Human Abilities: Vision & Cognition

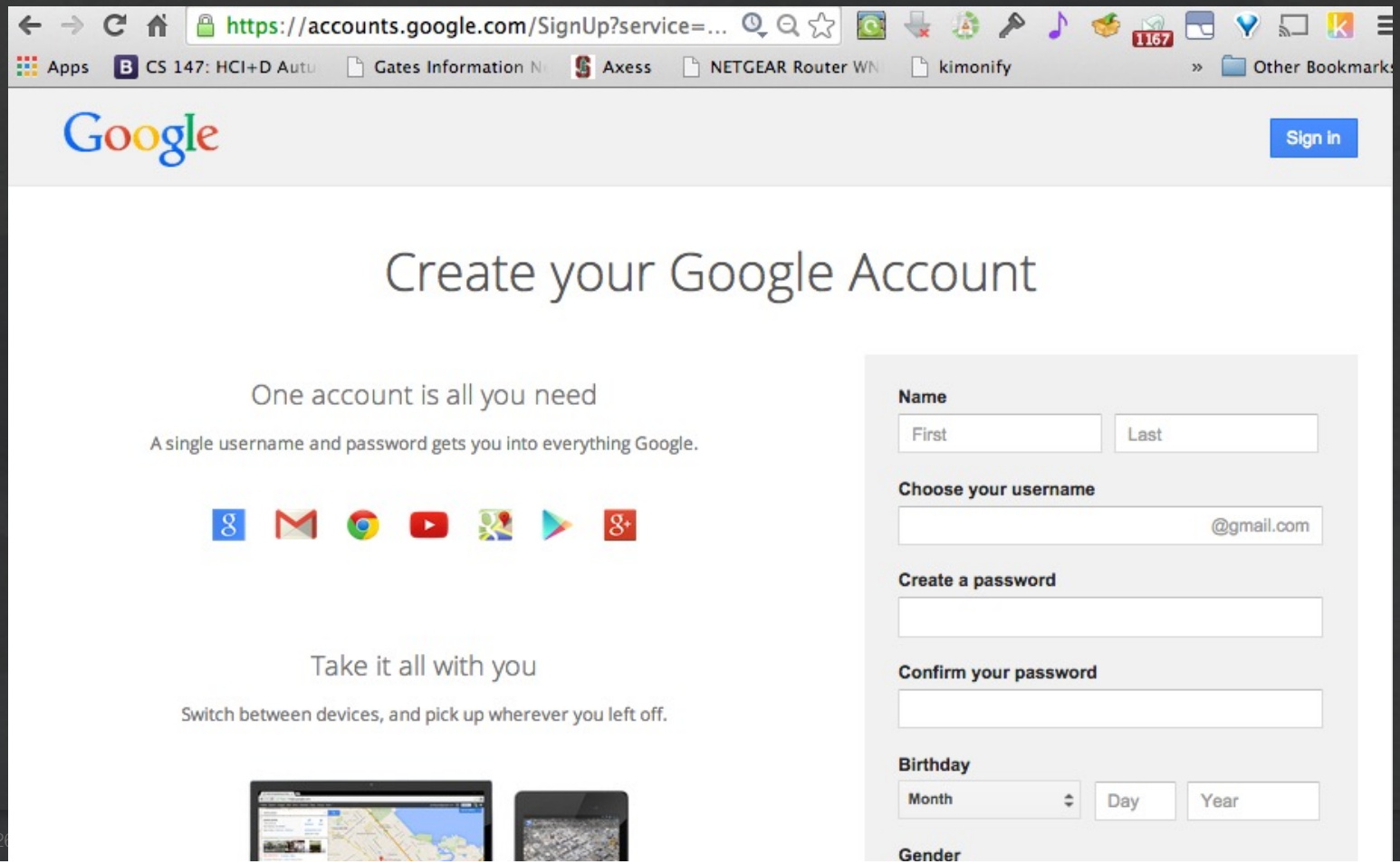
刘哲明
Prof. James A. Landay
Computer Science Department
Stanford University

Autumn 2026

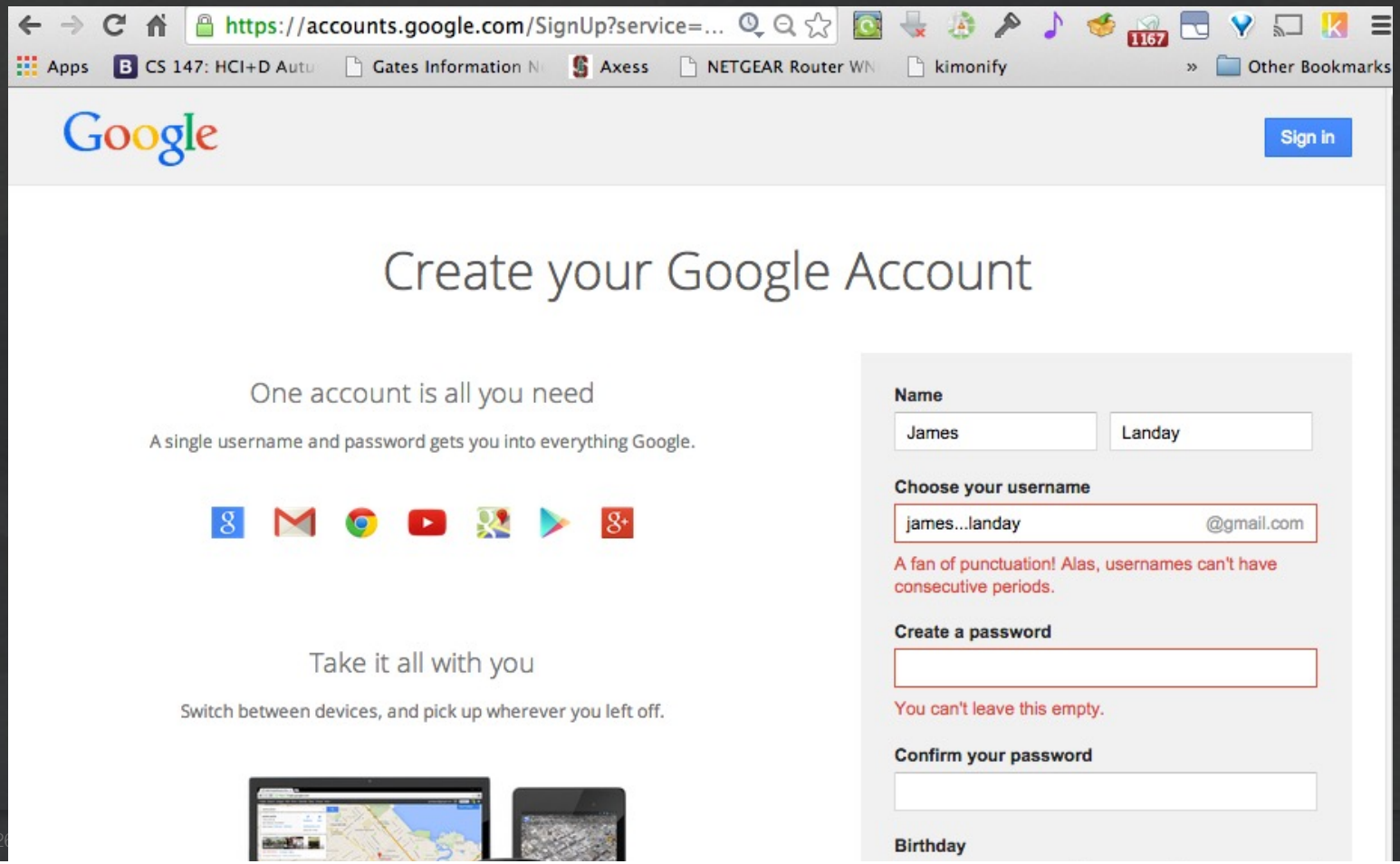
October 26, 2026

Music: https://soundcloud.com/dansuneroquette
https://open.spotify.com/album/4bNHHAs6m1rKuQU9gLpLHg?si=uVBwekOrTPWwEsqrhO7Q_g

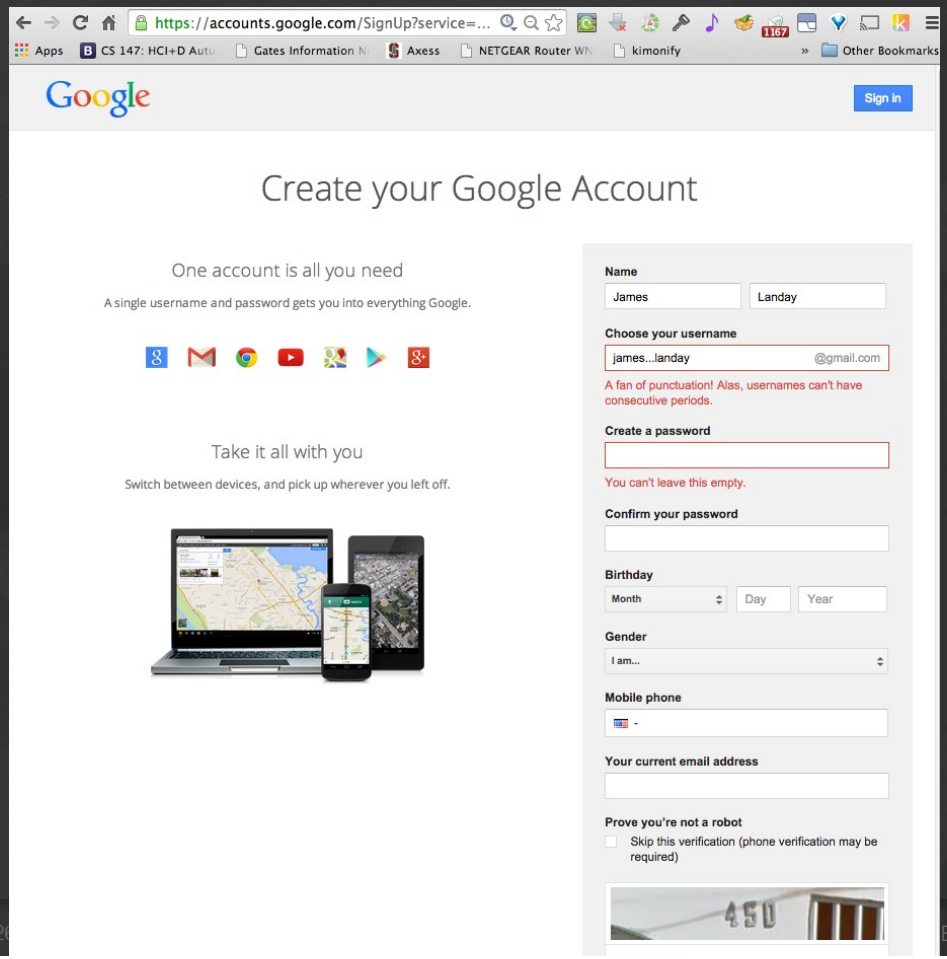
Hall of Fame or Shame?



Hall of Fame or Shame?



Hall of Fame! (but still some issues…)



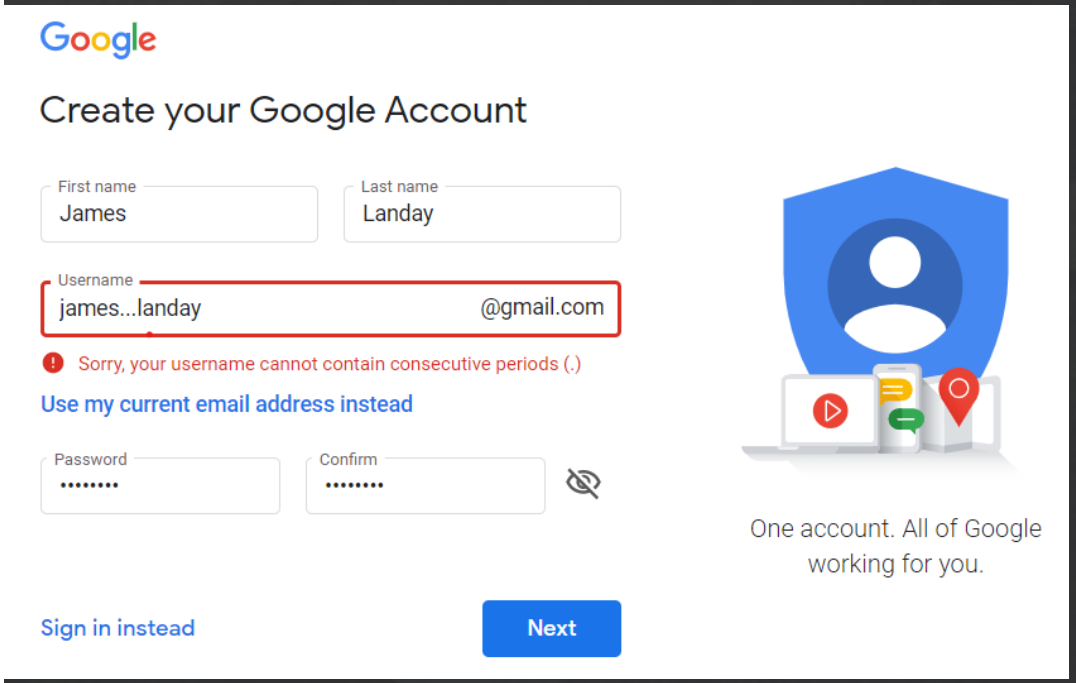
Clearly highlights error (red text & box)

Tells me what I did wrong/how to fix it

In user's language
(but, be careful w/ humor)

Red may be an issue when used alone, more later today (also cultural issue)

Hall of Fame!



Clearly highlights error (red text & box)

Tells me what I did wrong/how to fix it

In user's language
(but, be careful w/ humor)

Red may be an issue when used alone, more later (also cultural issue)

New version fixes these 2 problems
- adds caution icon & removes the humor

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Music: https://soundcloud.com/dansuneroquette
https://open.spotify.com/album/4bNHHAs6m1rKuQU9gLpLHg?si=uVBwekOrTPWwEsqrhO7Q_g

Outline

- Human visual system
- Guidelines for design
- Team Break
- Models of human performance (MHP)
- Two in class experiments
- Memory

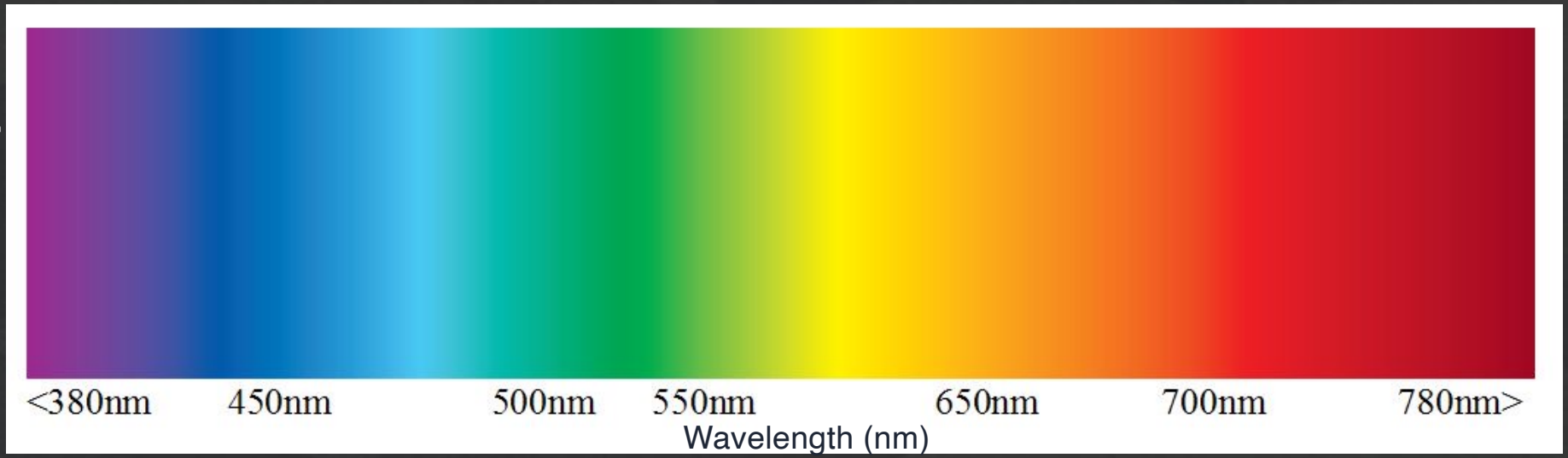
Why Study Color?

1) Color can be a powerful tool to *improve* user interfaces by communicating key information

2) Inappropriate use of color can severely *reduce the performance* of systems we build

Visible Spectrum

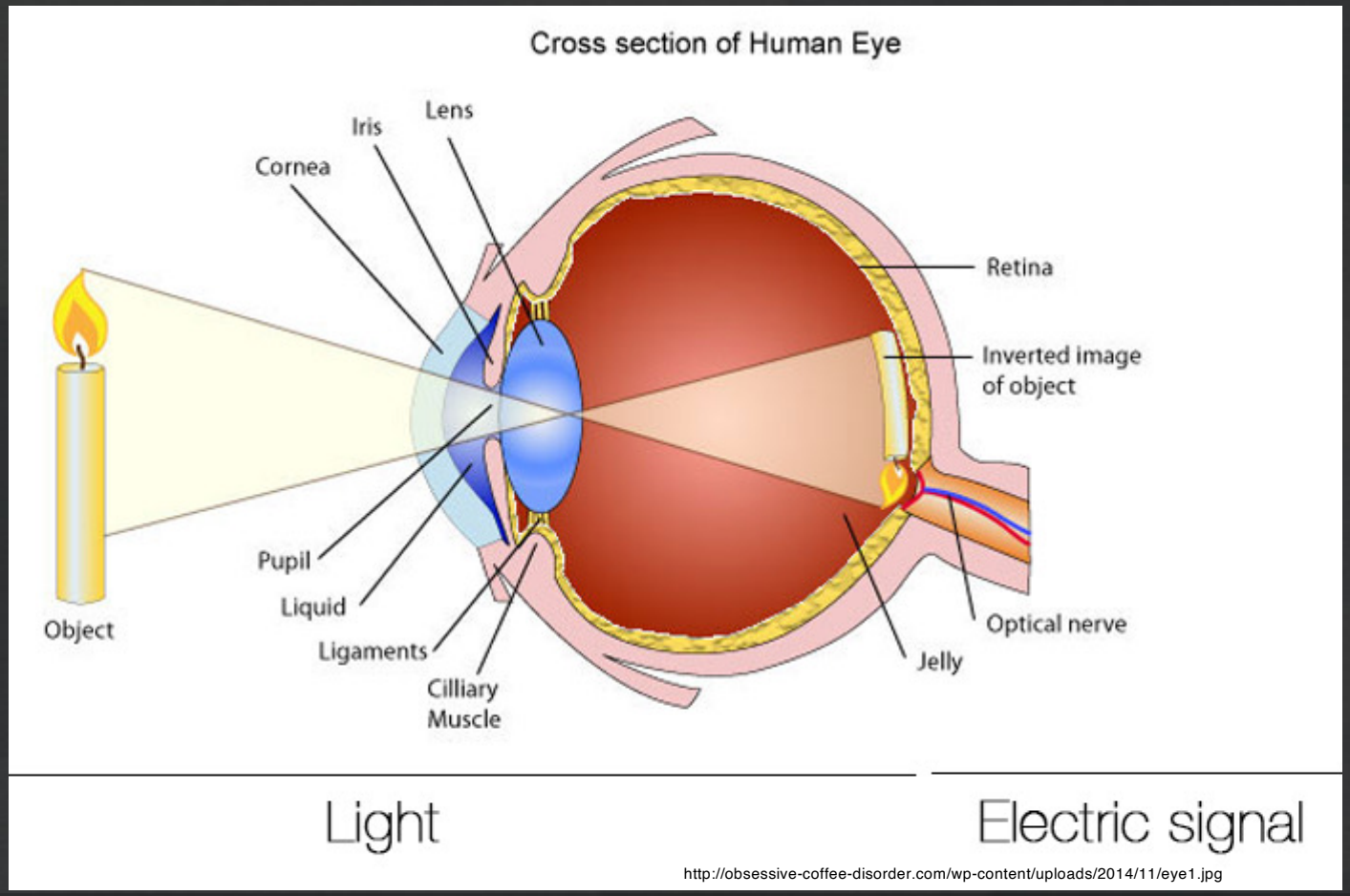
There is an order to the colors… ROY G. BIV



Do not use that ordering *to order data!*

(visual design lecture: how unusable a map is using this ordering for elevation)

Human Visual System

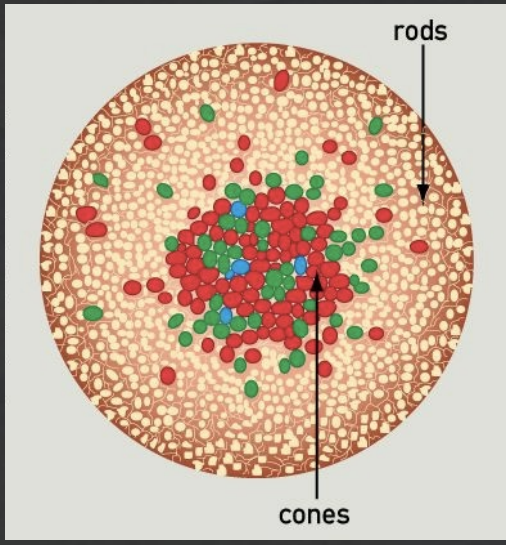


http://obsessive-coffee-disorder.com/wp-content/uploads/2014/11/eye1.jpg

- Light passes through lens
- Focused on retina

Retina

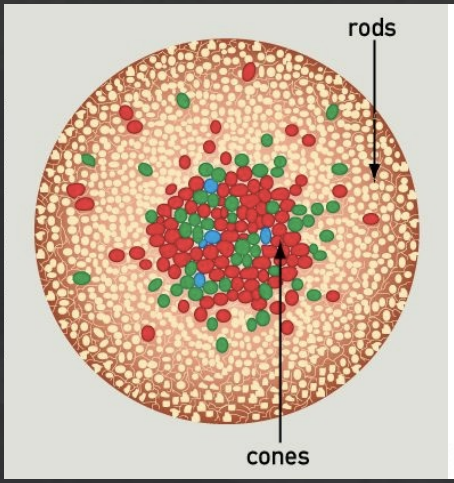
- Retina covered with two types of light-sensitive receptors called?
  - rods
    - primarily for night vision & perceiving movement
    - sensitive to broad spectrum of light
    - can't discriminate between colors
    - sense intensity or shades of gray
  - cones
    - used to sense color



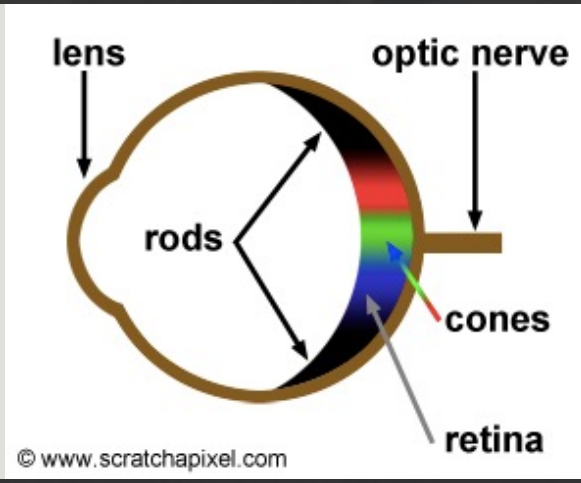
http://www.webexhibits.org/causesofcolor/1G.html

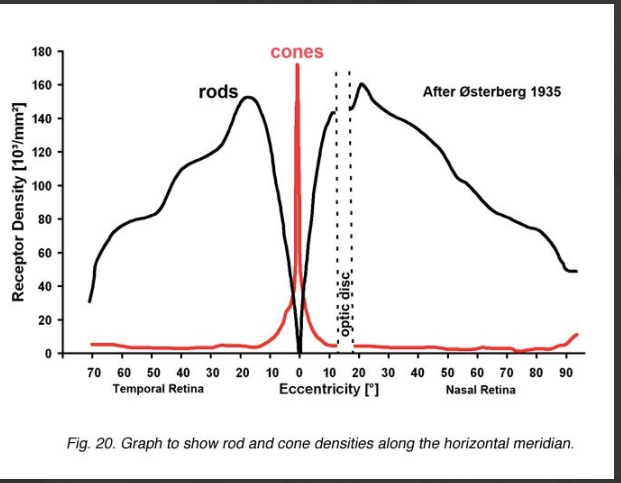
Retina

- Center of retina has most of the cones →
  - allows for high acuity of objects focused at center



http://www.webexhibits.org/causesofcolor/1G.html



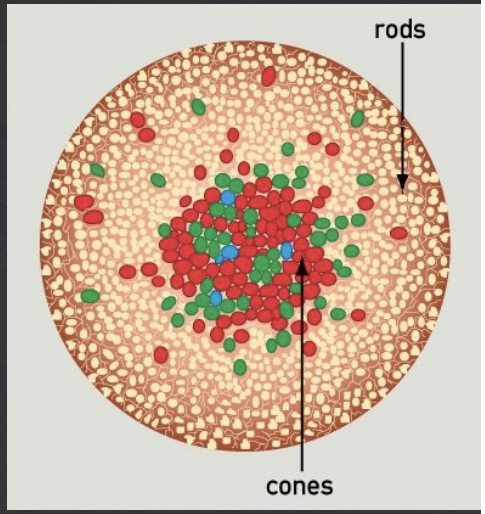


http://webvision.med.utah.edu/imageswv/Ostergr.jpeg

- Edge of retina is dominated by rods →
  - allows detecting motion of threats in periphery

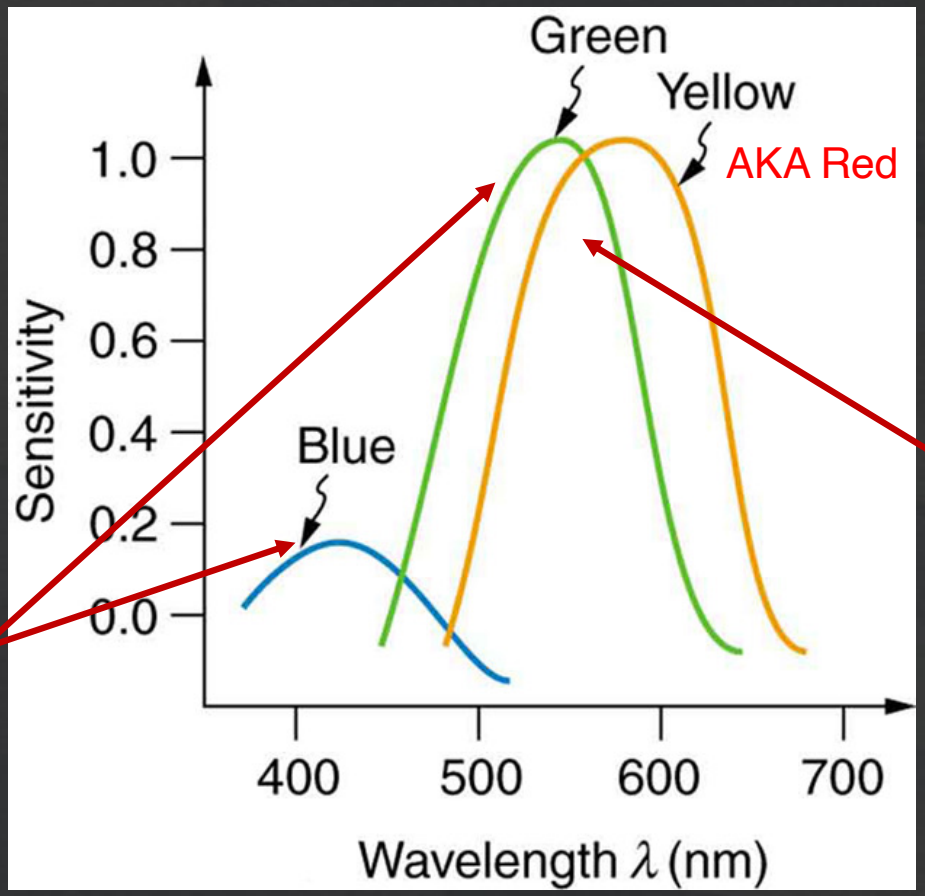
Color Perception via Cones

- "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



http://www.webexhibits.org/causesofcolor/1G.html

Color Sensitivity

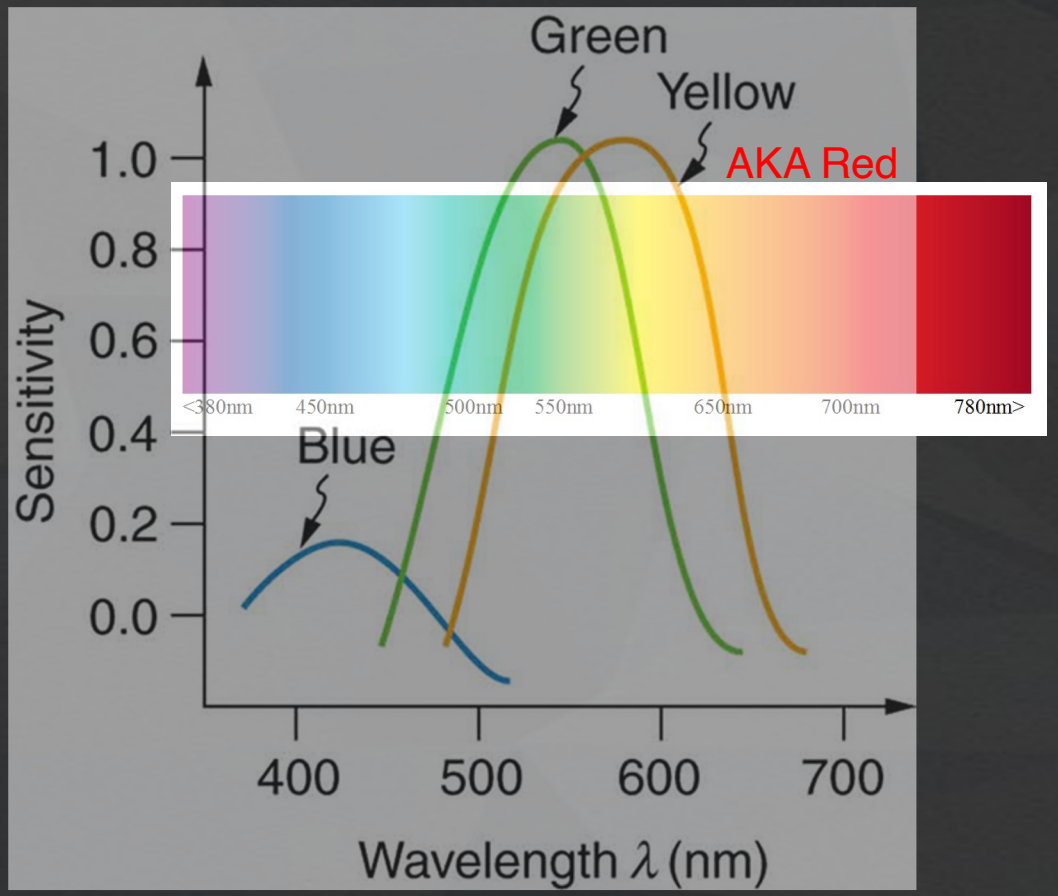


not as sensitive to blue

lots of overlap

http://archive.cnx.org/contents/d42c807d-a9fa-4e3d-83d0-0f7c745b51a0@4/color-and-color-vision#import-auto-id1844887

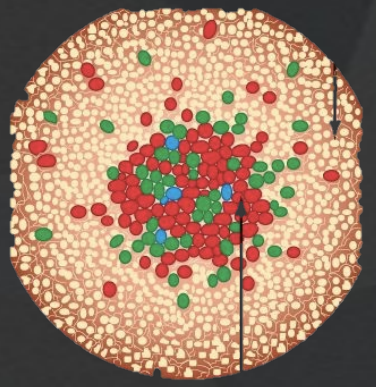
Color Sensitivity



http://archive.cnx.org/contents/d42c807d-a9fa-4e3d-83d0-0f7c745b51a0@4/color-and-color-vision#import-auto-id1844887

Distribution of Photopigments

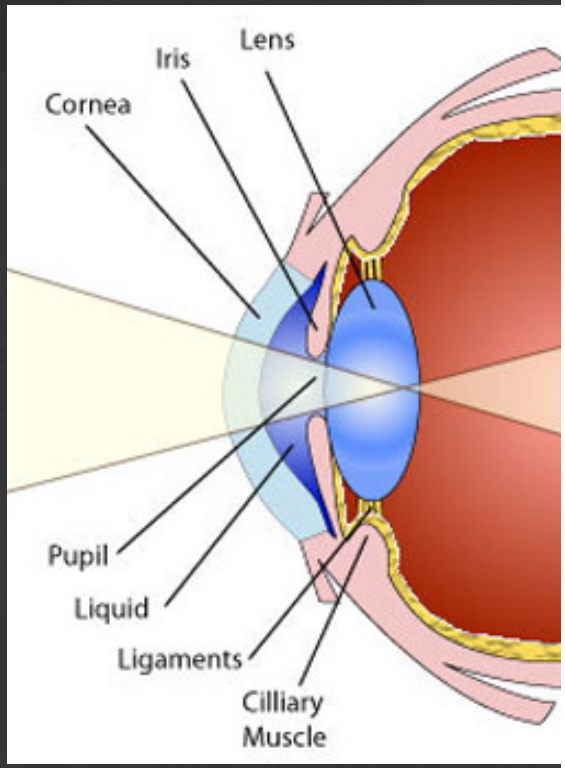
- Not distributed evenly – mainly reds (64%) & very few blues (4%) →
  - insensitivity to short wavelengths (blue)
- Few blue cones in retina center (high acuity) →
  - "disappearance" of small blue objects you fixate on
- As we age lens yellows & absorbs shorter wavelengths →
  - sensitivity to blue is even more reduced
- Implication
  - don't rely on blue for text or small objects!



http://www.webexhibits.org/causesofcolor/1G.html

Focus

- Different wavelengths of light focused at different distances behind eye's lens
  - need for constant refocusing → ?
    - causes fatigue
  - be careful about nearby color combinations



Focus

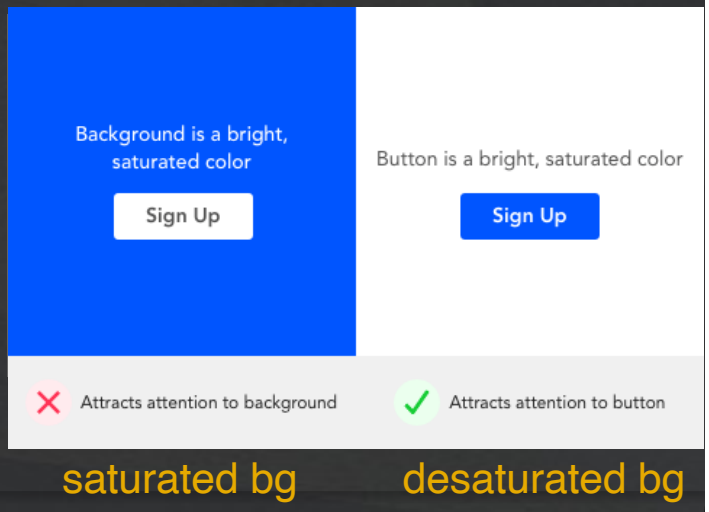
- Different wavelengths of light focused at different distances behind eye's lens
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  - be careful about nearby color combinations
- Pure (saturated) colors require more focusing than less pure (desaturated)
  - don't use saturated colors in UIs unless you really need something to stand out



https://physics.info/color/

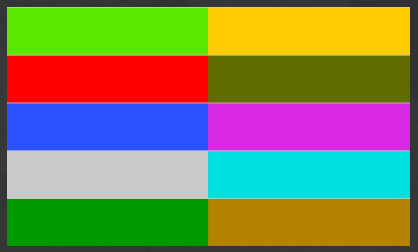
Focus

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Color Deficiency (Also known as “color blindness”)

- Trouble discriminating colors
  - besets about 4.5% of population (~8% men, ~½% women)
- Two main types
  - different photopigment response – most common
    - reduces capability to discern small color diffs
  - red-green deficiency – best known
    - lack of either green or red photopigment → can’t discriminate colors solely dependent on Red & Green
- Key is to avoid single color distinctions

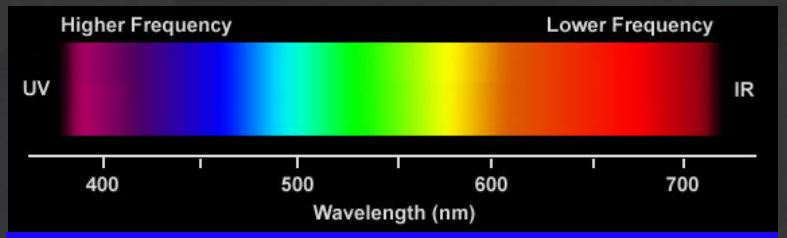


Difficult pairs for severe red deficient person to discern
https://www.color-blindness.com/red-green-color-blindness/

Color Guidelines

Avoid simultaneous display of highly saturated, spectrally extreme colors

- e.g., no cyans/blues at the same time as reds, why?
  - refocusing!



bad → A Bad Color Combo

- desaturated combinations are better → pastels

Use the Hue Circle

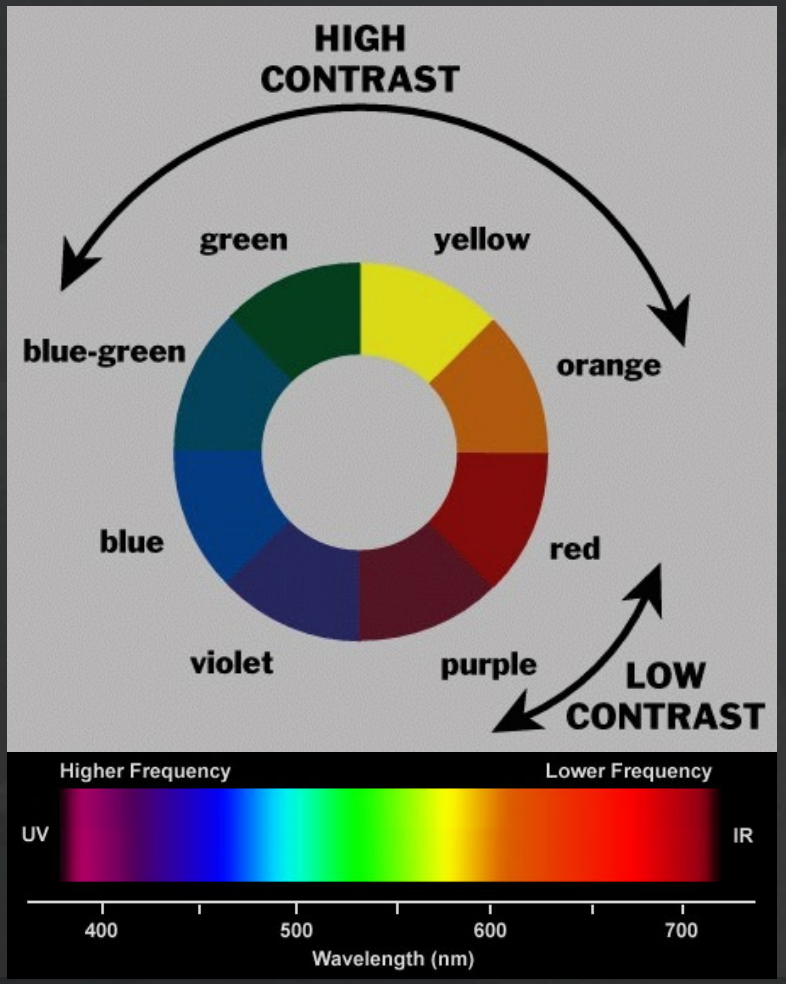
Pick non-adjacent colors

– opponent colors
go well together

red & green

or

yellow & blue



Color Guidelines (cont.)



- Avoid pure blue for text, lines & small shapes
- Avoid adjacent colors that differ only in blue

- Blue makes a great background color

Administrivia

- Questions about Medium-fi Prototype assignment?
  - Checkpoint this Thur/Fri & final due Monday 5pm (hard)
  - both the Figma Basics & Design Systems workshops are online (or soon will be for Design Systems). Check them out now for this & following assignments!

- Keep up w/ readings/HW on class website
  - http://cs147.stanford.edu/
  - midterm on Wed week 8 (weeks 7-8 have lighter work)

Midterm

Scope: Everything through Usability Testing (Week 8 - Lecture 14) including Reading/Videos/Podcasts, Lectures, Assignments.

Format: Will primarily be a multi-part design problem (but know and be able to demonstrate *all* aspects of the design process & use facts for reasoning for your answers), with several multiple choice/short answer on knowledge of HCI as well.

Place: Hybrid exam – part I in class & part II (design problem) at home (Gradescope)

Time: This midterm will take place during a 24-hour window starting in class Wed., Nov. 11, at 1:30 pm Pacific time. You will have ~1:30 for part I in class and ~2 hour for part II at home.

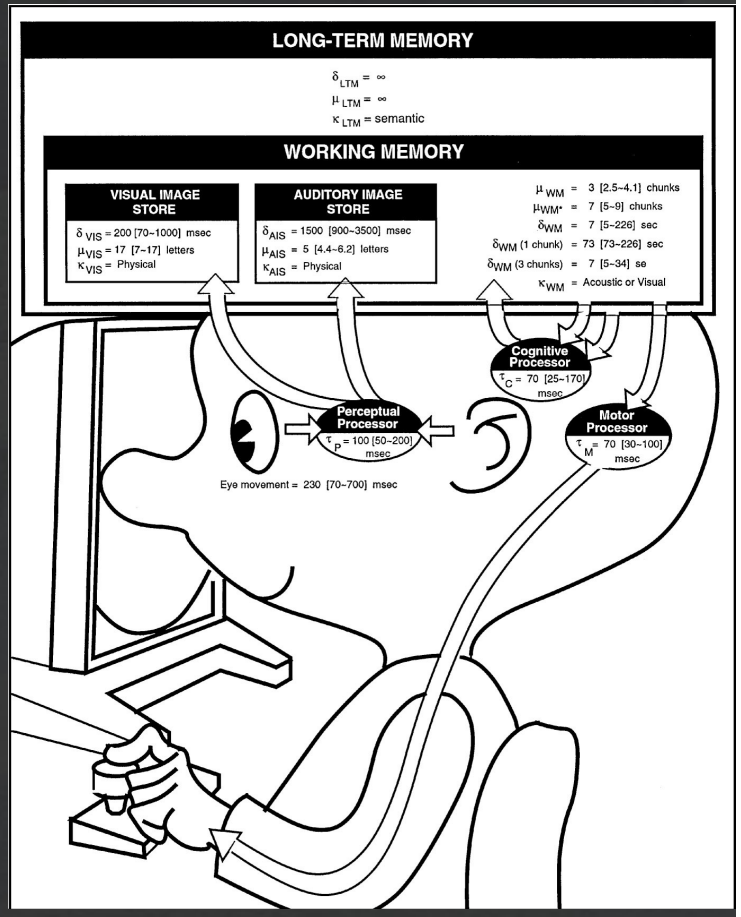
TEAM BREAK

The Model Human Processor

Developed by Card, Moran & Newell (’83)

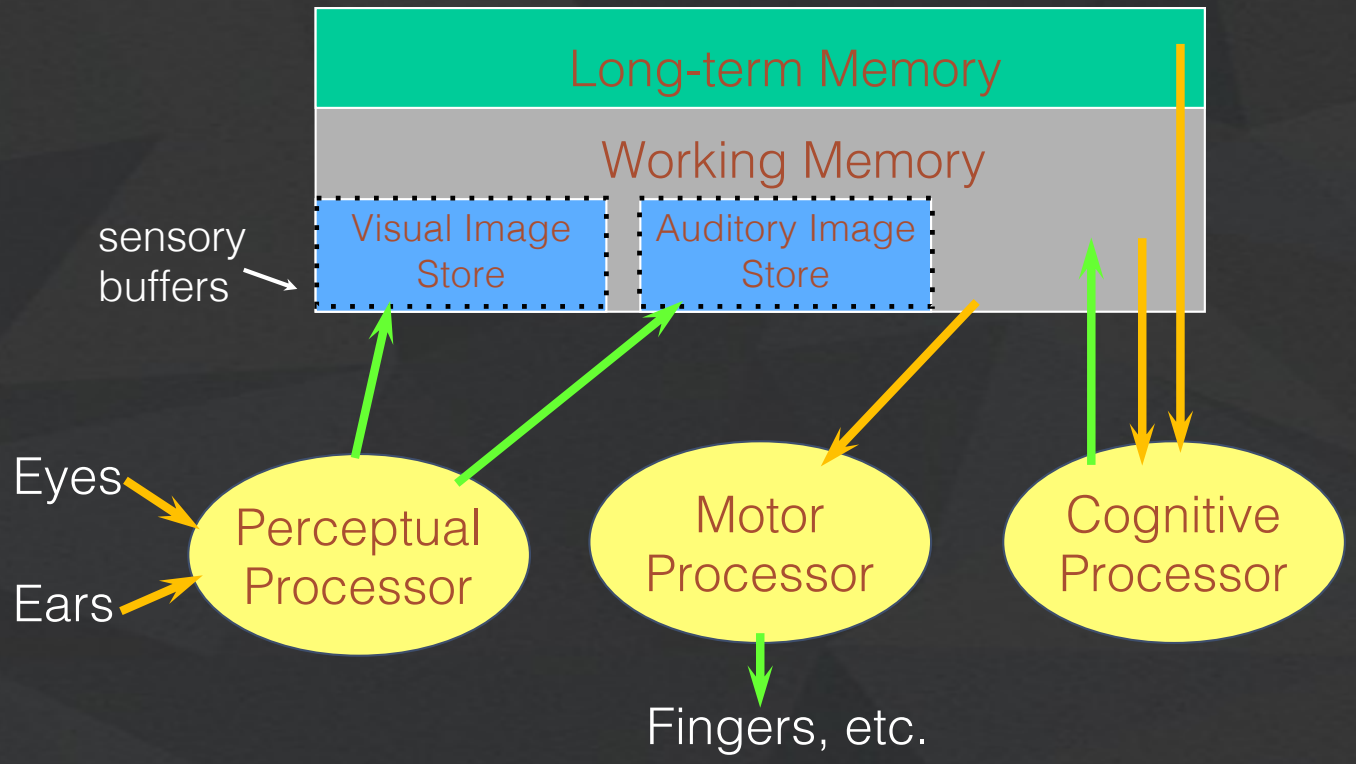
- based on empirical data

- Model can help us test understanding & make predictions
- Underlies other usability techniques
  - GOMS, KLM, tools, etc.



The Psychology of Human-Computer Interaction by Card, Moran & Newell

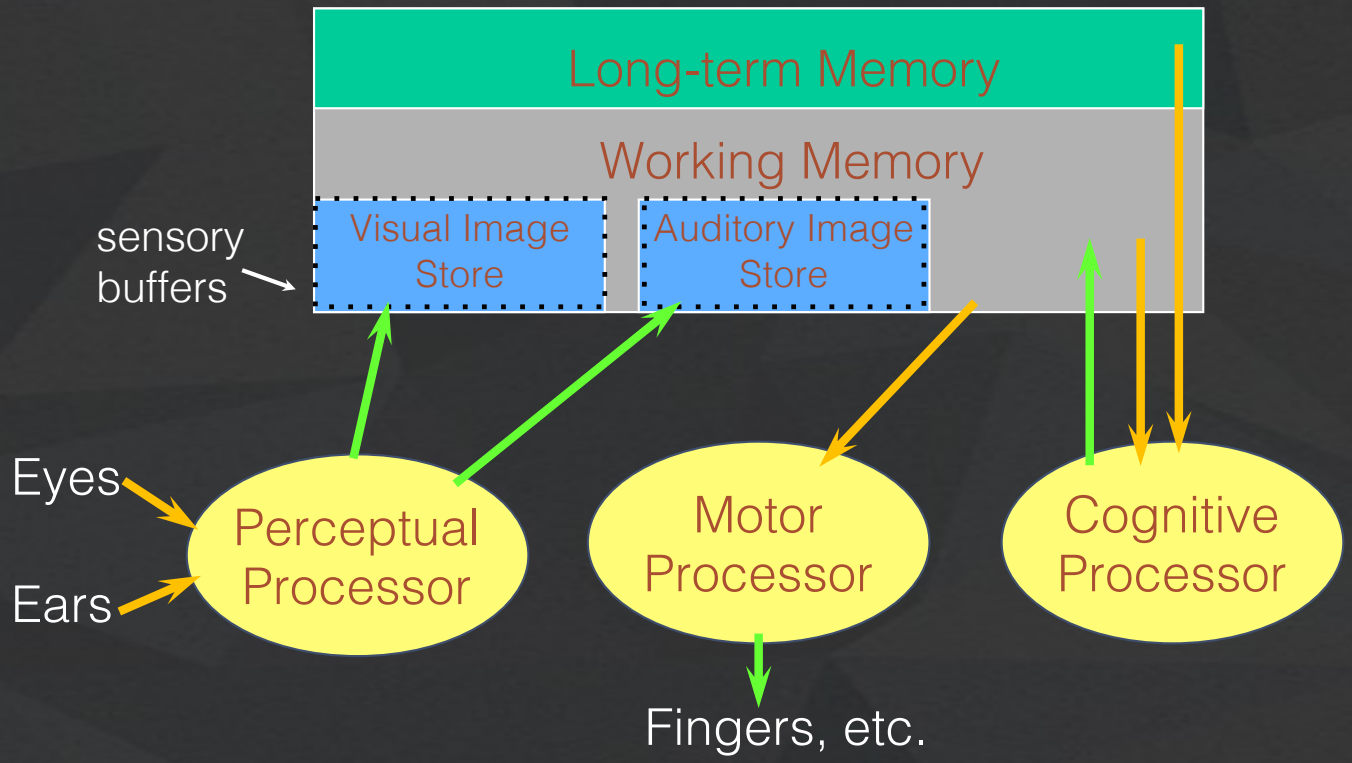
The Model Human Processor



MHP Basics

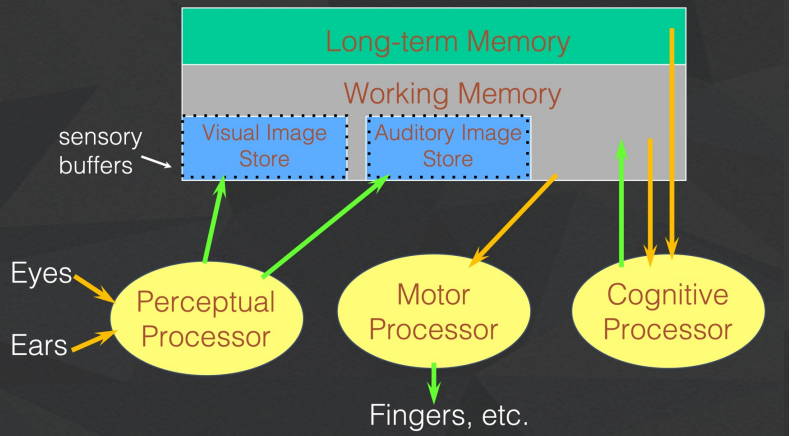
- Parameters
  - processors have cycle time (T) ~ 100 ms
  - memories have capacity, decay time & type

What is missing from MHP?



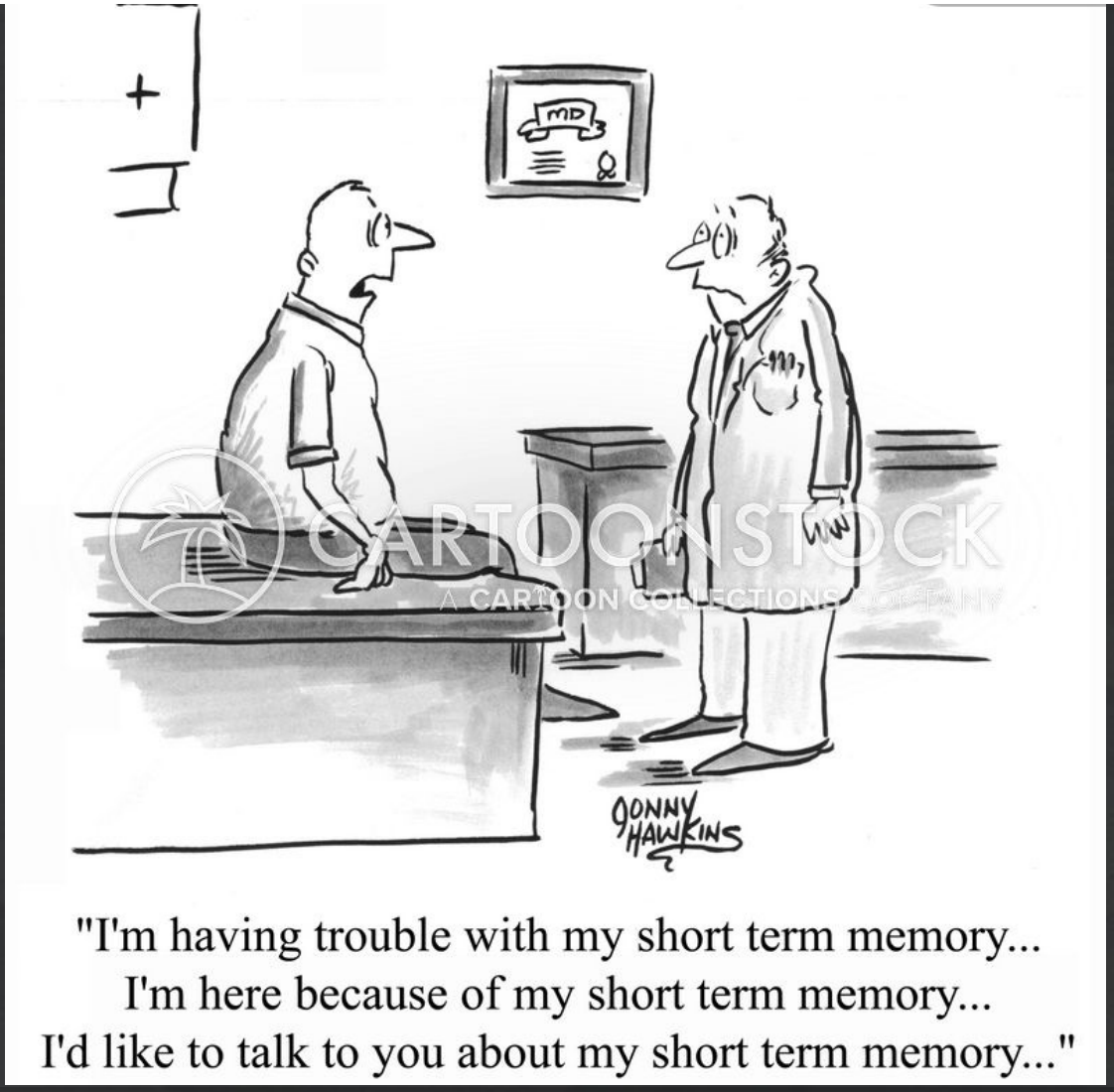
What is missing from MHP?

- Haptic memory
  - for touch



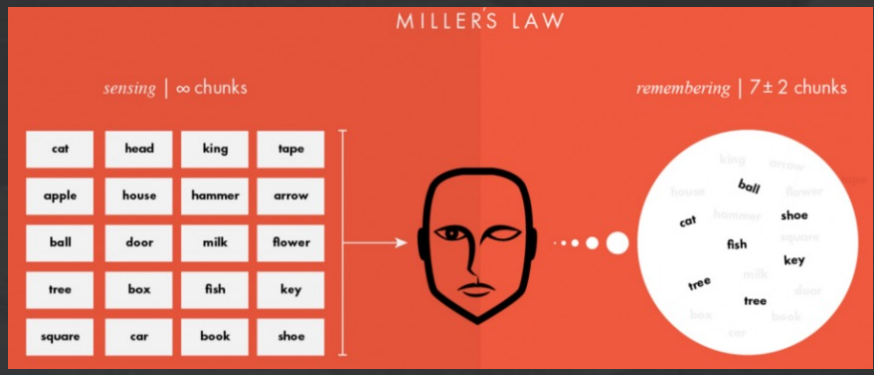
- Moving from sensory buffers (memory) to WM
  - attention filters stimuli & passes to WM

- Moving from WM to LTM
  - elaboration


MD
JONNY HAWKINS
"I'm having trouble with my short term memory...
I'm here because of my short term memory...
I'd like to talk to you about my short term memory..."

Memory

- Working memory (short term)
  - small capacity (7 ± 2 “chunks”)
    - 6174591765 vs. (617) 459-1765
    - NBCIBMGMC vs. NBC IBM GMC
  - rapid access (~70ms) & decay (~200 ms)
    - pass to LTM after a few seconds of continued storage

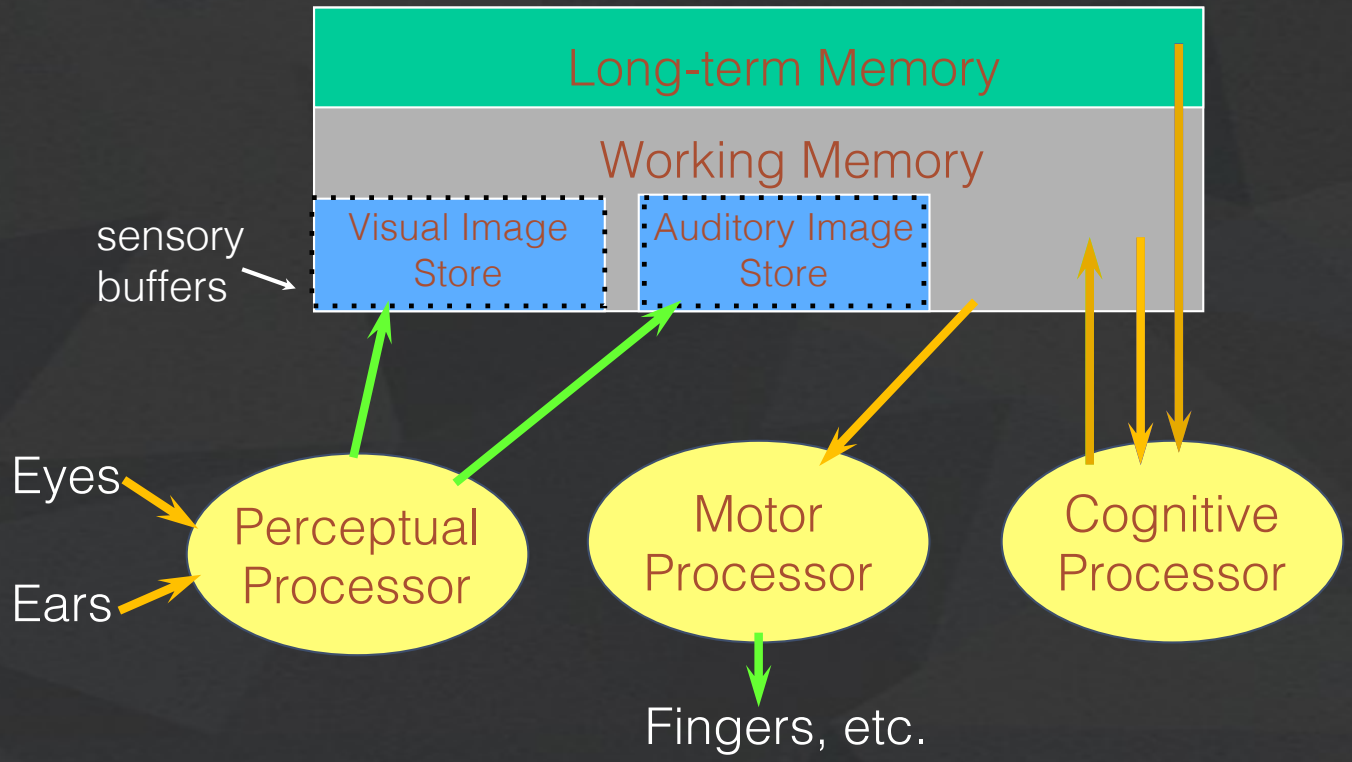


- Long-term memory
  - huge (if not “unlimited”)
  - slower access time (~100 ms) w/ little decay

MHP Principles of Operation

- Recognize-Act Cycle of the CP
  - on each cycle contents in WM initiate actions associatively linked to them in LTM
  - executed actions modify the contents of WM

MHP Principles of Operation



MHP Principles of Operation

- Recognize-Act Cycle of the CP
  - on each cycle contents in WM initiate actions associatively linked to them in LTM
  - executed 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

Motor Processor Experiment

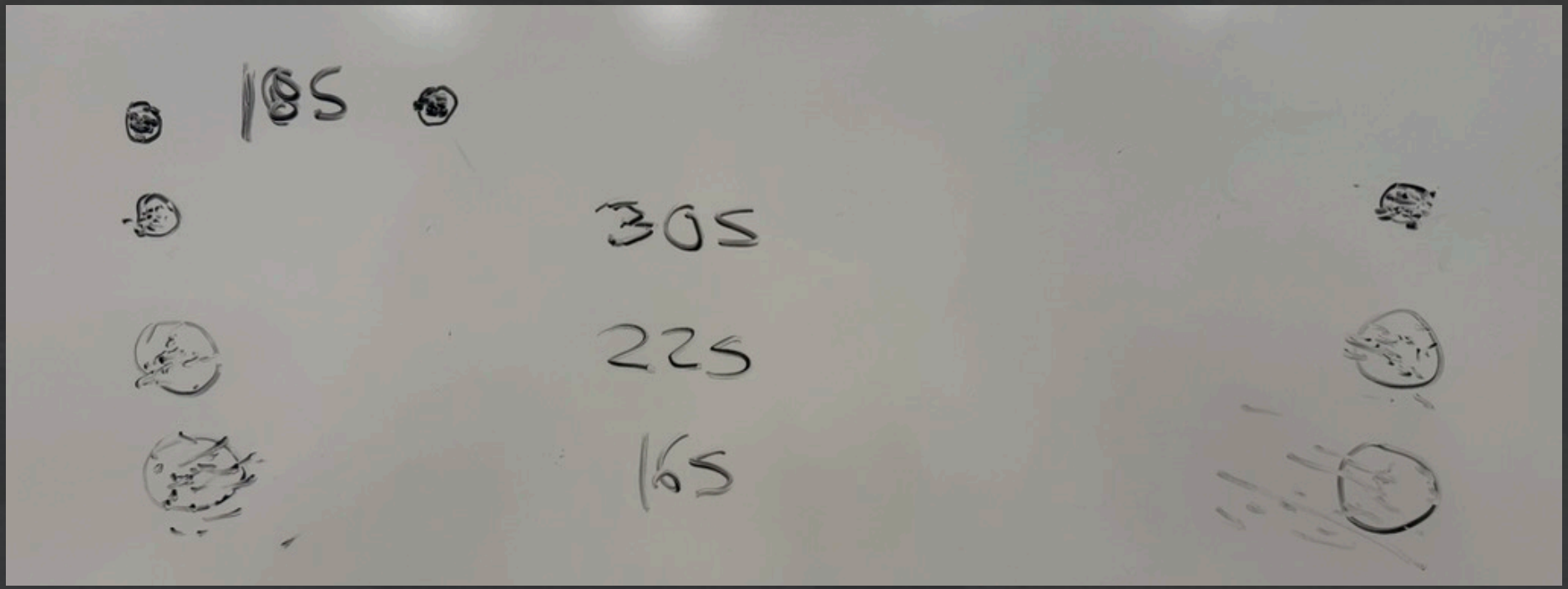
- Task:
  Quickly tap each target 50 times accurately

- Conditions:
  - Two ½” diameter targets 6” apart
  - Two ½” diameter targets 24” apart
  - Two 2” diameter targets 24” apart
  - Two 2” diameter targets 24” apart (no accuracy required)

- Turn to neighbor: discuss what will happen

Experimental Results (2025au)

- Task: Quickly tap each target 50 times accurately



If we plot the data…

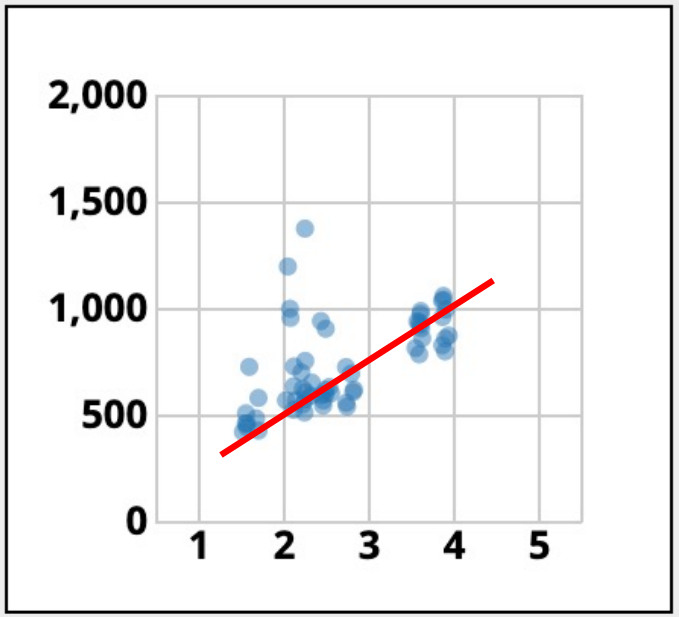
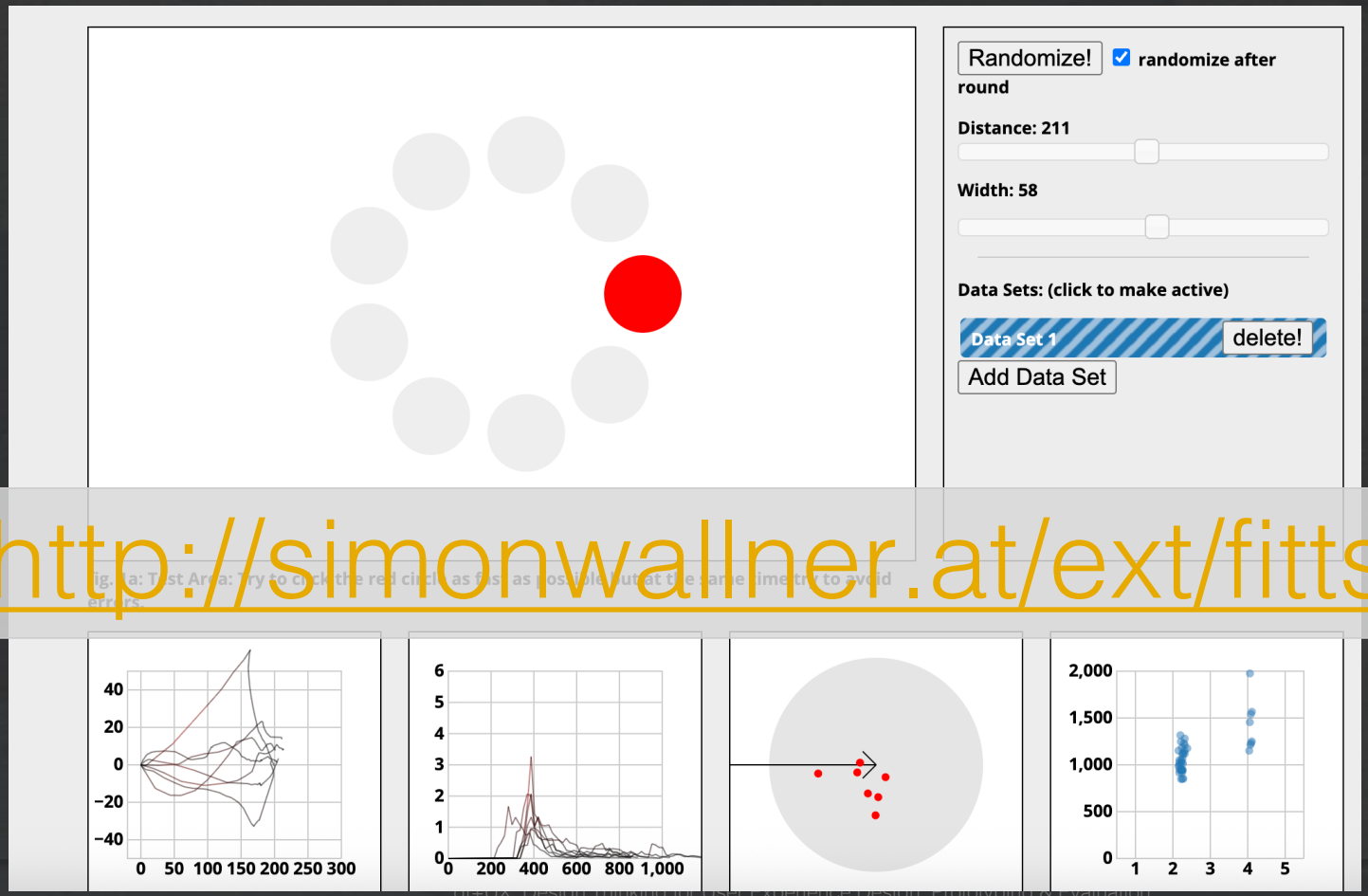


fig. 1e: Time in ms over ID.

Index of Difficulty: ID = log (D/W) + 1
D = distance to target, W = width of target (or size)

Run This Experiment On Your Own



http://simonwallner.at/ext/fitts/

Principles of Operation (cont.)

Fitts' Law

- time Tpos to move the hand to target size S, which is distance D away is given by:

  $Tpos = a + b \log_2 (D/S + 1)$

- summary
  - time to move hand depends only on the *relative precision (D/S)* required

Fitts' Law Example

Pop-up Linear Menu

Today
Sunday
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday

Pop-up Pie Menu



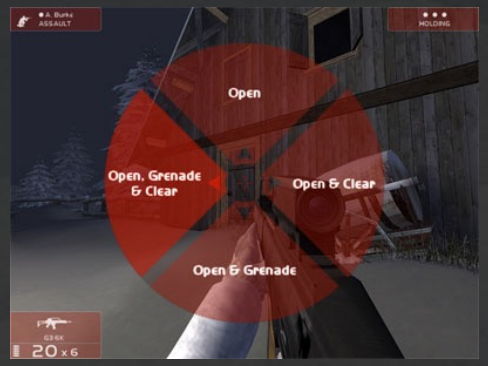
Which will be faster on average?

- pie menu (bigger targets & less distance)

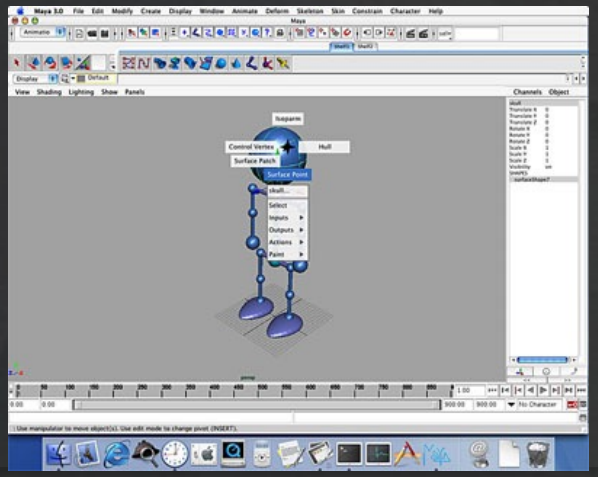
Pie Menus in Use

The Sims





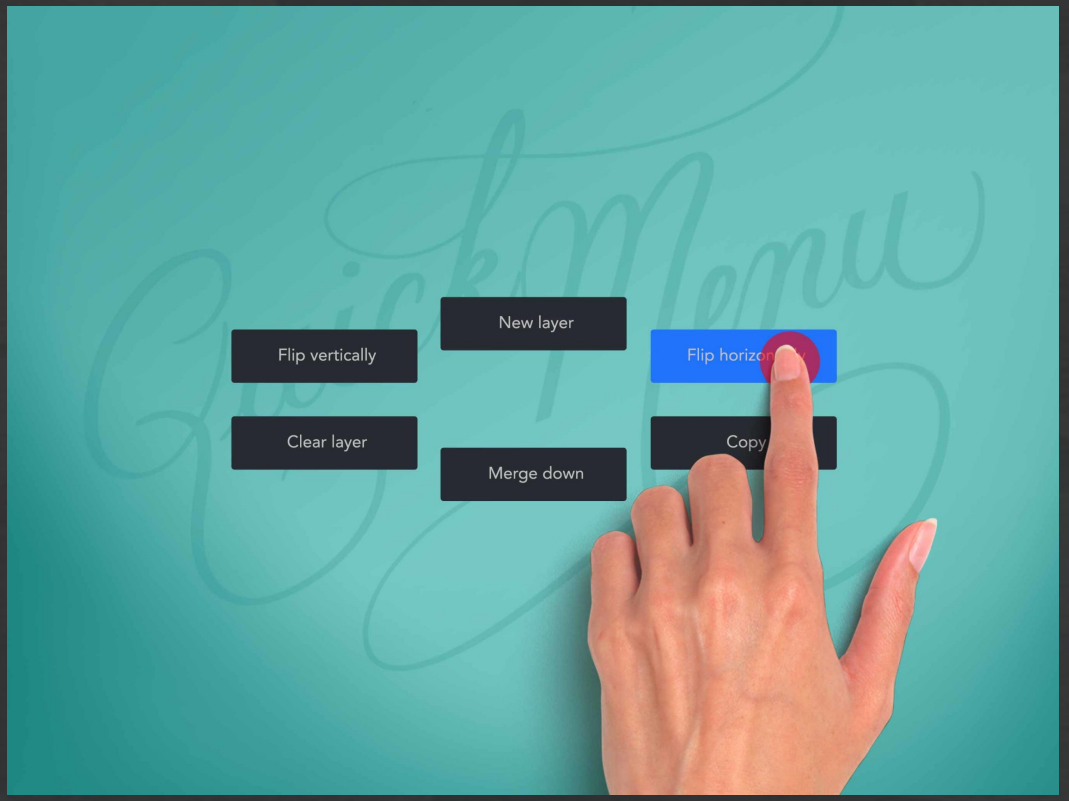
Rainbow 6



Maya

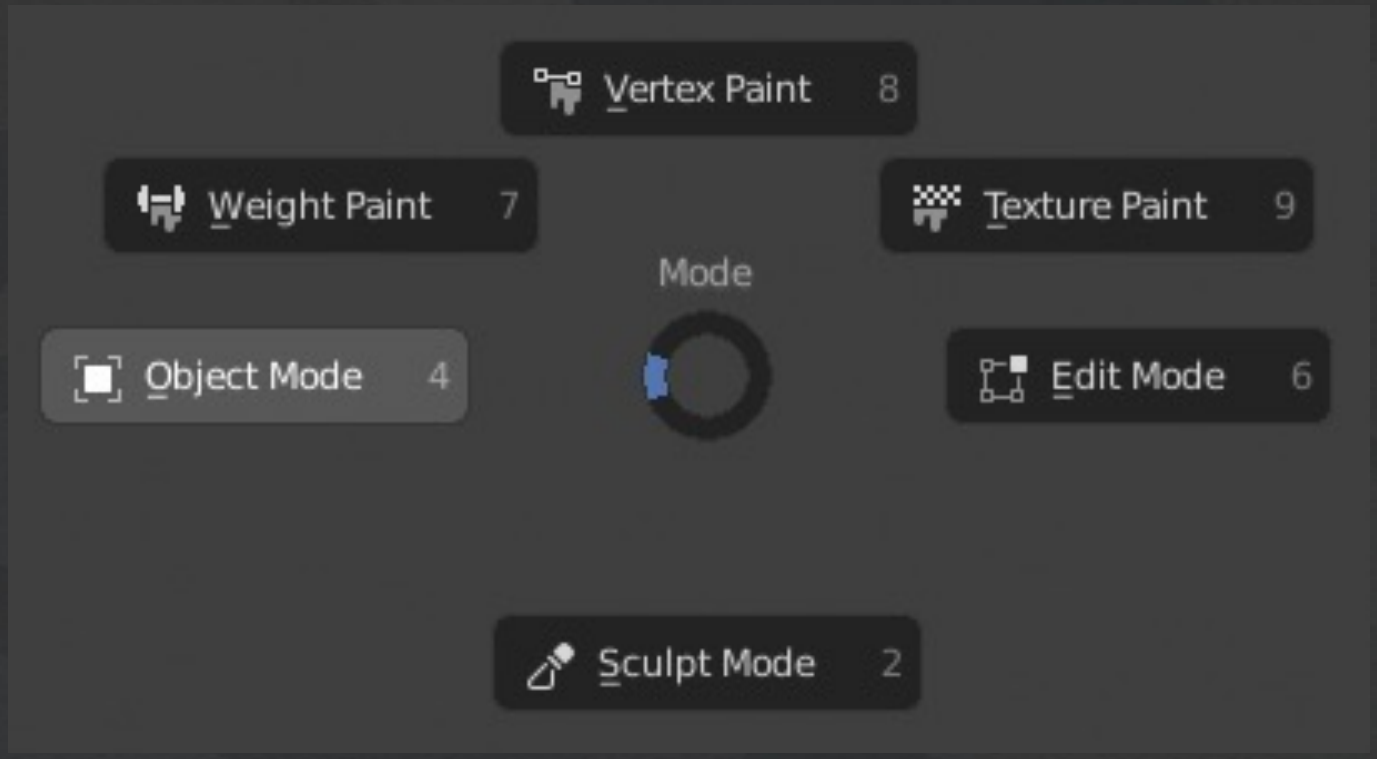
Procreate QuickMenu (2020-present)

Radial menu for fast tool access on iPad



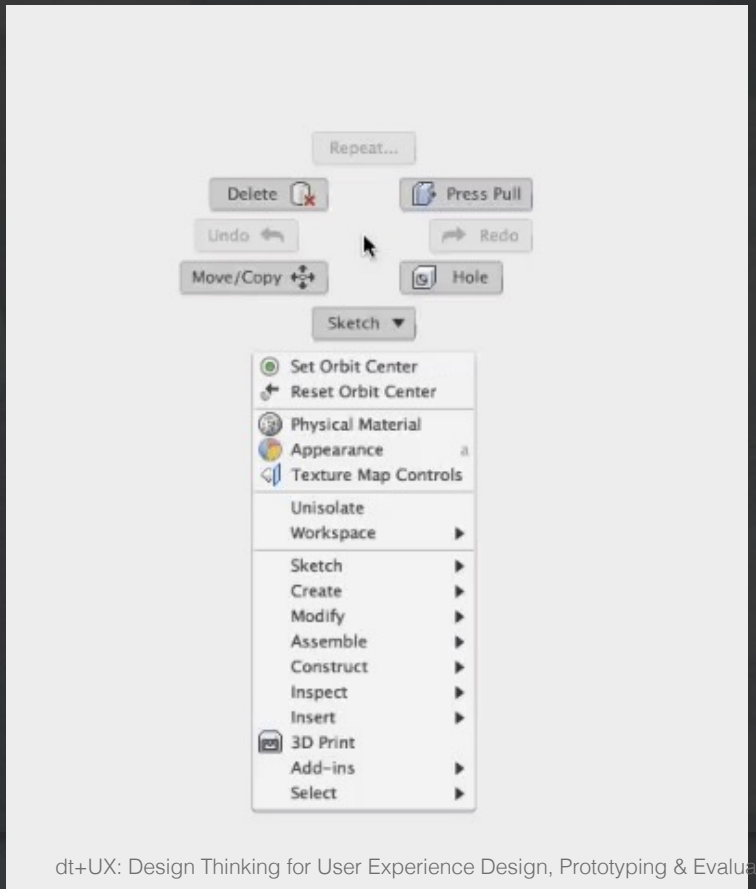
Blender Pie Menus (2019-present)

Radial UI for faster modeling workflow



Fusion 360 Marking Menu (c. 2014-present)

CAD radial gesture menu for 3D modeling



Steam Input Radial Menu (2016-present)

Controller radial menu system for games



Apple Watch Is a Negative Fitts' Law Example



Apple Watch Is a Negative Fitts' Law Example



Volunteer for Experiment

https://faculty.washington.edu/chudler/java/ready.html

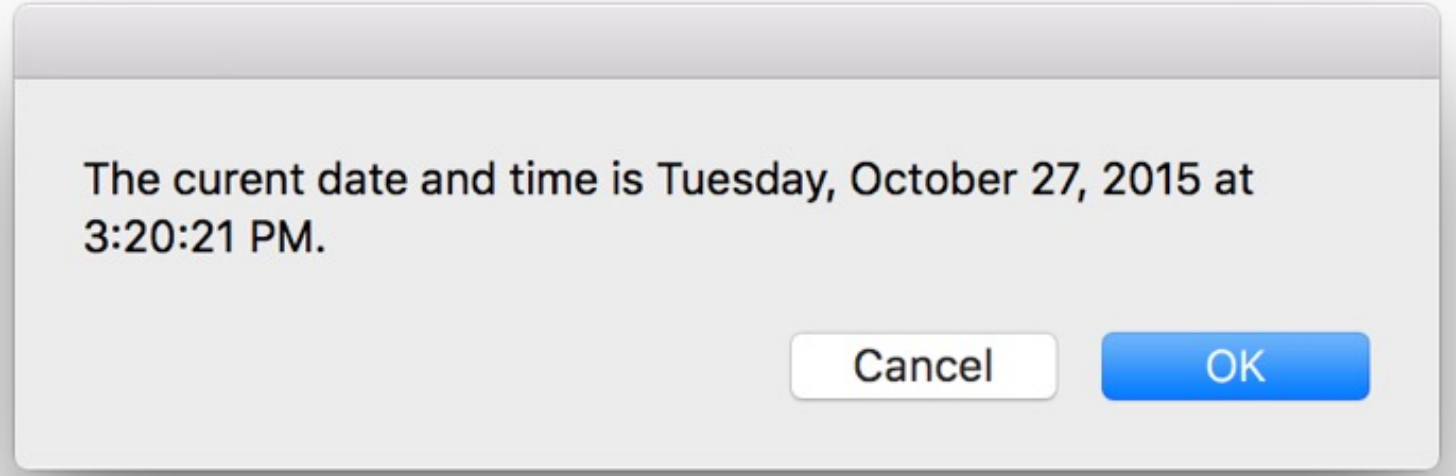
Volunteer for Experiment

Stroop Effect

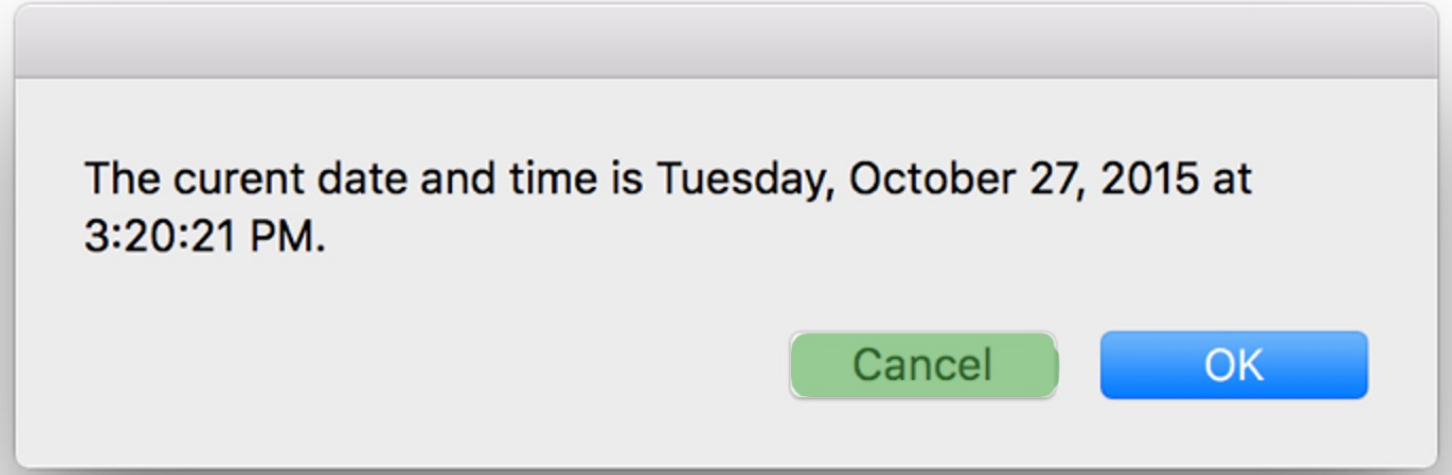
- interference in your working memory



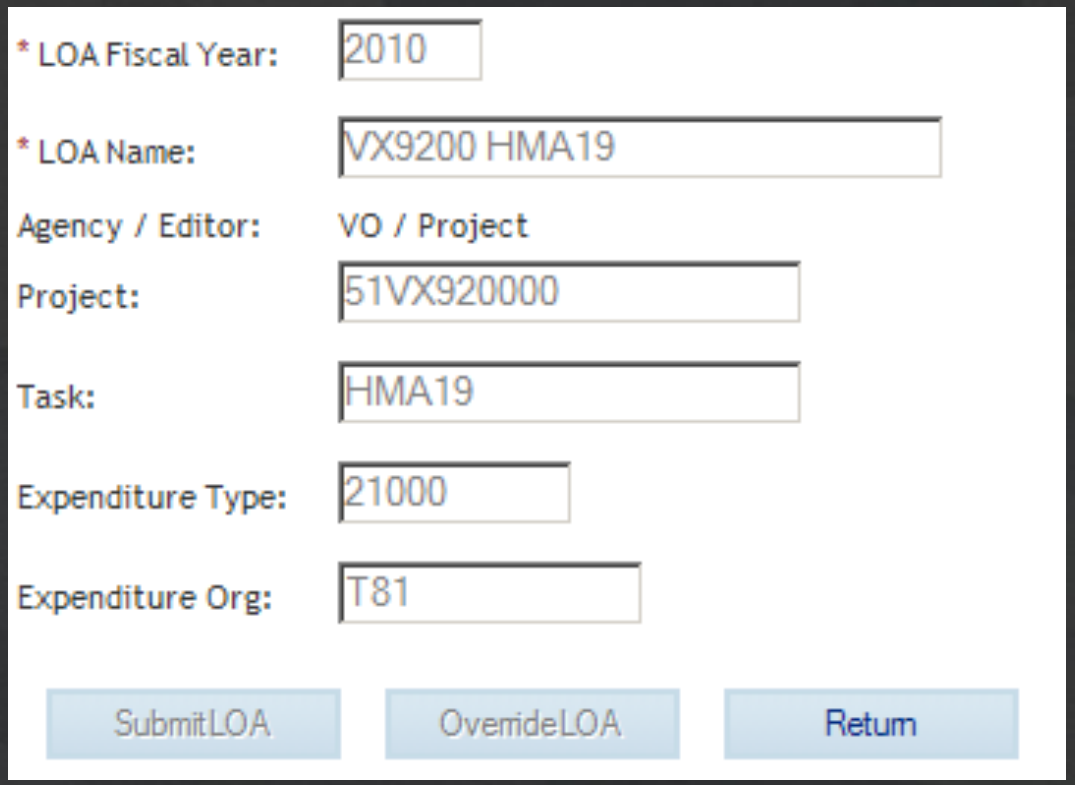
Memory Interference in Action: *Cultural*



Memory Interference in Action: *Cultural*



Memory Interference in Action: *Labels/Terms*



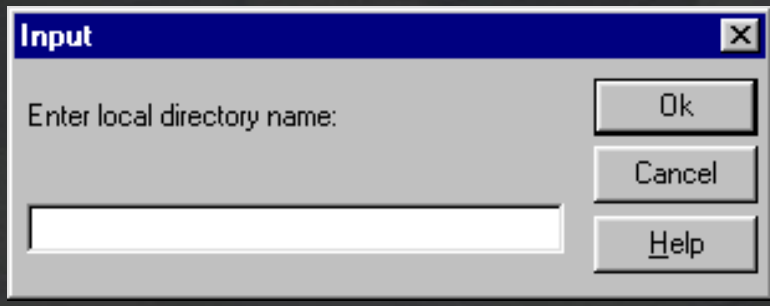
Memory Summary

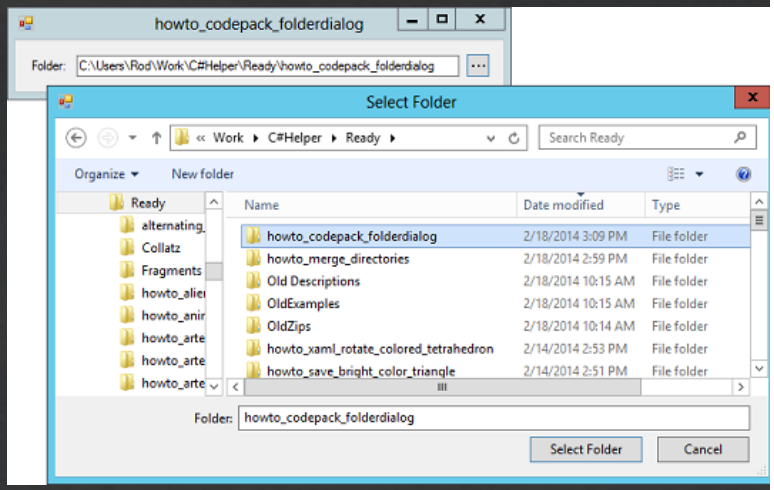
- Interference
  - two strong cues in working memory
  - link to different chunks in long term memory

- Why learn about memory?
  - know what's behind many HCI techniques
  - helps you understand what users will "get"
  - aging population of users

Design UIs for Recognition over Recall

- Recall
  - info reproduced from memory
  - e.g., command name & semantics
- Recognition
  - presentation of info provides knowledge that info has been seen before
    - e.g., command in menu reminds you
  - easier because of cues to retrieval
    - cue is related to item or situation learned in
    - e.g., hints, icons, labels, menu names, etc.





Human Abilities Summary

- Color can be helpful, but pay attention to
  - how colors combine
  - limitations of human perception
  - people with color deficiency
- Model Human Processor
  - perceptual, motor, cognitive processors + memory
  - model allows us to make predictions
- Memory
  - three types: sensory, WM & LTM
  - interference can make hard to access LTM
  - cues in WM can make it easier to access LTM
- Key time to remember from MHP: ~100 ms cycle time & memory access time

Further Reading
Vision and Cognition

- Books
  - *The Psychology Of Human-Computer Interaction*, by Card, Moran, & Newell, Erlbaum, 1983
  - *Human-Computer Interaction*, by Dix, Finlay, Abowd, and Beale, 1998.
  - *Perception*, Irvin Rock, 1995.

- Pages 66-99 of "Cognitive Aspects in Interaction Design", from *Interaction Design*, 3rd Edition by Rogers, Sharp, & Preece

- Applying Fitts' Law to Mobile Interface Design by Justin Smith

Next Time

- Lecture
  - Conceptual Models and Interface Metaphors
- Read
  - "The Psychology of Everyday Thing" (Ch 1) from *The Design of Everyday Things* by Donald Norman
- Studio
  - Half-way Review with Outside Experts