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Human-Computer Interaction: 2A. Vision and Colour

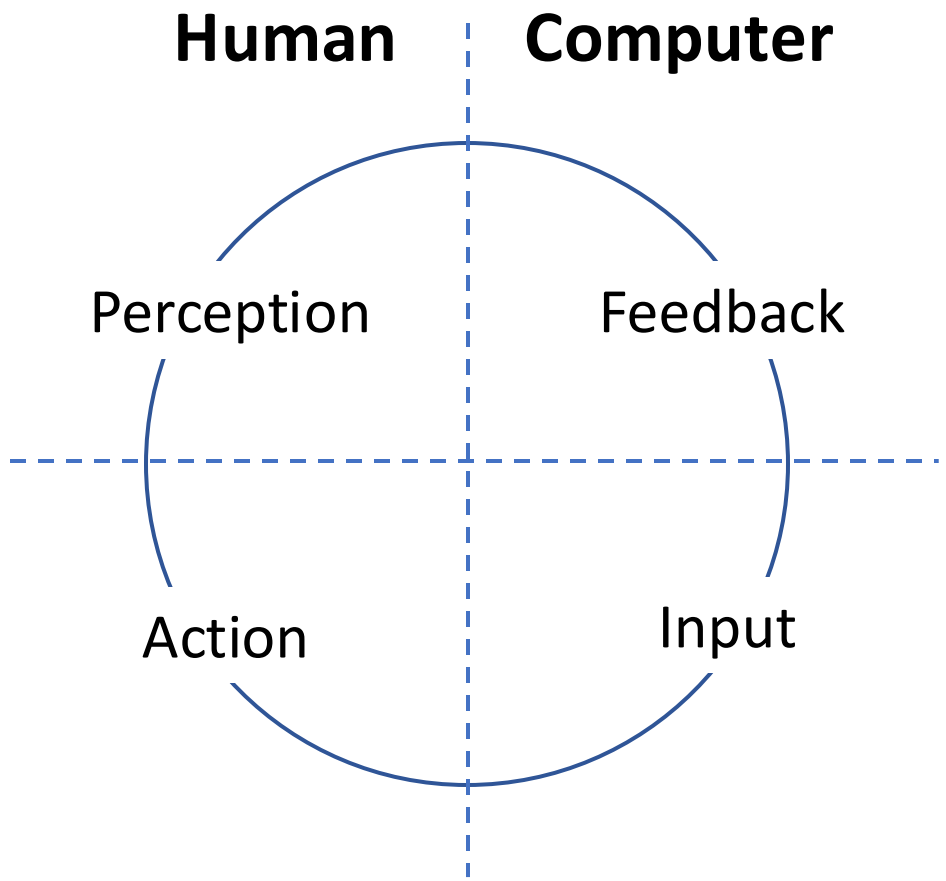
13/14 October 2025

Interaction Techniques

- An interaction technique is a method that allows a user to perform a task on a digital or physical product.
- It includes the input actions a user takes and the system's corresponding feedback.
- Combining hardware and software

Schmidt, A., Beigl, M., & Gellersen, H. W. (1999). There is more to context than location. *Computers & Graphics*, *23*(6), 893-901.

Interaction Techniques – Anatomy



Reading on User Interfaces

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- User Interface Software and Technology
- Online book by Amy J. Ko and colleagues at U. Washington
- Great complement to the course
  - The module covers fundamentals and study skills
  - The book is on innovation in user interfaces, with lots of examples

Exercises and Coursework

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- Exercises are for timely lecture revision and practice, and for discussion in workshops
  - no submission process
  - only way to get feedback is to attend workshops
- Coursework 1: week 5 in-class test on moodle
- Coursework 2: ongoing from week 2-10 with feedback in workshops
- Absence: notify teaching office with adequate evidence
  - Any justified absence will be taken into account

Vision and Colour

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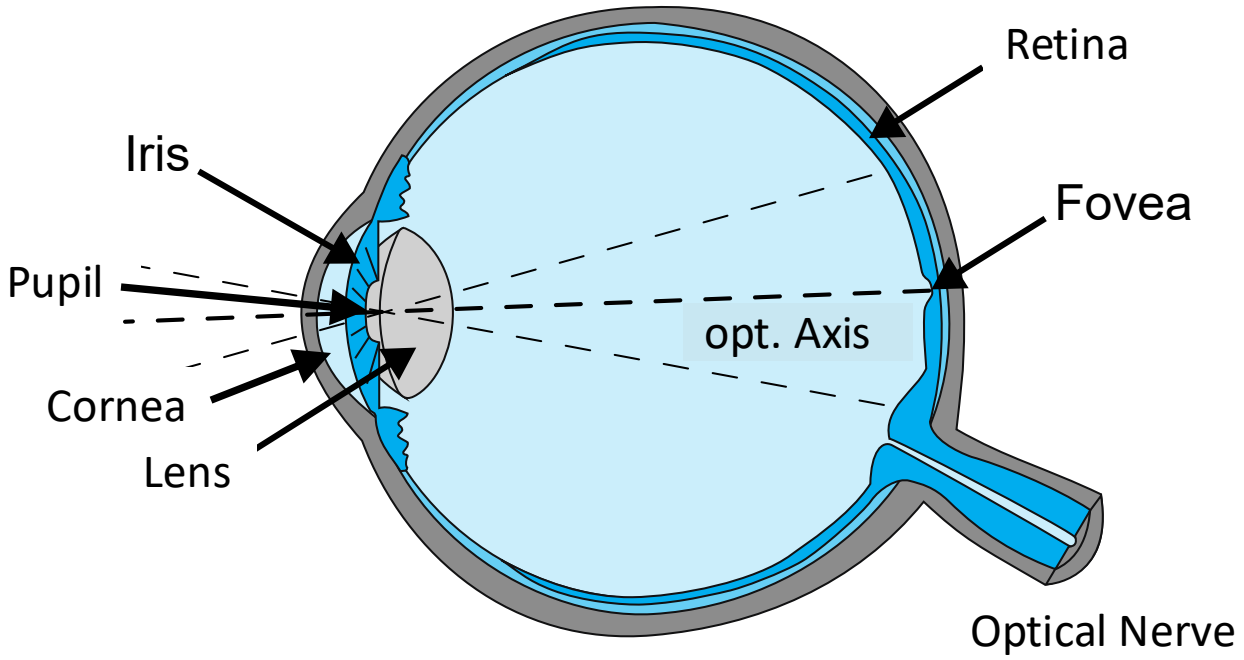
- Physiology of the Eye
  - Light Sensing
- Visual System
  - Foveal and Peripheral Vision
  - Eye and Head Movement
  - Binocular Vision
- Colour perception

Learning Objectives: be able to …

- Identify components of the visual system and describe how they work
- Apply knowledge of vision and colour perception in visual design
- Explain features, anomalies and conflicts that can affect perception

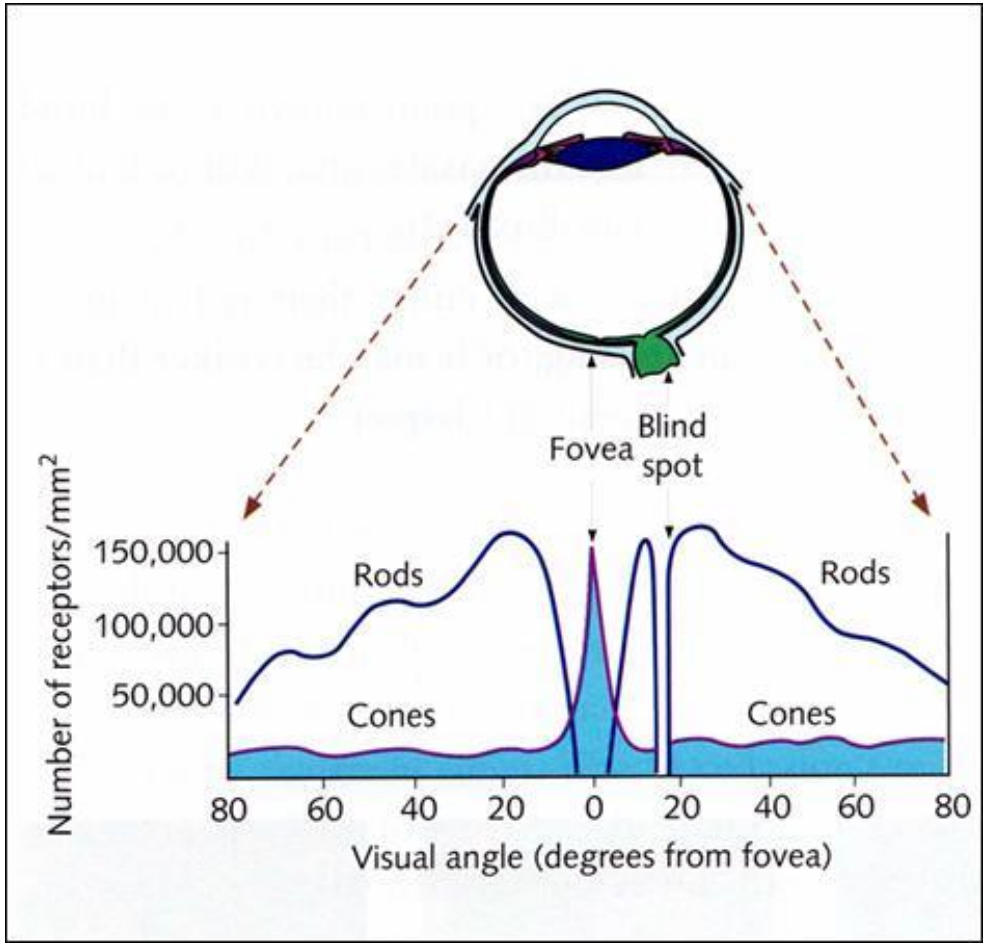
Phyisology of the Eye

- Iris controls light coming in (pupil size)
- Lens transmits incoming light to the retina, adapting to focus nearer/farther
- Retina: layer of photoreceptors (light sensors)
- Fovea: are of highest density on the retina



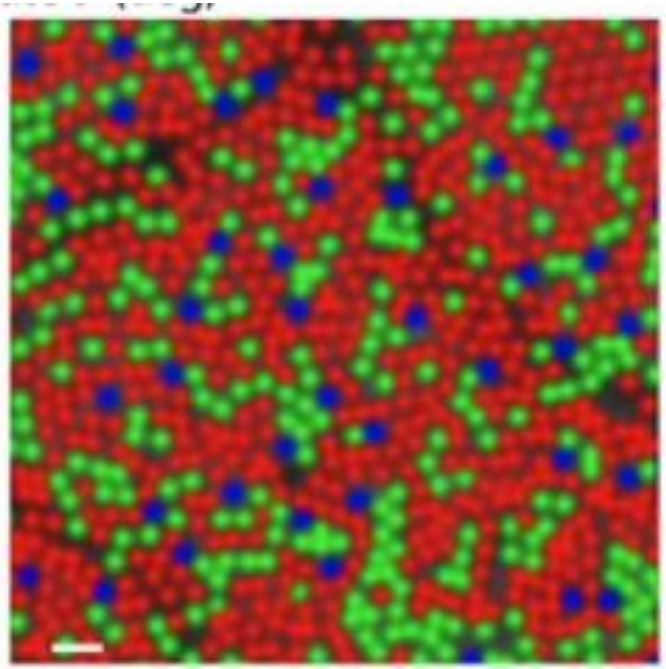
Retina: Photoreceptor layer

- Types of Photoreceptor
  - Rods – Sensitive to light intensity
  - Cones – Sensitive to light frequencies
- Central retina (fovea): only cones
  - High density: perception of form
  - 3 different types: perception of colour
- Peripheral retina: more rods
  - light detection, motion detection



Colour Sensitivity – Distribution of Cones

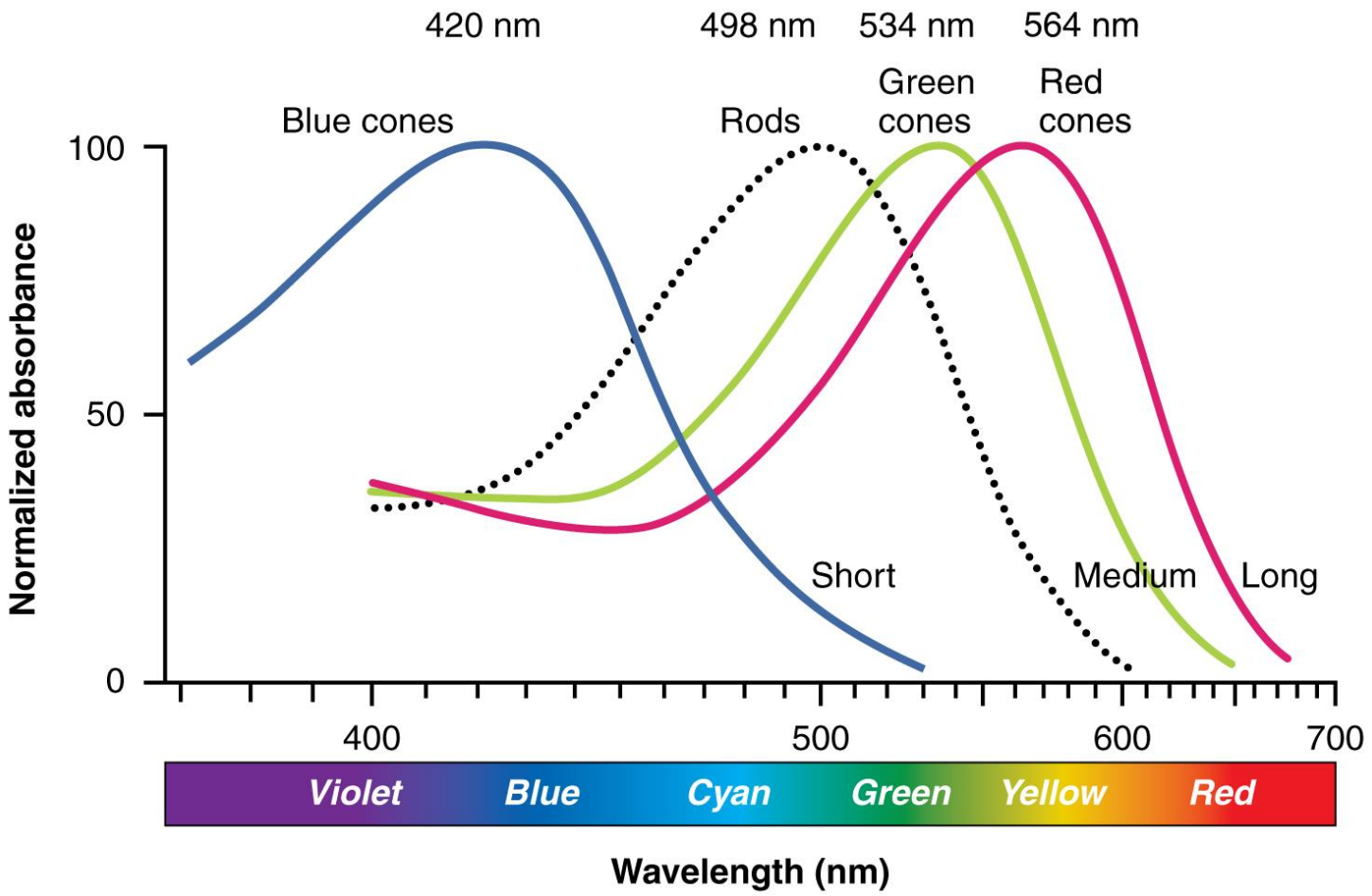
- Cones differ in their sensitivity to light of different wavelengths
  - Short (S): most sensitive to blue light
  - Medium (M): most sensitive to green light
  - Long (L): most sensitive to red light
- There are about 10 times more L and M cones than S cones in the retina
  - Higher sensitivity for red and green than blue



Cones are marked in the colour they respond to

https://doi.org/10.1371/journal.pone.0144891

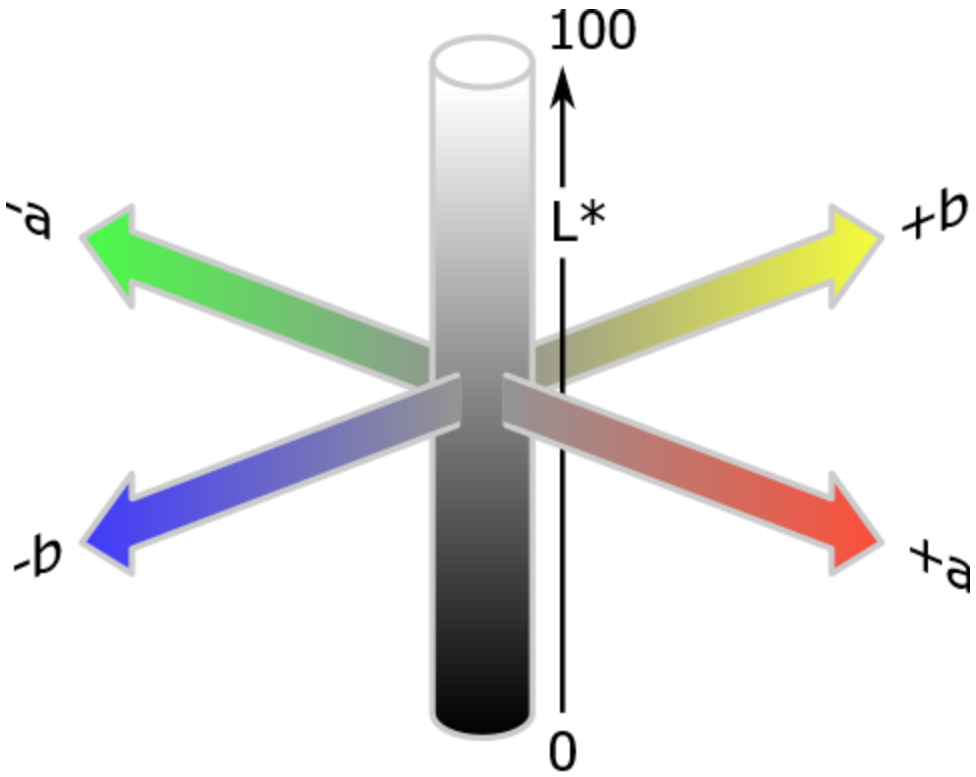
Colour Sensitivity – Frequency Response



- Cones convert light into a biological signal
- Blue, Green, Red cones differ respond differently to different wavelengths

Receptor Signal Processing

- Signals from LMS cones are combined into three opponent channels:
  - Lightness (adding up intensity values)
  - Red-green contrast
  - Yellow-blue contrast
- Explains perception of (e.g.) red and green as opposites



Colour Vision - Anomalies

- Protanopia: missing L cones, less sensitivity for red
- Deuteranopia: missing M cones
- Tritanopia: missing S cones

- Red/green deficiency quite common: 8% of male population

- CVSimulator app: https://asada.website/cvsimulator/e/

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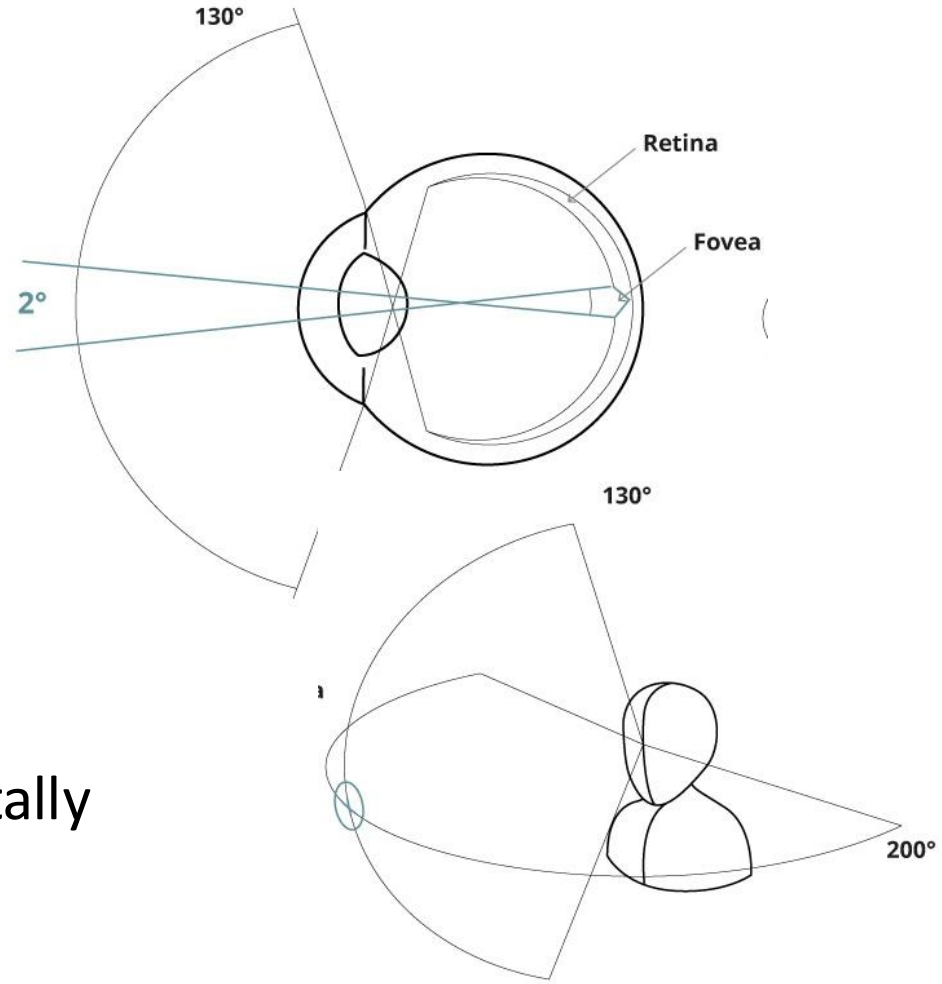
- **Visual System**
  - Foveal and Peripheral Vision
  - Eye and Head Movement
  - Binocular Vision
- Colour perception

Foveal and Peripheral Vision

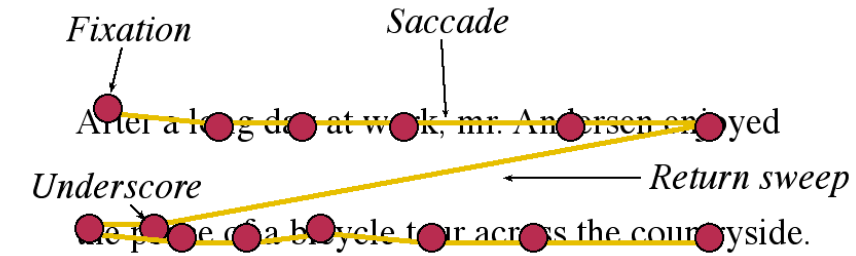
- Foveal vision
  - 1-2 degrees in the visual field (size of thumbnail at arm's lenght)
  - High acuity (resolution) and colour sensitivity
  - Perception of detail (for tasks such as reading, object recognition)
- Peripheral vision
  - Wide field-of-view, up to 200 degrees horizontally
  - Detection of stimuli (motion, salient features)



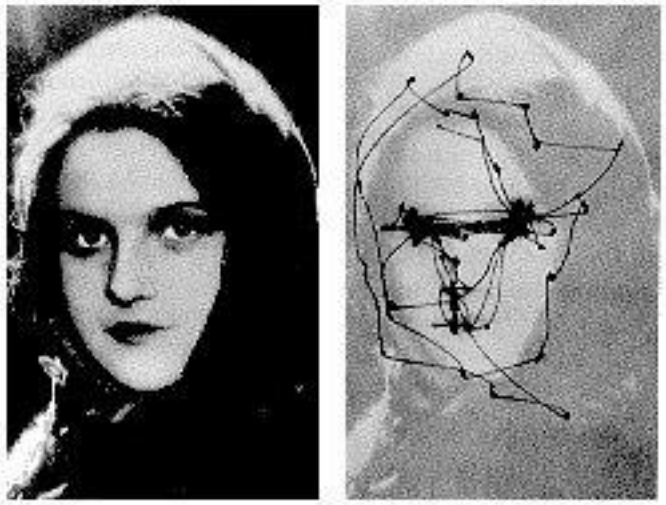
https://vr.tobii.com/sdk/media/foveation/fovea.jpg

Eye Movement – Fixation and Saccades

- Fixations
  - Aligning objects in the visual field with the fovea to access detail
  - For at least 200ms to have sufficient time for extraction of information
- Saccades
  - Fast ballistic movement from one fixation to the next object of interest
  - 20-30ms for small shifts
- Max. 3-4 cycles per second



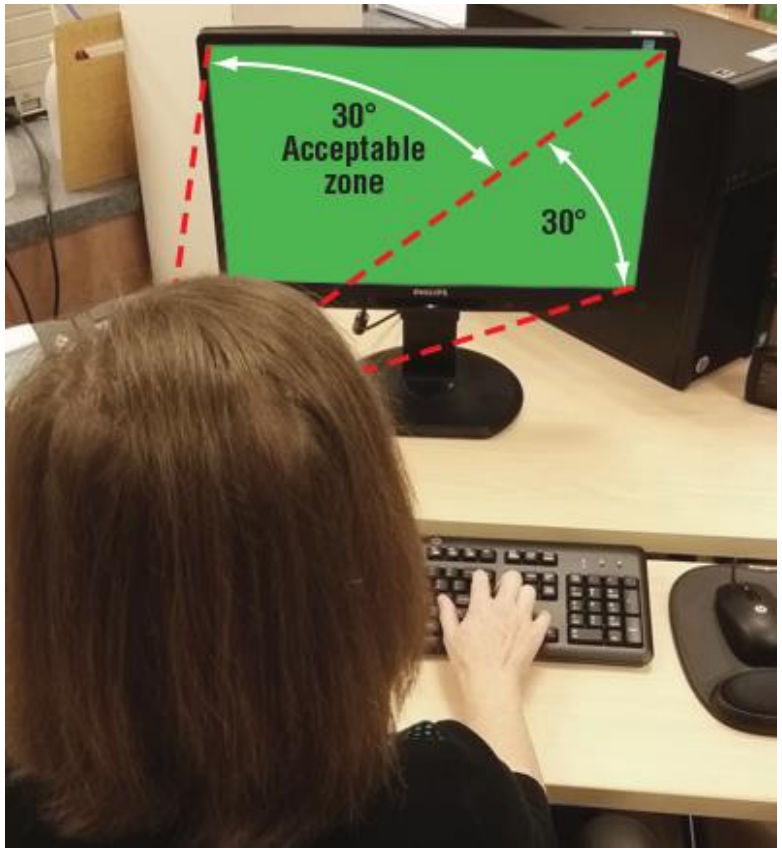
https://www.linkedin.com/pulse/eye-movement-during-reading-andrew-johnson/



A. L. Yarbus, *Eye Movements and Vision*. 1967

Eye Movement – Viewing Range

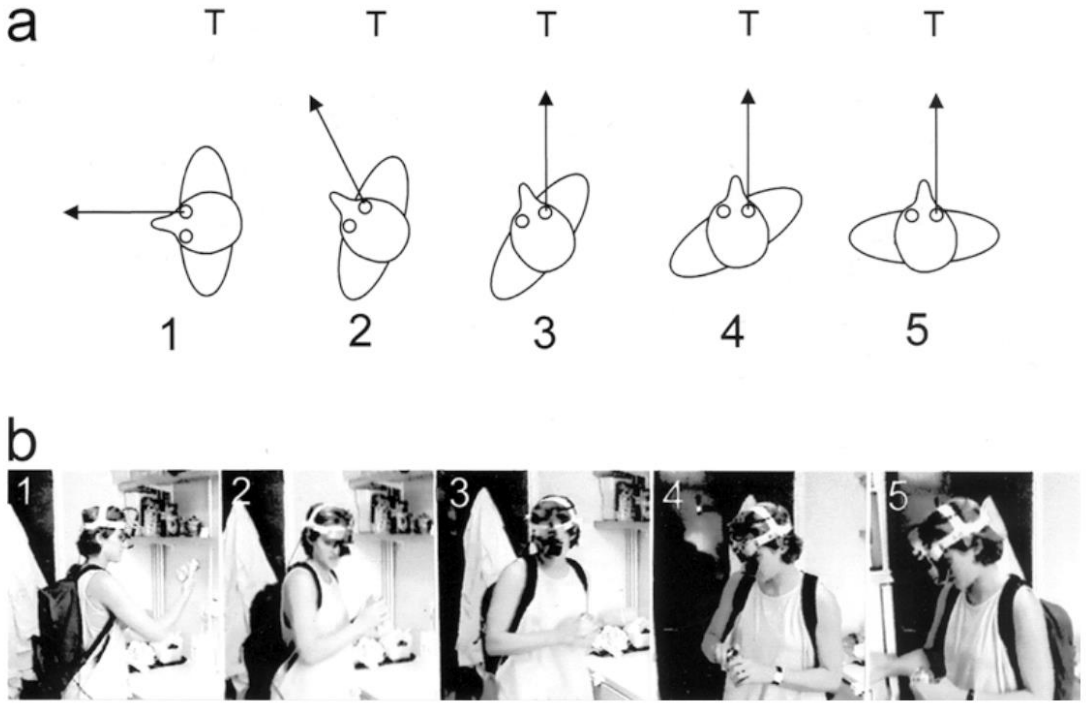
- Comfortable eye-in-head positions
  - Max. 20 degrees to left/right
  - Up to 30 degrees down from the head centre
- Ergonomic viewing range without need for head movement
- Display width versus viewing distance
- Workstation assessment for Health&Safety



https://www.ccohs.ca/oshanswers/ergonomics/office/monitor_positioning.html

Eye Movement – Eye-Head Coordination

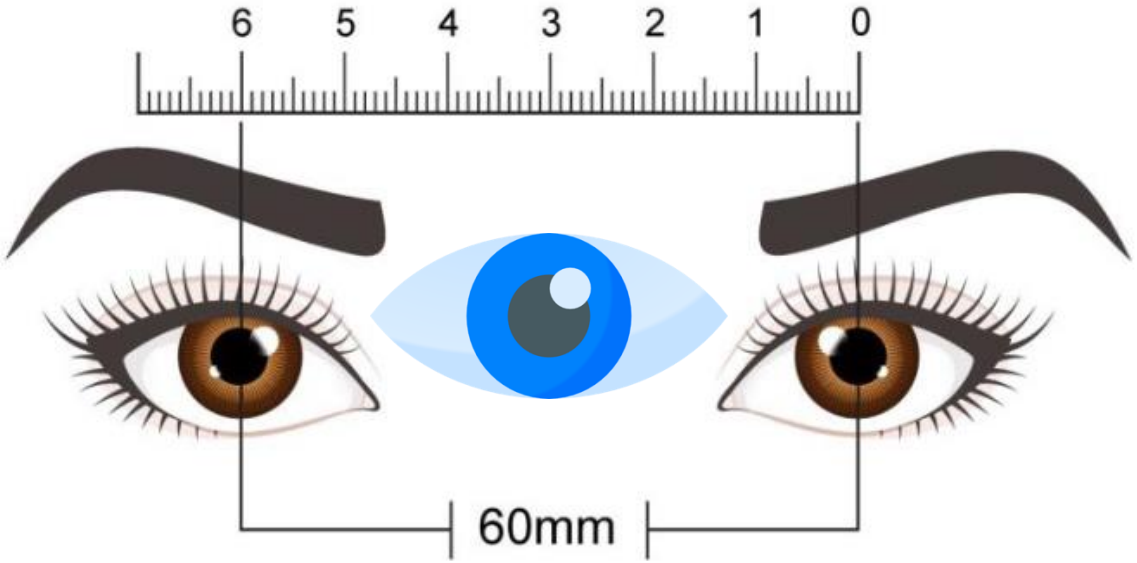
- Head movement supports vision, to have wider coverage
- Larger gaze shifts are a combination of eye saccade and head movement
  - Integrated eye-head movement
- Aligning objects of interest for comfortable viewing



M. Land & B. Tatler. Looking and Acting. OUP

Binocular Vision – Conceptual Models

- Cyclopean model
  - Signals from both eyes are fused in a single canvas of vision
- Binocular model
  - Two cameras at an offset from each other
  - IPD = Inter-pupillary distance



Binocular Vision – Binocular Disparity

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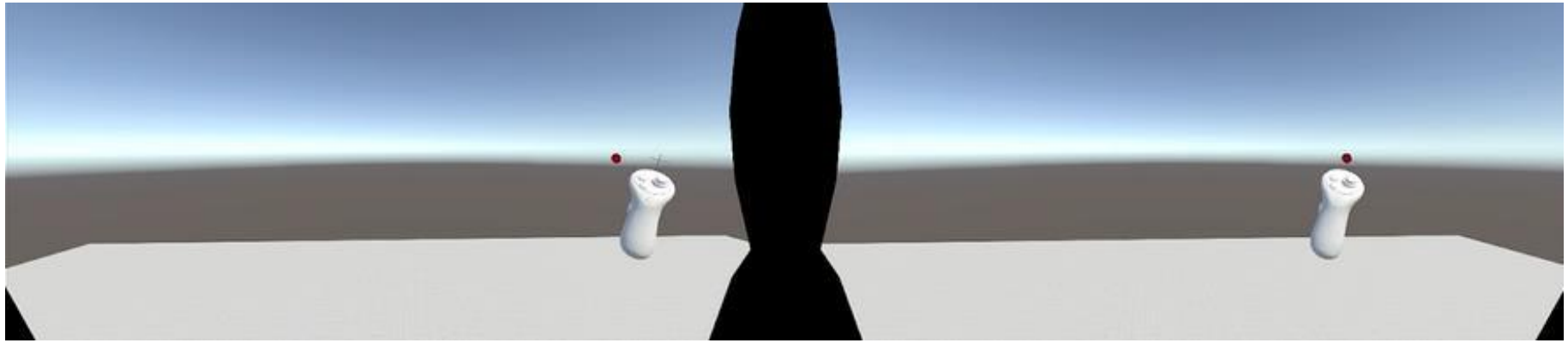
- Left and right eye differ in viewing angle toward an object of interest
- Difference in the images seen by each eye, caused by parallax
- Binocular disparity provides a depth cue
- Stereoscopic displays (e.g. VR headsets) displays use this to create a perception of a 3D environment



Vergence-Accommodation Reflex

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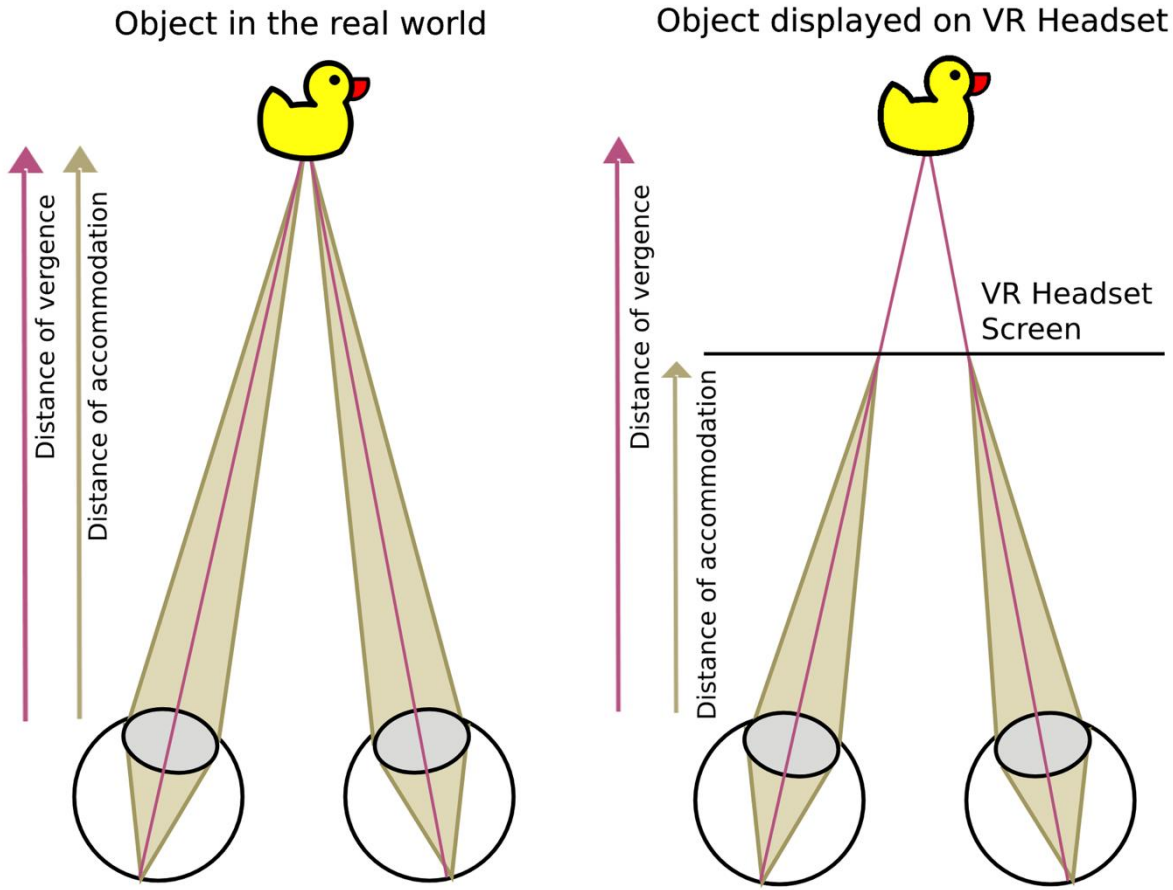
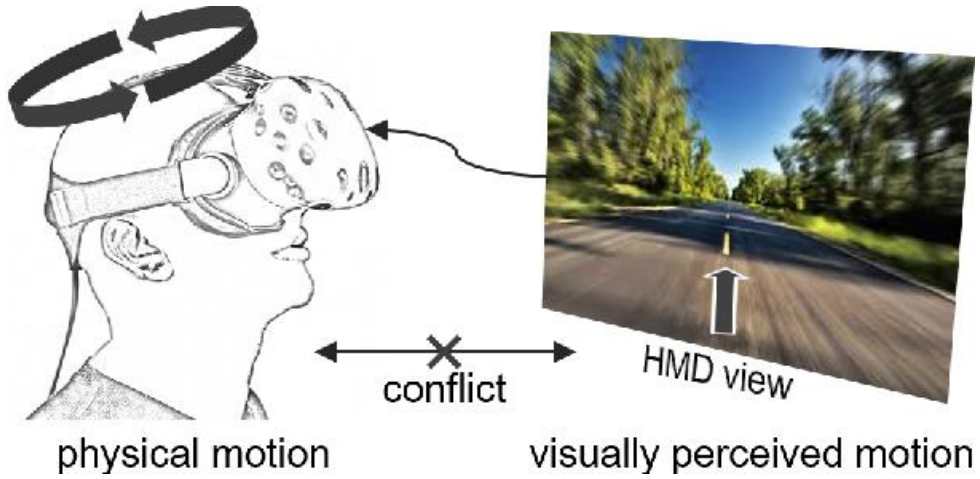
- Vergence
  - Eyes rotate in head so the lines of sight converge for a fixation
  - Depends on distance of object
- Accommodation
  - Eye lenses change shape to focus on an object
- Conflicting cues in 3D display
  - Fixed focal plane, on which disparate images are shown



Visual-Vestibular Interaction

- The vestibular system senses motion of the head in space
- Self-motion also induces optical flow
  - Patterns of motion across the retina
- Visual-vestibular information is integrated for perception of self-motion and navigation
- Conflicts in physical and visually perceived motion cause simulator sickness



Kim, J., Kim, W., Ahn, S., Kim, J., & Lee, S. (2018). Virtual Reality Sickness Predictor: Analysis of visual-vestibular conflict and VR contents. *2018 Tenth International Conference on Quality of Multimedia Experience (QoMEX)*, 1-6.

Key Points on Human Vision

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- Human eye is an integrated sensor, with optical apparatus (Iris, Cornea, Lens) and light-sensitive receptors in the retina (Rods, LMS cones)
- It produces visual signals derived from foveal vision (high acuity, colour detail) and peripheral vision (wide coverage, stimulus detection)
- Vision coverage is improved by saccadic movement of the eyes to fixate on points of interest, and by eye-head coordination
- Signals from left and right eye are integrated into a single field of view, and provide depth information
- Awareness of features/conflicts/anomalies is relevant for visual design

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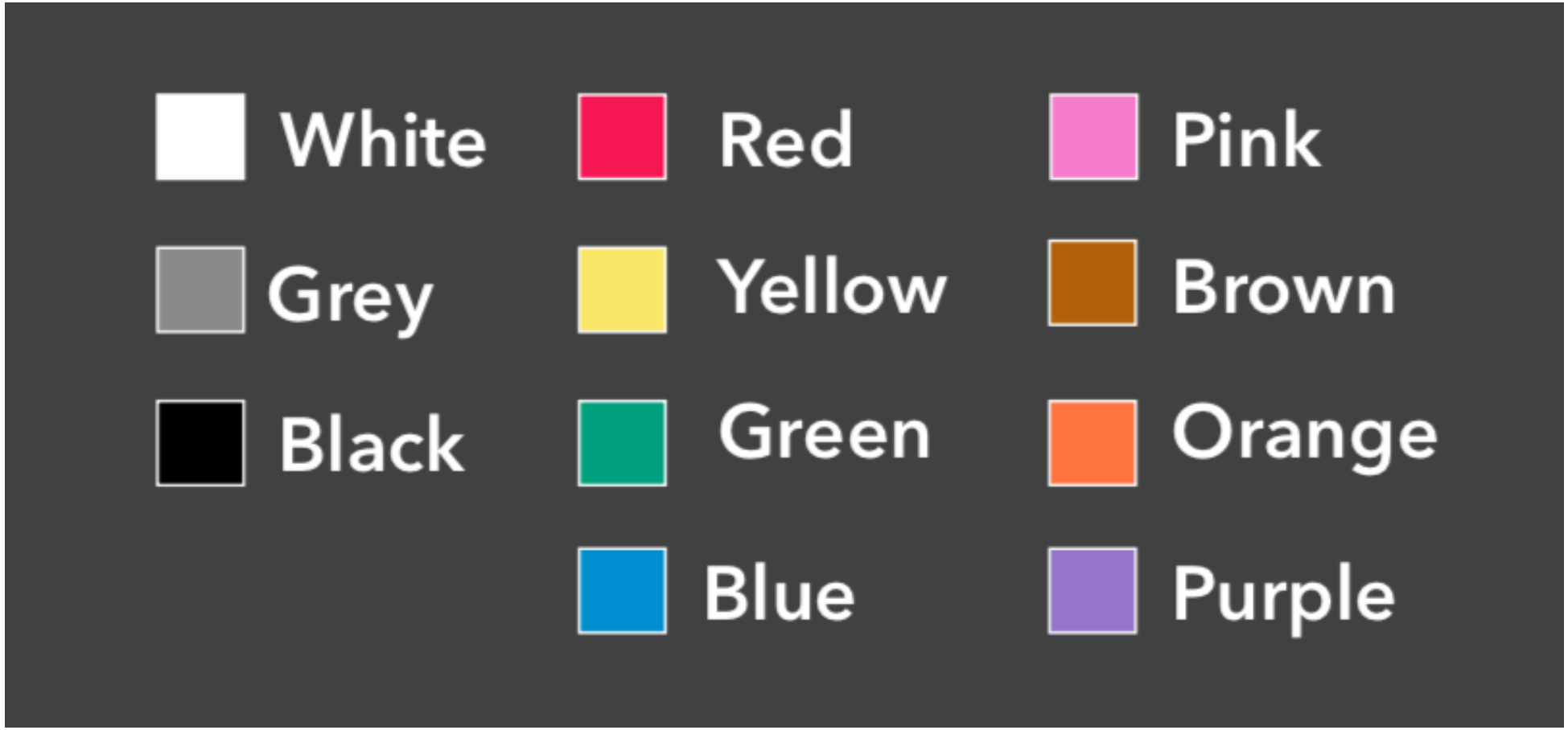
- **Colour perception**

Mentimeter

Colour perception

- Colour is not a physical property of light
  - Light has intensity, and frequency (wavelength)
- An object does not have a colour
  - The “colour” of the object is the wavelengths of light the object does not absorb
- Colour is an interpretation by the perceptual system, of the signals from the photoreceptors
  - “Colour is in the eye, and brain, of the beholder” https://knowablemagazine.org/content/article/mind/2022/science-of-color-perception
- Colour models help us describe colour.

Colour Description - Universal names



RGB – Red, Green, Blue

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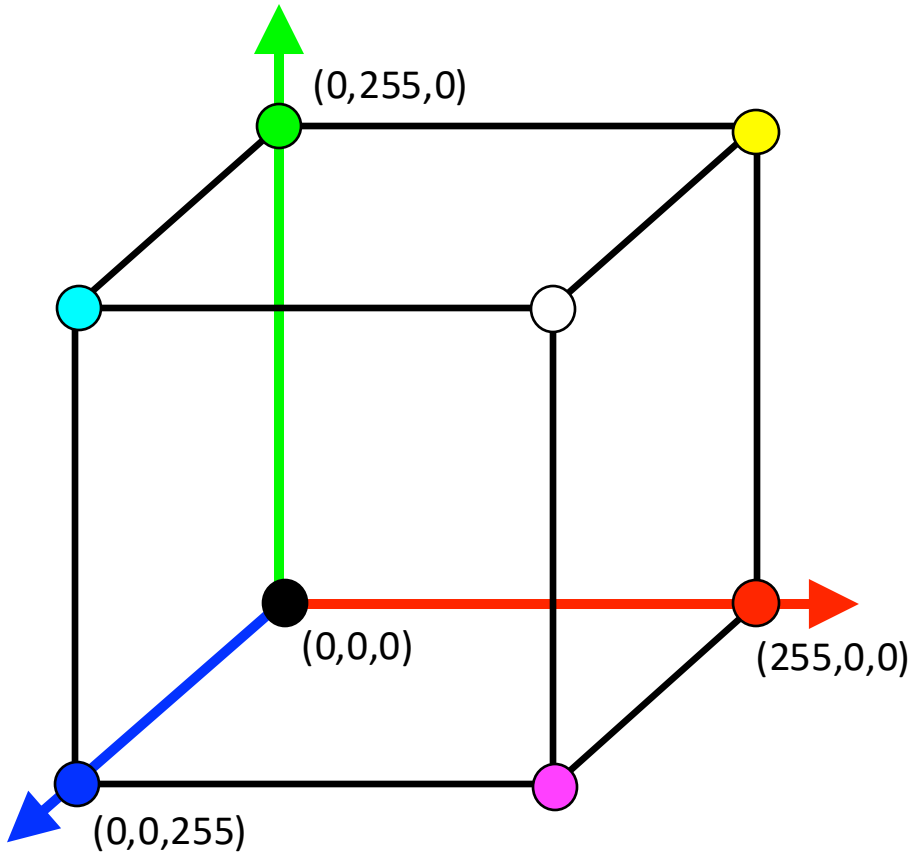

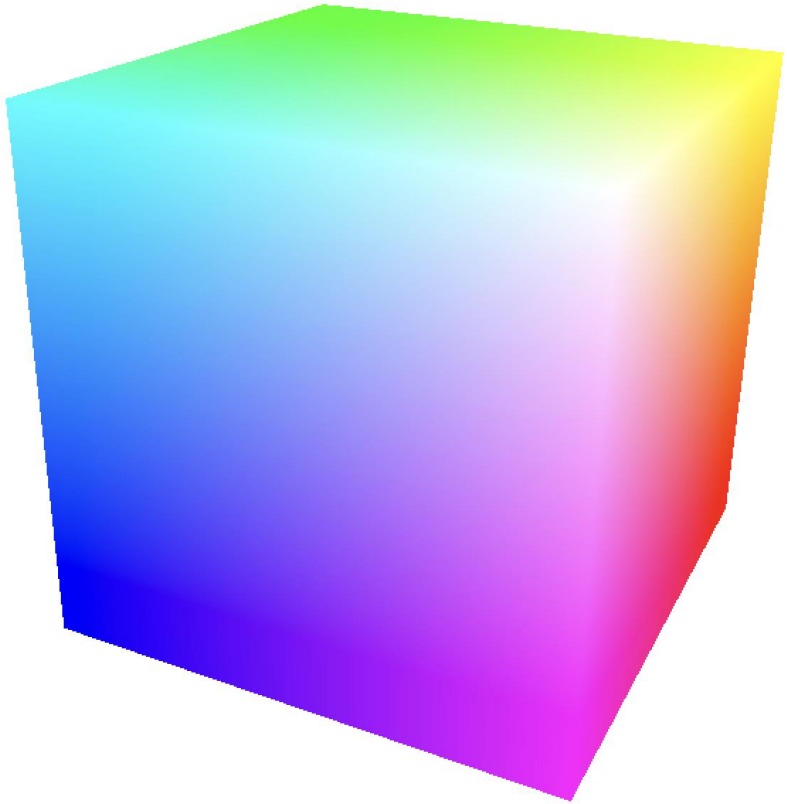

CMYK – Cyan, Magenta, Yellow, Key

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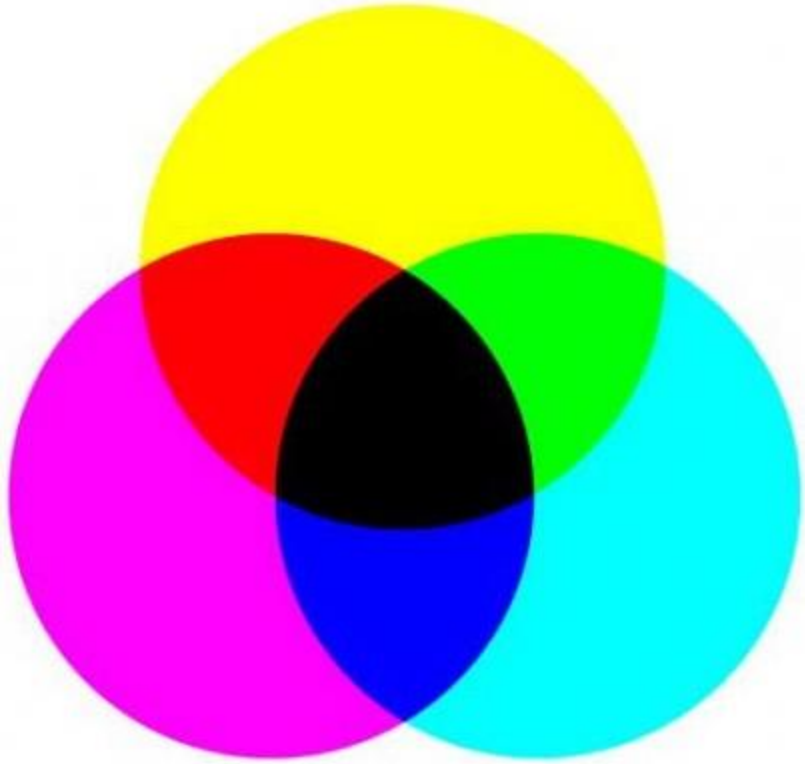
Print mediums use subtractive color models:

Each dye reflects only a set of frequencies

- **Cyan Magenta Yellow**
  - where it appears on the spectrum
  - consistent ordering
- **Key = Black**
  - Intensity / Paleness
  - How dark or light
  - Depth and shading



HSV – Hue, Saturation, Value

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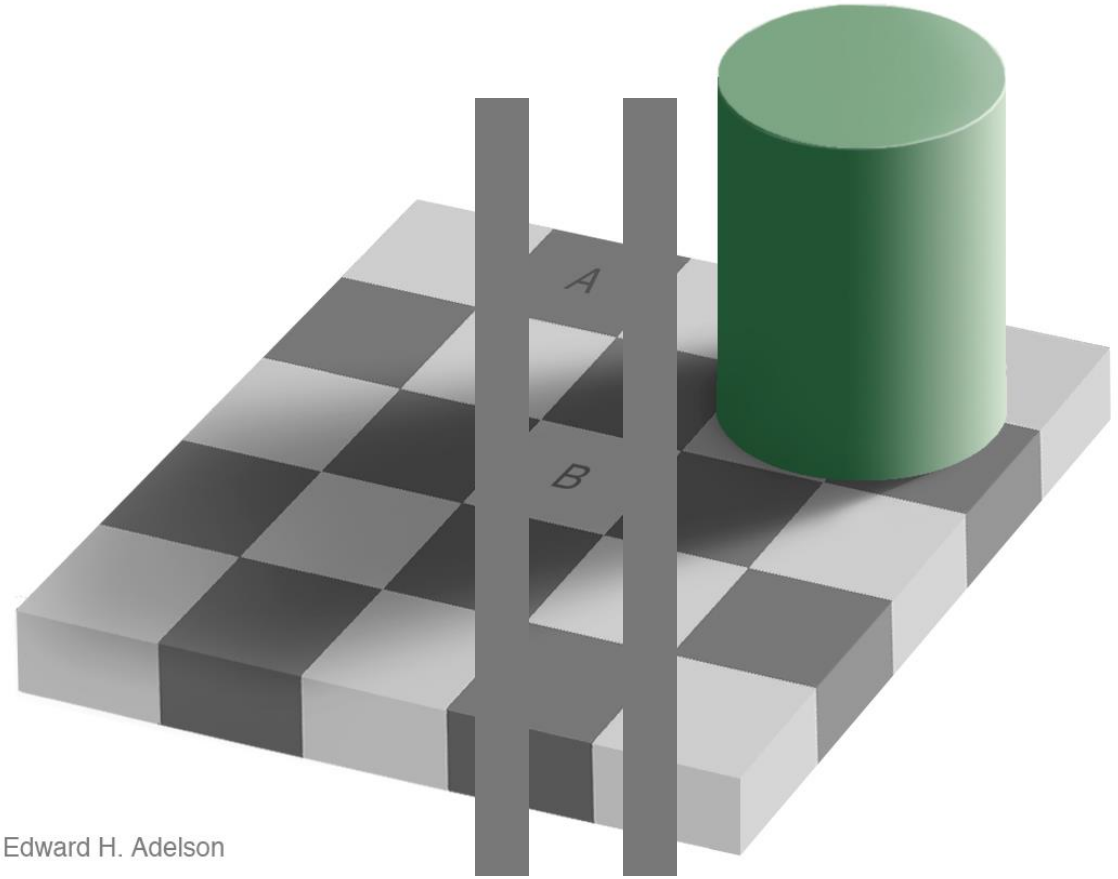
Colour defined by three perceptual properties:

- **Hue**
  - where it appears on the spectrum
  - consistent ordering
- **Saturation (or Chroma)**
  - Purity of the colour
  - Range from grey to pure
- **Lightness**
  - Intensity
  - Range from light/pale to dark

Colour Perception - Contrast

- Perception is affected by contrast, and other colours in the image
  - Look up Bezold Effect!
- Human vision is optimized for perception of contrast
- Not so good at perception of absolute levels of intensity (brightness)



Edward H. Adelson

Key Points on Colour

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- Colour is not a physical property – it emerges as a response of different types of photoreceptors to light
- Colour is not straightforward to describe – only a small set of names are agreed. We use models to be more specific: RGB (additive), CMYK (subtractive), HSV (perceptual)
- Colour perception is affected by presence of adjacent colours.
- We are more sensitive to contrast and better at colour discrimination than detection of absolute values

Next Lecture: Visual Perception

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- Gestalt – perception of form
- Visual search – finding information in the visual field
- Preattentive processing – perceiving information “at a glance”
- Visualisation – encoding information visually

Lecture Revision

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- Computer monitors on the desktop are usually set up so that they do not extend over more than 40 degrees in the user's visual field. Why is that?
- In the early days of the WWW, hyperlinks were often highlighted by blue font colour. Was that a good choice? What might be limitations of blue for highlighting text?
- Do we have better colour vision in the fovea or in the periphery?
- What colour do we find at the center of an RGB cube?
- In colouring a map, how can we ensure that people with colour vision deficiency can discriminate the different regions?