CS160: Sensori-motor Models

Prof Canny

Why Model Human Performance?

- ✔ To test understanding of behavior
- ✔ To predict impact of new technology – we can build a simulator to evaluate user interface designs

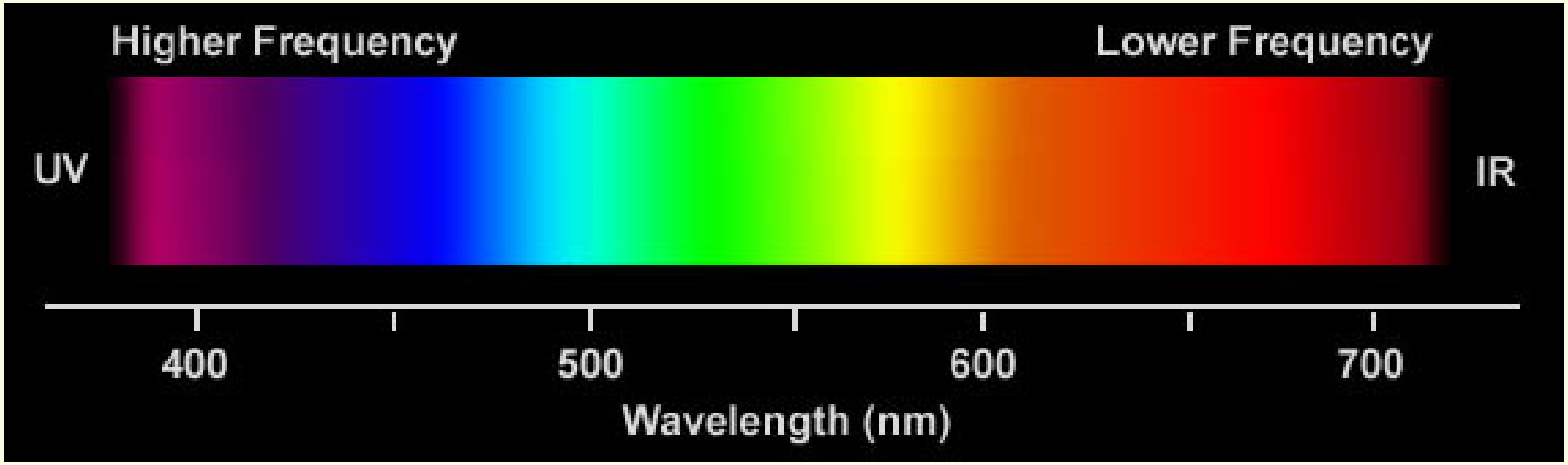
Outline

- ✔ Color perception
- ✔ MHP: Model Human Processor
- ✔ Memory principles

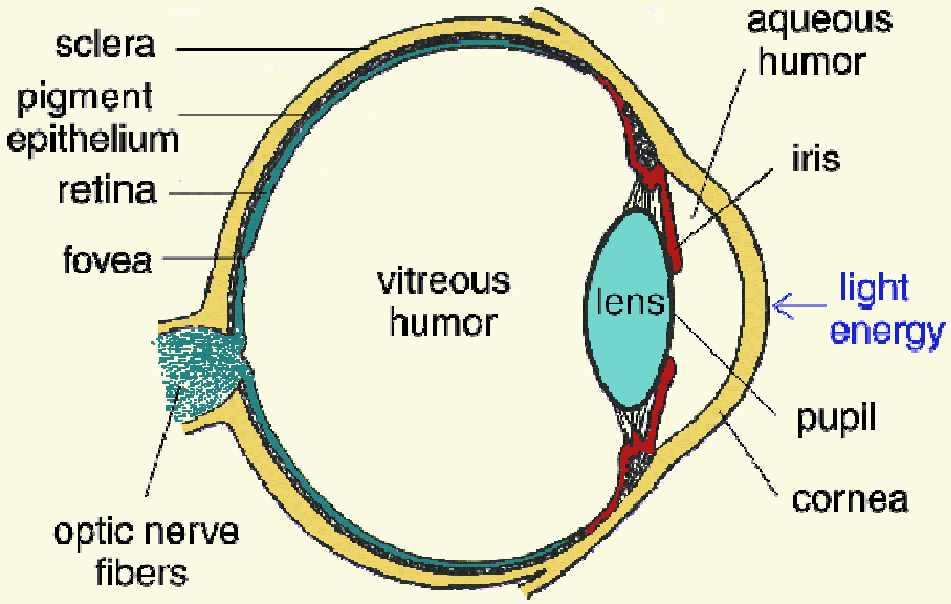
Why Study Color?

Color can be a powerful tool to improve user interfaces, but its inappropriate use can severely reduce the performance of the systems we build

Visible Spectrum



Human Visual System



- ✔Light passes through lens
- ✔Focussed on retina

Retina

- Retina covered with light-sensitive receptors.
  - Rods
    - Primarily for night vision & perceiving movement
    - Sensitive to broad spectrum of light
    - Can't discriminate between colors
    - Sense intensity or shades of gray
  - Cones
    - Used to sense color

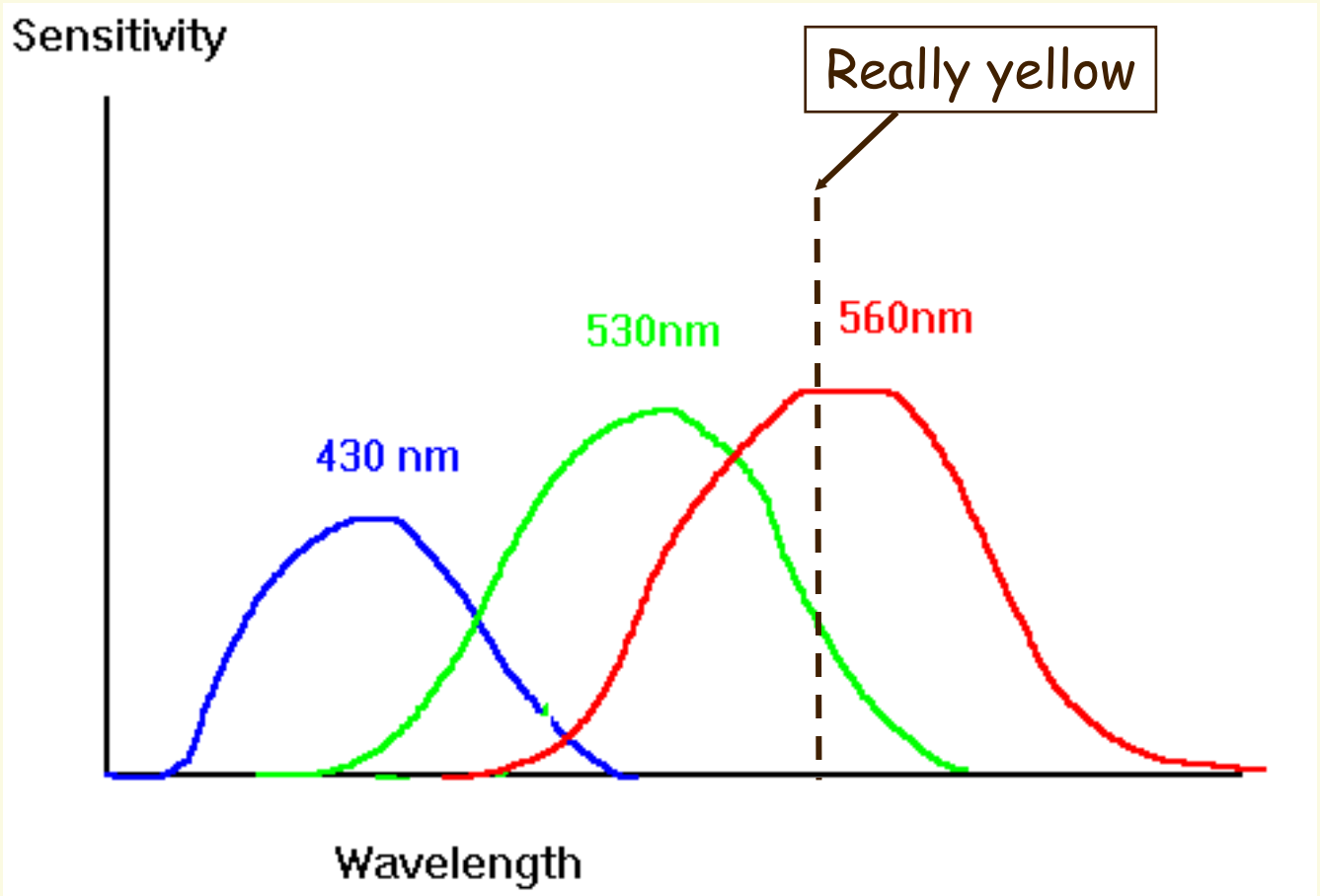
Retina

- ✔ Center of retina has most of the cones ➠?
  - * Allows for high acuity of objects focused at center, good color perception.
- ✔ Edge of retina is dominated by rods ➠?
  - * Allows detecting motion of threats in periphery, poor color sensitivity there.
- ✔ What's the best way to perceive something in near darkness?
  - * Look slightly away from it.

Color Perception via Cones

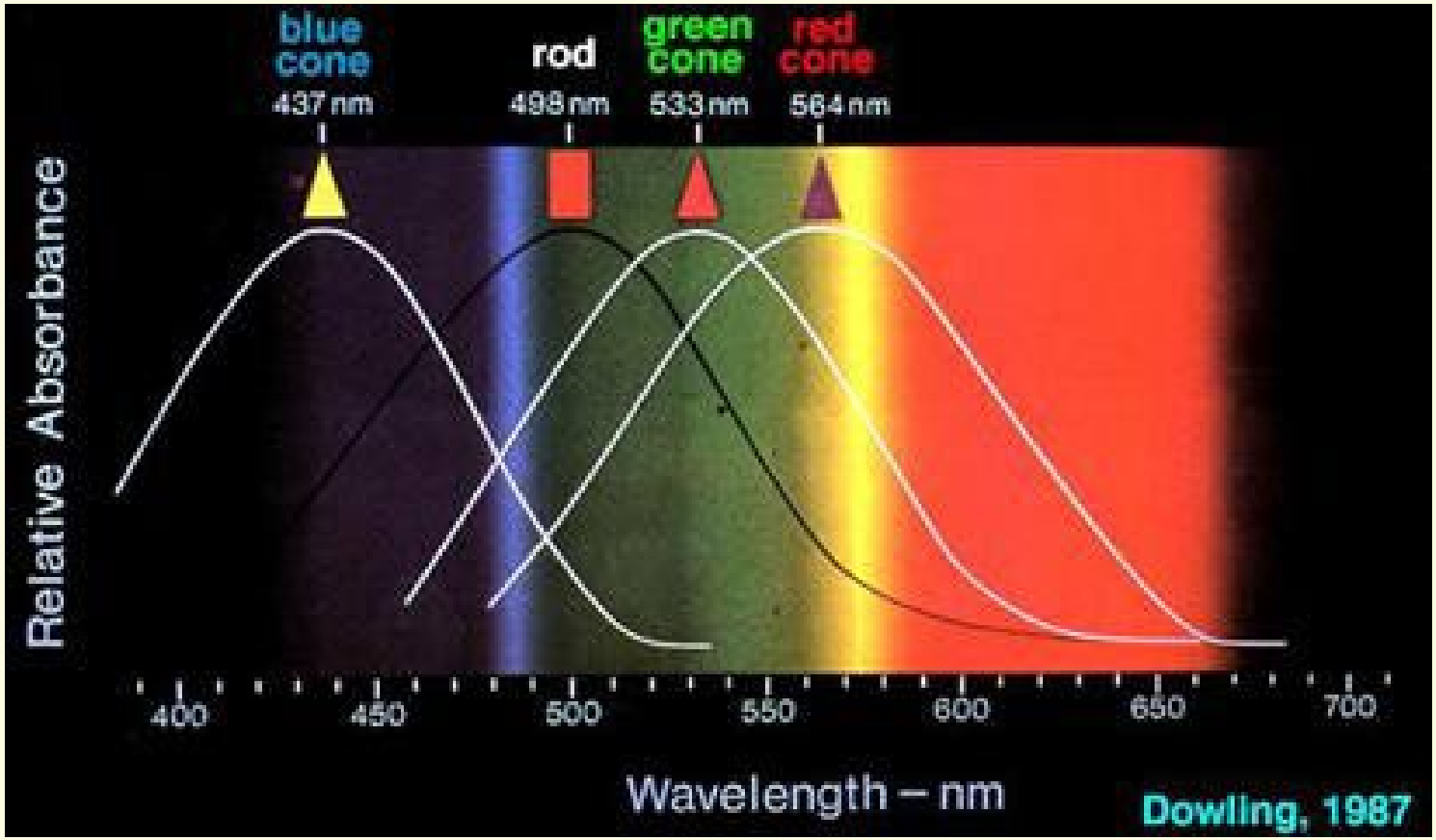
- ✔ "Photopigments" used to sense color
- ✔ 3 types: blue, green, "red" (really yellow)
  - * Each sensitive to different band of spectrum
  - * Ratio of neural activity of the 3 → color
    - + other colors are perceived by combining stimulation

Color Sensitivity



from: http://www.cs.gsu.edu/classes/hypgraph/color/coloreff.htm

Color Sensitivity



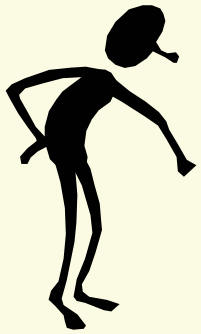
from http://insight.med.utah.edu/Webvision/index.html

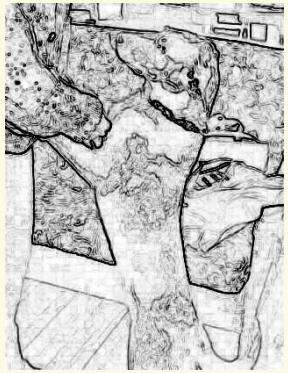
Distribution of Photopigments

- ✔ Not distributed evenly
  - * Mainly reds (64%) & very few blues (4%) ➠?
    - + insensitivity to short wavelengths
      - ~ cyan to deep-blue
- ✔ Center of retina (high acuity) has no blue cones ➠?
  - * Disappearance of small blue objects you fixate on

Color Sensitivity & Image Detection

- ✔ Most sensitive to the center of the spectrum
  - * Pure blues & reds must be brighter than greens & yellows
- ✔ Brightness determined mainly by R+G
- ✔ Shapes detected by finding edges
  - * Combine brightness & color differences for sharpness
- ✔ Implications?
  - * Hard to deal w/ blue edges & blue shapes





Color Sensitivity (cont.)

- As we age
  - Lens yellows & absorbs shorter wavelengths ➠?
    - sensitivity to blue is even more reduced
  - Fluid between lens and retina absorbs more light
    - perceive a lower level of brightness
- Implications?
  - Don't rely on blue for text or small objects!
  - Older users need brighter colors

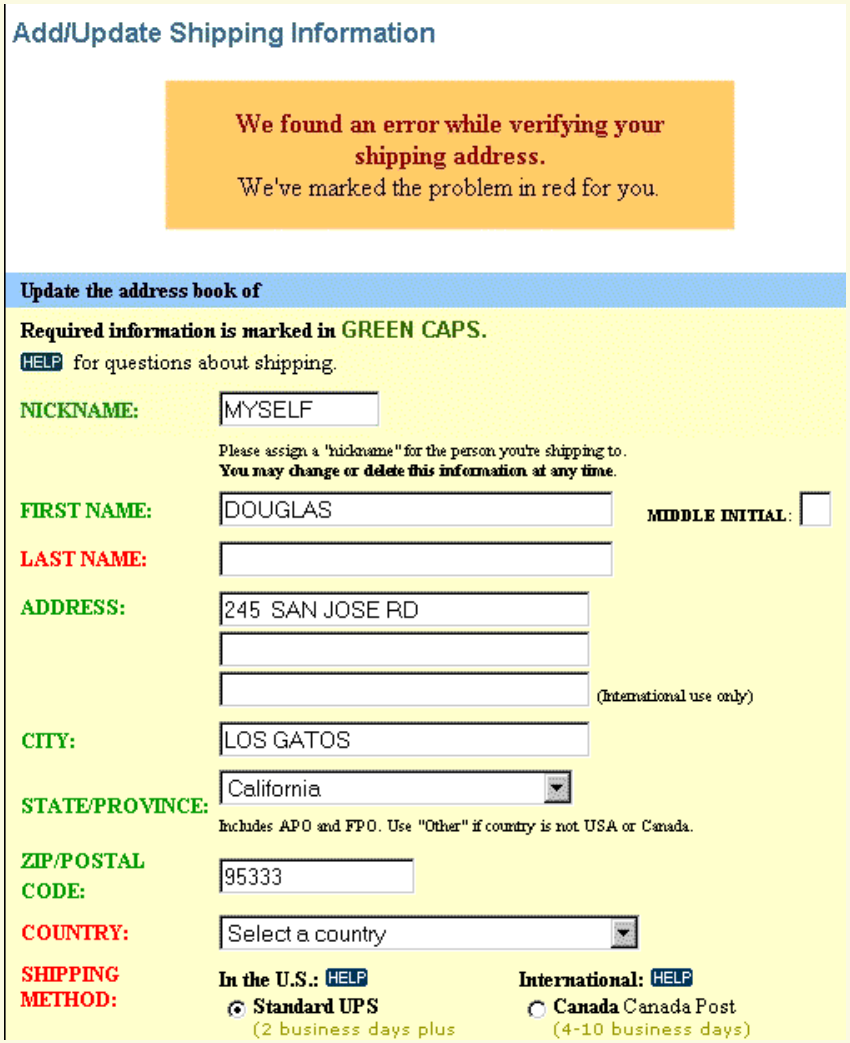
Focus

- Different wavelengths of light focused at different distances behind eye's lens
  - Need for constant refocusing → ?
    - Causes fatigue
  - Be careful about color combinations
- Pure (saturated) colors require more focusing then less pure (desaturated)
  - Don't use saturated colors in UIs unless you really need something to stand out (stop sign)

Color Deficiency (also known as "color blindness")

- ✔ Trouble discriminating colors
  - * Besets about 9% of population
  - * Two major types
- ✔ Different photopigment response
  - * Reduces capability to discern small color diffs
    - + particularly those of low brightness
  - * Most common
- ✔ Red-green deficiency is best known
  - * Lack of either green or red photopigment → ?
    - + can't discriminate colors dependent on R & G

Color Deficiency Example

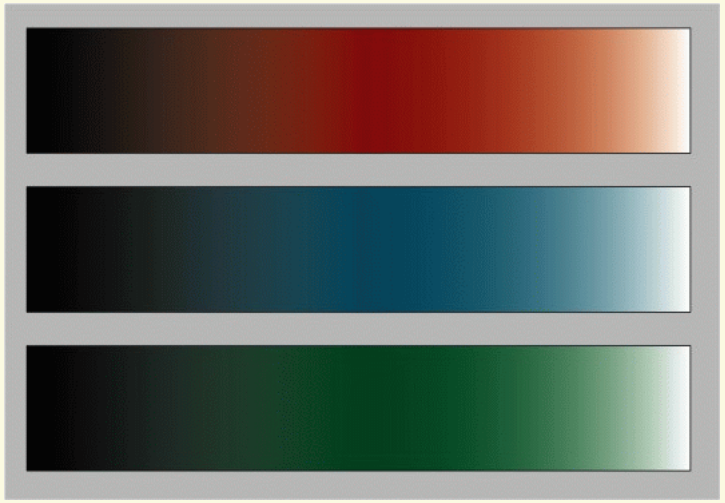


Color Components

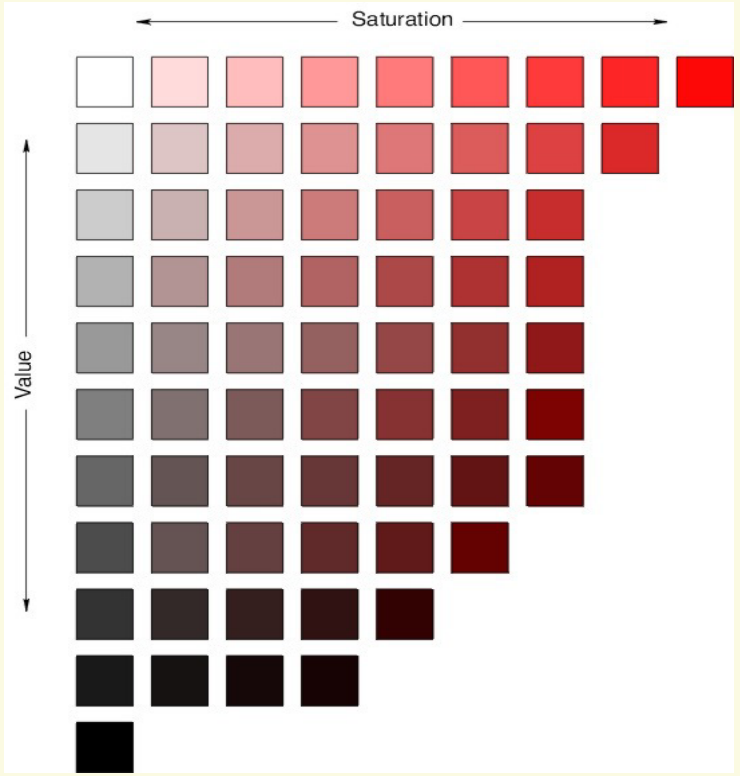
- Hue
  - property of the wavelengths of light (i.e., "color")
- Lightness (or value)
  - How much light appears to be reflected from the object
- Saturation
  - Purity of the hue relative to gray
    - e.g., red is more saturated than pink
  - Color is mixture of pure hue & gray
    - portion of pure hue is the degree of saturation

Color Components (cont.)

- Lightness



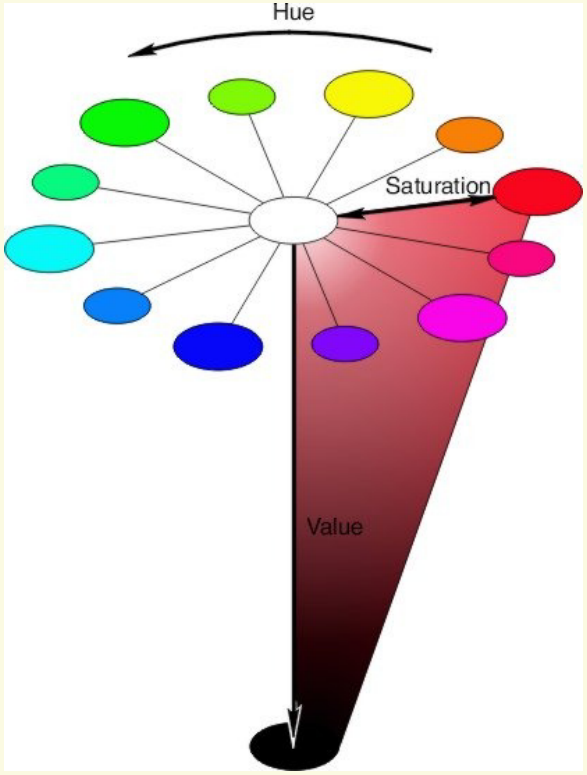
- Saturation

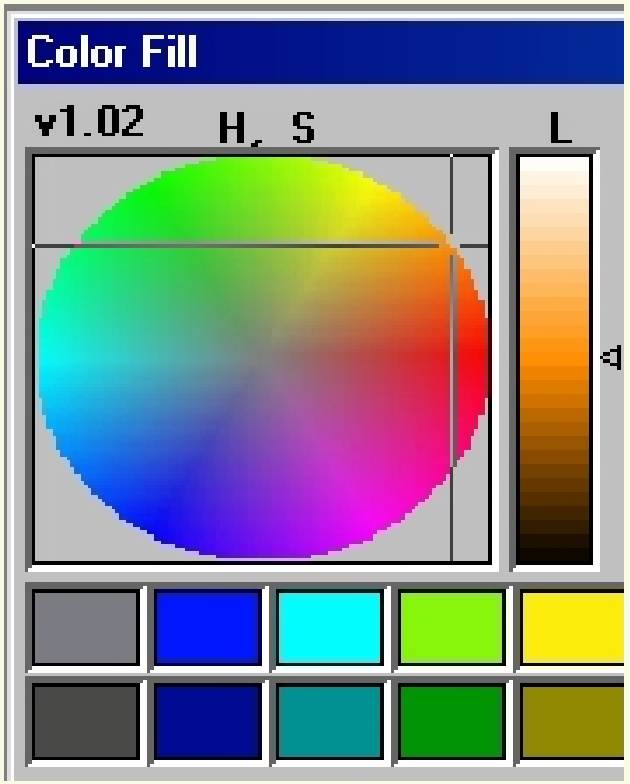


from http://www2.ncsu.edu/scivis/lessons/colormodels/color_models2.html#saturation.

Color Components (cont.)

- Hue, Saturation, Value model (HSV)



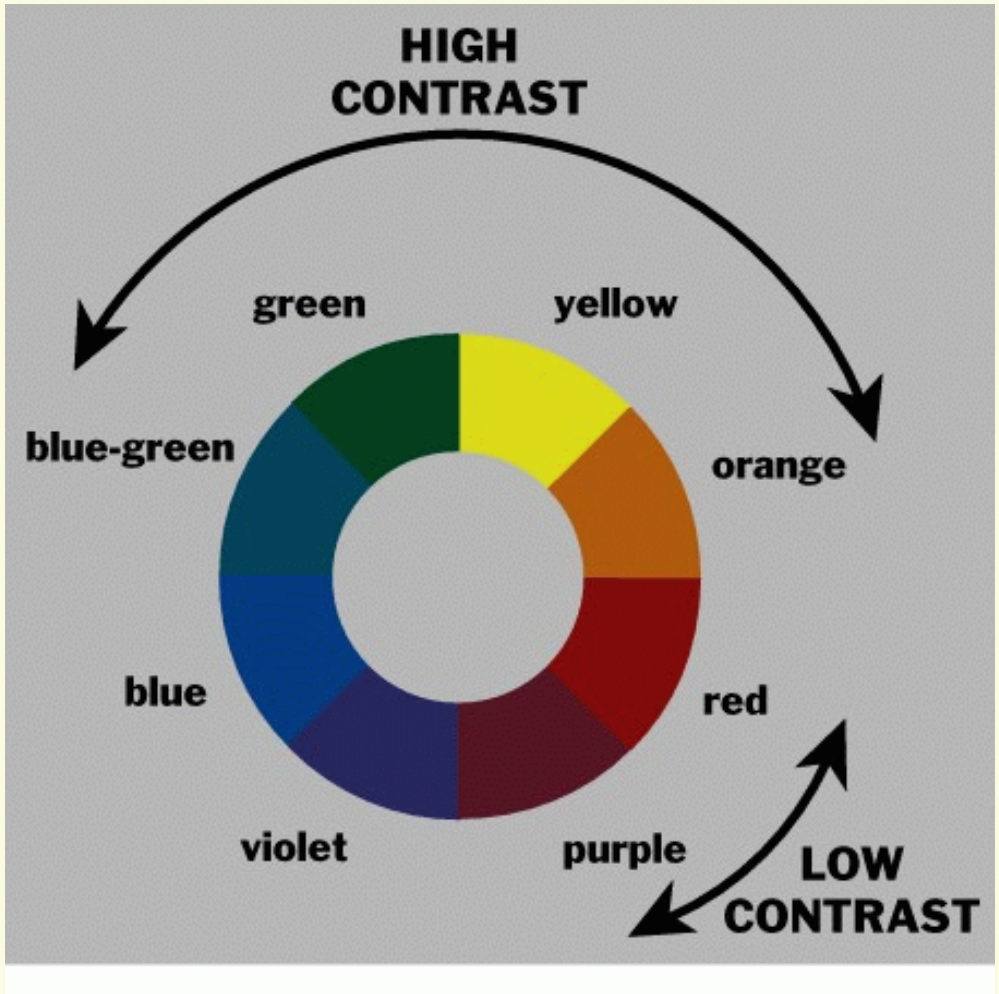


from http://www2.ncsu.edu/scivis/lessons/colormodels/color_models2.html#saturation.

Color Guidelines

- ✔ Avoid simultaneous display of highly saturated, spectrally extreme colors
  - e.g., no cyans/blues at the same time as reds, why?
    - refocusing!
  - Desaturated combinations are better → pastels

Pick Non-adjacent Colors on the Hue Circle



Color Guidelines (cont.)

- ✔ Size of detectable changes in color varies
  - * Hard to detect changes in reds, purples, & greens
  - * Easier to detect changes in yellows & blue-greens
- ✔ Older users need higher brightness levels to distinguish colors
- ✔ Hard to focus on edges created by color alone?
  - * Use both brightness & color differences

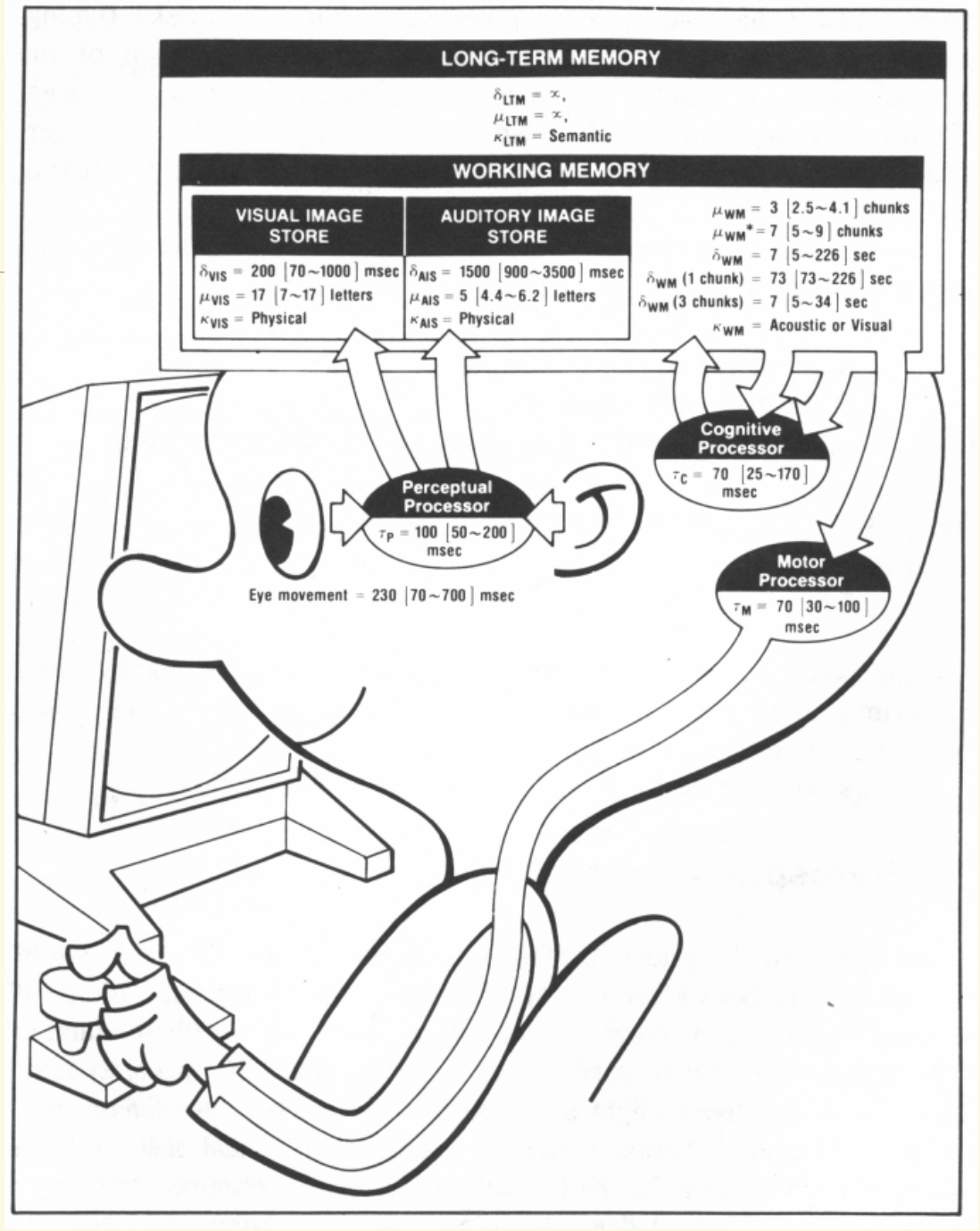
Color Guidelines (cont.)

- ✔ Avoid red & green in the periphery - why?
  - lack of RG cones there -- yellows & blues work in periphery
- ✔ Avoid pure blue for text, lines, & small shapes
  - blue makes a fine background color
  - avoid adjacent colors that differ only in blue
- ✔ Avoid single-color distinctions
  - mixtures of colors should differ in 2 or 3 colors
    - e.g., 2 colors shouldn't differ only by amount of red
  - helps color-deficient observers

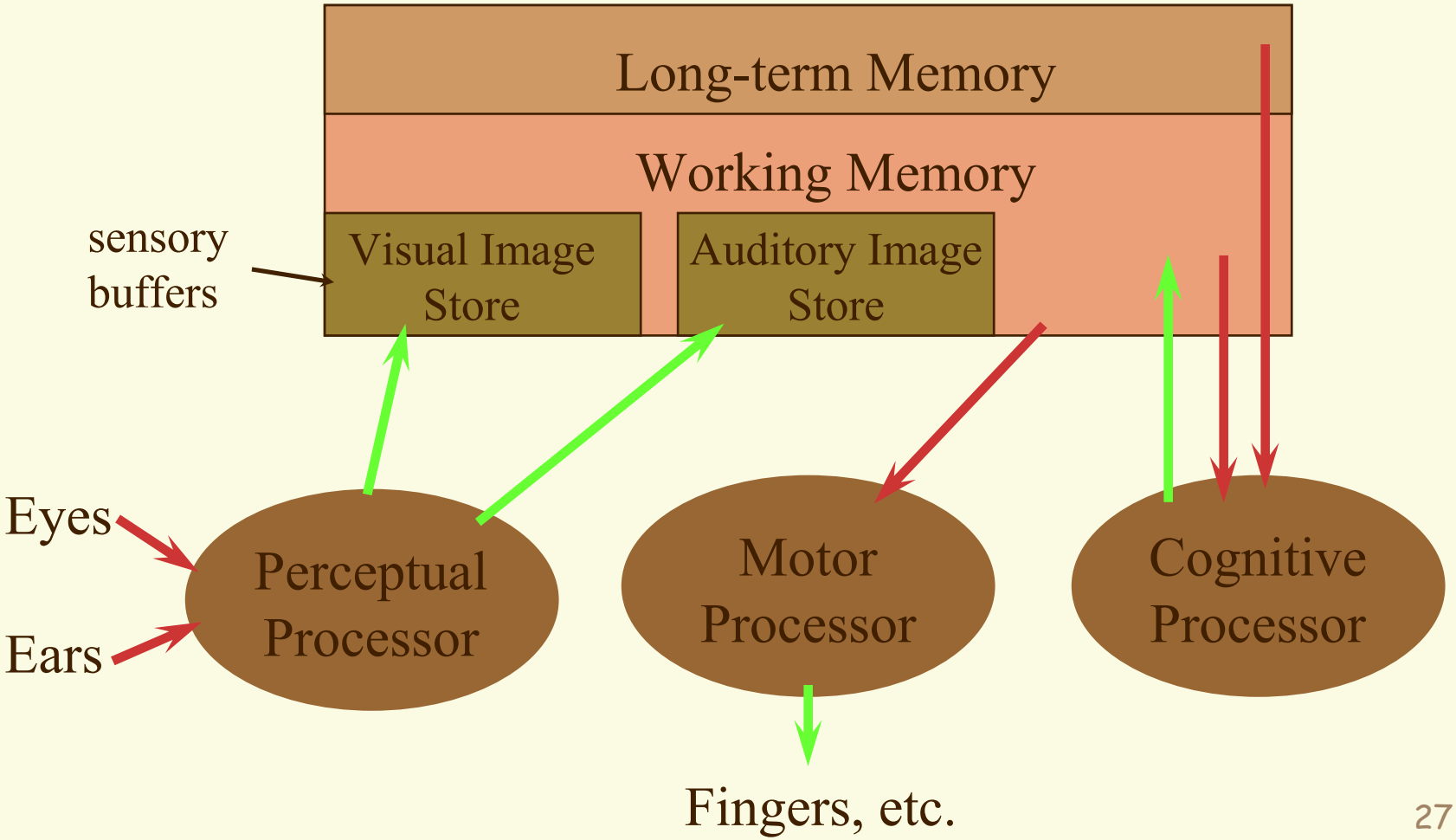
Break

- ✔ Reminder that hi-fi reports are due on Monday.
- ✔ 10-minute presentations should also be placed on the Swiki by Monday.
- ✔ Schedule: groups 1-6 Monday, groups 7-11 Wednesday.

Model Human Processor



The Model Human Processor



What is missing from MHP?

- ✔ Haptic memory
  - For touch
- ✔ Moving from sensory memory to WM
  - Attention filters stimuli & passes to WM
- ✔ Moving from WM to LTM
  - Rehearsal

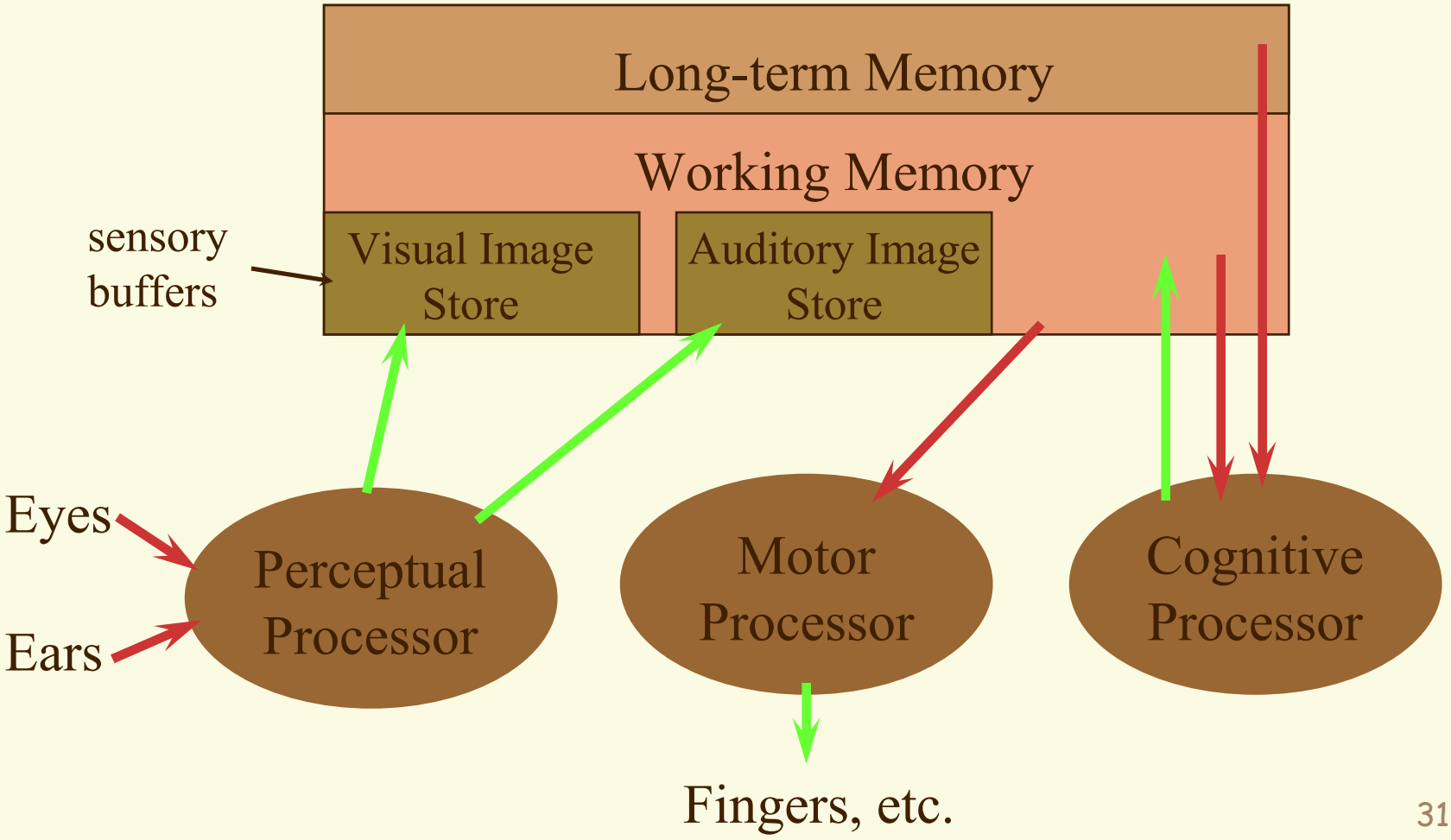
MHP Basics

- ✔ Based on empirical data
  - * Years of basic psychology experiments in the literature
- ✔ Three interacting subsystems
  - * Perceptual, motor, cognitive

MHP Basics

- ✔ Sometimes serial, sometimes parallel
  - * Serial in action & parallel in recognition
    - + Pressing key in response to light
    - + Driving, reading signs, & hearing at once
- ✔ Parameters
  - * Processors have cycle time (T) ~ 100-200 ms
  - * Memories have capacity, decay time, & type

The Model Human Processor



Memory

- Working memory (short term)
  - Small capacity (7 ± 2 "chunks")
    - 6174591765 vs. (617) 459-1765
    - DECIBMGMC vs. DEC IBM GMC
  - Rapid access (~ 70ms) & decay (~200 ms)
    - pass to LTM after a few seconds
- Long-term memory
  - Huge (if not "unlimited")
  - Slower access time (~100 ms) w/ little decay

MHP Principles of Operation

- Recognize-Act Cycle of the CP
  - On each cycle contents in WM initiate actions associatively linked to them in LTM
  - Actions modify the contents of WM
- Discrimination Principle
  - Retrieval is determined by candidates that exist in memory relative to retrieval cues
  - Interference by strongly activated chunks

Principles of Operation (cont.)

- Variable Cog. Processor Rate Principle
  - CP cycle time T_c is shorter when greater effort
  - Induced by increased task demands/information
  - Decreases with practice

Principles of Operation (cont.)

- Fitts' Law
  - Moving hand is a series of microcorrections, each correction takes $T_p + T_c + T_m = 240$ msec
  - Time T_{pos} to move the hand to target size S which is distance D away is given by:

$$T_{pos} = a + b \log_2 (D/S + 1)$$

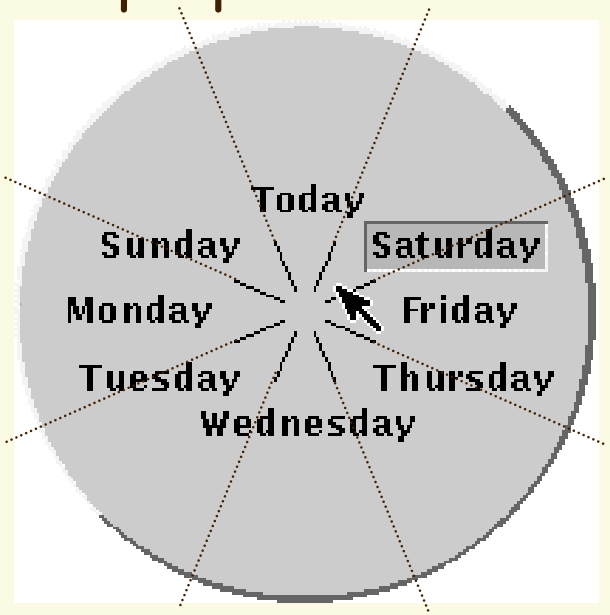
- Summary
  - Time to move the hand depends only on the ***relative precision*** required

Fitts' Law Example

Pop-up Linear Menu

Today
Sunday
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday

Pop-up Pie Menu



- Which will be faster on average?

Fitts' Law Example

Pop-up Linear Menu

Today
Sunday
Monday
Tuesday
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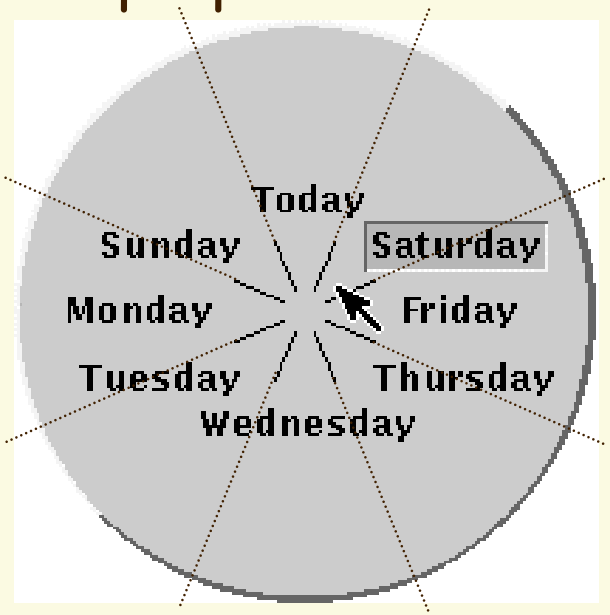
Thursday
Friday
Saturday

Pop-up Pie Menu



- Pie menu: bigger targets for a given distance;
- 6.2 / k vs. 2 / k

Pie Menus

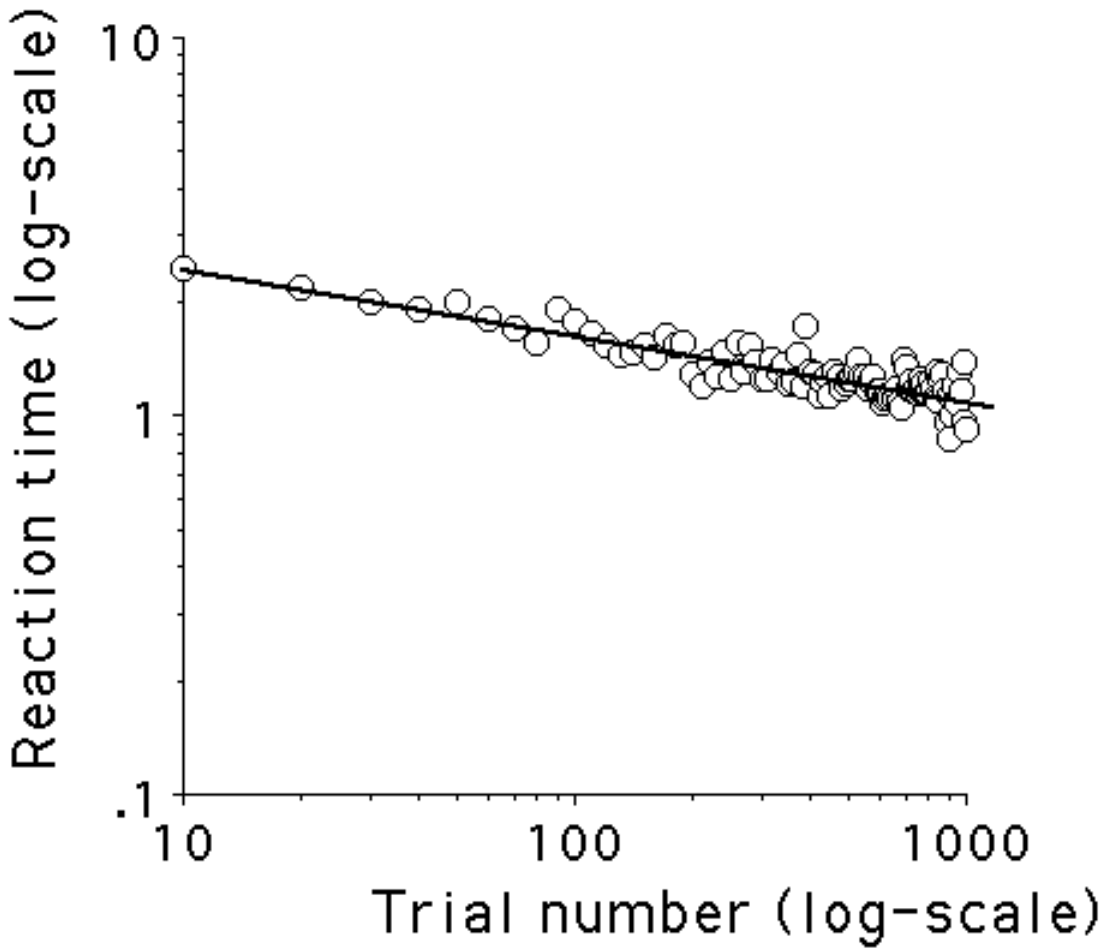
- Pie menus have proven advantages, but you rarely see them (QWERTY phenomenon?).
- Examples: Maya (animation tool), and many research systems like DENIM.
- Still, open-source code for them exists.

Principles of Operation (cont.)

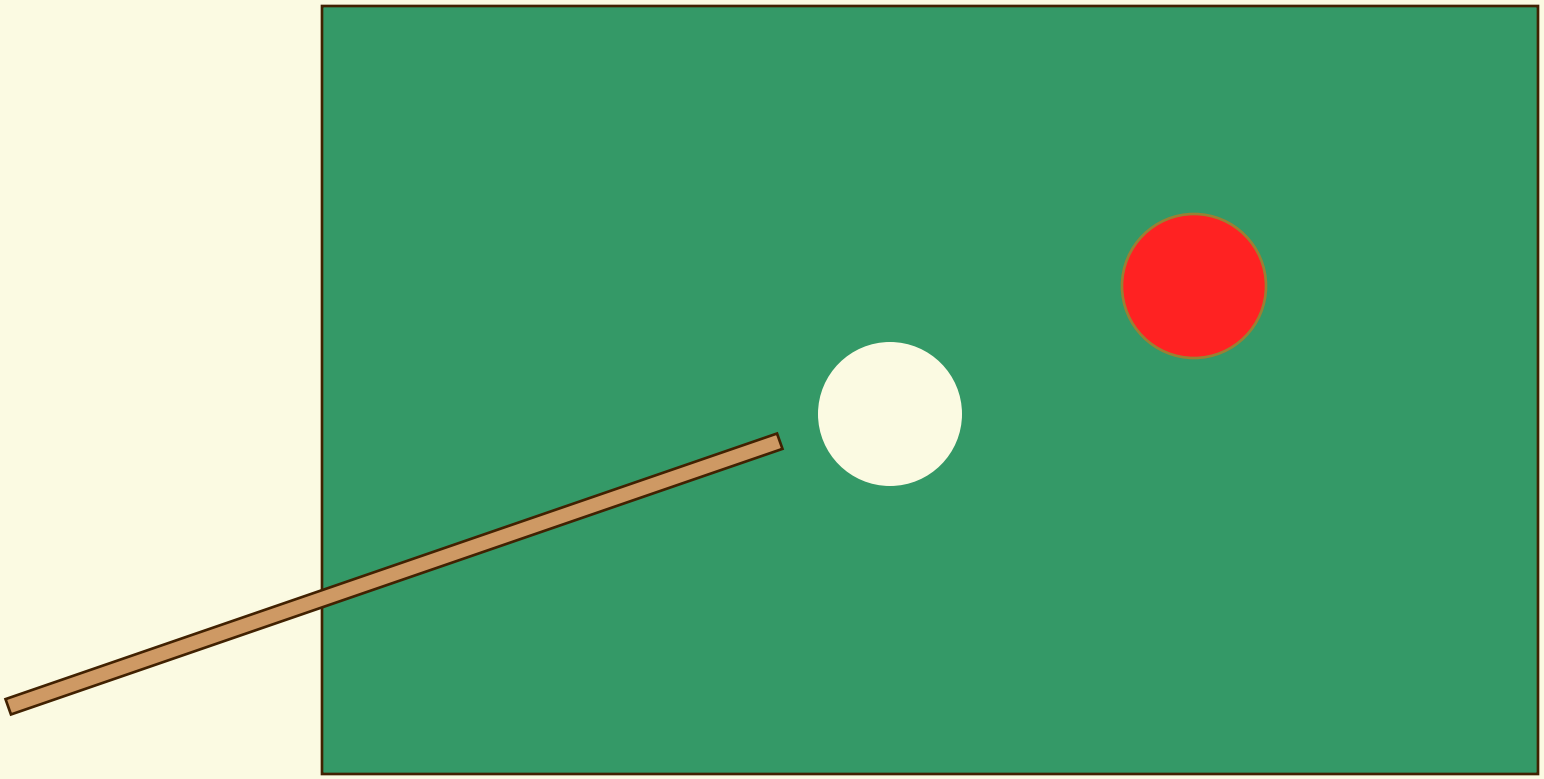
- Power Law of Practice
  - Task time on the nth trial follows a power law

    $T_n = T_1 n^{-a} + c$, where a = .4, c = limiting constant
  - i.e., you get faster the more times you do it!
  - Applies to skilled behavior (sensory & motor)
  - Does not apply to knowledge acquisition or quality

Power Law of Practice

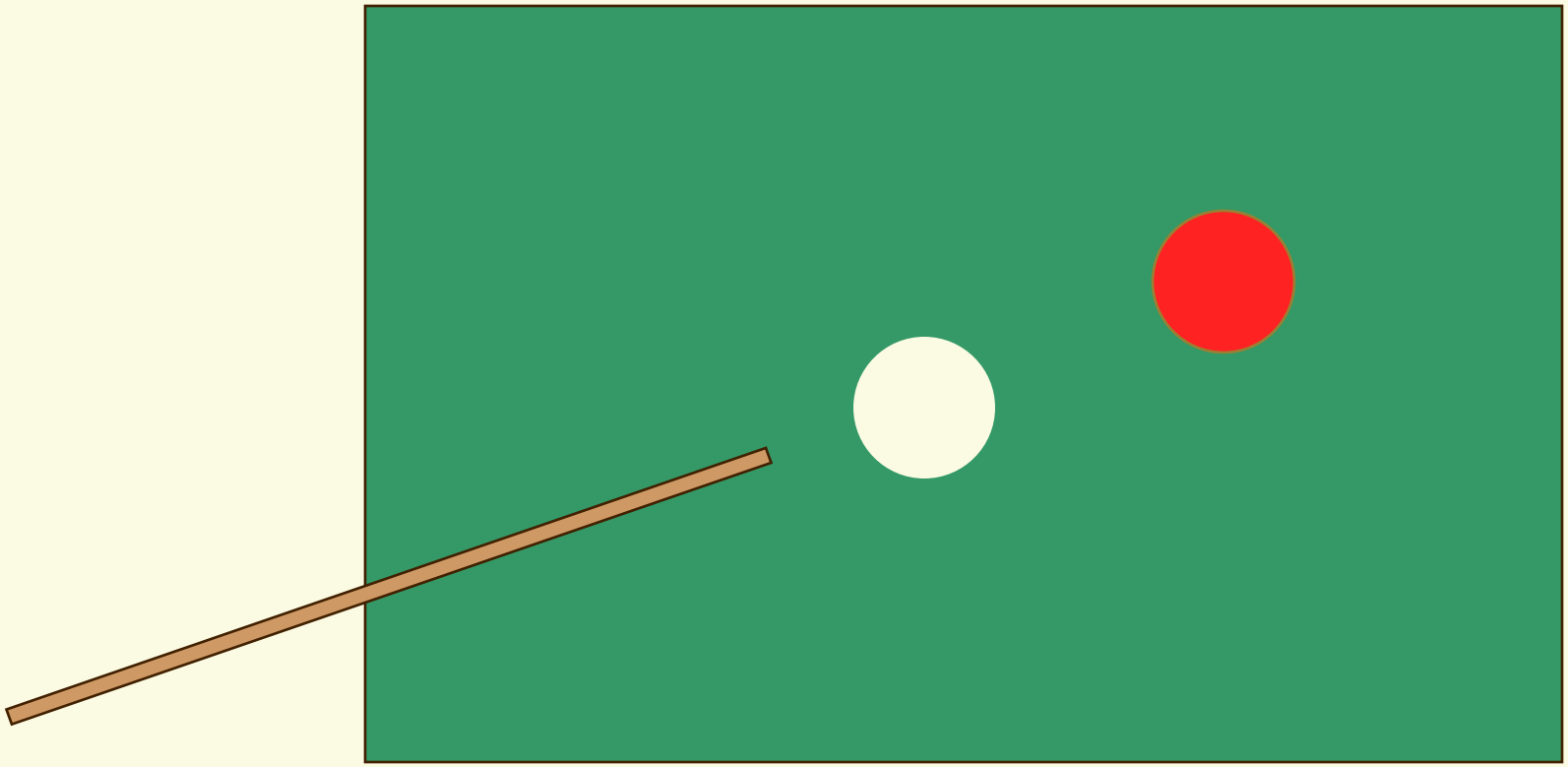


Perceptual Causality



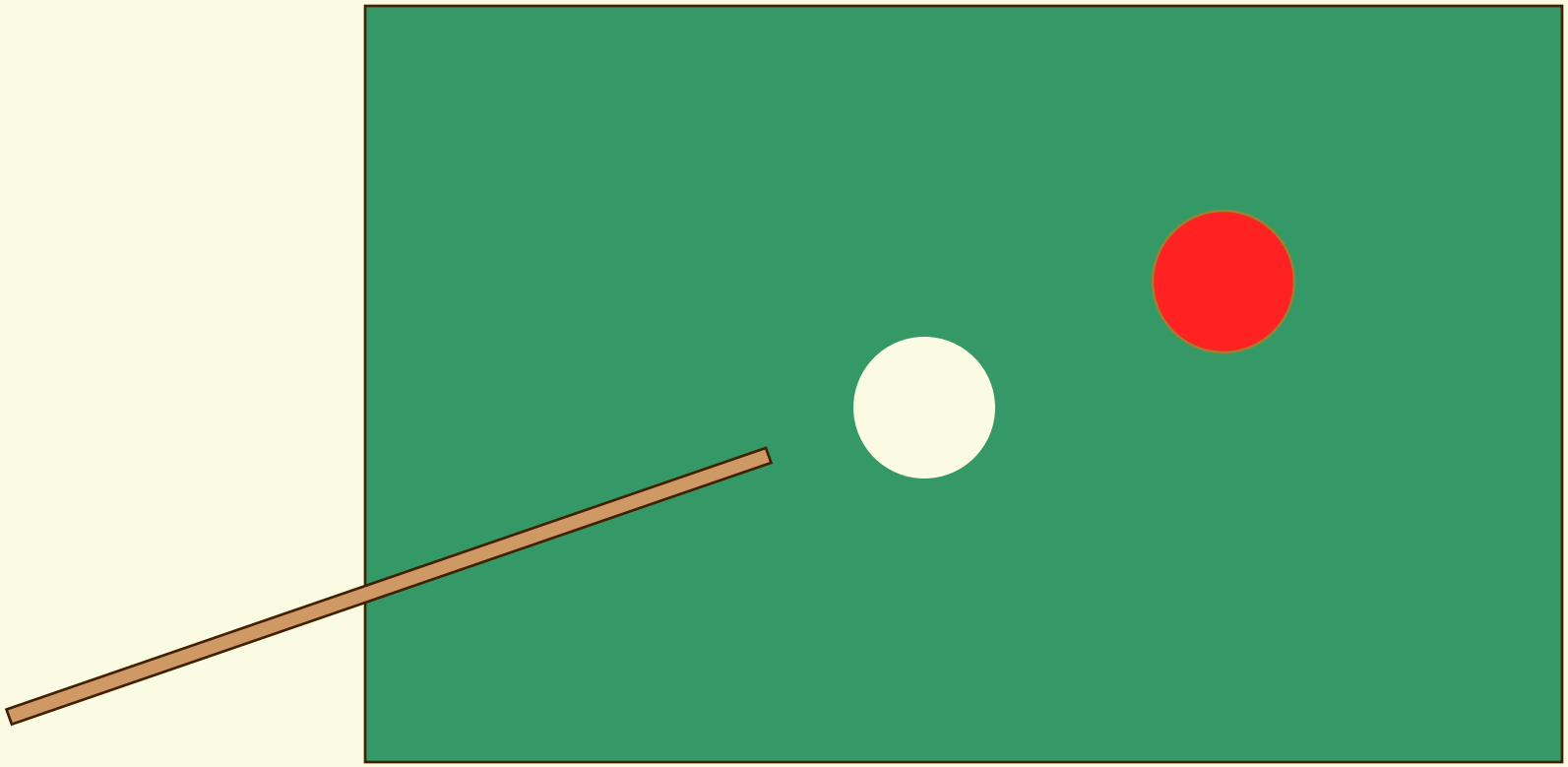
- How soon must red ball move after cue ball collides with it?

Perceptual Causality



- ✔ Must move in < Tp (100 msec)

Perceptual Causality



- ✔ Must move in < Tp (100 msec)

Perception

- ✔ Stimuli that occur within one PP cycle fuse into a single concept
  - * Frame rate necessary for movies to look real?
    - + time for 1 frame < Tp (100 msec) -> 10 frame/sec.
  - * Max. morse code rate can be similarly calculated
- ✔ Perceptual causality
  - * Two distinct stimuli can fuse if the first event appears to *cause* the other
  - * Events must occur in the same cycle

Simple Experiment

- ✔ Volunteer
- ✔ Start saying **colors** you see in list of words
  - When slide comes up
  - As fast as you can
- ✔ Say "done" when finished
- ✔ Everyone else time it…

Paper

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Page

Change

Simple Experiment

- ✔ Do it again
- ✔ Say "done" when finished

Blue

Red

Black

White

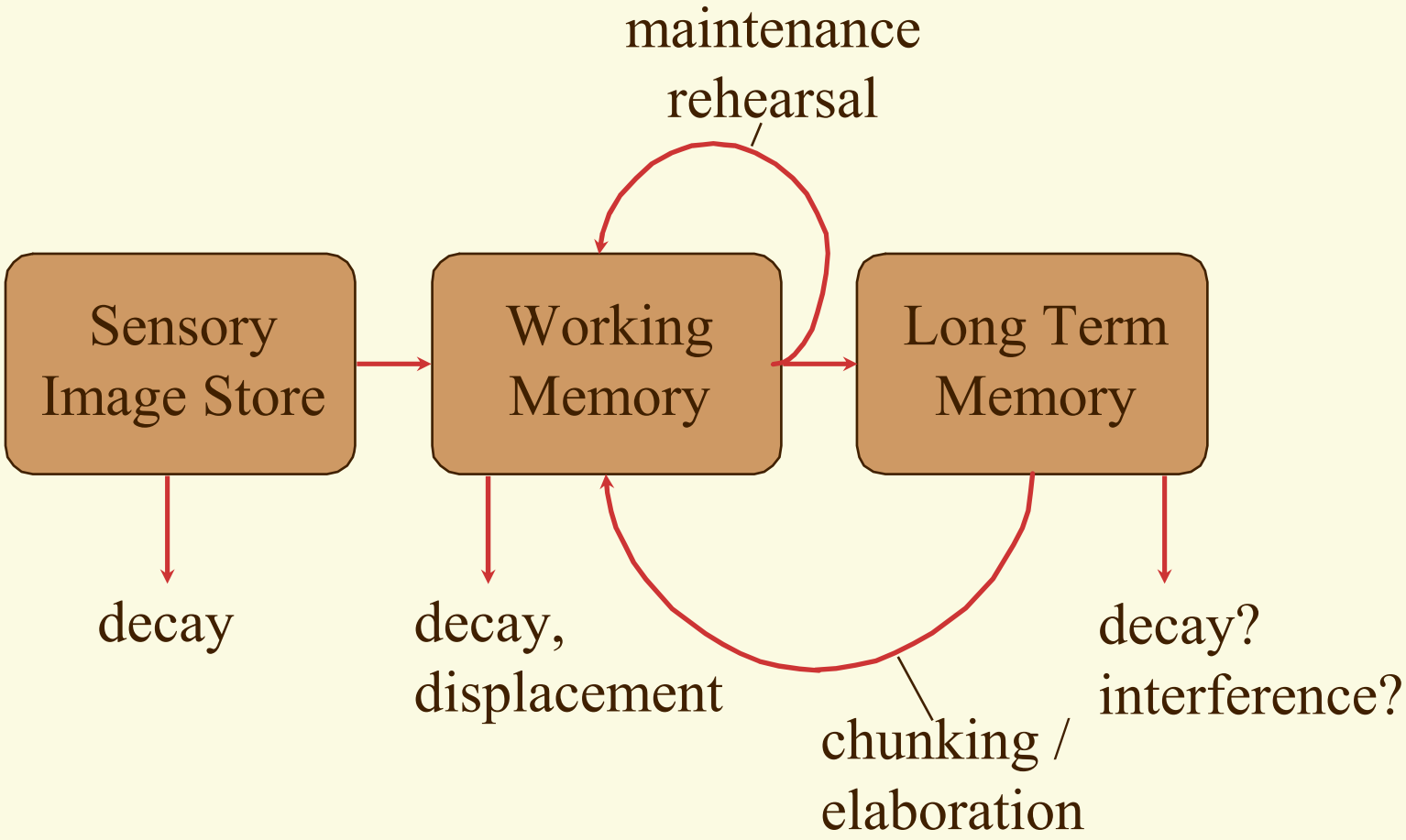
Green

Yellow

Memory

- Interference
  - Two strong cues in working memory
  - Link to different chunks in long term memory

Stage Theory



Stage Theory

- ✔ Working memory is small
  - * Temporary storage
    - + decay
    - + displacement
- ✔ Maintenance rehearsal
  - * Rote repetition
  - * Not enough to learn information well
- ✔ Answer to problem is organization
  - * Faith Age Cold Idea Value Past Large
  - * In a show of faith, the cold boy ran past the church

Elaboration

- ✔ Relate new material to already learned material
- ✔ Recodes information
- ✔ Attach meaning (make a story)
  - * e.g., sentences
- ✔ Visual imagery
- ✔ Organize (chunking)
- ✔ Link to existing knowledge, categories

LTM Forgetting

- Causes for not remembering an item?
  - 1) Never stored: encoding failure
  - 2) Gone from storage: storage failure
  - 3) Can't get out of storage: retrieval failure

Recognition over Recall

- Recall
  - Info reproduced from memory
- Recognition
  - Presentation of info provides knowledge that info has been seen before
  - Easier because of cues to retrieval
- We want to design UIs that rely on recognition!

Facilitating Retrieval: Cues

- ✔ Any stimulus that improves retrieval
  - * Example: giving hints
  - * Other examples in software?
    - + icons, labels, menu names, etc.
- ✔ Anything related to
  - * Item or situation where it was learned
- ✔ Can facilitate memory in any system
- ✔ What are we taking advantage of?
  - * Recognition over recall!

Summary

- ✔ Color perception
- ✔ MHP: Model Human Processor
- ✔ Memory principles