

## Lecture 4: Human Capabilities

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## Today's Topics

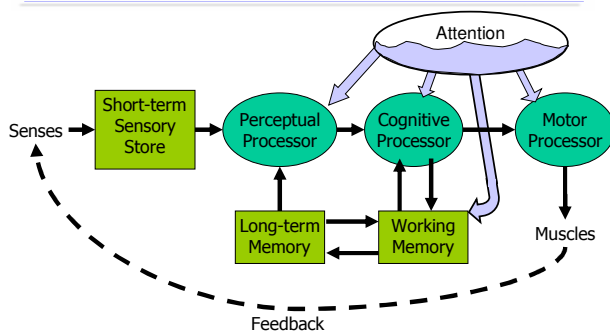
- Human information processing
  - Perception
  - Motor skills
  - Memory
  - Decision making
  - Attention
  - Vision

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## Human Information Processing



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## Memories



- Memory properties
  - Encoding: type of things stored
  - Size: number of things stored
  - Decay time: how long memory lasts

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## Short-Term Sensory Store

- Visual information store
  - encoded as physical image
  - size ~ 17 [7-17] letters
  - decay ~ 200 ms [70-1000 ms]
- Auditory information store
  - encoded as physical sound
  - size ~ 5 [4.4-6.2] letters
  - decay ~ 1500 ms [900-3500 ms]

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## Processors

- Processors have a cycle time
  - $T_p \sim 100\text{ms}$  [50-200 ms]
  - $T_c \sim 70\text{ms}$  [30-100 ms]
  - $T_m \sim 70\text{ms}$  [25-170 ms]



- Fastman may be 10x faster than Slowman

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## Perceptual Fusion

- Two stimuli within the same PP cycle ( $T_p \sim 100\text{ms}$ ) appear **fused**
- Consequences
  - $1/T_p$  frames/sec is enough to perceive a moving picture (10 fps OK, 20 fps smooth)
  - Computer response  $< T_p$  feels instantaneous
  - Causality is strongly influenced by fusion

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## Bottom-up vs. Top-Down Perception

- Bottom-up uses features of stimulus
- Top-down uses context
  - temporal, spatial
  - draws on long-term memory

T A E    C A T

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## Chunking

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- “Chunk”: unit of perception or memory
- Chunking depends on presentation and what you already know  
B M W R C A A O L I B M F B I  
MWR CAA OLI BMF BIB  
BMW RCA AOL IBM FBI
- 3-4 digit chunking is ideal for encoding unrelated digits

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## Attention and Perception

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- Spotlight metaphor
  - Spotlight moves serially from one input channel to another
  - **Visual dominance**: easier to attend to visual channels than auditory channels
  - All stimuli within spotlighted channel are processed in parallel
    - Whether you want to or not

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## Say the Colors of These Words Aloud

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Book  
Pencil  
Slide  
Window  
Car  
Hat

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## Now Do It Again

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Green  
Orange  
Red  
Black  
Pink  
Blue

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## Cognitive Processing

- Cognitive processor
  - compares stimuli
  - selects a response
- Types of decision making
  - Skill-based
  - Rule-based
  - Knowledge-based

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## Hick-Hyman Law of Choice Reaction Time

- Reaction time depends on information content of stimulus

$$RT = c + d \log_2 1/\Pr(\text{stimulus})$$

- e.g., for N equiprobable stimuli, each requiring a different response:

$$RT = c + d \log_2 N$$

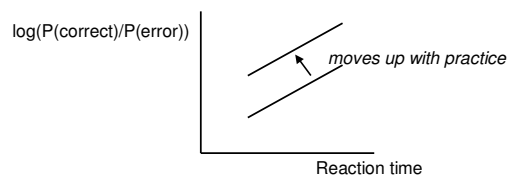
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## Speed-Accuracy Tradeoff

- Accuracy varies with reaction time
  - Can choose any point on curve
  - Can move curve with practice



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## Divided Attention (Multitasking)

- Resource metaphor
  - Attention is a resource that can be divided among different tasks simultaneously
- Multitasking performance depends on:
  - Task structure
    - Modality: visual vs. auditory
    - Encoding: spatial vs. verbal
    - Component: perceptual/cognitive vs. motor vs. WM
  - Difficulty
    - Easy or well-practiced tasks are easier to share

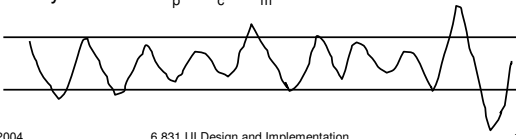
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## Motor Processing

- Open-loop control
  - Motor processor runs a program by itself
  - cycle time is  $T_m \sim 70$  ms
- Closed-loop control
  - Muscle movements (or their effect on the world) are perceived and compared with desired result
  - cycle time is  $T_p + T_c + T_m \sim 240$  ms



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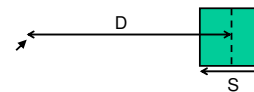
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## Fitts's Law

- Fitts's Law
  - Time  $T$  to move your hand to a target of size  $S$  at distance  $D$  away is:

$$T = RT + MT = a + b \log(2D/S)$$



- Depends only on *index of difficulty*  $\log(2D/S)$

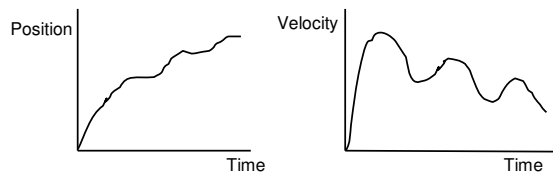
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## Explanation of Fitts's Law

- Moving your hand to a target is closed-loop control
- Each cycle covers remaining distance  $D$  with error  $\epsilon D$



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## Implications of Fitts's Law

- Targets at screen edge are easy to hit
  - Mac menubar beats Windows menubar
  - Unclickable margins are foolish
- Hierarchical menus are hard to hit
  - Gimp/GTK: instantly closes menu
  - Windows: .5 s timeout destroys causality
  - Mac does it right: triangular zone
- Linear popup menus vs. pie menus

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## Power Law of Practice

- Time  $T_n$  to do a task the  $n$ th time is:

$$T_n = T_1 n^{-\alpha}$$

$\alpha$  is typically 0.2-0.6

## Working Memory (WM)

- Small capacity:  $7 \pm 2$  "chunks"
- Fast decay (7 [5-226] sec)
- **Maintenance rehearsal** fends off decay
- **Interference** causes faster decay

## Long-term Memory (LTM)

- Huge capacity
- Little decay
- **Elaborative rehearsal** moves chunks from WM to LTM by making connections with other chunks

## The Eye

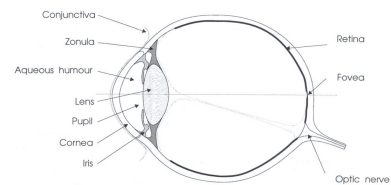


Figure 3: The human eye.

## Photoreceptors

- Rods
  - Only one kind (peak response in green wavelengths)
  - Sensitive to low light ("scotopic vision")
    - Multiple nearby rods aggregated into a single nerve signal
  - Saturated at moderate light intensity ("photopic vision")
    - Cones do most of the vision under photopic conditions
- Cones
  - Operate in brighter light
  - Three kinds: S(hort), M(edium), L(ong)
  - S cones are very weak, centered in blue wavelengths
  - M and L cones are more powerful, overlapping
  - M centered in green, L in yellow (but called "red")

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## Signals from Photoreceptors

- Brightness  
M + L + rods
- Red-green difference  
L - M
- Blue-yellow difference  
weighted sum of S, M, L

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## Color Blindness

- Red-green color blindness (protonopia & deuteranopia)
  - 8% of males
  - 0.4% of females
- Blue-yellow color blindness (tritanopia)
  - Far more rare
- Guideline: don't depend solely on color distinctions
  - use redundant signals: brightness, location, shape

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## Chromatic Aberration

- Different wavelengths focus differently
  - Highly separated wavelengths (red & blue) can't be focused simultaneously
- Guideline: don't use red-on-blue text
  - It looks fuzzy and hurts to read



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## Blue Details Are Hard to Resolve

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- Fovea has no S cones
  - Can't resolve small blue features (unless they have high contrast with background)
- Lens and aqueous humor turn yellow with age
  - Blue wavelengths are filtered out
- Lens weakens with age
  - Blue is harder to focus
- Guideline: don't use blue against dark backgrounds where small details matter (text!)

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## Fovea Has No Rods

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- Rods are more sensitive to dim light
- In scotopic conditions, peripheral vision (rod-rich) is better than foveal vision
  - Easier to see a dim star if you don't look directly at it

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