

Human Visual System

What we can't see

Your first test: test_One

You will see a movie of two teams of students playing with two basketballs.

One team is wearing white t-shirts, one wearing black t-shirts.

Your task:

Count how many times the white team passes the ball during the movie.

Daniel Simons, The Monkey Business Illusion

QI S13 E9 23 mins and 5 seconds.

The Eye and the Limits of Visual Perception

Light

Visible electromagnetic radiation.

The visible **spectrum** of light is shown here.

Different **wavelengths** are perceived as different **colours**.



The visible spectrum extends from 380 to 760 nm.

Human Vision

Eye/brain combination detects & interprets light.

70% of **all** the sense receptors in your body are in your eyes.



The eye includes mechanisms to:

Focus light Control brightness Detect light using the lens. using the iris & pupil. using the retina.

The "image" is sent along the optic nerve to the brain where the contents are interpreted and perceived. Perception of size Ebbinghaus illusion



Perceptual illusion : motion



Brightness perception



Which square is brighter?

A or B ?

By derivative work: Sakurambo (talk)Grey_square_optical_illusion.PNG -Grey_square_optical_illusion.PNG, Copyrighted free use, https://commons.wikimedia.org/w/index.php?curid=4443183

Brightness perception



Which square is brighter?

Answer – neither

... when measured with a luminance meter rather than judged by eye.

Brightness perception



Which square is brighter? Answer – none of them.

Which suggests a visualization design guideline: Avoid gradients as backgrounds in visualizations.

Colour perception



Grey images will be placed in a cube of different colours.

Colour perception



In left image do you see them as yellow in right as blue? Land (polaroid) named this retinex theory (illuminant theory)¹³

3D: The Ponzo Illusion



Indicates that the brain is, or learns to be, "wired for 3D".

Illusions of 3D shape

Charlie Chaplin. (Richard Gregory, Bristol)

Ames window. (Richard Gregory, Bristol)

Both of these illustrate how the brain is hardwired to interpret images as being part of a 3D world.

What do you conclude about perception?

Perception : why study it?

Role of a digital image when presented to someone is to *communicate* some information to them.

1) Anything we do in creating a digital image that doesn't make it into the visual system wastes effort.

2) We want to avoid creating distractions in images that interrupt perception of the information.

3) We need to be aware of creating a false impression of the information we are trying to convey.

The Canvas: Electronic Displays

Display types



Pixels

Displays form an image from an array of *pixels*. The word pixel comes from "picture element".



Pixel is smallest addressable area of **colour** on a display.

RGB Colour Model

Additive colour model:

colours are made up by combining proportions of three primary colours:

Red, Green and Blue



© The Colour Group of Great Britain

How many pixels?



2Mpix desktop display pixel size, **p** = **0.3 mm**

therefore the eye could benefit from **9x** the number of pixels i.e. we could use **5760x3240 = 18Mpix**.

Resolution: Retina Displays

What about Apple's retina display ? iPad3: 9.7" has **2048x1536 = 3Mpix**

Equates to 10.4 pixels per mm and therefore:

This is the same as the size we calculated we want so the pixels are at the 1arcmin limit if viewed from 300mm.

p = 0.096

Is this good enough1 arcmin = 20/20 vision but many people have better acuity than this at 0.6 arcmin.

.. and there are also vernier and hyper acuity up to 0.13 arcmin (you can see electricity wires) **8192x6144 = 50Mpix**.

Resolution : Matching Human Acuity?

_				
		Samsung Tab S3	Dell UltraSharp	Samsung UE55MU6400
	Device	9.7	U2414H	55in
١	/iewing Dist (mm)	300	500	1700
١	/isual acuity (mins			
C	of arc)	Actual and calculated Mpix		
	Actual	3.15	2.07	8.31
	1	3.83	7.38	3.41
	0.6	10.63	20.50	9.47
	0.13	226.43	436.65	201.73

Tablet, desktop monitor and TV viewing, which one(s) match the acuity limits of the human eye at the normal viewing distance?

Only the TV beats eyes needs, at the lowest estimate of acuity at 8.31 > 3.41 Mpixels required.





Display brightness is **subjective**, defined by the CIE as:

... the degree to which an area **appears** to exhibit more or less light.



To objectively measure display brightness the CIE defined **luminance** which:

...measures the power of **visible** light from an area.

Display manufacturers often quote luminance in units of: candelas per square meter cd m⁻² (also known as a nit) Contrast



Defined as the ratio of : max brightness : min brightness

Lowest level should be, but never is, completely black.

Important because higher contrast images look a lot sharper and text is more readable.

(Which is why these slides are black on white)



Brightness and Contrast



What we can see

What do we notice?



An important feature of the visual system is that it can be primed.

There is a distinct image of an animal hidden in the rose – can you find it?

What do we notice?





Because priming is so important in *visual search* the inclusion of keys on maps and in any visualizations is often critical.

Generally we can only search efficiently for one thing at a time – asking us to search for two or more things slows us down.

What do we remember?



The flow of information from light to thought is captured above, in a widely used model of the stages of memory.

Iconic memory – short term < 1 second Short-term memory – good with 1 or 2 things, may store up to 5. Long-term memory – stores some of everything we encounter.

Overloading the HVS



This graph, while not very complex with nine measures, overloads short term memory – it therefore takes time to understand it and identify trends in the data, before we can reason about them.

What stands out?

5647902894728624092406037070**5555**927**5**

Popout is an important characteristic of the visual system.

Those visual features that popout provide us a tool for designing more effective visualizations.

(You will also see this referred to as pre-attentive processing)

What stands out?









Grey value

Shape





Added surround color



Convex and concave



Misalignment

Cast shadow





Sharp vertex



Direction of motion







Phase of motion

The brain detects some features more easily than others.

Popout happens when there is strong enough feature contrast between the object and its surroundings:

Colour, Brightness, Position, Shape, Sharpness, Lighting, Shadows, Blinking, Motion, and stereo 3D

Popout is best when there is a single feature we want to highlight.

© Colin Ware, Visual Thinking for Design



Do all differences work?



Even within a single cue channel it can be hard to find a target even when it is different from other channels.

Need to check carefully we have enough cue contrast.

Can we learn and do this better?



Even if you look at this from the side the dot still pops out, the 6s don't.

This is an innate ability – you can't improve your ability to find the 6s by practice.

Can we combine cues?



Find the three green squares.

Combining cues is not always a good idea as many cue combinations are hard to see. Here green circles mask the three green squares – no popout.

Can we combine cues?



These seven symbols are designed to be independently searchable. You could include them in the same diagram and you should be able to easily spot the one you are looking for.

There are lots of opinions published in this area, and far to few scientific studies.

HVS Key Points

Short term memory has a limited capacity. Show a small number of chunks of information at once.

Visual search is the mechanism we primarily use to see.

Visual search is most effective when primed. Using keys and icons helps highlight important information.

Certain features popout, when in contrast to the rest of the image. Brightness, colour, shape, orientation, flashing, motion, stereo.

Designing symbols to be independently visible when used together is hard – but possible if distinct enough feature channels are used.