Psychology of HCI

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Announcements

- Should read Norman's book this week
- Projects
  - Peer evaluations
  - Team workload
  - Last 15 minutes to form project teams

Recap From Last Time

- We are surrounded by ineffective interfaces
- To develop an effective user interface:
  - Understand human information processing
  - Understand basic principles of design
  - Follow proven design practices and guidelines, borrow from successful designs

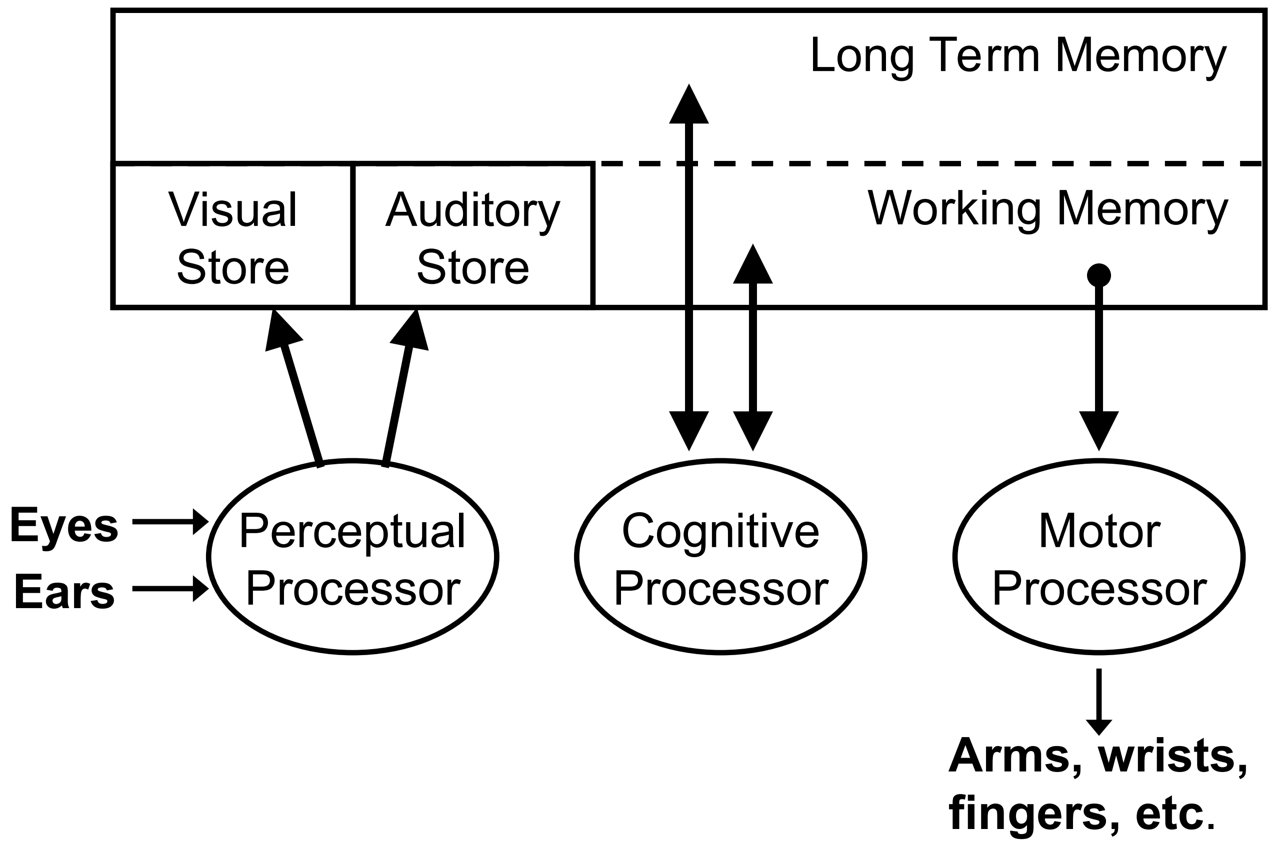
Messages

- Humans are information processors
  - Input: seeing and hearing most important to HCI
  - Processors: cognitive, perceptual, and motor
  - Output: wrist, arm, leg, etc. movements
- Model the human information processor to
  - Validate understanding of ourselves
  - Inform the design of better user interfaces
- Fitts Law models skilled motor behavior
- Hicks Law models choice reaction time

Model Human Processor

- Contains three interacting systems: perceptual, cognitive, and motor systems
  - For some tasks, systems operate in serial (pressing a key in response to a stimulus)
  - For other tasks, systems operate in parallel (driving, talking to passenger, listening to radio)
- Each system has its own memory and processor
  - Memory: storage capacity and decay time
  - Processor: cycle time (includes access time)
- Each system guided by principles of operation

Model Human Processor



Why Is the MHP Useful?

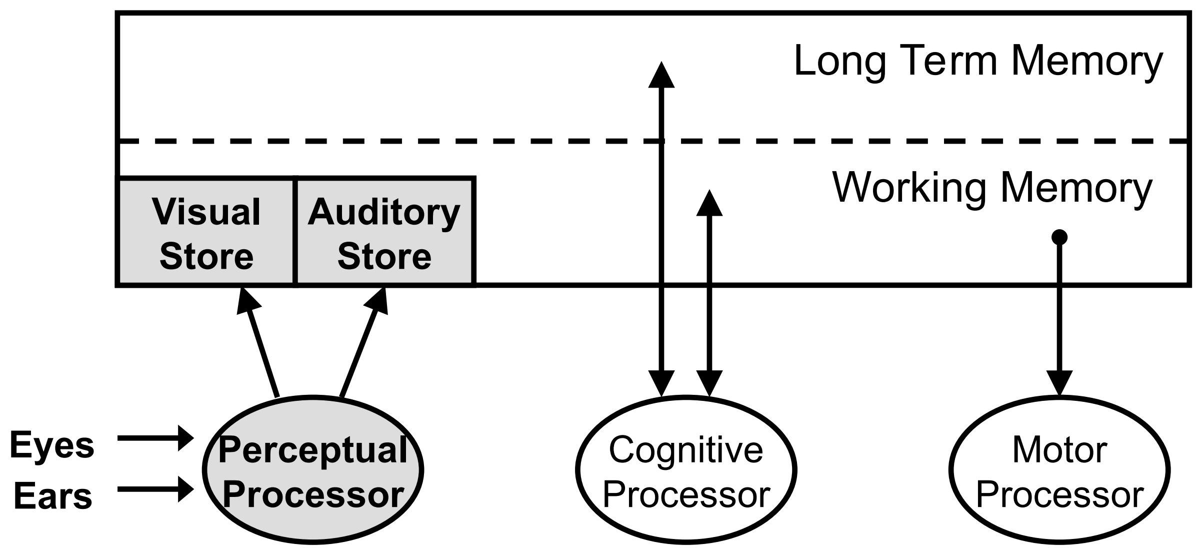
- Use empirical studies to validate the model
  - Validates our understanding of the three systems
- Use model to:
  - Predict and compare usability of different interface designs
    - Task performance, learnability, and error rates
    - No users or functional prototype required!
  - Develop guidelines for interface design
    - Color, spatial layout, recall, response rates, etc.
- To be useful, a model must:
  - Be easy to use and learn
  - Produce reasonably accurate results

What’s Not in the MHP

- Haptic sensory processor and memory
- Motor (or muscle) memory
- Attention
  - Active “chunk” in WM + cognitive processing
  - Affects perceptual processing of sensory stimuli and filters what information is transferred from sensory memory to WM

Perceptual System

- Responsible for transforming external environment into a form that cognitive system can process
- Composed of *perceptual memory* and *processor*



Perceptual Memory

- Shortly after onset of stimulus, representation of stimulus appears in perceptual memory
  - Representation is physical (non-symbolic)
  - E.g., “7” is just the pattern, not the recognized digit
- As contents of perceptual memory are symbolically coded, they are passed to WM
  - Which processor does the coding?
- Decay time
  - 200ms for visual store
  - 1500ms for auditory store

Perceptual Processor

- Codes information in perceptual memory for about 100ms and then retrieves next stimulus
  - Cycle time = ~100ms
- Processor cannot code all information before the next stimulus arrives
  - Type and order of coding influenced by:
    - Gestalt principles (perceive shape from atomic parts)
    - Attention - directs processing or filters information
- Can utilize information about perceptual system to improve and better understand HCI

Take Home Exercises

- **Assume perceptual cycle time = 100ms**
- If 20 clicks per second are played for 5 seconds, about how many clicks could a person hear?
- If 30 clicks per second are played for 5 seconds, about how many clicks could a person hear?

Take Home Exercises

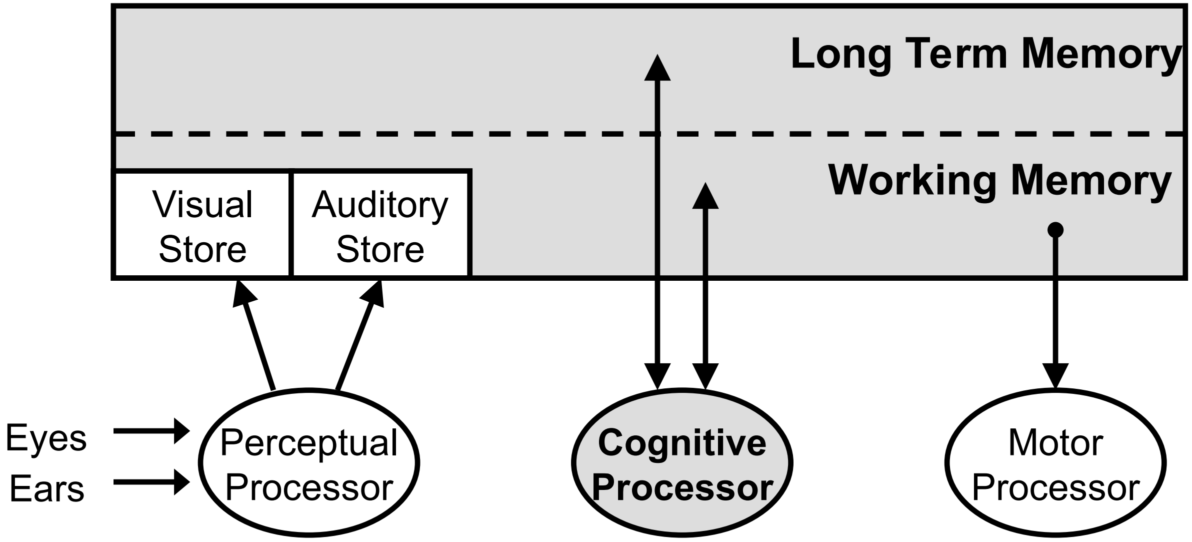
- How many frames per second must a video be played to give illusion of motion?
- In a talking head video, how far off can the audio and video be before a person perceives the video as unsynchronized?
- In a simulation of a pool game, when one ball bumps into another, how much time can the application take to compute the path of the bumped ball?

Principles of Perceptual System

- Gestalt Principles
  - Govern how we perceive shapes from atomic parts
- Variable Processor Rate Principle
  - Processor cycle time varies inversely with stimulus intensity; brighter screens need faster refresh rates
- Encoding Specificity Principle
  - Encoding at the time of perception impacts what and how information is stored
  - Impacts what retrieval cues are effective at retrieving the stored information

Cognitive System

- Uses contents of WM and LTM to make decisions and schedule actions with motor system
- Composed of a processor and two memories
  - WM and LTM



Working Memory

- Holds intermediate products of thinking and representations produced by perceptual system
- Comprised of activated sections of LTM called "chunks"
  - A chunk is a hierarchical symbol structure
  - 7 +/- 2 chunks active at any given time

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Working Memory

- Decay caused by:
  - Time: about 7s for three chunks, but high variance
  - Interference: more difficult to recall an item if there are other similar items (activated chunks) in memory
- Discrimination Principle
  - Difficulty of retrieval determined by candidates that exist in memory relative to retrieval cues
- Not a fixed section of LTM, but a dynamic sequence of activated chunks (may not need transfer)

Long-Term Memory

- Holds mass of knowledge; facts, procedures, history
- Consists of a network of related chunks where edge in the network is an association (semantic network)
- Fast read, slow write
- Infinite storage capacity, but you may forget because:
  - Cannot find effective retrieval cues
  - Similar associations to other chunks interfere with retrieval of the target chunk (discrimination principle)

Memory Example

- Suppose you are verbally given 12 arbitrary filenames to remember. In which order should you write down the filenames to maximize recall?
- What if you are given 3 sets of filenames, where each set starts with the same characters?
  - E.g., Class1, Class2, Class3, Class4; Day1, Day2, Day3, Day4, etc.

Cognitive Processor

- Based on recognize-act cycle
  - Recognize: activate associatively-linked chunks in LTM
  - Act: modify contents of WM
  - Cycle time = ~70ms

Cognitive System Principles

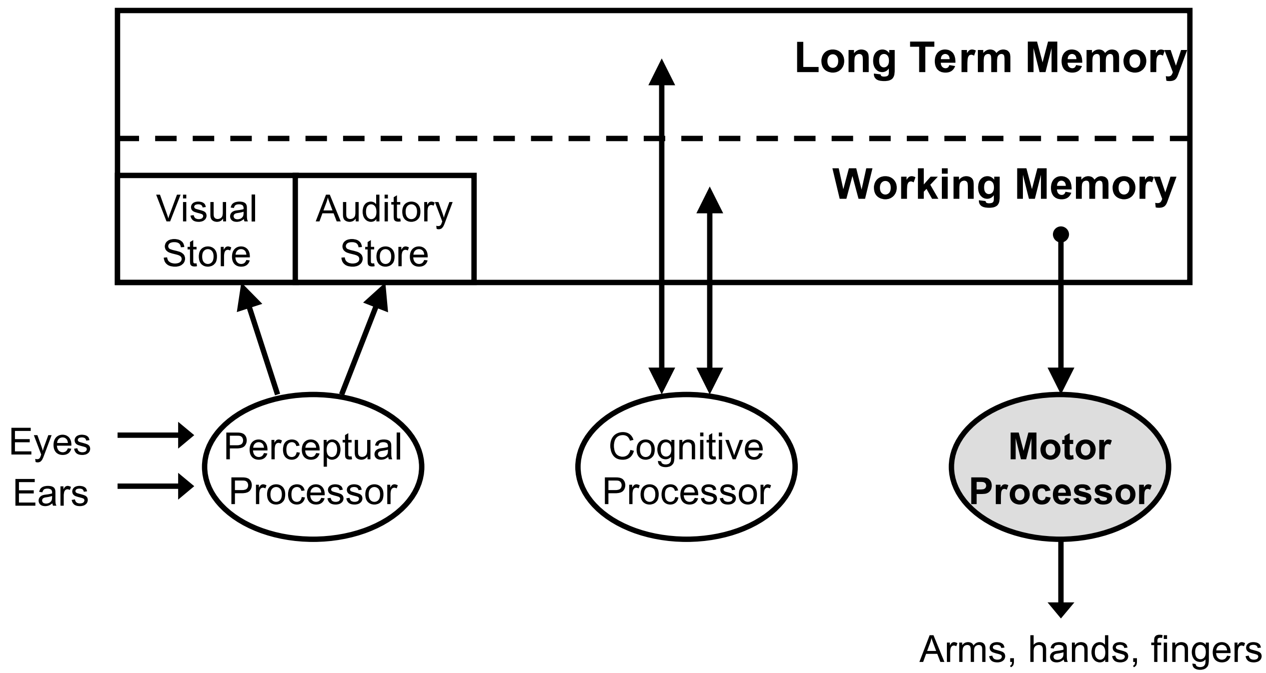
- Uncertainty Principle
  - Decision time increases with the uncertainty about the judgment to be made, requires more cognitive cycles

- Variable Rate Principle:
  - Cycle time Tc is shorter when greater effort is induced by increased task demands or information loads; it also diminishes with practice.
  - Power Law of Practice: $T_n = T_1 * n^{-\alpha}$

    where alpha is learning constant

Motor System

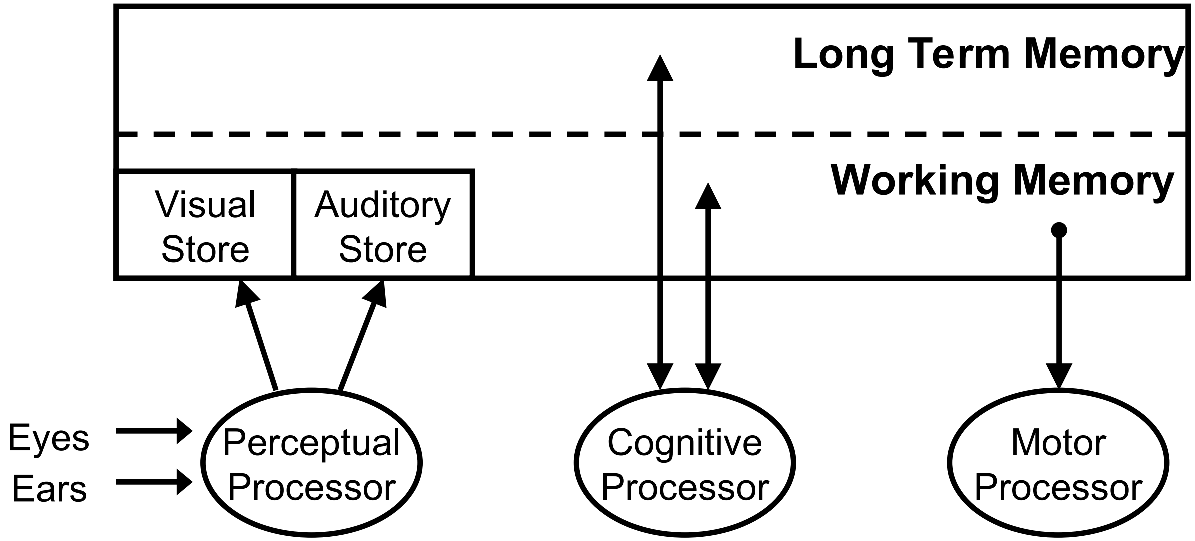
- Translates thoughts into actions
  - Head-neck and arm-hand-finger actions



Motor Processor

- Controls movements of body
  - Movement composed of discrete micro-movements
  - Micro-movement lasts about 70ms
  - Cycle time of motor processor about 70ms
- Caches common behavioral acts such as typing and speaking
  - No mention of this cache in the model

What We Know So Far



Cycle Times

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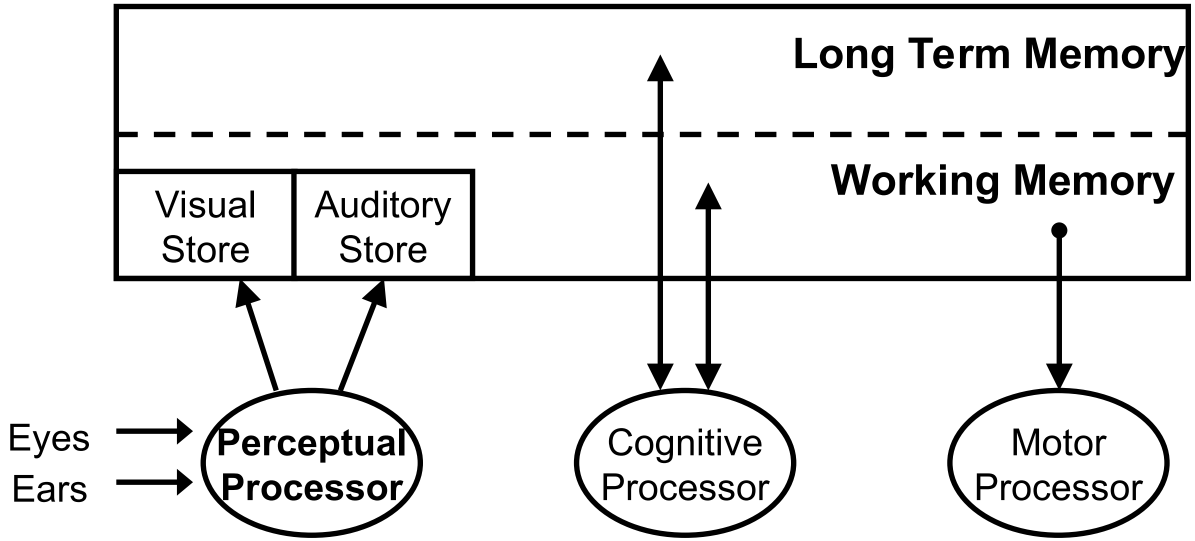

Cycle Times **100 ms**

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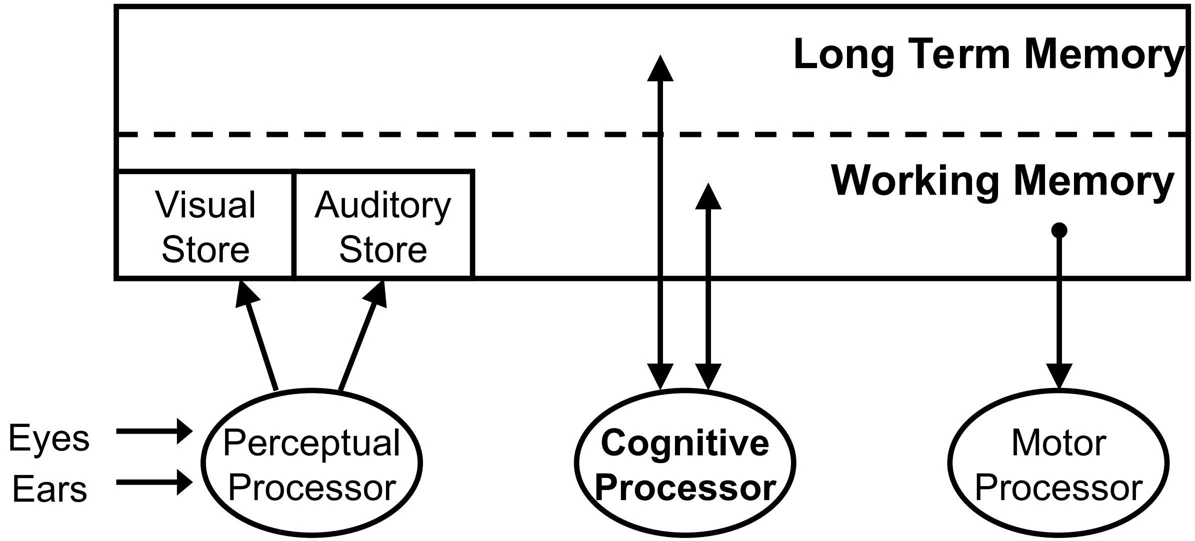

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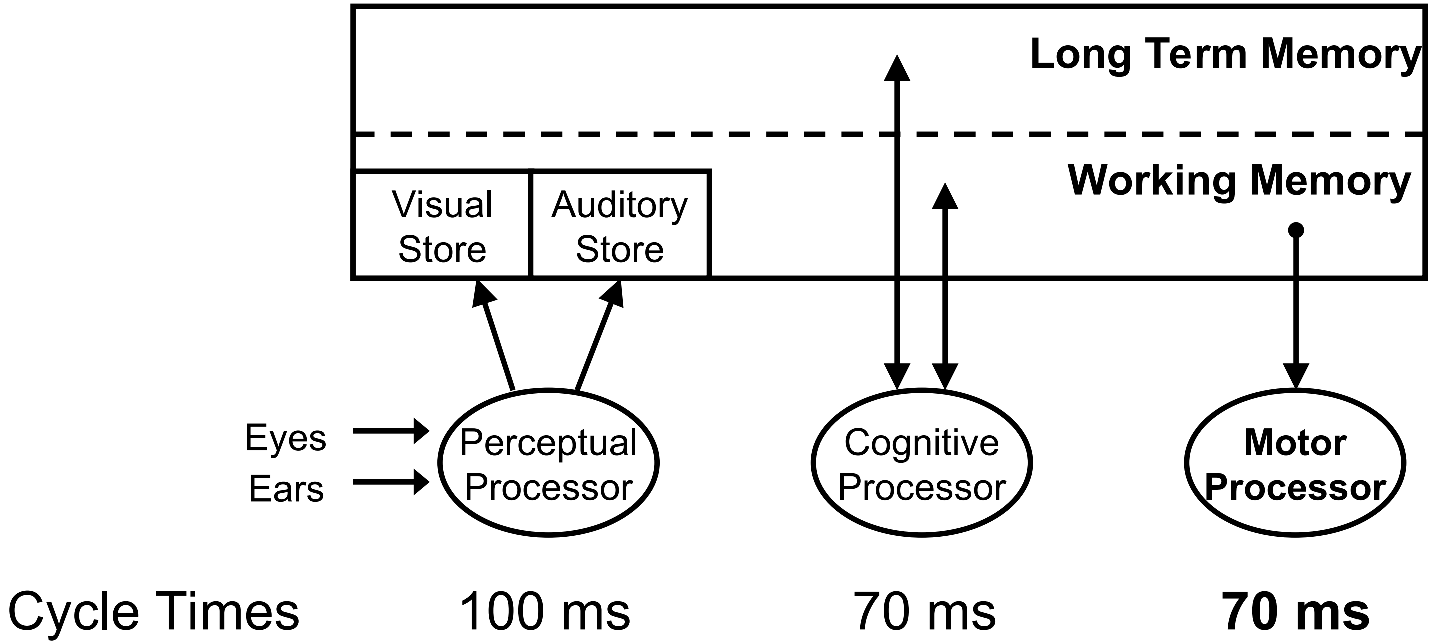
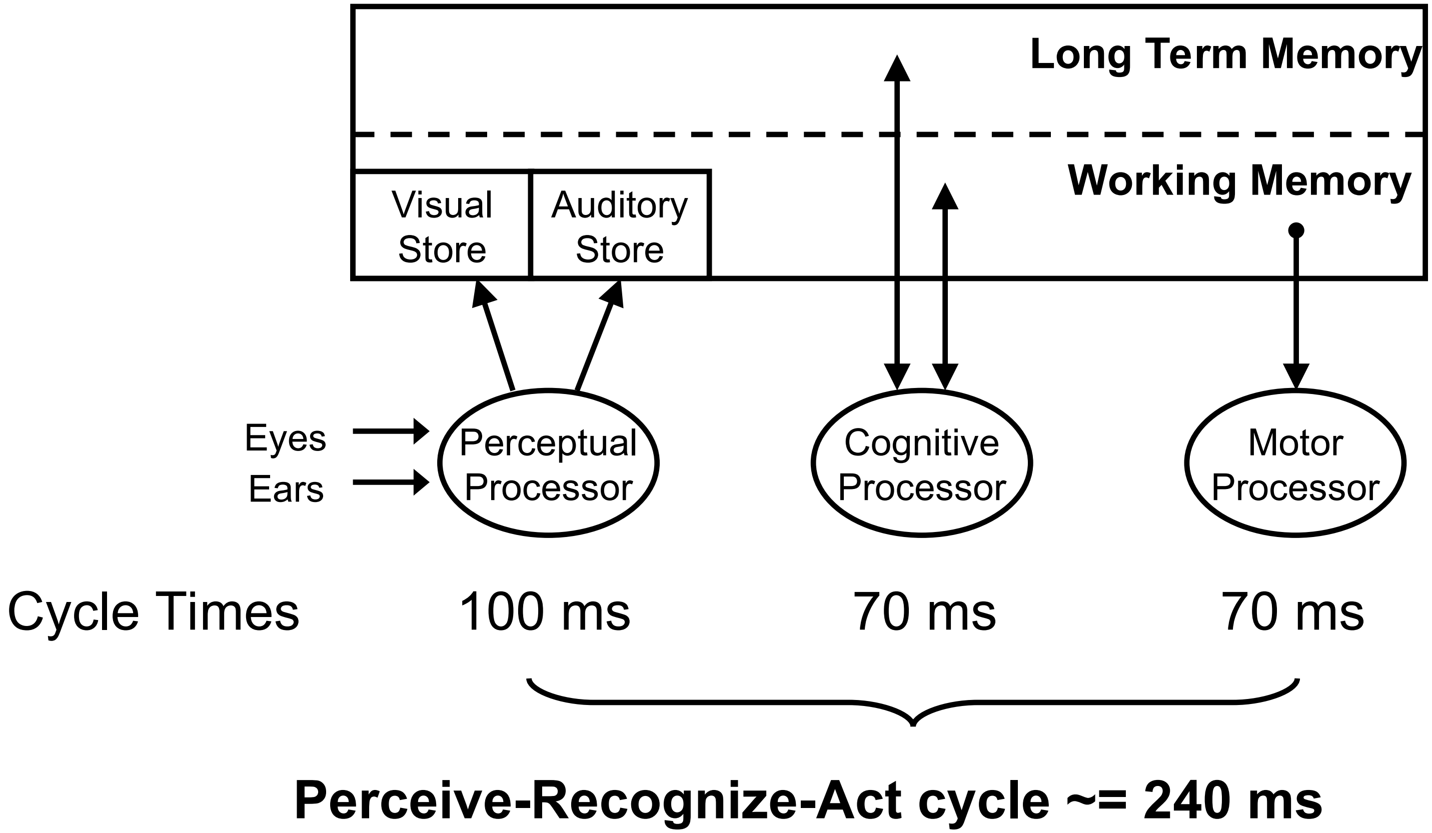


Model Human Processor



Use Model to Compute Reaction Time for Simple Matching Task

- A user sits before a computer terminal. Whenever a symbol appears, s/he must press the space bar. What is the time between stimulus and response?

Use Model to Compute Reaction Time for Simple Matching Task

- A user sits before a computer terminal. Whenever a symbol appears, s/he must press the space bar. What is the time between stimulus and response?

Tp + Tc + Tm = 240 ms

Use Model to Compute Reaction Time for a Symbol Matching Task

- Two symbols appear on the computer terminal. If the second symbol matches the first, the user presses “Y” and presses “N” otherwise. What is the time between the second signal and response?

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- Two symbols appear on the computer terminal. If the second symbol matches the first, the user presses “Y” and presses “N” otherwise. What is the time between the second signal and response?

Tp + 2Tc (compare + decide) + Tm = 310 ms

In General Case

- Need a bridge from task structure to MHP
  - Enables top down as opposed to bottom up analysis
- Analyze goal structure of the task, then for each step:
  - Analyze user actions required (motor system)
  - Analyze user perception of the output (perceptual system)
  - Analyze mental steps to move from perception to action (cognitive system)
- Sum the processing times from each step to get a reasonably accurate prediction of task performance

GOMS

- Models task structure (goals) and user actions (operators, methods, selection rules)
  - Goals: cognitive structure of a task
  - Operators: elementary acts that change user state or task environment
  - Methods: sets of goal-operator sequences to accomplish a sub-goal
  - Selection: rules to select a method
- Assumes error free and rational behavior

GOMS

- Concentrates on expert users
- Concentrates on error-free performance
- Good analysis tool for comparing designs
- Has spawned many similar techniques
- Will do a full GOMS of simple interface in a couple weeks

Example – Online Dictionary Lookup

- Goal: Retrieve definition of a word
  - Goal: Access online dictionary
    - Operator: Type URL sequence
    - Operator: Press Enter
  - Goal: Lookup definition
    - Operator: Type word in entry field
    - Goal: Submit the word
      - Operator: Move cursor from field to Lookup button
      - Operator: Select Lookup
    - Operator: Read output

GOMS – Advantages

- Enables quantitative comparison of task performance before implementation
  - Empirical data shows model provides a good approximation of actual performance
- Could be embedded in sketch simulation tool
  - Designer provides GOMS model and interface sketch, tool returns performance prediction

GOMS – Disadvantages

- Goals not used in prediction of performance
  - Define task structure, not user behavior
  - Difficult to determine when a user switches between goals and how goals are intertwined with operators
- Requires that a designer define a task to the level of elementary operators; could address this by:
  - Defining task to coarser level and empirically deriving times for high-level operators
  - Aggregating/reusing results from other interfaces
  - Automating generation of task models

GOMS – Disadvantages

- Predicting movement time based on the level of micro-movements not plausible
  - Need a higher-level method for predicting movement time
- Fitt’s Law

Fitts Law

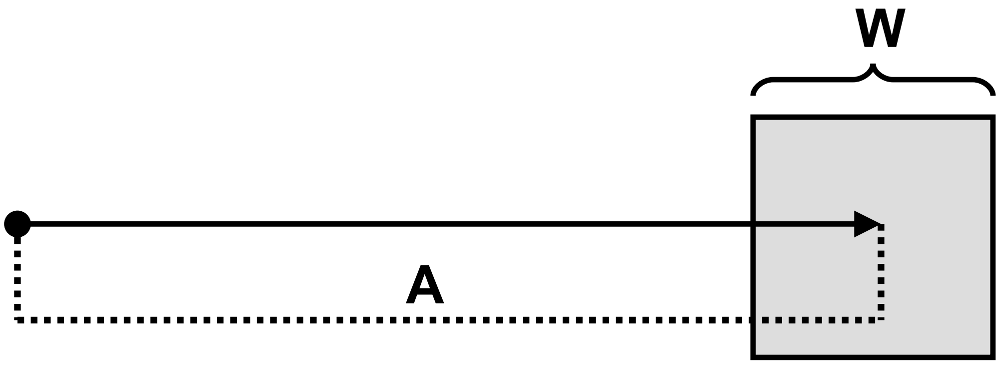
- Models human motor performance
  - Aimed at arm-hand movement
  - Original model developed in 1954
- Enables prediction of movement time (MT)
  - Movement assumed to be rapid, error-free, and targeted
- MT is a function of target *distance* and *width*

Origins

- Psychologists using information theory to model perceptual, cognitive, and motor skills
  - Information theory developed by Shannon in late 1940s at Bell Labs
  - Transform information into sequence of binary digits and transmit over a noisy channel
- Two laws that are still with us:
  - Fitts Law: Movement time
  - Hicks Law: Choice reaction time

Task Environment

- Models movement of arm-hand to a target
  - Hand is A cm from the target (Amplitude)
  - Target is W cm wide (tolerance)
  - Assume movement follows straight horizontal path



Model – Movement Time (MT)

- MT linear with respect to index of difficulty

$$\mathbf{MT = a + b * I_d}$$

  - a: y-intercept
  - b: slope (msec/bit)
  - 1/b: Index of Performance (bits/msec)
  - Originally: $I_d = -\log_2(W / 2A) = \log_2(2A / W)$

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  - Today:
    - $I_d = \log_2(A / W + 1)$
    - $I_d = \log_2(A / W + 0.5)$ when $I_d < 3$ bits

Interpretation of $\log_2(A/W + 1)$

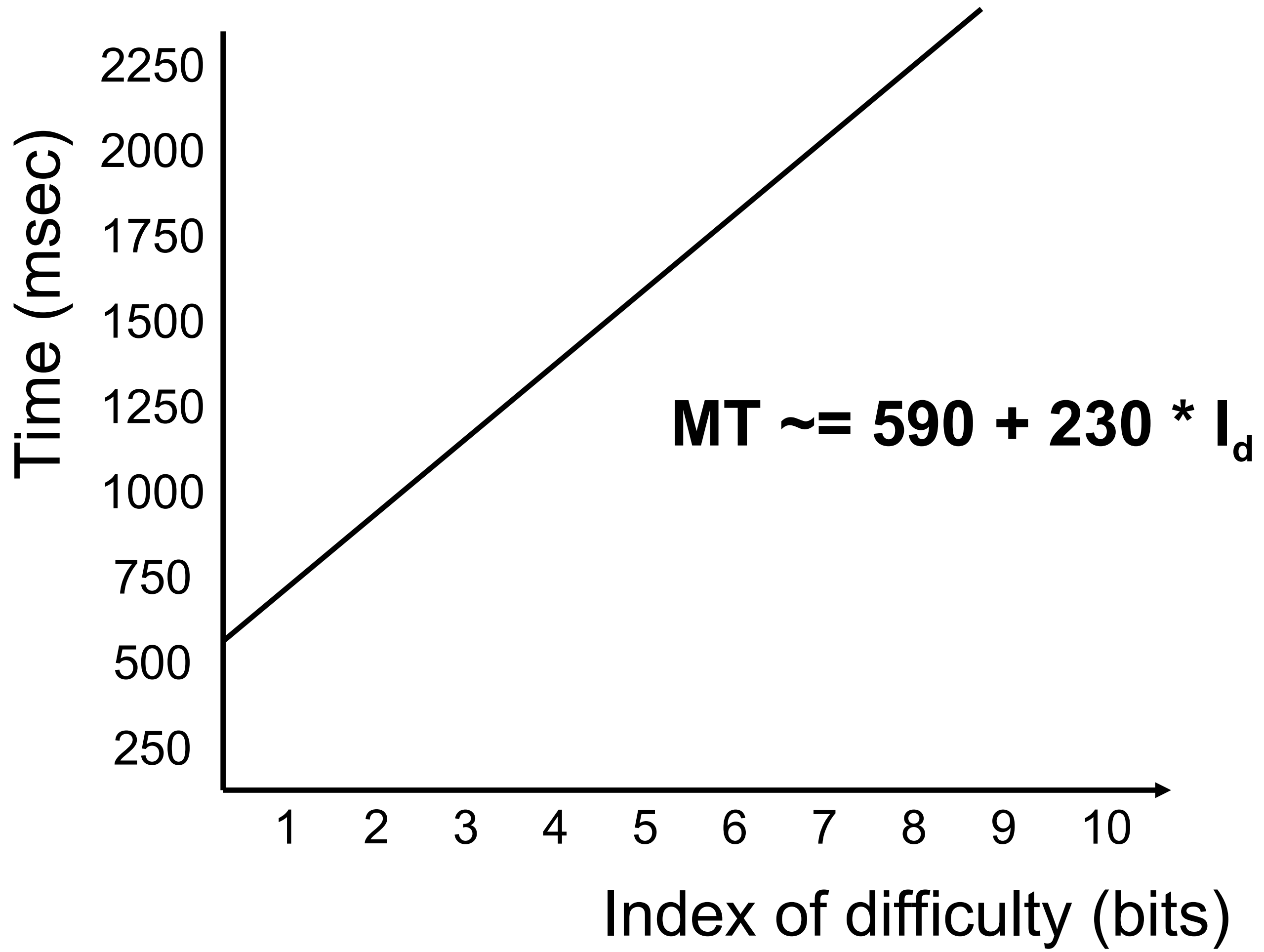
- Arm-hand movement require more time when
  - Distance to target (A) increases
  - Error tolerance (W) decreases
  - Target is further away and of smaller size

- Arm-hand movement requires less time when
  - Distance to target (A) decreases
  - Error tolerance (W) increases
  - Target is closer and of larger size

Fitting the Model

- $MT = a + b * I_d$
  - Three parameters must be filled (a, b, and I_d)
- I_d computed from task environment
  - $I_d = Log_2(A / W + 1)$
- a and b found with regression line
  - Done lots of times in the past with close but not exact agreement
  - $MT \sim= 590 + 230 * I_d$
- $I_p = 1 / b \sim= 1/230 = 4.35$ bits / msec

Common Graph of Fitt's Law



Exercise

- Predict time for user to move the cursor from current location to a button
  - Button is 400 pixels to the right of the cursor
  - Button is 50 pixels wide
  - $MT \sim= 590 + 230 * \mathrm{Log}_2(A / W + 1)$

Adapting Model to 2D Tasks

- What happens for:
  - vertical or diagonal movements to targets?
  - Targets that are not rectangular?
  - Fitts Law does not fit these environments well

- Possible solutions
  - Use area of target
  - Use perimeter of target
  - Use smaller of width and height
  - Measure width along approach angle

Take Home Exercise

- Predict time for user to move the cursor from current location to a pull down menu
  - Menu is 400 pixels up and to the right of the cursor
  - Menu is 40 pixels wide by 20 pixels high

$$MT \sim= 590 + 230 * \text{Log}_2(A / W + 1)$$

Take Home Exercise

- Derive an approximate Fitts Law model using the Model Human Processor

Compare Input Devices

- Input devices are transducers
- Compare task performance with input devices against optimal task performance

- Studies show that mouse is a near optimal device
  - May explain why it is still with us today
  - But stylus can outperform mouse in some cases, especially when gestures are used

Hicks Law - Choice Reaction Time

- Models human reaction time under uncertainty
- Decision time T increases with uncertainty about the judgment or decision to be made
  - T = k H, where H is the entropy of the decision and k is a constant.
  - $H = \sum_{i=1} p_i \log_2(1/p_i + 1)$
  - $H = \log_2(n + 1)$, if probabilities are equal

Take Home Exercise

- A telephone call operator has 10 buttons. When the light behind one of the buttons comes on, the operator must push the button and answer the call.

  When a light comes on, how long does it take the operator to decide which button to press?