CS160: Sensori-motor Models

Prof Canny

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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

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Outline

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

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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

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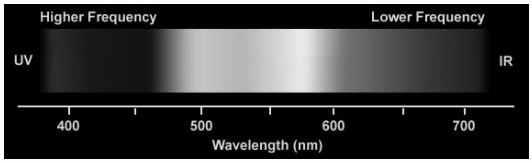
Visible Spectrum



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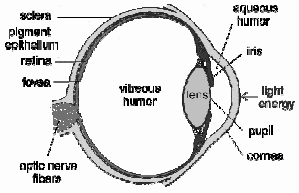
Human Visual System



- ✔Light passes through lens
- ✔Focussed on retina

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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

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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.

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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

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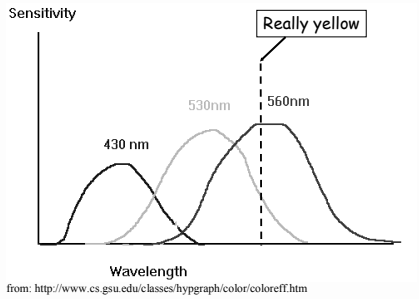
Color Sensitivity



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

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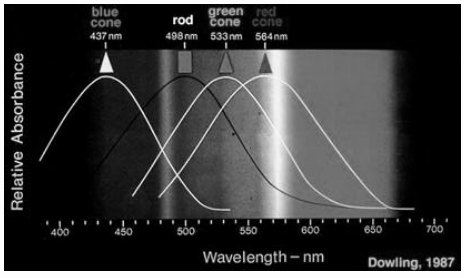
Color Sensitivity



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

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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

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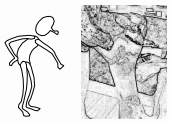
Color Sensitivity & Image Detection

- ✔ 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



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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

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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)

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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

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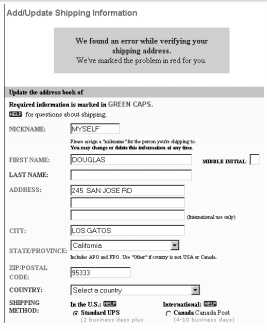
Color Deficiency Example



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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

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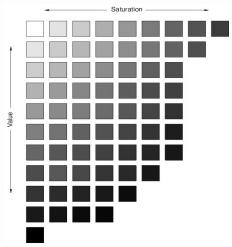
Color Components (cont.)

✔ Lightness

✔ Saturation



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

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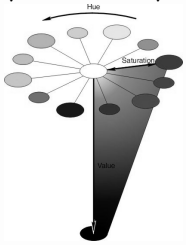
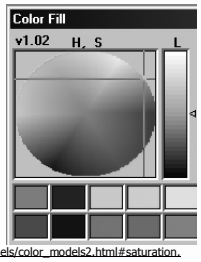
Color Components (cont.)

✔ Hue, Saturation, Value model (HSV)





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

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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

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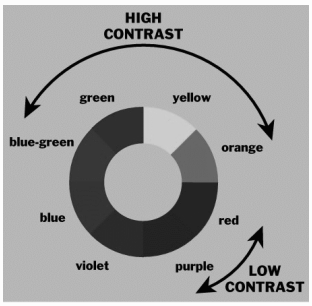
Pick Non-adjacent Colors on the Hue Circle



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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

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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

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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.

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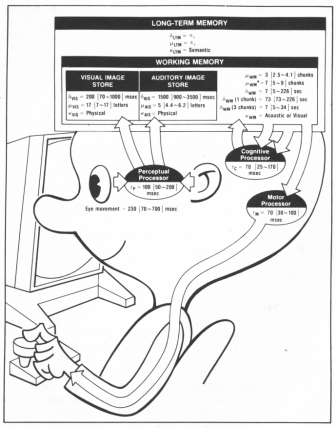
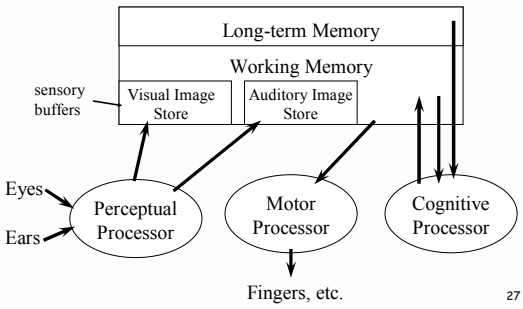
Model Human Processor



The Model Human Processor



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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

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MHP Basics

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

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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

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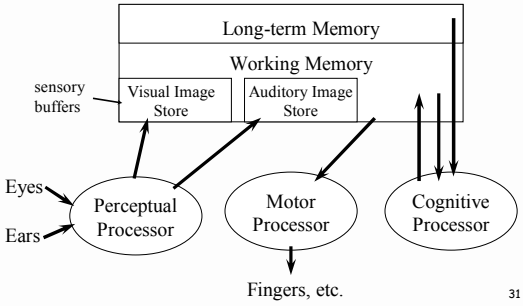
The Model Human Processor



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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

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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

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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

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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

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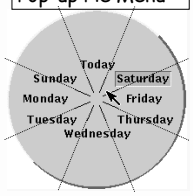
Fitts' Law Example

Pop-up Linear Menu

Today
Sunday
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday

Pop-up Pie Menu



- ✔ Which will be faster on average?

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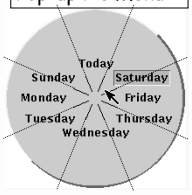
Fitts' Law Example

Pop-up Linear Menu

Today
Sunday
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday

Pop-up Pie Menu



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

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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.

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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

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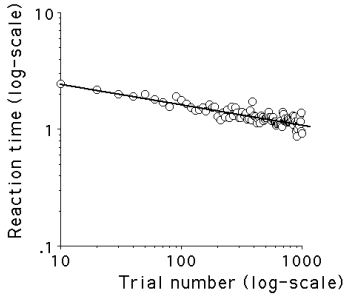
Power Law of Practice



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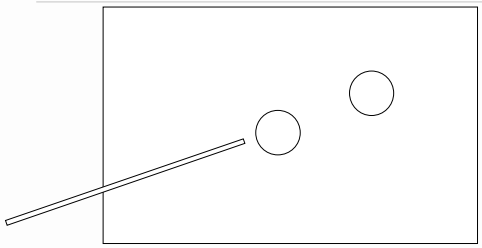
Perceptual Causality



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

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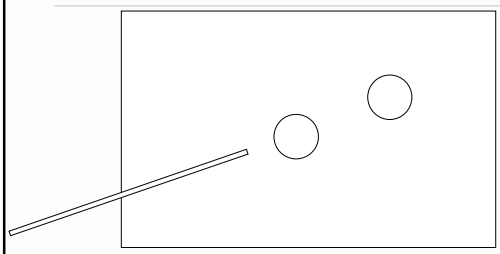
Perceptual Causality



- ✔ Must move in < Tp (100 msec)

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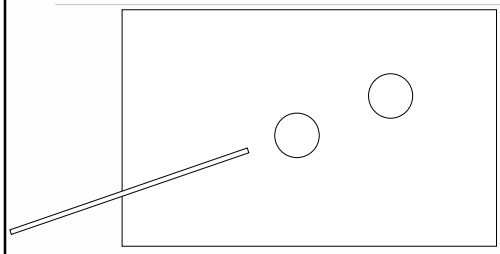
Perceptual Causality



✔ Must move in < Tp (100 msec)

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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

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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…

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Paper
Home
Back
Schedule
Page
Change

Simple Experiment

✔ Do it again
✔ Say "done" when finished

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Blue
Red
Black
White
Green
Yellow

Memory

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

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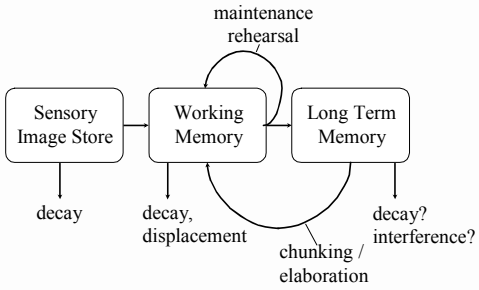
Stage Theory



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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

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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

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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

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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!

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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!

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Summary

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

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