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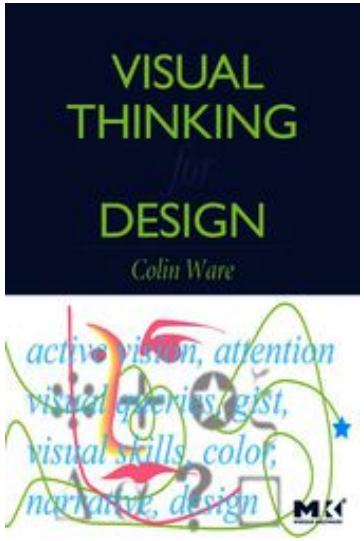
VISUAL DATA ANALYSIS

LECTURE 3

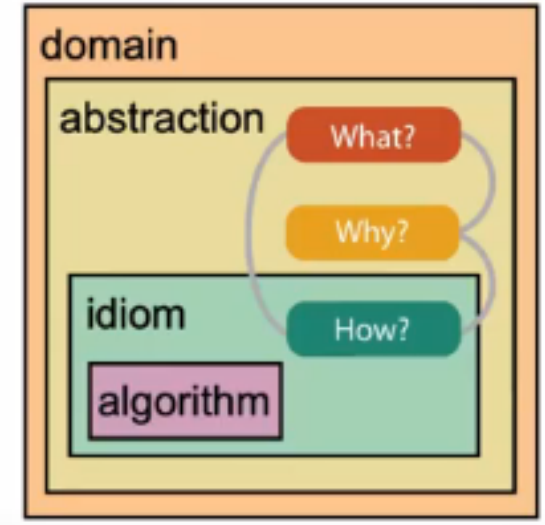
AGENDA



- F1: Introduction
- F2: Information visualization 1
- F3: Human perception and cognition
- F4: Information visualization 2
- F5: Guest lecture - Spotfire
- F6: Human-computer interaction and evaluation of VDA applications

Evaluation

Human-computer interaction



Human perception and cognition

Information visualization

OUTLINE

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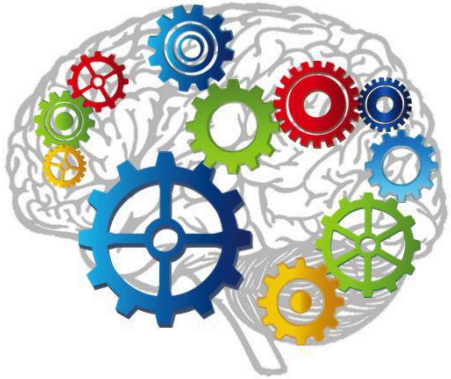
- Perception, cognition and attention – central concepts
- The process of seeing
- Bottom-up vs top-down processing
- Visual queries
- Pop-out effects
- Designing with colours
- Designing relationships and depth



WHAT IS PERCEPTION?

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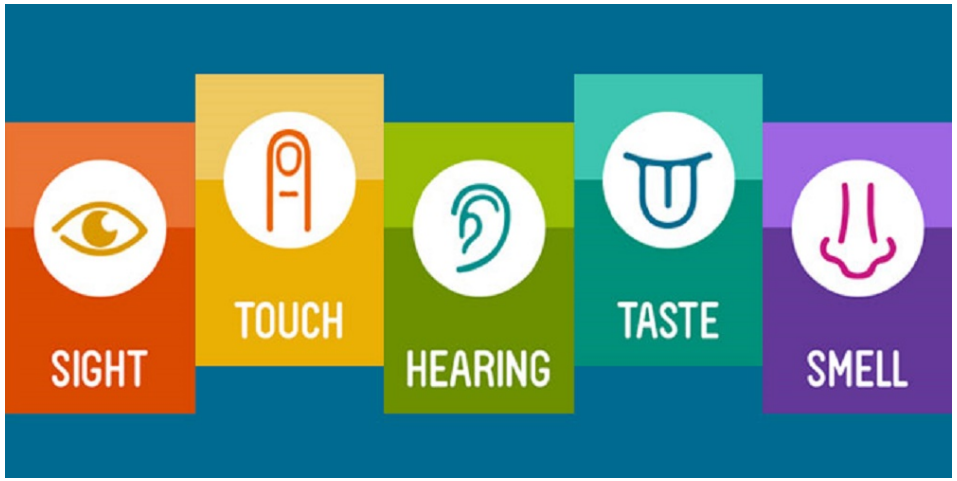
Perception – *"the organization, identification and interpretation of sensory information in order to represent and understand the environment"*
(Schacter, D., 2011)

All perception involves signals in the nervous system, which in turn result from physical or chemical stimulation of the sense organs



WHAT IS COGNITION?

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Cognition – is the set of all mental abilities and processes related to knowledge, attention, memory, reasoning, problem solving, decision making, comprehension, learning etc.

WHAT IS ATTENTION?

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"Everyone knows what attention is. It is the taking possession by the mind, in clear and vivid form, of one out of what may seem several simultaneously possible objects or trains of thought. It implies withdrawal from some things in order to deal effectively with others"

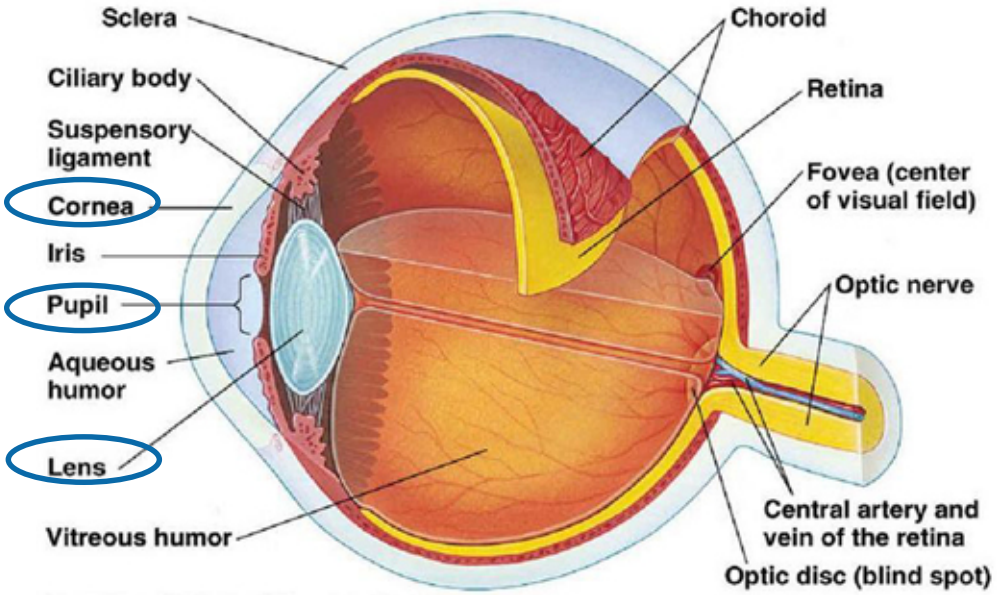
(William James, Principles of Psychology, 1890)

THE PROCESS OF SEEING

Cornea: protects the eye, a lens focusing the light from the surrounding scene onto the main lens.

Pupil: from the cornea, light comes to the pupil, a hole in the iris. The iris can change the size of the pupil opening. Thus the pupil determines how much light will enter the rest of the eye.

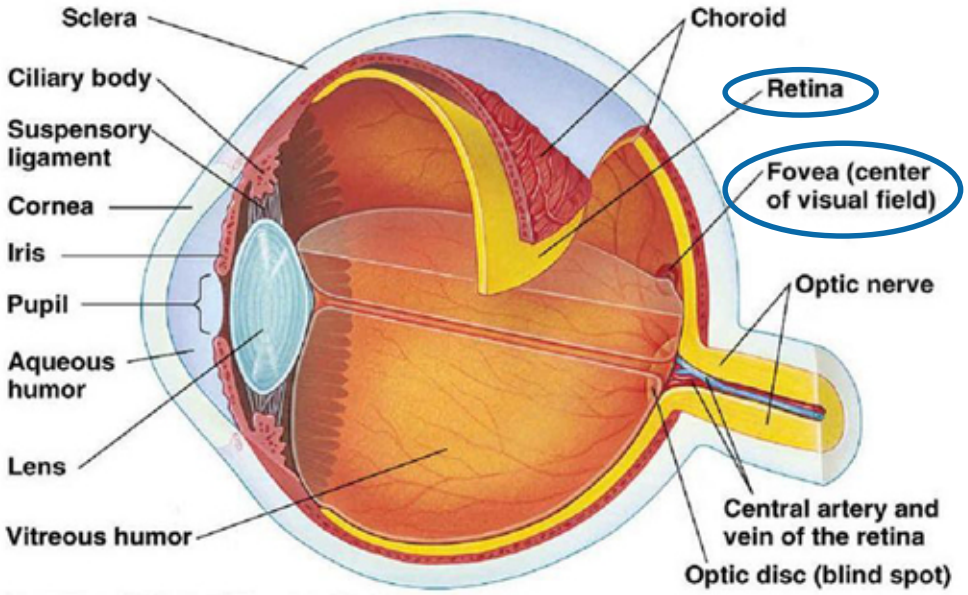
Lens: can be stretched and compressed, i.e. focus on near and relatively far objects.
Light travels from here to the retina



THE PROCESS OF SEEING

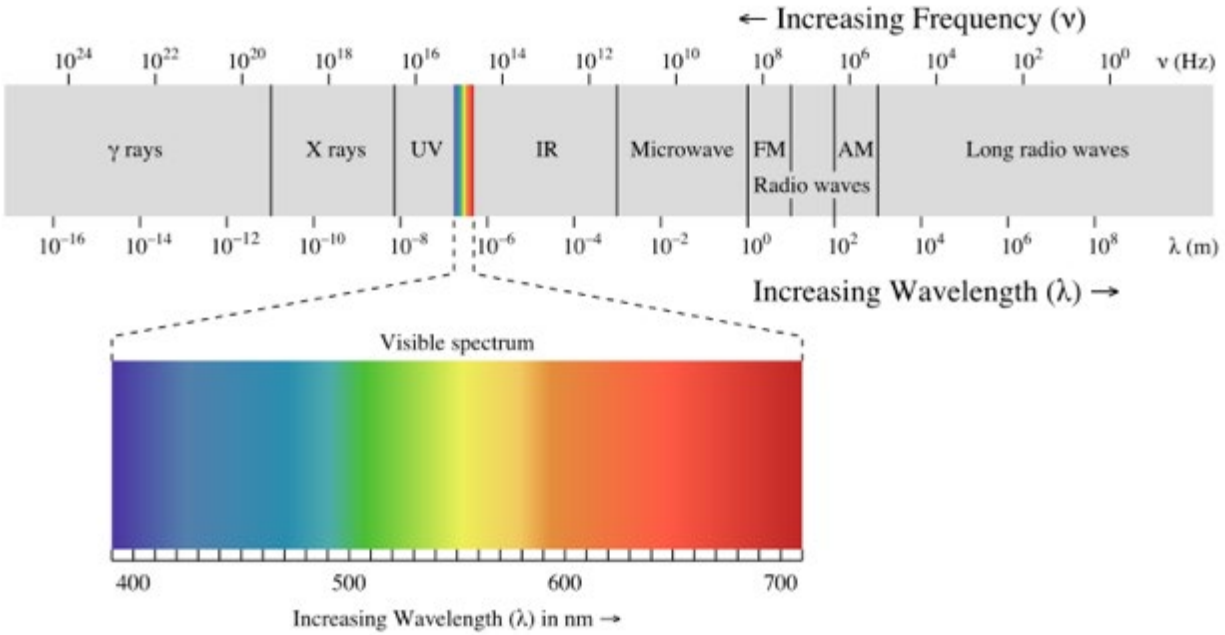
Retina: contains the photoreceptors responsible for the visual perception: rods and cones. These respond differently to light stimulation. Rods are primarily responsible for intensity perception and cones for colour perception.

Fovea: contains only cones and is the region of sharpest vision. Because the human eye contains a limited amount of rods and cones, it can only manage a certain amount of visual information over a given time frame. At the edge of the visual field, the vision is terrible



THE PROCESS OF SEEING

- Visible light: the light waves that are capable of being perceived by human eyes.
- Represents a very small section on the electromagnetic spectrum: from near ultraviolet toward the infrared.
- The range is much dependent on the individual and generally shrinks in size after the age of 20.
- Colour blindness and total blindness are the result of an individual not responding to certain wavelengths (about 8% male, 0,5 % female - colour deficient).



Tove Helldin, tove.helldin@his.se
Spring 2021

THE ACT OF PERCEPTION

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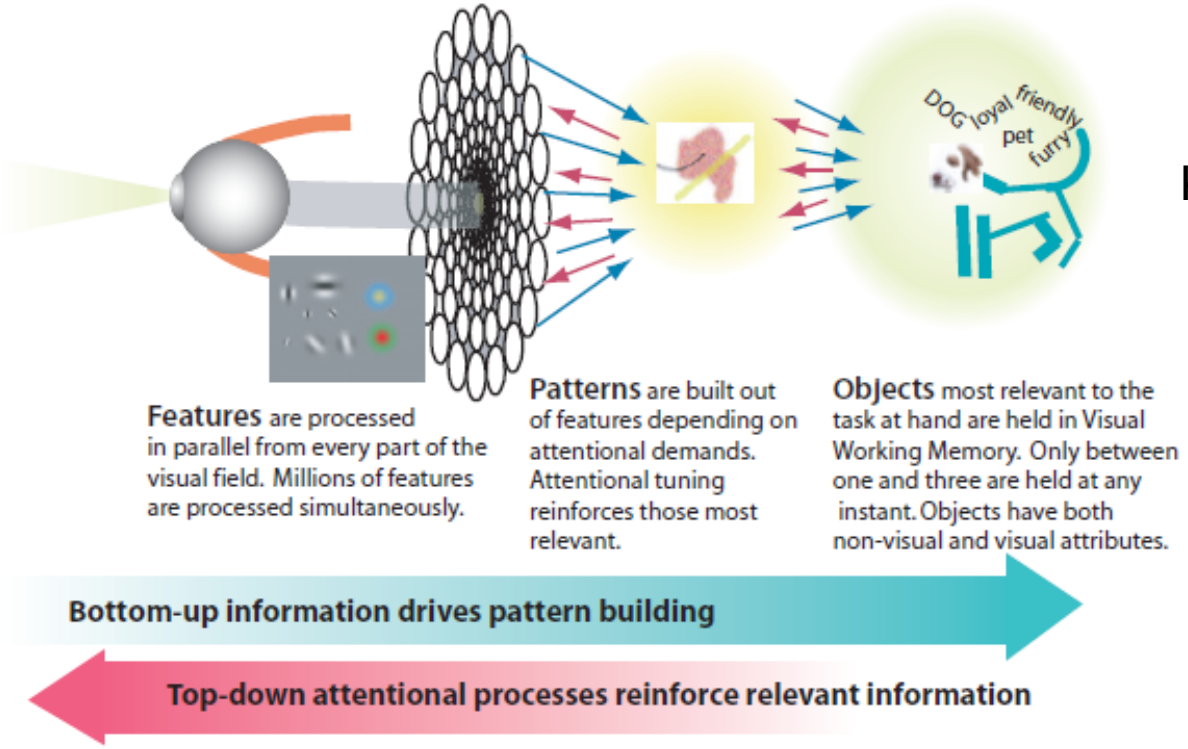
- A visual object –we bind features from the outside world together with things we already know.
- When we look at something, ~ 95% of what we consciously perceive is not what is out there, but what is already in our heads in long term memory.
- Recognizing an object can cause both physical and cognitive action patterns to be primed, facilitating future neural activation sequences.
- Visual working memory (or short term memory) has a very limited capacity → can critically influence how well a design works

THE ACT OF PERCEPTION

The act of perception is determined by two kinds of processes:

- Bottom-up: driven by the visual information in the pattern of light falling on the retina
- Top-down: driven by the demands of attention

Senses



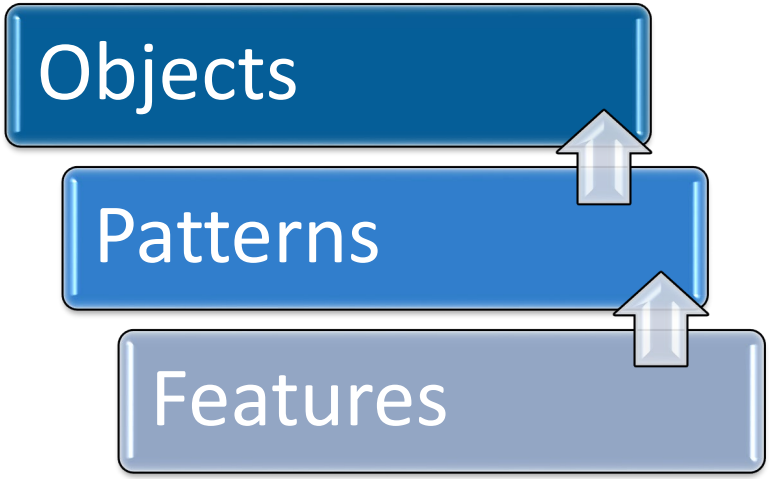
Knowledge

BOTTOM-UP PROCESSING

When stimuli drives the process of perception

Information is successively selected and filtered

1) Features – orientation, size, motion etc.
2) Patterns – regions with common textures, colours are created. Space is organized with linked/segregated objects (Gestalt laws).
3) Objects – the features and patterns build visual objects.



BOTTOM-UP PROCESSING

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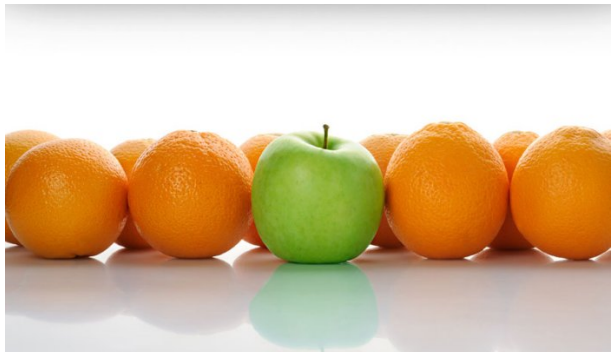
If we see a dog – we extract features and bind that with general knowledge that we have about dogs (and we prepare our actions)

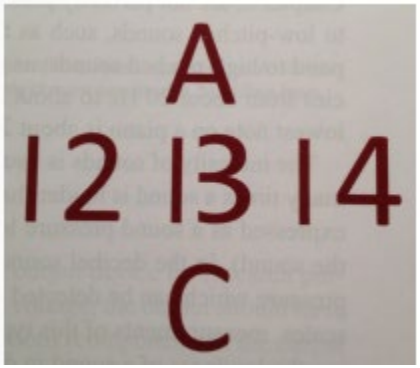
→ This binding of visual information with non-visual concepts and action priming is central to what it means to perceive something

TOP-DOWN PROCESSING

When earlier knowledge/experience/information/context affects our perception

→ top-down attention biases which signals we are looking for

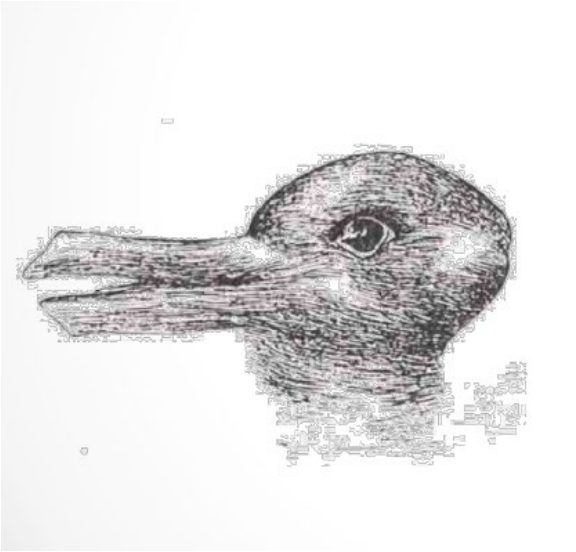




- Is driven by our need to accomplish some goal (i.e. understanding a diagram, finding something)
- We constantly link/re-link visual information with non-visual information
- Constant priming of actions

HUMAN PERCEPTION

Perception – interpretation



HUMAN PERCEPTION

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HUMAN PERCEPTION

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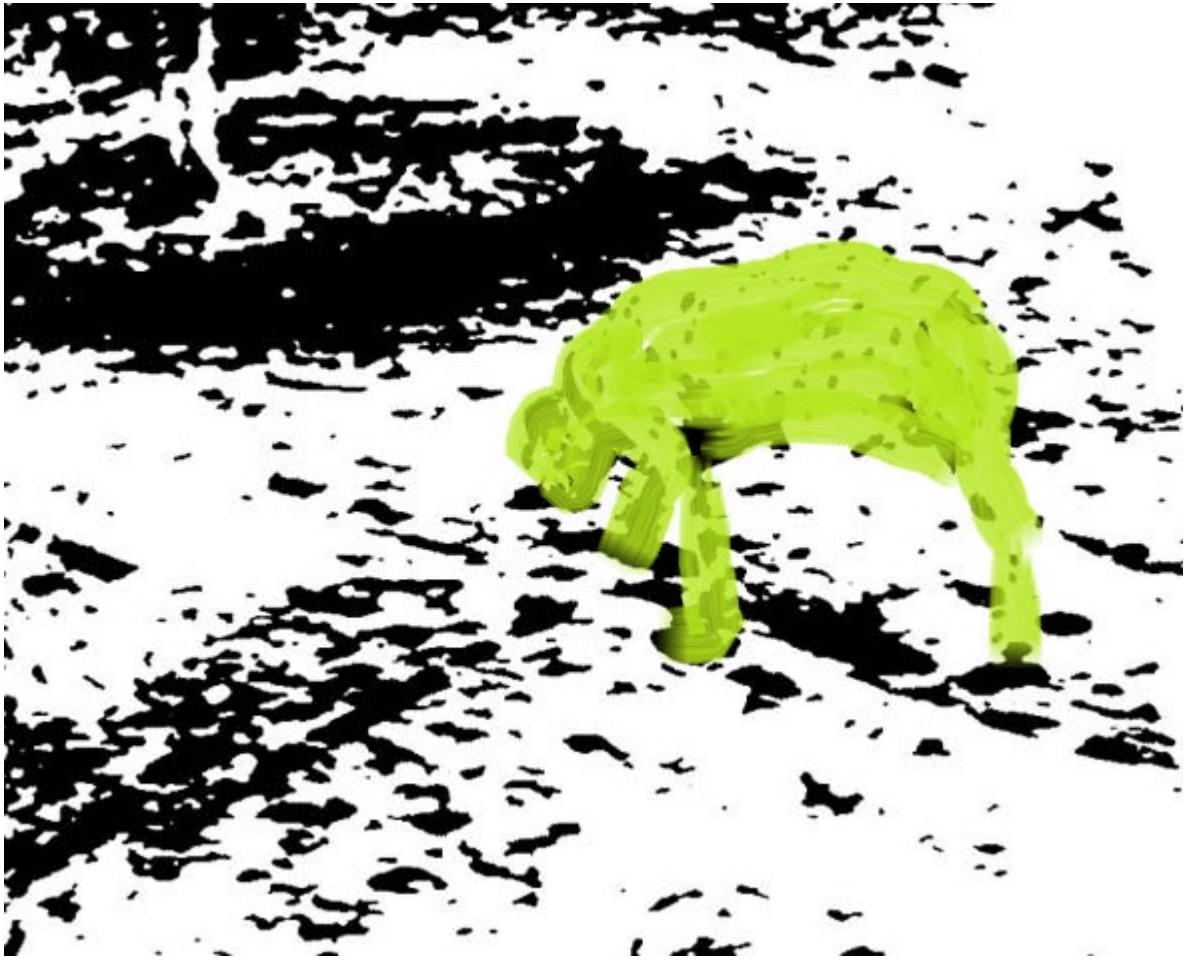

MEMORY

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Short term memory

- Very limited capacity, we store information only shortly.
- Chunking: organization of material into shorter, meaningful groups to make them more manageable
- 7+/- 2 meaningful chunks according to Miller's law (1956), even fewer by other researchers.
- Information can easily disappear if one is interrupted.

Long term memory

- Storage of information over a long period of time
- Short term memories can become long-term memories, involving rehearsal and meaningful association
- Recognition is easier than recall!
    - Recall – slow, needs effort: What did you eat yesterday?
    - Recognition – quick and easy: Did you eat pasta yesterday?

VISUAL THINKING AND VISUAL QUERIES

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"Visual thinking consists of a series of acts of attention, driving eye movements and tuning our pattern-finding circuits. These acts of attention are called visual queries."
(Ware, 2008, p.3)

Constructing and executing a visual query

1) Identification of problem components based on visual patterns
2) The low level visual system is tuned to be sensitive to the query pattern. Extracted features are weighed according to the query pattern. A visual scanning strategy is activated based on prior knowledge, display cores and the task.
3) We move our eyes to the likely locations of targets.
4) Patterns and objects are formed.

DESIGN FOR VISUAL QUERIES

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We must design displays so that visual queries are processed both rapidly and correctly for every important cognitive task the display is intended to support.

- We must understand the cognitive tasks and visual queries a graphic is intended to support

  → Start with a visual task analysis, determine the sets of visual queries to be supported by a design, and then use colour, form and space to efficiently serve those queries

GOOD DESIGN?

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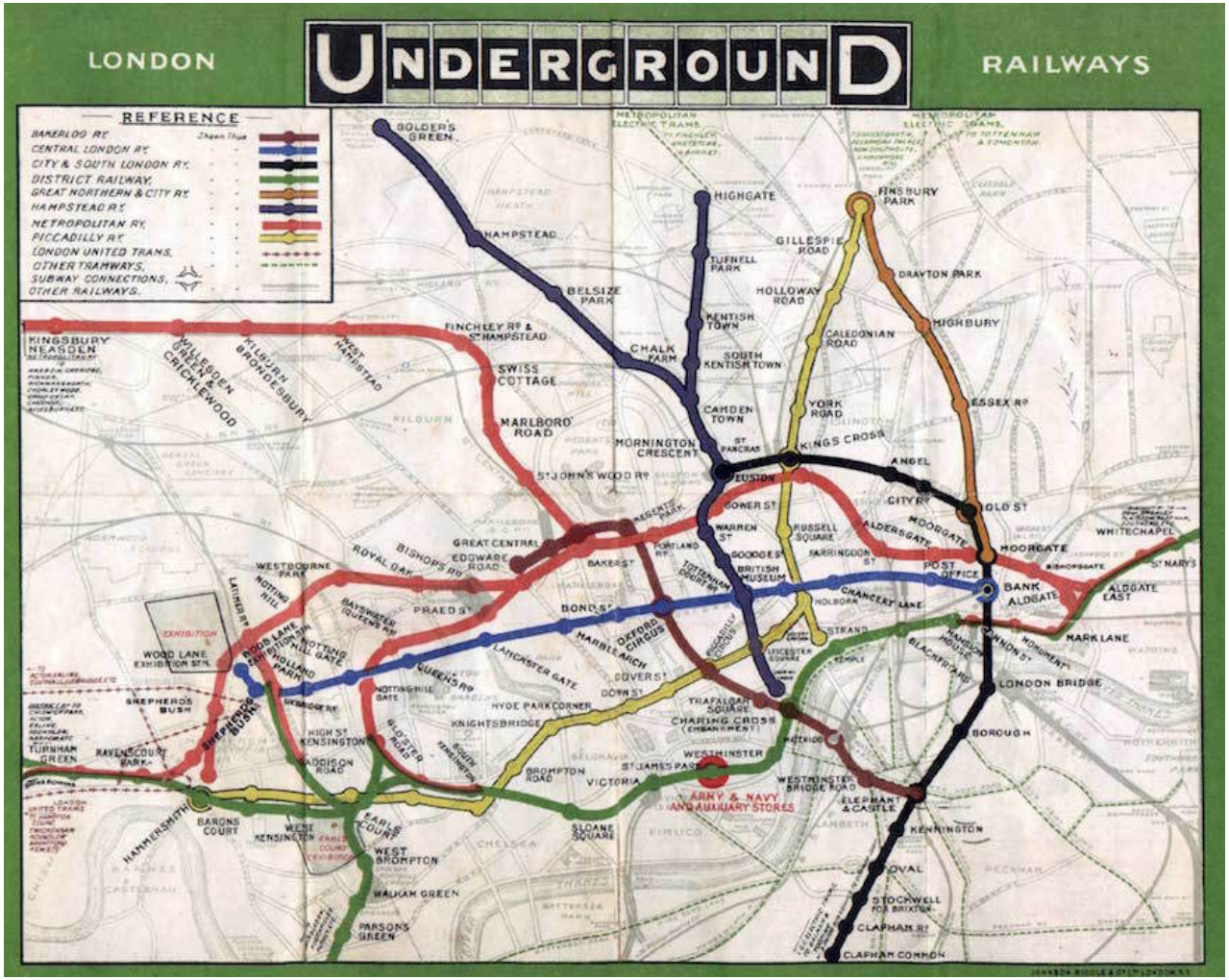
GOOD DESIGN?


LONDON
UNDERGROUND
RAILWAYS
REFERENCE
BAKERLOO RY.
CENTRAL LONDON RY.
CITY & SOUTH LONDON RY.
DISTRICT RAILWAY.
GREAT NORTHERN & CITY RY.
HAMPSTEAD RY.
METROPOLITAN RY.
PICCADILLY RY.
LONDON UNITED TRAMS.
OTHER TRAMWAYS.
SUBWAY CONNECTIONS.
OTHER RAILWAYS.
GOLDERS GREEN
HAMPSTEAD
HIGHGATE
FINSBURY PARK
GILLESPIE ROAD
TUFNELL PARK
DRAYTON PARK
HOLLOWAY ROAD
BELSIZE PARK
KENTISH TOWN
HIGHBURY
CALEDONIAN ROAD
KINGSBURY NEASDEN
WILLESDEN GREEN
CRICKLEWOOD
KILBURN
BRONDESBURY
WEST HAMPSTEAD
FINCHLEY RD & ST JOHNS WOOD
CHALK FARM
SOUTH KENTISH TOWN
SWISS COTTAGE
CAMDEN TOWN
YORK ROAD
ESSEX RD
MARLBORO' ROAD
MORNINGTON CRESCENT
ST PANCRAS
KINGS CROSS
ANGEL
ST JOHN'S WOOD RD
EUSTON
CITY RD
OLD ST
GOWER ST
WARREN ST
RUSSELL SQUARE
ALDERSGATE
MOORGATE
WHITECHAPEL
GREAT CENTRAL
EDGWARE ROAD
BAKER ST
PORTLAND RD
GOODGE ST
BRITISH MUSEUM
POST OFFICE
BANK
ALDGATE
ALDGATE EAST
WESTBOURNE PARK
ROYAL OAK
BISHOPS RD
PRAED ST
BOND ST
OXFORD CIRCUS
HOLBORN
CHANCERY LANE
STRAND
MARK LANE
WOOD LANE
EXHIBITION
LADBROKE GROVE
NOTTING HILL GATE
HOLLAND PARK
QUEENSWAY
LANCASTER GATE
COVENT GARDEN
LONDON BRIDGE
SHEPHERDS BUSH
HYDE PARK CORNER
TRAFALGAR SQUARE
CHARING CROSS
KNIGHTSBRIDGE
BOROUGH
TURNHAM GREEN
RAVENSCOURT PARK
HIGH ST KENSINGTON
ADDISON ROAD
WESTMINSTER
BROMPTON ROAD
ST JAMES'S PARK
VICTORIA
ARMY & NAVY
AND AUXILIARY STORES
HAMMERSMITH
BARONS COURT
WEST KENSINGTON
EARLS COURT
WEST BROMPTON
SLOANE SQUARE
ELEPHANT & CASTLE
KENNINGTON
OVAL
WALHAM GREEN
PARSONS GREEN
STOCKWELL
CLAPHAM RD
CLAPHAM COMMON

BAD DESIGN?

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HOW TO SUPPORT VISUAL QUERIES?

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The most important and frequent visual queries should be supported with the most visually distinct objects. The perceptual laws of visual distinctness are based on the low-level early-stage processing in the visual system.

ehklhfdiyaiorywekIblkhockxlyhirhupwerlkhlkuyxoiasusifdh
lksajdhflkihqdaklljerlajesljselusdslfjsalsuslcjlsdsjaf;ljdulafjluj
oufojrtopjhklghqlkshlkfhlkdshflymcvciwopzlsifhrmckreieui

The two p's have been highlighted – easy to find since they pop out.
It is more difficult to find the two q's…

HOW TO SUPPORT VISUAL QUERIES?

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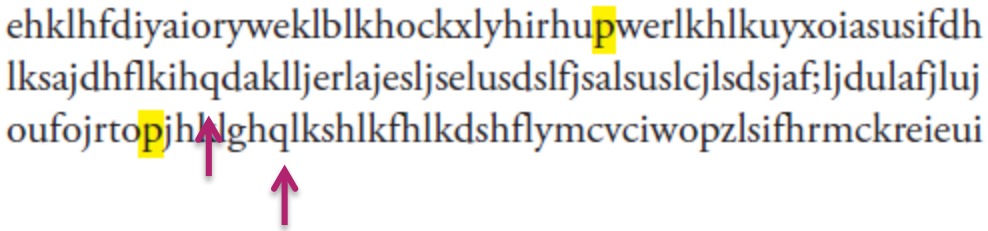

The two p's have been highlighted – easy to find since they pop out.
It is more difficult to find the two q's…

POP-OUT EFFECTS

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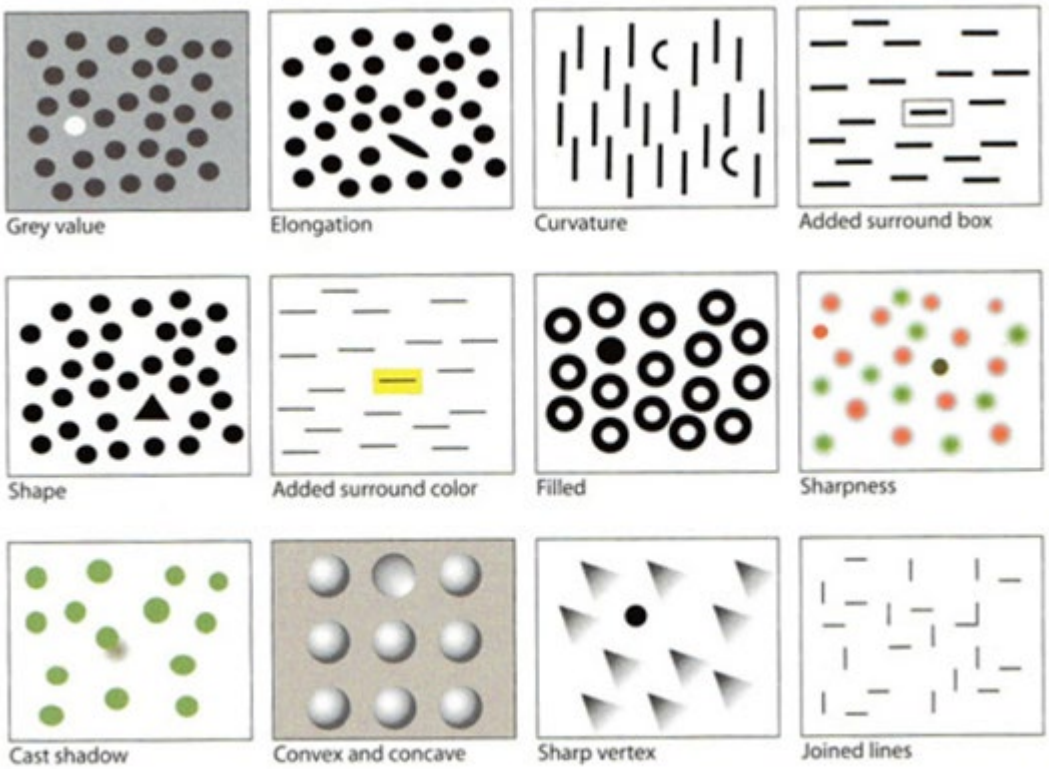
Strong pop-out effect
- When a single target differs in some features from all other objects
- Where the other objects are identical (or similar to each other)
- Where the surrounding environment makes it easy to detect the targets

To achieve a pop-out effect use
- Colours
- Shapes
- Textures
- Motion
- Stereoscopic depth



WHAT DOES NOT STAND OUT?

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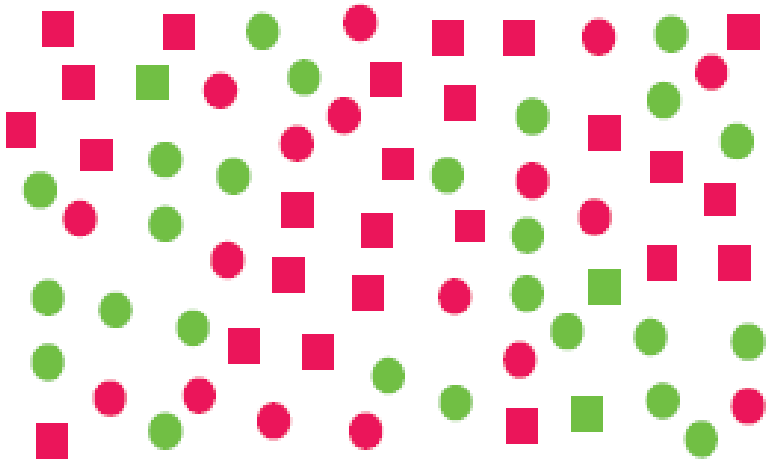
Where are the three green squares?

- These do not pop-out even though you know what to look for.

Why?

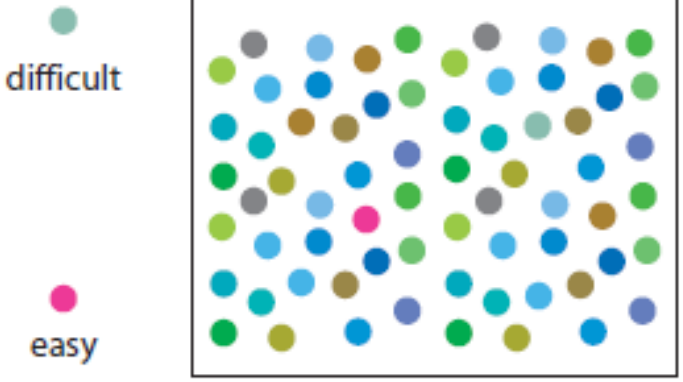
We can either tune our search for square shapes, or the green things, but not both.

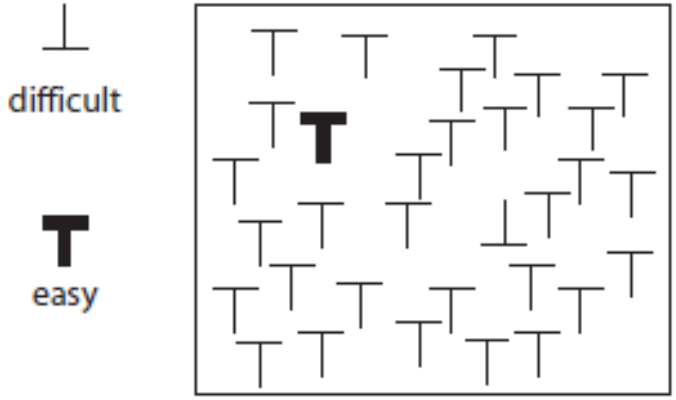


POP-OUT EFFECTS

To achieve a pop-out effect, the low-level feature **differences** must be **sufficiently large**, and the **background** must support the feature detection

Use **different feature channels** (i.e. colours, size…) if you want to make several things be easily searchable at the same time



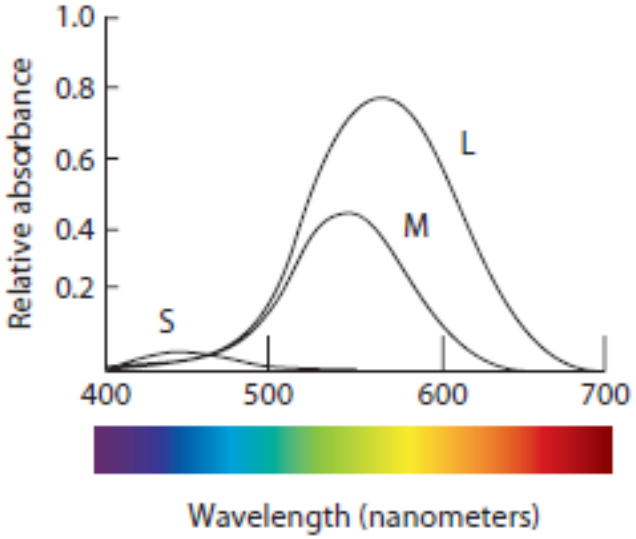


COLOUR

There are two basic types of light receptors in the retina:

Rods: the most numerous type, are specialized for very low light levels
Cones: basis for normal, daytime vision. Comes in three subtypes:

- Long wavelength (red)
- Medium wavelength (green)
- Short wavelength (blue, the least light sensitive)

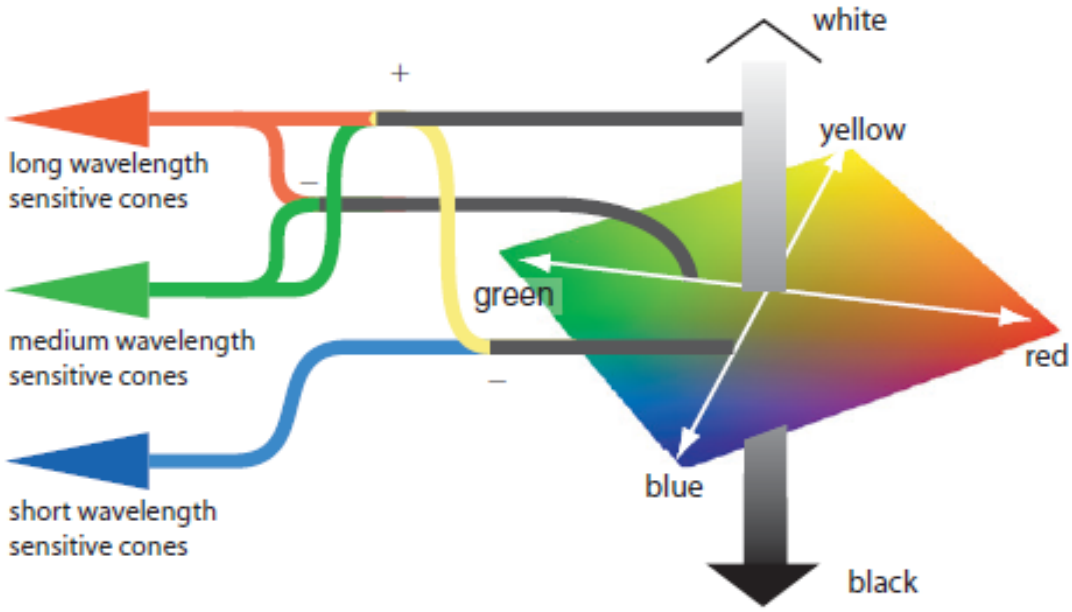


OPPONENT PROCESS THEORY

We are very sensitive to **contrasts** in the following three channels:

- Red-green
- Yellow-blue
- Black-white

Use these contrasts when designing: object vs background

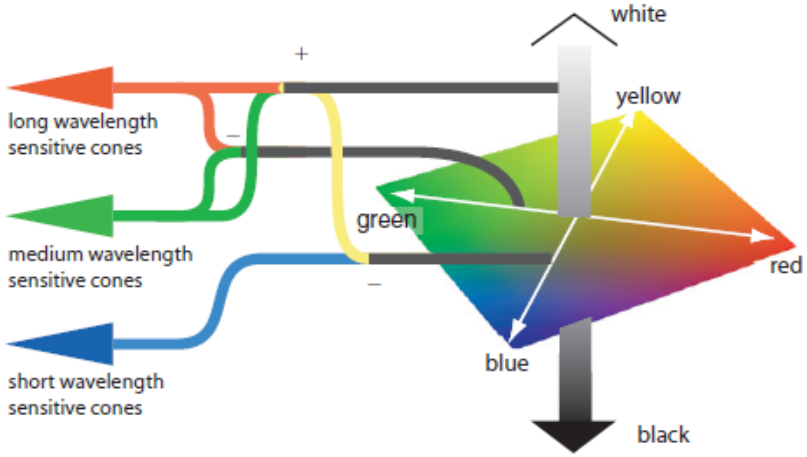


CONTRASTS

How to use the contrasts?
For example, do not show text/details using

- Blue on a black background
- Yellow on a white background

since there is too little luminance contrast



Showing small blue text on a black background is a bad idea.
There is insufficient luminance contrast.

Showing small blue text on a black background is a bad idea.
There is insufficient luminance contrast.

Showing small yellow text on a white background is a bad idea.
There is insufficient luminance contrast.

Showing small yellow text on a white background is a bad idea.
There is insufficient luminance contrast.

CONTRASTS

Chromatic contrast (red-green and yellow-blue channels)

- More difficult than grey-scale contrast, i.e. it is easier to see details in black and white figures than in chromatic figures

Note also that colours are changed in appearance by adjacent colours….

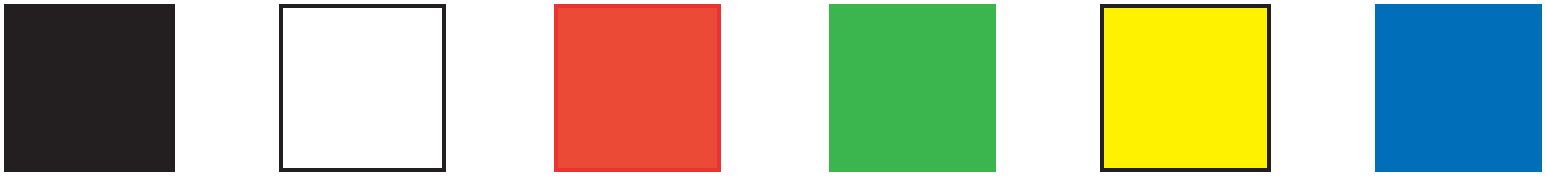
same shade…

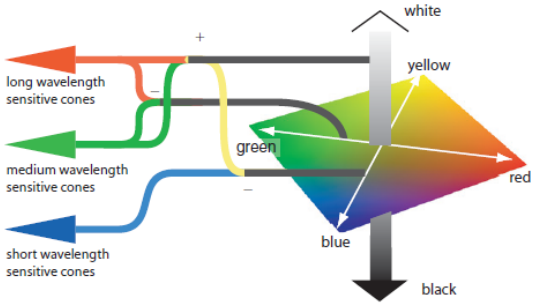
same hue…

COLOURS – UNIQUE HUES

Unique hues – these colours are special

→ There is a strong signal on one of the channels and a neutral signal on the other two channels





TEST
WHICH COLOURS DO YOU SEE?

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Try to name the colour of which the text is painted.

TEST
WHICH COLOURS DO YOU SEE?

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BLACK

GREEN

WHITE

YELLOW

RED

TEST
WHICH COLOURS DO YOU SEE?

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BLACK

GREEN

WHITE

YELLOW

RED

TEST
WHICH COLOURS DO YOU SEE?

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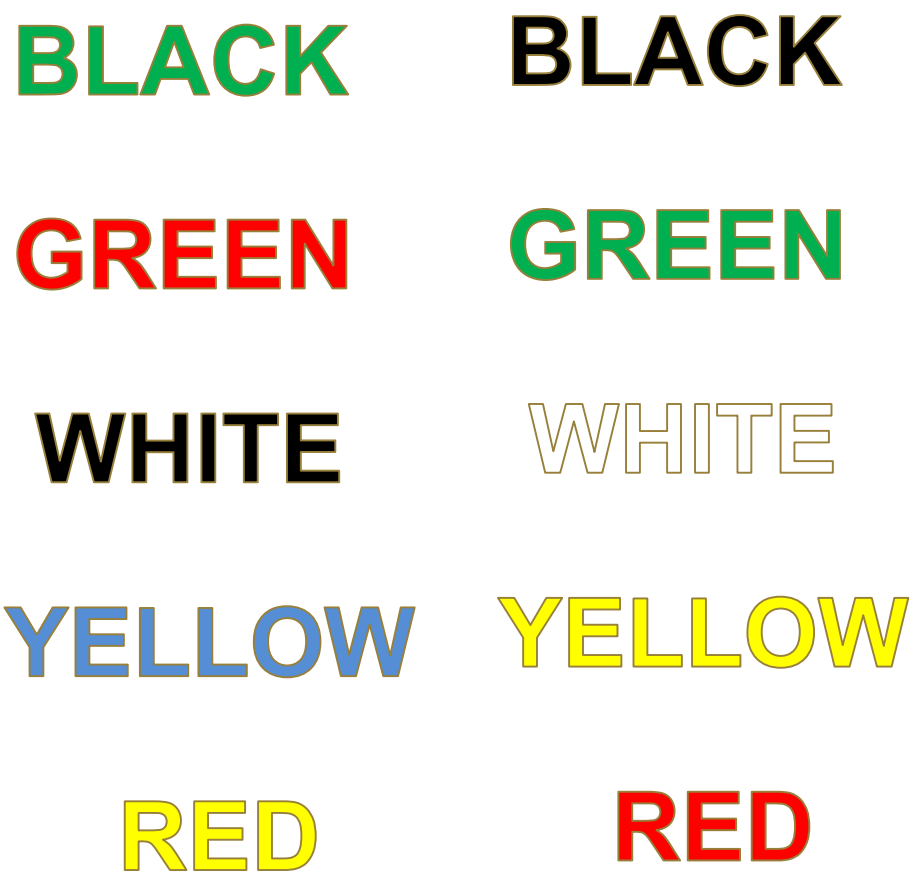
Stroop effect

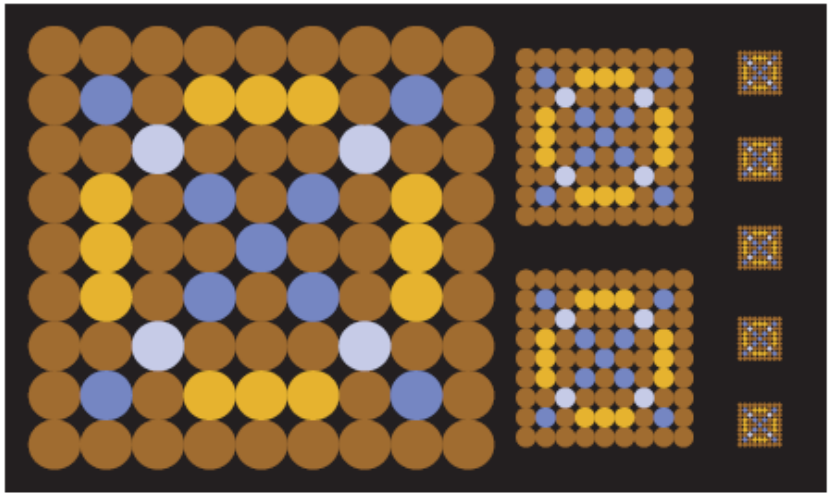
When the name of the colour is printed in a colour not denoted by the name, naming the colour of the word takes longer and is more prone to errors than if there had been a match.



DESIGN WITH COLOURS

Whenever detailed information is to be shown
→ Luminance (light) contrast is necessary

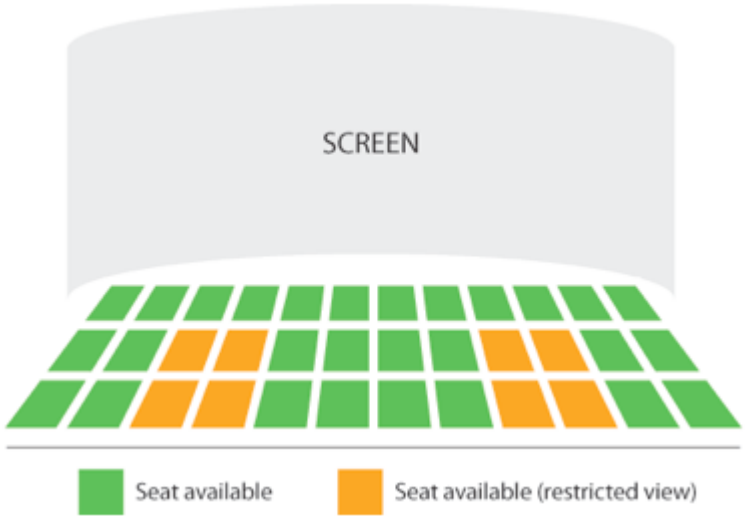
- As graphical features get larger, need for extreme luminance contrast declines
- Luminance contrast is especially critical for small text

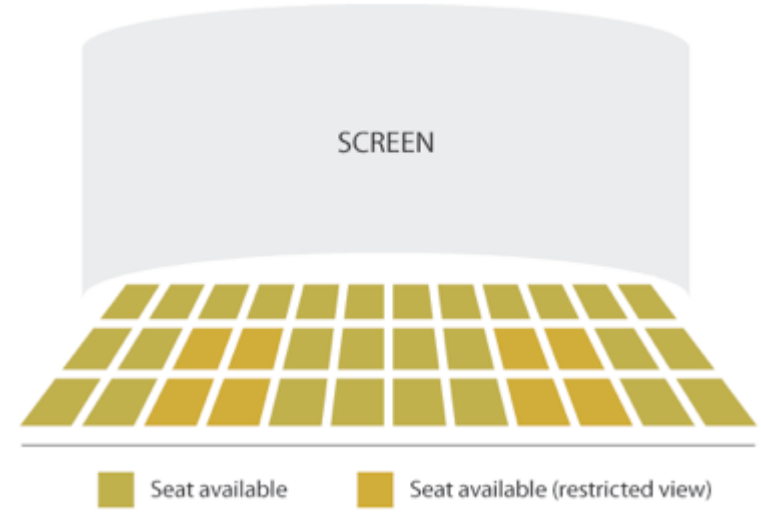


Large picture: colours most salient

Small picture: luminance values dominate – the pattern 0 becomes the most distinct feature

DESIGN WITH COLOURS





Dichromats with *protanopia* (ca 1% of men and 0.01% of women) have absent or non-functioning L cones. As a result, they see reds, oranges and yellows as shifted towards green, and as being less bright than people with normal colour vision. This makes it hard to distinguish between these colours.

COLOUR SEMANTICS

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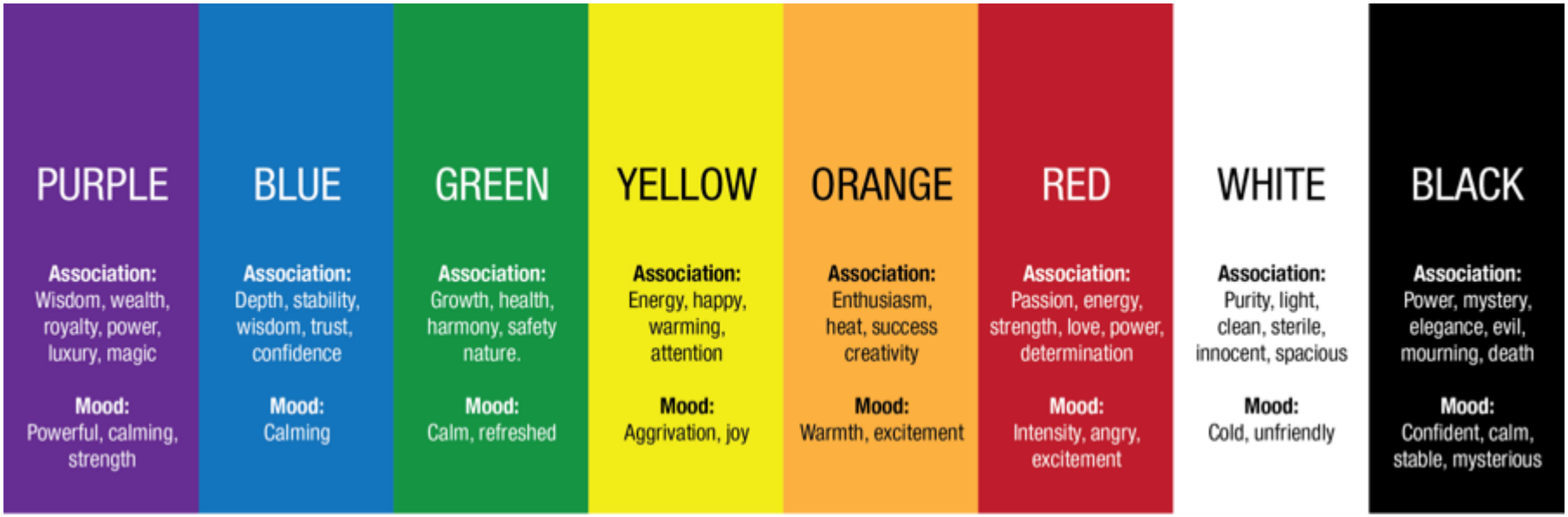
Colours have different meanings in different cultures
For example, in China, red is used to symbolize good fortune and renewal, and white is the colour of death/mourning



DESIGN WITH COLOURS SUMMARY

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- Use colour codes for visual distinctness – support visual search operations!
- Luminance (light) contrast is necessary for details
- Use first and foremost signal colours
  - Limit the amount of colours depending on the design, size, background
- Make sure to design for people who have different colour vision
  - The most common problem is red-green (around 8% male, 0,5% women)
- Use standard colour conventions (but be careful!)

http://www.ted.com/talks/beau_lotto_optical_illusions_show_how_we_see#t-579540

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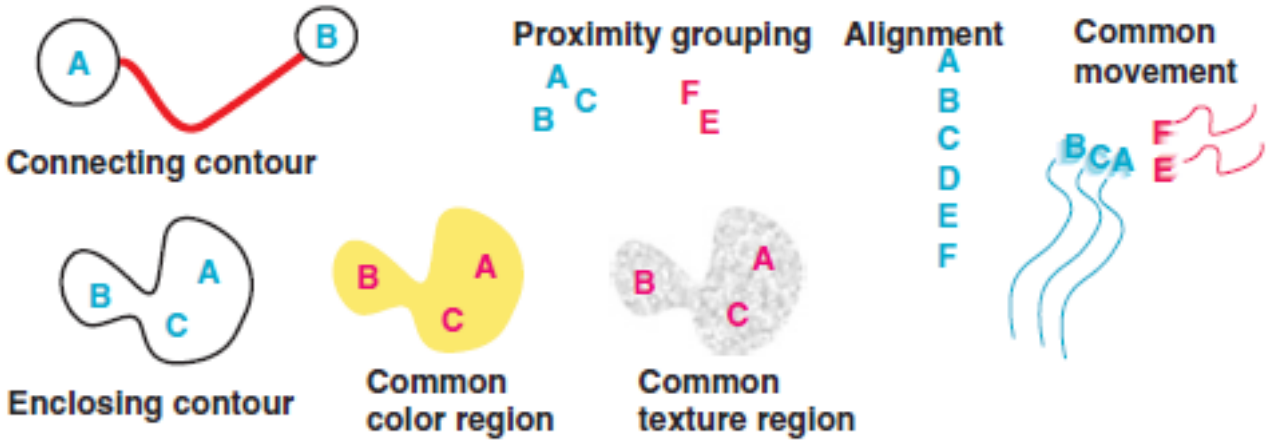
DESIGN OBJECT RELATIONSHIPS AND DEPTH

DESIGN OBJECT RELATIONSHIPS

Depicting relationships: both **learned** and enforced by **design**

Relationships can be established through basic **pattern-defining** mechanisms:

- Connecting contours
- Proximity
- Alignment
- Enclosing contour
- Colour
- Texture
- Common movement
- …



GESTALT PRINCIPLES

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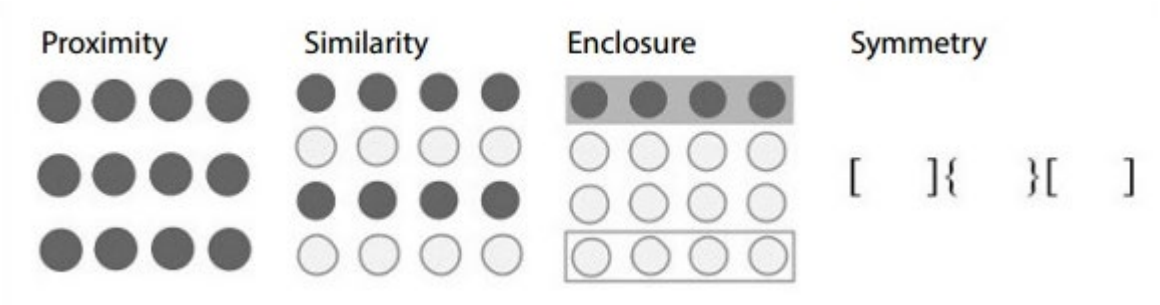
Proximity: we see three rows of dots instead of four columns of dots because they are closer horizontally than vertically

Similarity: we see similar looking objects as part of the same group

Enclosure: we group the first four and last four dots as two rows instead of eight dots

Symmetry: we see three pairs of symmetrical brackets rather than six individual brackets



GESTALT PRINCIPLES

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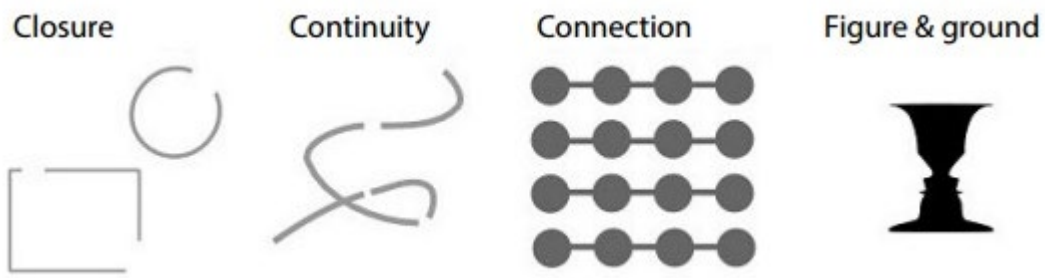
Closure: We automatically close the square and the circle instead of seeing three disconnected paths

Continuity: we see one continuous path instead of four arbitrary ones

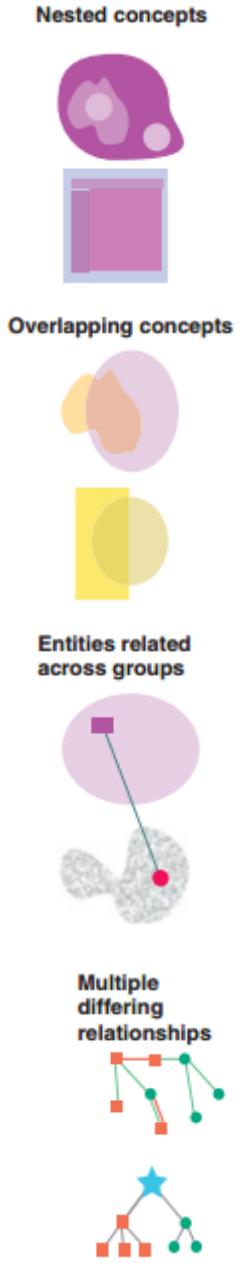
Connection: we group the connected dots as belonging to the same group

Figure and ground: we either notice the two faces, or the vase. Whichever we notice becomes the figure and the other the ground



DESIGN OBJECT RELATIONSHIPS

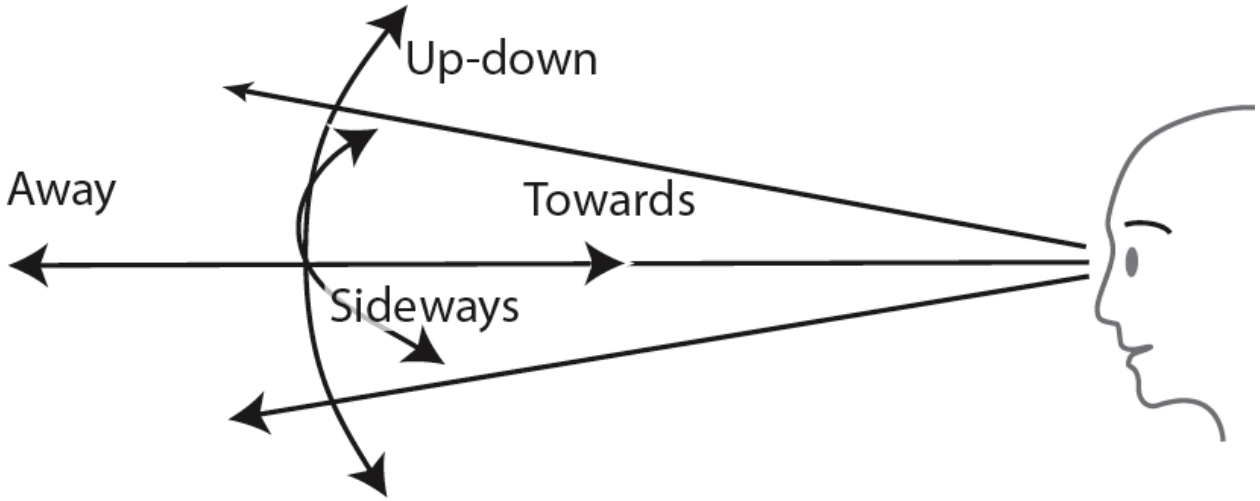
Graphical Code	Semantics
Shapes connected by contour.	Related entities, path between entities.
Thickness of connecting contour.	Strength of relationship.
Color and texture of connecting contour.	Type of relationship.
Shapes enclosed by a contour, or a common texture, or a common color.	Contained entities. Related entities.
Nested regions, partitioned regions.	Hierarchical concepts.
Attached shapes.	Parts of a conceptual structure.



DEPTH VISUALIZATION

Our perception is sometimes called a 2,5 dimensional phenomenon

- Up and sideways – directly available from the image on the retina
- Towards and away – much less information here!



DEPTH VISUALIZATION

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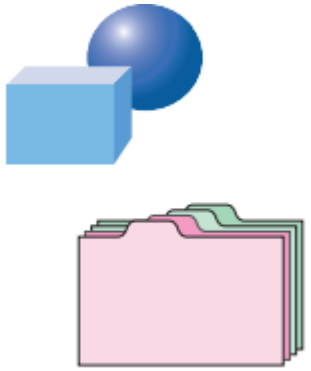
Depth can be depicted through

- **Occlusion:** objects near to us visually block objects farther away
- **Perspective:** more distant objects are smaller on the picture plane than those nearby
- **Perspective:** reduction in size and increase in density of texture elements with distance



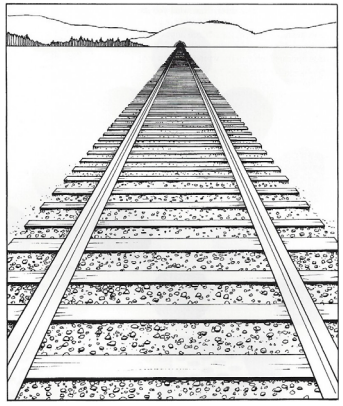
DEPTH VISUALIZATION

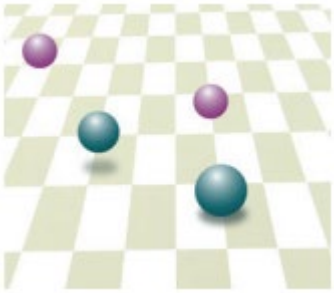
Our perception is sometimes called a 2,5 dimensional phenomenon

- Up and sideways – directly available from the image on the retina
- Towards and away – much less information here!

Depth can be depicted through

- **Linear perspective:** projections of parallel lines converge on the picture plane
- **Cast shadows:** shadow cast by one object on another provides information regarding the distance between them
- **Height on the picture plane:** objects higher up on the visual field are generally farther away





WHAT TO THINK ABOUT DURING DESIGN?

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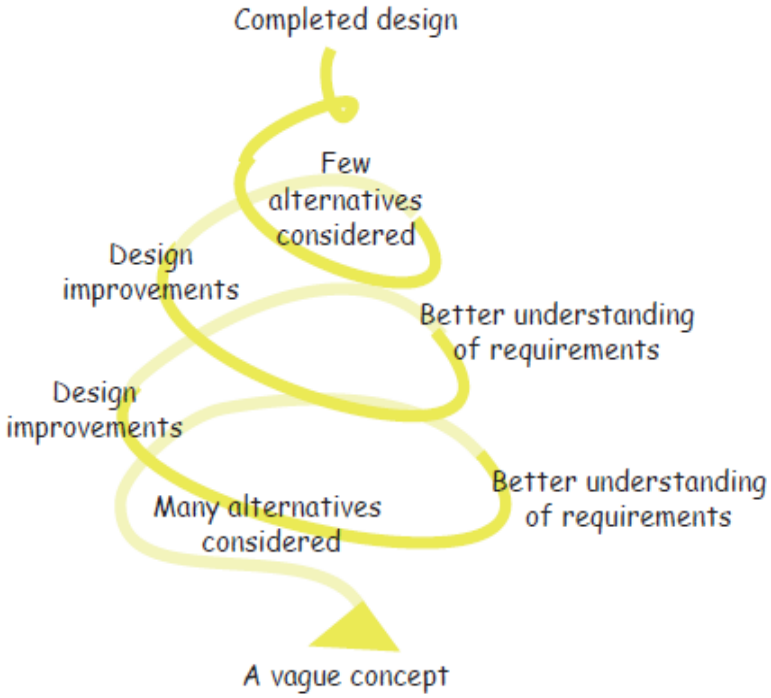
Understand the requirements of the design and the problem to be solved

→ Visual task analysis
Identify the cognitive tasks that must be supported by a design

→ Break these down to formulate a set of visual queries that will be executed by an individual in performing a cognitive task with the product

→ Presentation of early, and iterative design solutions



WHAT TO THINK ABOUT DURING DESIGN?

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- Enable/support both our top-down and bottom-up processes
- Don’t make the user remember everything!
- Design for visual queries
  - pop-out effects
  - colour, contrast, colour semantics
  - object relationships, depth

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QUESTIONS?

COURSE TIMELINE

DEADLINES AND PRESENTATIONS