aligned with each other”



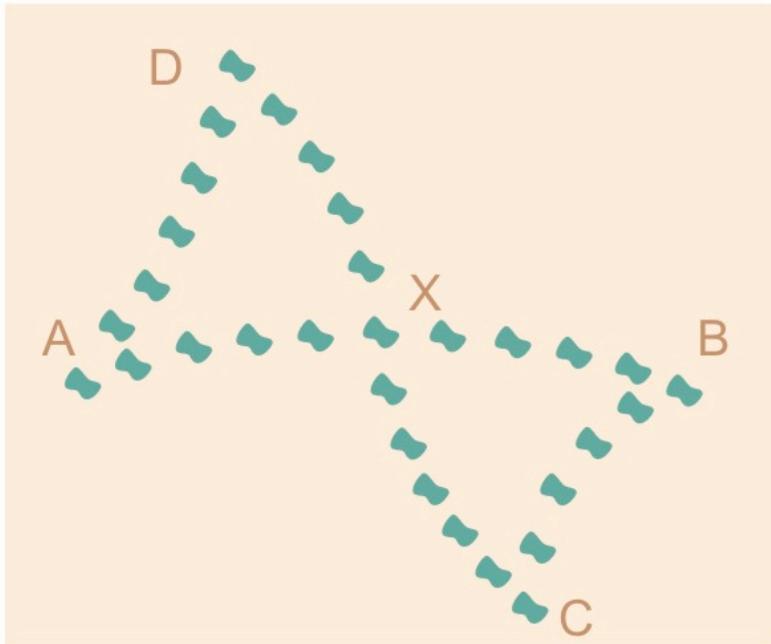


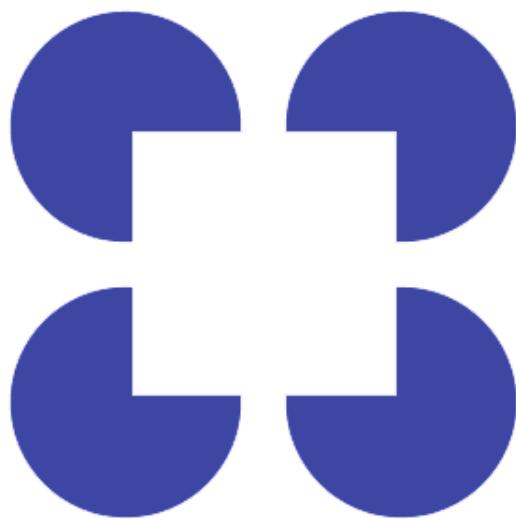
Closure Principle

“elements tend to be grouped together if they are parts of a closed figure”



Gestalt principles, Dejan Todorovic (2008), Scholarpedia, 3(12):5345.
http://www.scholarpedia.org/article/Gestalt_principles





Past Experience Principle

“elements tend to be grouped together if they were together often in the past experience of the observer”

minimum

(a)

minimum

(c)

minimum

(e)

minimum

(b)

mininnum

(d)

mininnum

(f)

minimum

(a)

minimum

(b)

minimum

(c)

n i n i n u n

(d)

minimum

(e)

minimum

(f)

Connectedness Principle

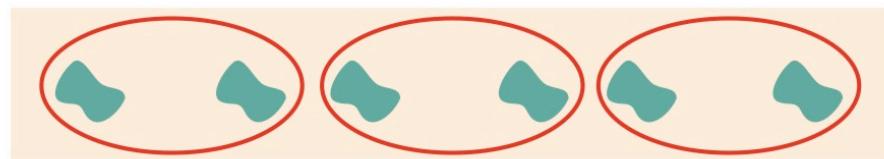
“elements tend to be grouped together if they are connected by other elements”



(a)



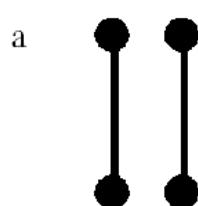
(b)



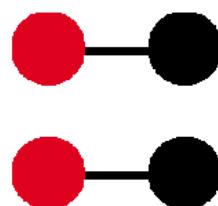
(a)



(b)



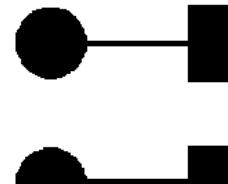
a



b



c



d

Confounding Gestalt Principles

Remember the Gestalt principles are tendencies rather than strict rules

- The '*ceteris paribus*' (all other things being equal) clause

Confounding Gestalt principles lessens the effect of any individual principle

There is not an agreed ordering of Gestalt principles

Gestalt principles, Dejan Todorovic (2008), Scholarpedia, 3(12):5345.
http://www.scholarpedia.org/article/Gestalt_principles

Confounding Gestalt Principles



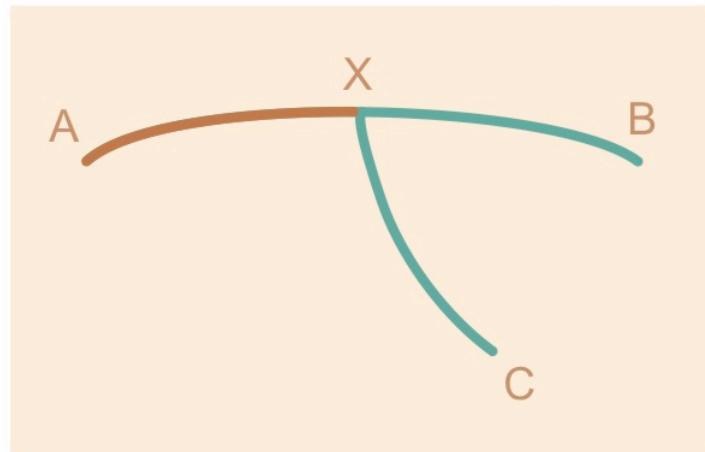
(g)



(h)

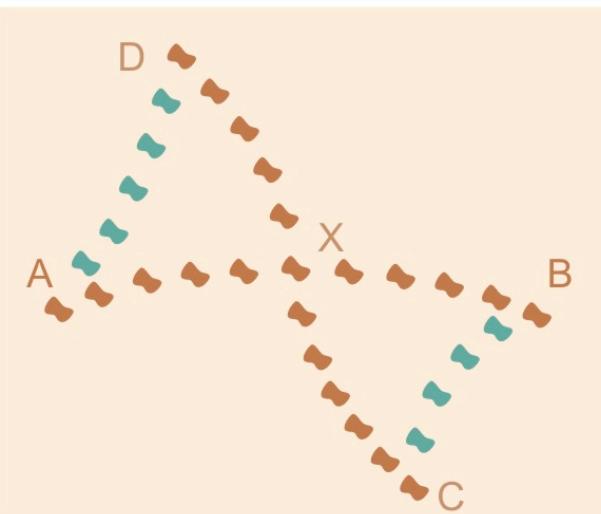
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Confounding Gestalt Principles



Gestalt principles, Dejan Todorovic (2008), Scholarpedia, 3(12):5345.
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Confounding Gestalt Principles



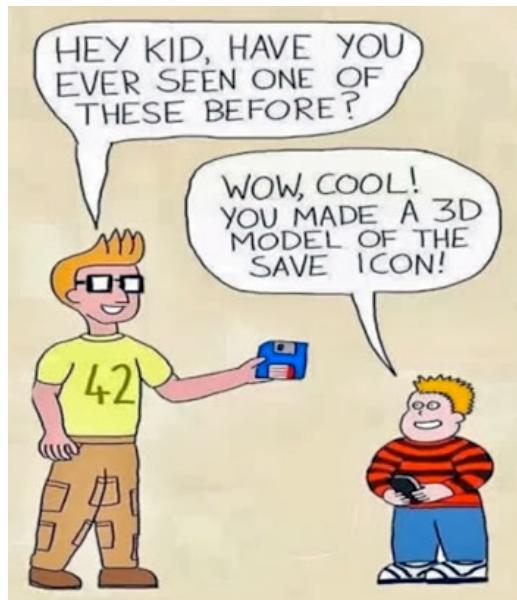
Gestalt principles, Dejan Todorovic (2008), Scholarpedia, 3(12):5345.
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Gestalt Principles

The principles of Gestalt offer an insight into the ways in which people organise visual stimuli

By remaining cogniscent of these principles we can harness people's natural tendencies to design more effective visualisations

SEMIOTICS



via Programming Geeks
<https://plus.google.com/+GeeksfunBlogspot/posts/SaacofYh8Dh>

Definitions



"It is... possible to conceive of a science which studies the role of signs as part of social life. It would form part of social psychology, and hence of general psychology. We shall call it semiology (from the Greek *semeîon*, 'sign'). It would investigate the nature of signs and the laws governing them. "

- Ferdinand de Saussure, 1916

Semiotics for Beginners, Daniel Chandler
<http://visual-memory.co.uk/daniel/Documents/S4B/>

Definitions



"semiotics is concerned with everything that can be taken as a sign"

- Umberto Eco, 1976

Semiotics for Beginners, Daniel Chandler
<http://visual-memory.co.uk/daniel/Documents/S4B/>

Definitions



Semiotics embraces semantics, along with the other traditional branches of linguistics:

- semantics: the relationship of signs to what they stand for;
- syntax (or syntax): the formal or structural relations between signs;
- pragmatics: the relation of signs to interpreters

- CW Morris, 1938

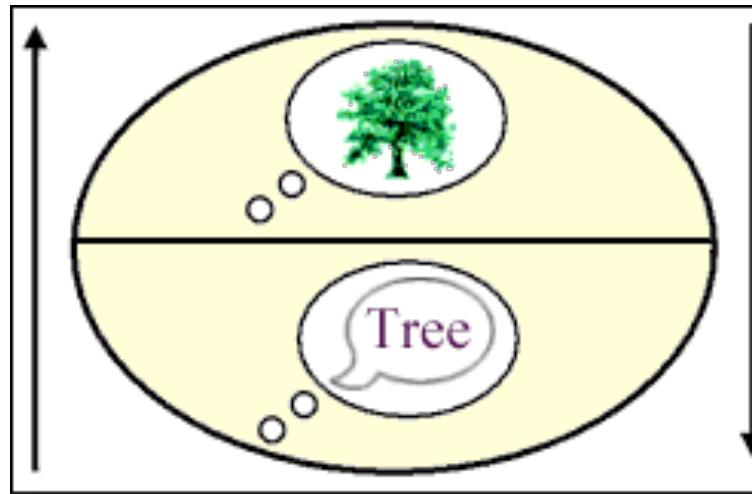
Semiotics for Beginners, Daniel Chandler
<http://visual-memory.co.uk/daniel/Documents/S4B/>

Key Concepts



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Key Concepts

Three key sign modes:

- **Symbol/symbolic:** a mode in which the signifier does *not* resemble the signified but which is fundamentally *arbitrary* or purely conventional - so that the relationship must be learnt
 - e.g. language in general, numbers, morse code, traffic lights, national flags

Key Concepts

Three key sign modes:

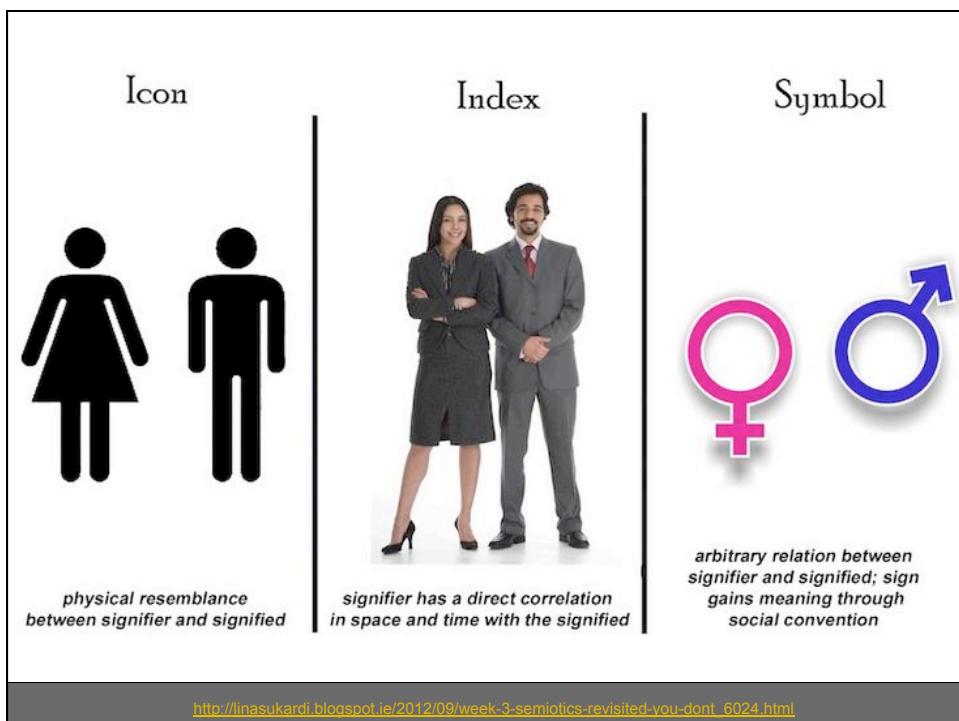
- **Icon/iconic:** a mode in which the signifier is perceived as *resembling* or imitating the signified - being similar in possessing some of its qualities
 - e.g. a portrait, a cartoon, a scale-model, onomatopoeia, metaphors, sound effects in radio drama, imitative gestures

Key Concepts

Three key sign modes:

- **Index/indexical:** a mode in which the signifier is *not arbitrary* but is *directly connected* in some way to the signified - this link can be observed or inferred
 - e.g. 'natural signs' (smoke, thunder, footprints, echoes, non-synthetic odours and flavours), medical symptoms (pain, a rash, pulse-rate), measuring instruments (weathercock, thermometer, clock, spirit-level), pointers (a pointing 'index' finger, a directional signpost)

Semiotics for Beginners, Daniel Chandler
<http://visual-memory.co.uk/daniel/Documents/S4B/>



http://linasukardi.blogspot.ie/2012/09/week-3-semiotics-revisited-you-dont_6024.html

SUMMARY

Summary

Our sense organs are **passive** and **biologically understandable**

Perception is an **active** process that is only somewhat **psychologically understandable**

By using an understanding of how perception works, we can design more effective visualisations