Modeling Interaction and Cognition

People-Oriented Computing

14.10.2019

Announcements

- Exercise #3 posted on OLAT
- Lab this Wednesday, October 16th
- Project Assignment #1 will be distributed next week
  - Assignment is to be completed in groups of 2 students
  - We will open a forum thread for people to find project partners

Agenda

- Brief overview of interaction modeling
- Fitts’s Law for physical interaction modeling
- KLM for predicting interaction time
- GOMS Model
- Seven Stage Model of Interaction
- (Model Human Processor)
- Comparison of models

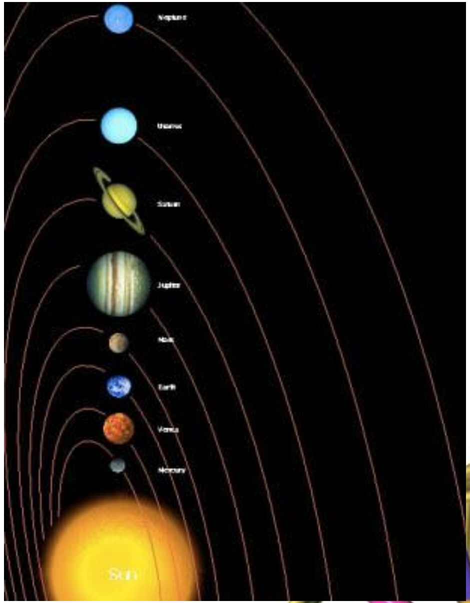
Learning Goals

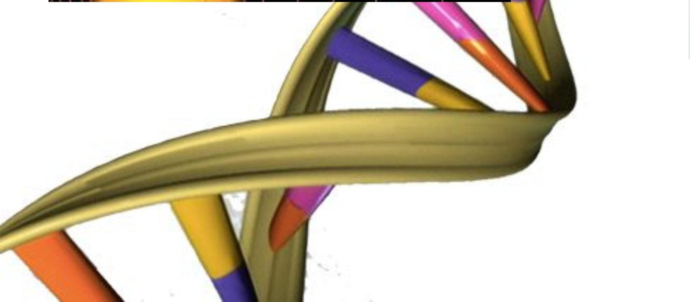
After this lecture, you should...

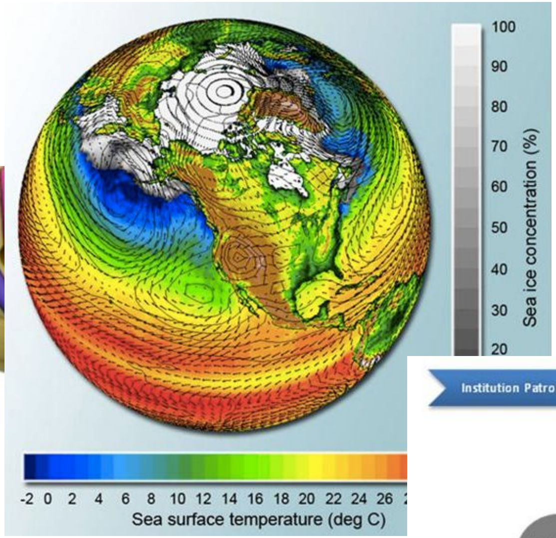
- Have an understanding of what an interaction model is and why they are important
- Be familiar with several types of interaction models, the differences between them, and what purposes each serves
- Be able to apply various models for predictive or evaluative tasks
- Be able to determine which interaction model(s) would be most useful depending on your goal

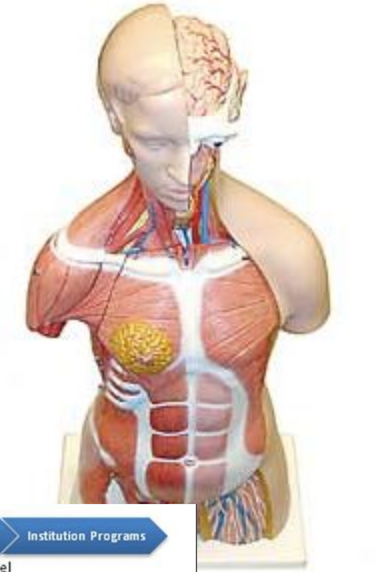
INTERACTION MODELS

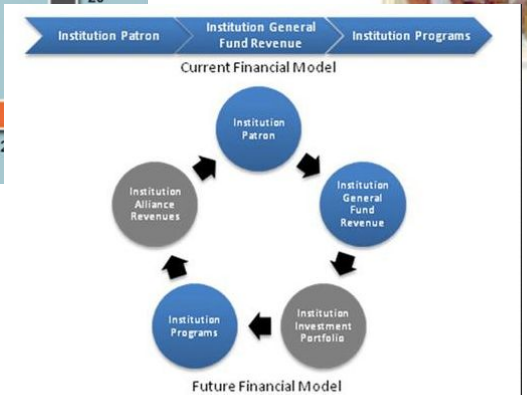
What is a Model?











What is a Model?

A constructed representation intended to help understand and reason about the world, or some phenomenon in the world

- Abstracted and simplified
- Generalized
- Not necessarily reflective of how the world actually works

Purpose of Interaction Models

Many potential uses:

- Predict human performance
- Understand the interactions and interaction cycles
- Explain physical and cognitive processes
- Examine individual parts of the interaction
- Diagnose breakdowns
- Examine mappings between user language and system language

Interaction Models

- Tools for modeling and thinking about how humans interact with objects or systems
- Different models enable different types of thought, tasks, explanations

Consider Maps...

What kind of maps would be helpful for

- Understanding the spatial relationships between countries or continents?
- Talking about changes in elevation in given terrain?
- Learning about the public transit systems of different large cities?
- Designing a new public transit system for a municipality?
- Figuring out how long it will take to get to a friend's house?

FITTS'S LAW

Fitts's Law for Physical Modeling

Essentially a formulation of the idea that movement time is proportional to distance and target size

Fitts’s Law Live!

Fitts’s Law Demo

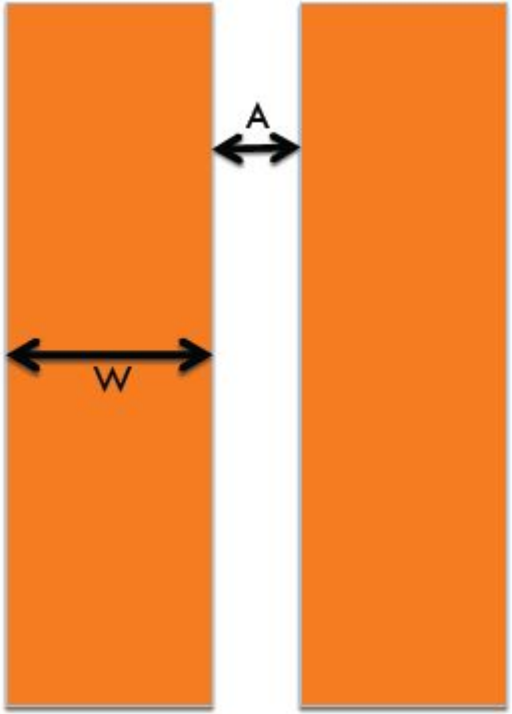
Tap back and forth between the two rectangles as quickly as you can!

- Don’t worry about where in the rectangle you tap – just tap as many times as you can somewhere within the shape

Fitts's Law Basics

- Movement Time (MT) is proportional to the Index of Difficulty (ID) of a selection task
- I.E., the harder the selection task is, the longer it will take

Fitts's Law for Physical Modeling



Fitts's Law Basics

The movement time for a well-rehearsed selection task:

- Increases as the distance A to the target increases; and
- Decreases as the size of the target W increases

Index of Difficulty (ID)

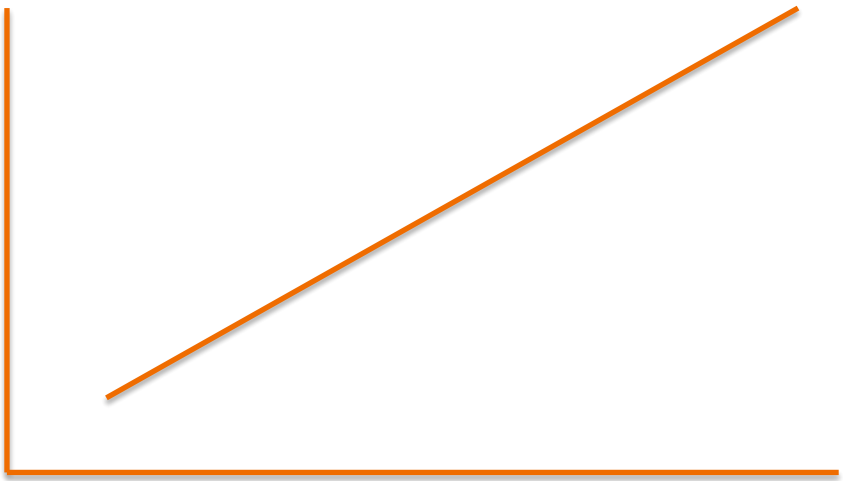
Difficulty of a selection task can be calculated as:

$$ID = \log_2(2A/W)$$

A = distance between targets

W = target width

Movement Time (MT)



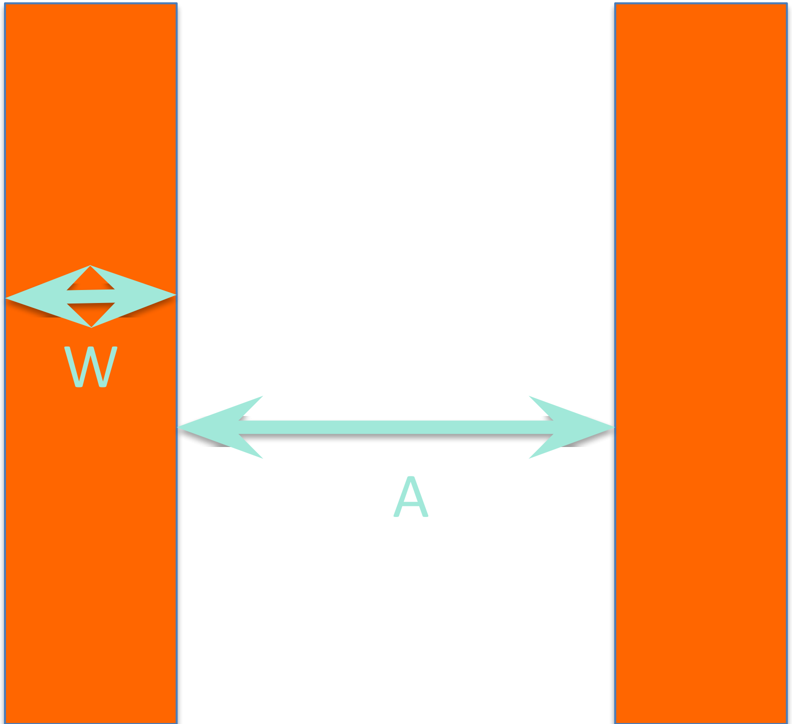
MT = a + b ID
(a = 0 if line passes through origin)

How MT is Determined

- Empirical measurement establishes constants a and b
- a and b are different for different devices and different ways a device is used

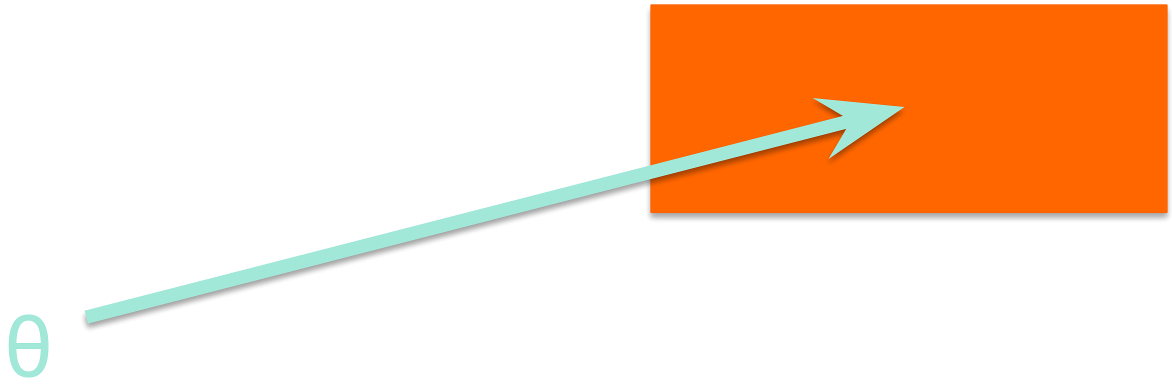
Original Application of Fitts's Law

One-dimensional selection



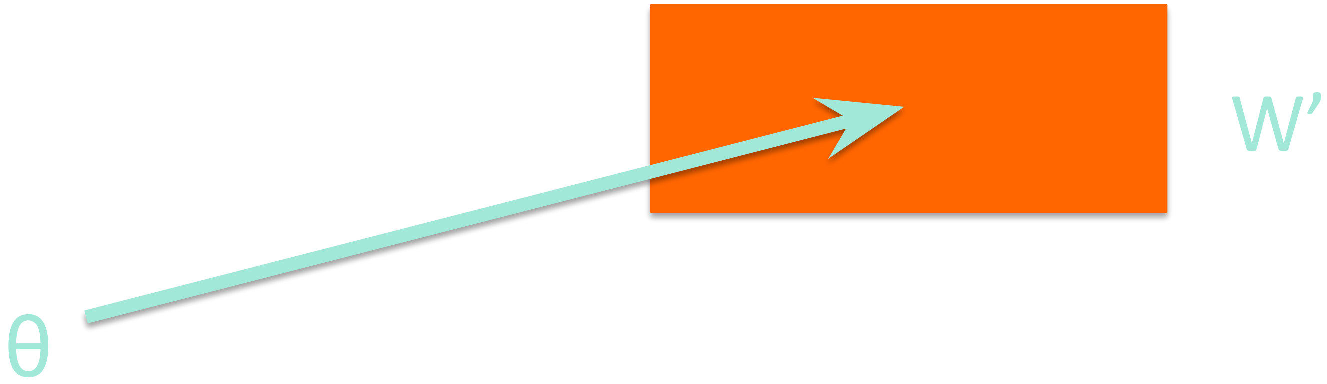
Extending to 2-D Targets

- What is W when we consider 2-dimensions in the selection task?



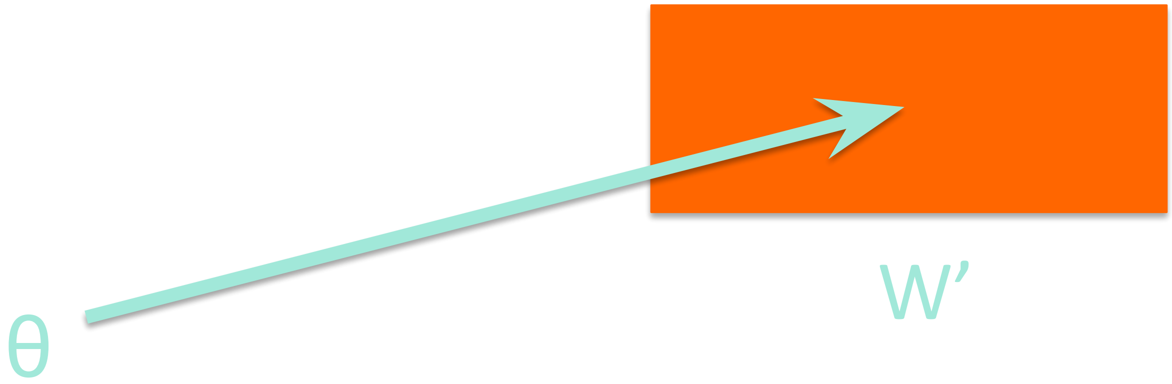
Extending to 2-D Targets

- What is W when we consider 2-dimensions in the selection task?
  - Smaller dimension as lower bound



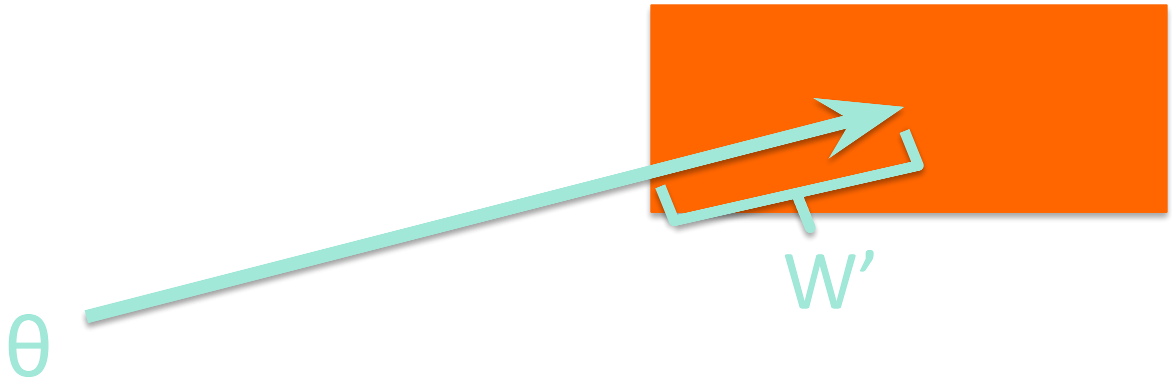
Extending to 2-D Targets

- What is W when we consider 2-dimensions in the selection task?
  - Can use same W as before



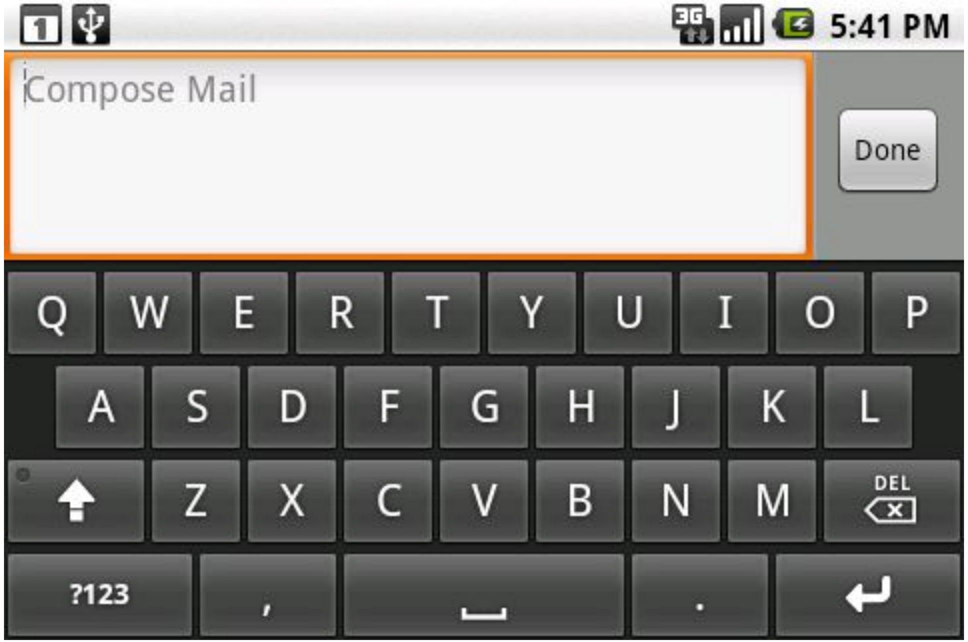
Extending to 2-D Targets

- What is W when we consider 2-dimensions in the selection task?
  - Distance from target edge to centroid



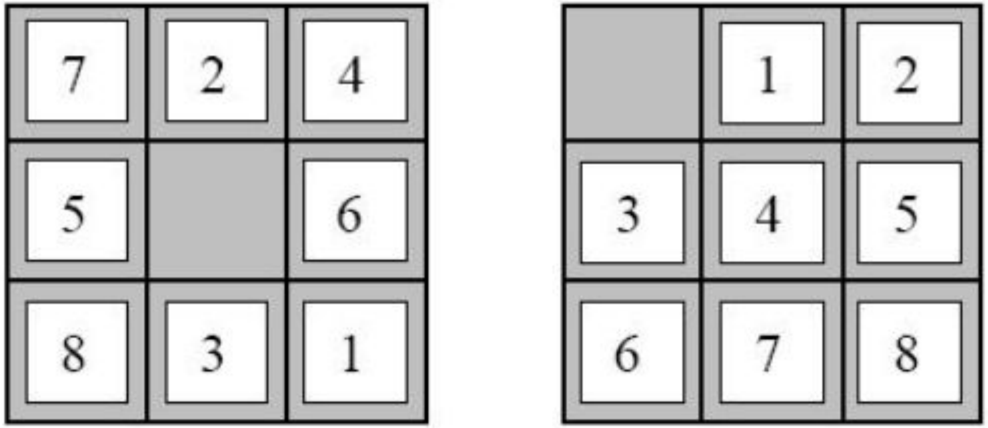
Applying Fitts's Law

Does it apply?



Applying Fitts's Law

- Does it apply?



Start State

Goal State

Applying Fitts's Law

- Used for predicting performance on low-level physical actions
- For "automatic" tasks and actions
- For tasks with minimal cognition – don't have to "think" about them
- Useful for early interface testing, comparing alternative interface layouts

KEYBOARD-LEVEL MODEL (KLM)

Adding Cognition into Models

- Not all human tasks involve no cognition
- Even making simple decisions about how to accomplish a task or what the next step should be involves some mental processing
- KLM is a simple model that begins to incorporate mental processes

Keystroke-Level Model (KLM)

- Developed by Card et al. in 1983
- Another way of doing physical modeling
- Decompose tasks into low-level elements with time values
- Calculate prediction for total execution time
- Best for automated behavior

Keystroke-Level Model (KLM)

- **K** – striking keys
- **B** – pressing a mouse button
- **P** – pointing (dragging a pointer to a target)
- **H** – homing (switching the hand between the mouse and keyboard)
- **D** – drawing lines using the mouse
- **M** – mentally preparing for a physical action
- **R** – system response time

KLM Process

Calculate time required for individual generic actions

Decompose tasks into individual actions

Calculate the total time for a task as a sum of the time for each action

Operator Name	Description	Time (s)
K	Pressing a single key or button Skilled typist (55 wpm) Average typist (40 wpm) Unskilled typist Pressing shift or control key	0.35 (average) 0.22 0.28 1.20 0.08
P P_1	Pointing with a device to a target on display Clicking the device	1.10 0.20
H	Homing hands on the keyboard or other device	0.40
D	Draw a line using the mouse	Varies depending on line length
M	Mentally prepare for an action, make decision	1.35
R(t)	System response time – counted only if it causes the user to wait during the task	*t*

Keystroke-Level Model (KLM)

How long will it take to insert the word “not” into the following sentence using Microsoft Word:

Running through the streets naked is normal.

To change it to:
Running through the streets naked is not normal.

Keystroke-Level Model (KLM)

1. Select what method to use (M)
2. Move cursor to appropriate point in sentence ($H + P + P_1$)
3. Move hands to home position on keys (H)
4. Mentally prepare (M)
5. Type “n” + “o” + “t” + space (K + K + K + K)

1.35 + .40 + 1.10 + .20 + 1.35 + .22 + .22 + .22 + .22 = 5.68 seconds

Keystroke-Level Model (KLM)

- Can be used for comparing alternate ways of executing a task
- Does not take time for cognition into account
- Limited capacity for tasks that require complicated decisions or cognition
- Card et al. formulation assumes conventional keyboard, mouse, and display; does not cover modern input devices and channels (but could be extended to)

GOMS MODEL

GOMS Model

- Developed in the early 1980s by Card, Moran, and Newell
- Stands for **G**oals, **O**perators, **M**ethods, and **S**election rules
- Attempts to model the knowledge and cognitive processes involved when users interact with system

GOMS Model

Goal:
a particular state the user wants to achieve

- E.g., find a website on interaction design

GOMS Model

Operators:
the cognitive processes and physical actions that need to be performed in order to attain goals

- E.g., decide on which search engine to use, think up and then enter keywords into the search engine
- Difference between goals and operators: goals are obtained; operators are executed

GOMS Model

Methods:
learned procedures for accomplishing goals. Consist of the exact sequence of steps required

- E.g., type in keywords in a Google search box and press the search button

GOMS Model

Selection rules:
determine which method to select when there is more than one available for a given stage of a task.

- E.g., once keywords have been entered into a search engine entry field, you can press the return key or click on the “search” button using a mouse or pointer. Selection rule determines which of the methods to use in this instance.

GOMS Model

- **Goals**: refer to a particular state the user wants to achieve
- **Operators**: refer to the cognitive processes and physical actions that need to be performed in order to attain those goals
- **Methods**: learned procedures for accomplishing the goals
- **Selection rules**: used to determine which method to select when more than one is available for a given stage of a task

GOMS Model Example

Goal: Delete some text in a sentence (using MS Word)

Two possible *methods*: Delete using menu option; Delete using delete key

GOMS Model Example

Method for accomplishing goal of deleting a word using menu option

- Step 1. Recall that word to be deleted must be highlighted
- Step 2: Recall that command is “cut”
- Step 3: Recall that “cut” is in edit menu
- Step 4: Accomplish goal of selecting and executing the “cut” command
- Step 5: Return with goal accomplished

GOMS Model Example

Method for accomplishing goal of deleting a word using delete key

- Step 1: Recall where to position cursor in relation to a word to be deleted
- Step 2: Recall which key is delete key
- Step 3: Press delete key to delete each letter
- Step 4: Return with goal accomplished

GOMS Model Example

Operators to use in the above methods

- Click mouse
- Drag cursor over text
- Select menu
- Move cursor to command in menu
- Press key

GOMS Model Example

Selection rules to decide which method to use

1. Delete text using mouse and selecting from menu if a large amount of text is to be deleted
2. Delete text using delete key if a small number of letters are to be deleted

SEVEN-STAGE MODEL OF INTERACTION

Language in Interaction

Language in Interaction

System language

what the system understands, expects, and communicates

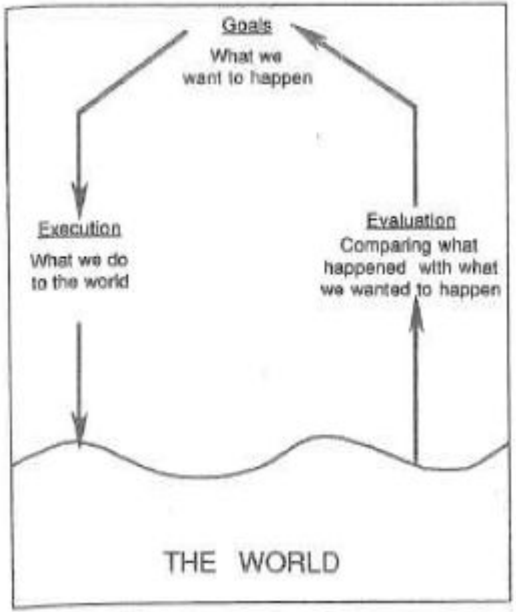
User language

what the person understands, expects, and communicates

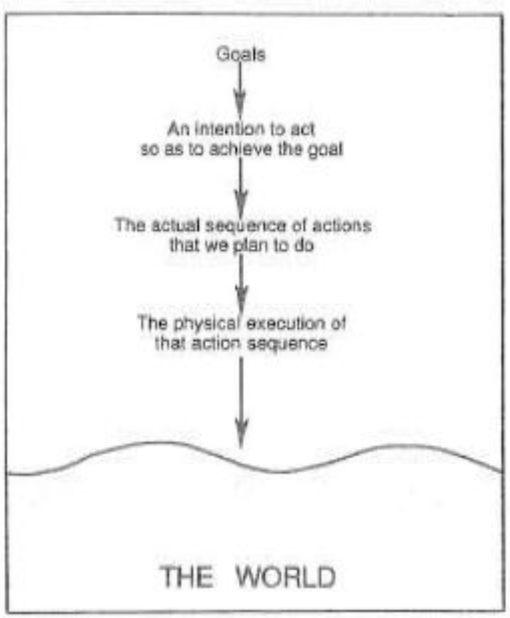
Modeling Interaction with a System

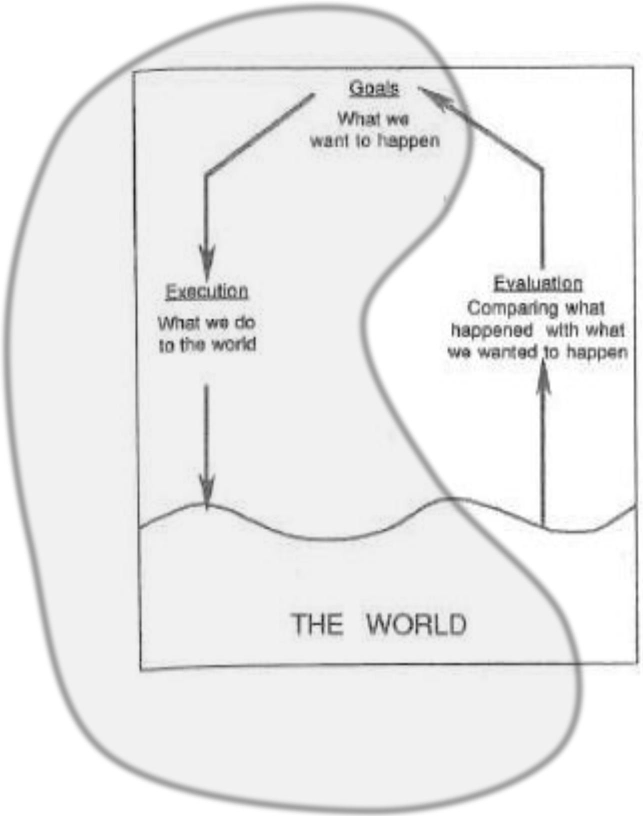
- Goes beyond just the human actions and choices
- Models the “dialogue” between the system and the user
- Broader than just commands and output

At the highest level



Breaking Down the Execution



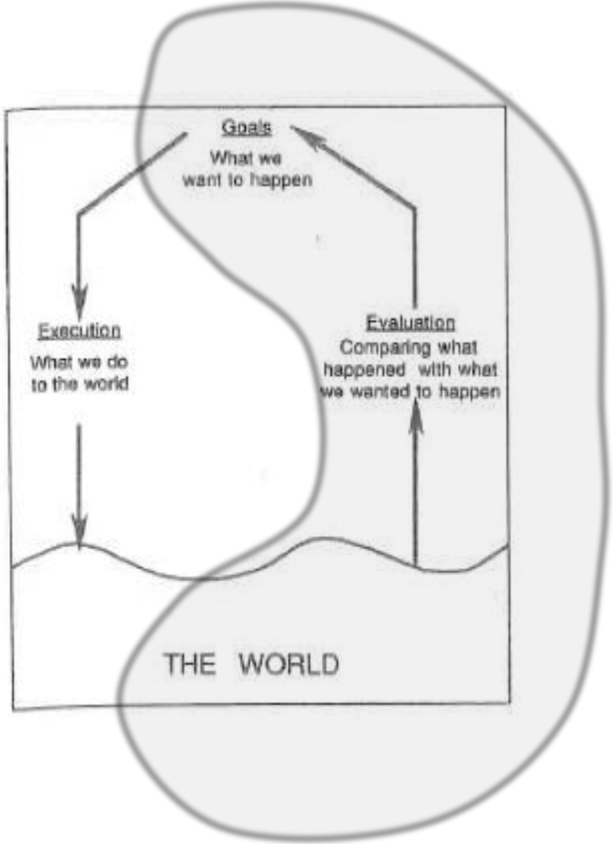


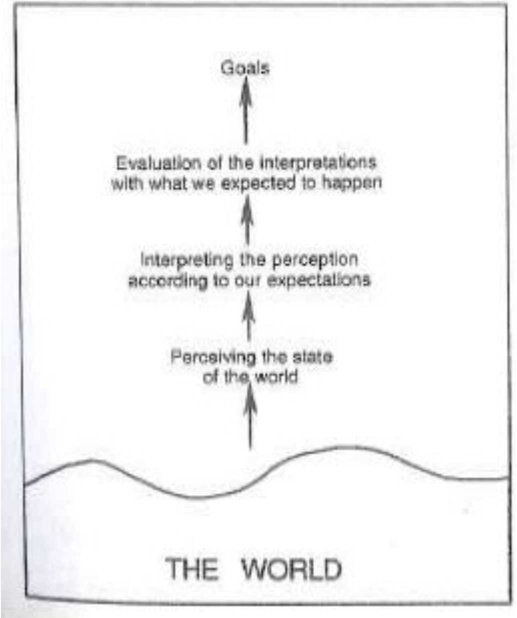
Seven-Stage Model: Execution

Once a goal is formulated, the next steps:

- **Forming the Intention**: What does the person want to do in this step?
- **Specifying an Action**: What are the exact steps the person decides to take to address the intention?
- **Executing the Action**: Actually doing the steps that have been chosen, thus acting upon the world

Breaking Down the Evaluation



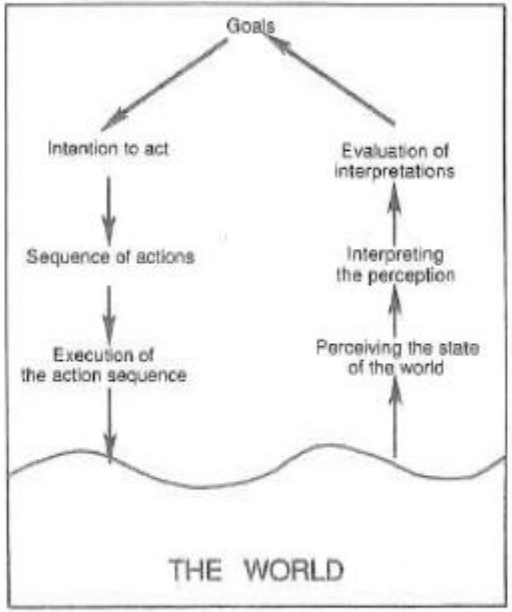


Seven-Stage Model: Evalution

Once the world has responded (i.e., changed):

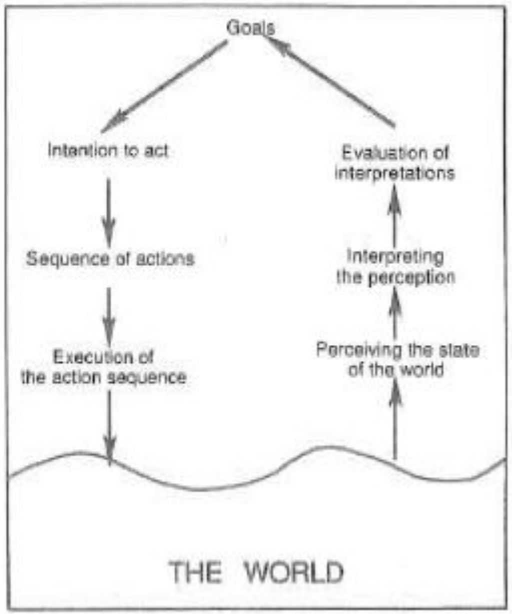
- **Perceiving the state of the world**: The person must *physically perceive* the current state of the world, whether changed or unchanged (i.e., see, hear, feel, etc.)
- **Interpreting the state of the world**: The person must figure out what the perceived changes mean, i.e., what just happened?
- **Evaluating the outcome**: The person must come to a conclusion about whether the original goal has been addressed

Putting it All Together



The Gulfs of Execution and Evaluation

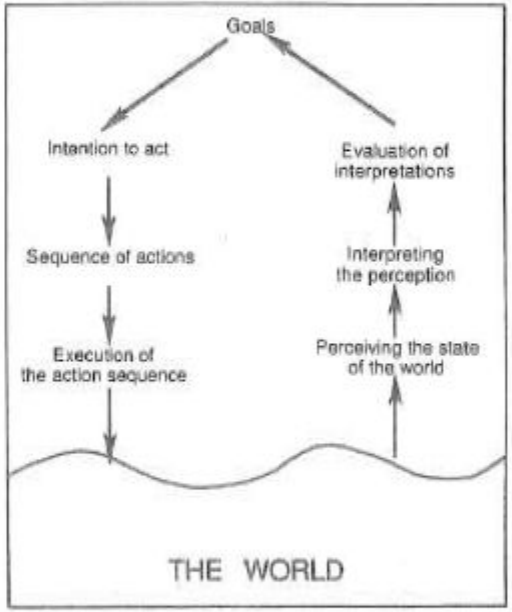
Execution: Do the actions provided by the system correspond to the intentions of the user?



Evaluation: Does the system respond in a way that the user can perceive and interpret?

Seven-Stage Model Example

- Example 1: It's too dark



Seven-Stage Model Example

Goal: Make it brighter in the room.

Forming the Intention: Turn on the lights

Specifying the Action: Devise plan to walk to light switch and flip light switch to on position

Executing the Action: Physically walk to light switch and flip switch

Seven-Stage Model Example

World: Lights are now on and room is brighter

Perceiving the State of the World: Person perceives increased brightness (visually), hears slight “click” from light switch

Interpreting the State of the World: Person determines that light has been successfully switched on and that the light in the room is increased

Evaluating the Outcome: Person decides that the original goal of making the room brighter has been successfully achieved

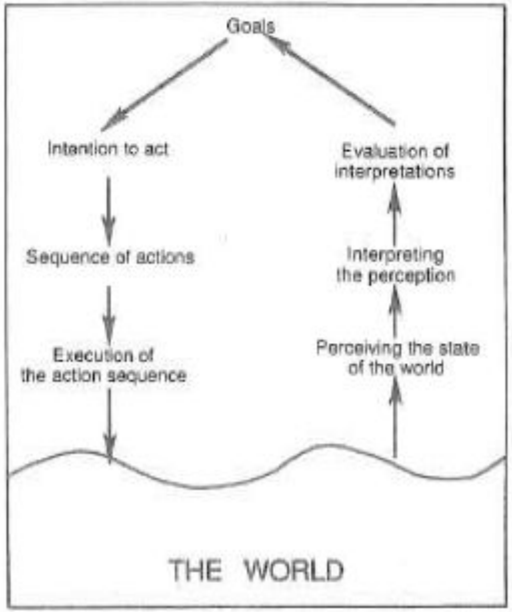
Seven-Stage Model Example

- This interaction is not the only successful possibility to address this goal
- Possible other intentions:
  - Open the curtains to let in more light
  - Light a candle
- Possible other action specifications (for turning on lights)
  - Go to lighting control app on phone and click on icon for desired light
  - Clap hands to turn on audio-controlled light
  - Yell for mom and ask her to turn on light
  - Throw shoe at light switch
- If Intention and Action Specification are correct and Action Execution is successful, evaluation of outcome should be the same

Explaining Breakdowns

Where do problems occur?

- Breakdowns can occur at any stage in the cycle
- A breakdown at one stage usually prevents correct execution of some or all later stages



Seven-Stage Model Example

What if it the action isn't successful? Where do the following breakdowns occur?

- I don't know where the light switch is
- Light switch is stuck and doesn't move when I try to press it
- Light bulb is broken
- I coincidentally go blind just as I flip the switch

Seven-Stage Model Example

What if it the action isn't successful? Where do the following breakdowns occur?

- I don't know where the light switch is
  - Breakdown in **specifying the action**
- Light switch is stuck and doesn't move when I try to press it
  - Breakdown in **executing the action**
- Light bulb is broken
  - Possible breakdown in the **interpreting the perception**
- I coincidentally go blind just as I flip the switch
  - Breakdown in **perceiving the state of the world**

Seven-Stage Model: Another Example

You are using an application on your mobile phone that allows you to adjust the temperature of your home remotely. Where do these breakdowns occur?

- You want to adjust the temperature but the scroll bar on the interface is too small for your fingers
- You choose a temperature and hit “Set” and the app takes you back to the “Set a temperature” dialogue
- You want to turn the heating off but you can’t find the option for that
- You want to use the app to turn on the humidifier in your home but the app doesn’t support that

Seven-Stage Model: Another Example

You are using an application on your mobile phone that allows you to adjust the temperature of your home remotely. Where do these breakdowns occur?

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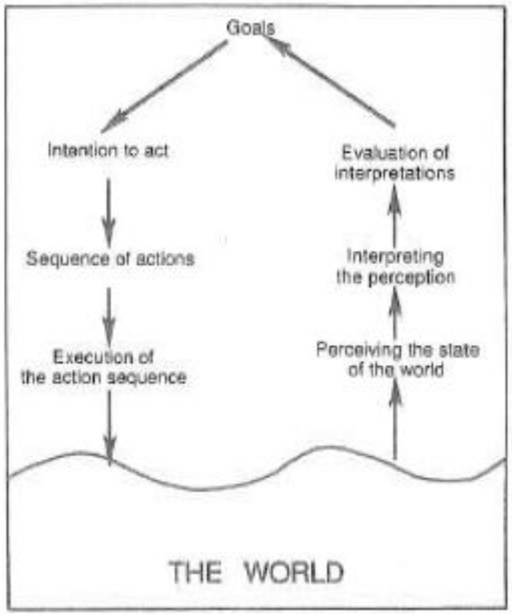
- You choose a temperature and hit “Set” and the app takes you back to the “Set a temperature” dialogue
  - Breakdown in **interpreting the perception**
- You want to turn the heating off but you can’t find the option for that
  - Breakdown in **specifying the action**
- You want to use the app to turn on the humidifier in your home but the app doesn’t support that
  - Breakdown in **forming the intention**

The Gulfs of Execution and Evaluation

Execution: Do the actions provided by the system correspond to the intentions of the user?



Evaluation: Does the system respond in a way that the user can perceive and interpret?

Bridging the Gulfs

- The **Gulf of Execution** is small when:
  - The actions provided by the system match the intentions of the user
  - The actions can be executed without extra effort
- The **Gulf of Evaluation** is small when
  - The system provides information about its state that can be easily accessed and interpreted
  - The system's state matches the way the user thinks about the system

Bridging the Gulfs

Provide good **discoverability** to enable the user to develop a good conceptual model

- Make use of natural mappings
- Provide clear feedback
- Make use of constraints
- Provide perceivable affordances, meaningful signifiers

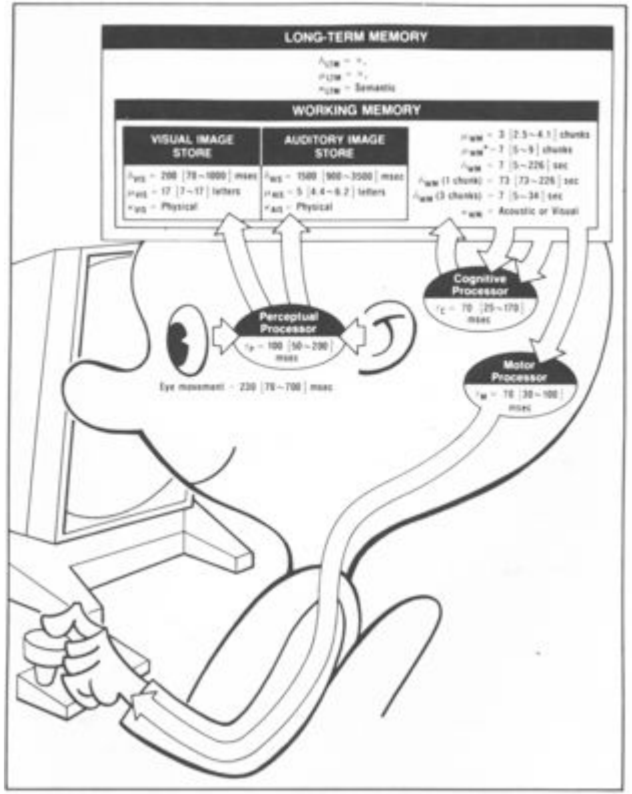
Using the Seven-Stage Model

- Identify where problems occur in the cycle
  - Provides a basic checklist
- Design to make the gulfs as small as possible
- Helps break down a design problem into smaller pieces

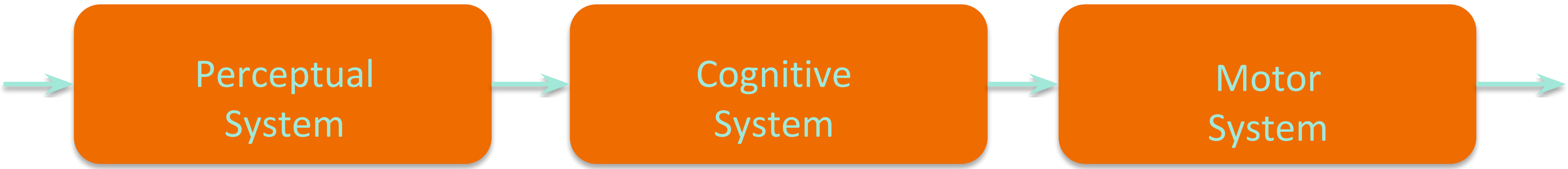
MODEL HUMAN PROCESSOR

The Model Human Processor

- Three systems: **perceptual**, **cognitive**, and **motor**
- Each system has **processor** and **memory**
- Each system has **principles of operation**



The Model Human Processor



Model Human Processor

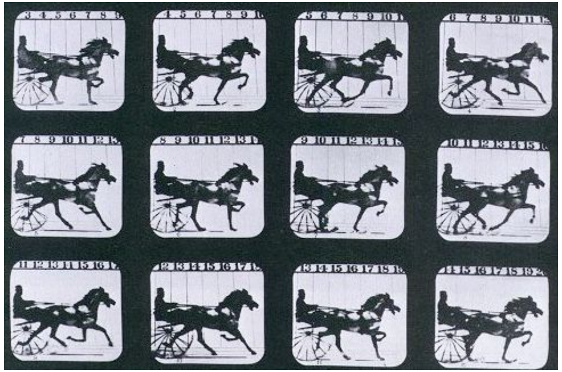
- Not meant to explain how the human brain works
- Intended to help understand, predict, and calculate human performance in interaction

MHP Perceptual System

- Create internal representation of physical sensations
  - Stores temporary information buffers
    - Auditory Image Store, Visual Image Store
- Transfers information in buffers into working memory

MHP Perceptual Processor

- Cycle time: time between when stimulus is presented and when it is available in buffers
- Multiple similar stimuli can combine during one cycle
- Principle: Cycle time varies inversely with stimulus intensity



MHP Cognitive System

- Connects inputs from Perceptual System to outputs of Motor System
- Handles learning, remembering, and problem solving
- Includes working memory (WM) and long term memory (LTM)
    - WM: limited, symbolic, an activated subset of LTM
    - LTM: a person’s available knowledge, can be treated as unlimited

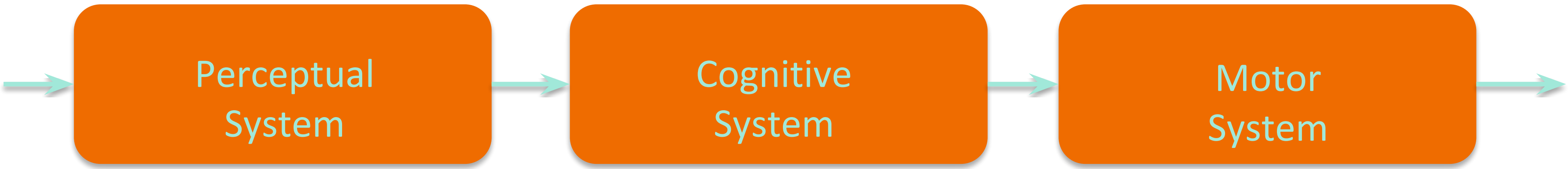
MHP Cognitive Processor

- Recognize-act cycle: contents of WM trigger actions in LTM which modify WM
- Principle: CP cycle time is shorter when greater effort is induced by task or information. Cycle time diminishes with practice

MHP Motor System

- Thought is translated into physical (muscular) actions
- Motor system corrections require cycles of perceptual and cognitive systems

Quick Example: Country Capitals



Quick Synopsis of Models

Model	What it represents	Features
Fitts's Law	Automated physical actions	- Predictive of performance - Quantitative - Assumes no cognition
KLM	Interaction sequences with a computer system	- Predictive of performance - Quantitative - Takes low-level mental processes into account
GOMS	Tasks, processes, and associated knowledge	- Accounts for decisions - Represents knowledge about tasks - Low and higher level processes
MHP	Human Input, Cognitive Processing and Output	- Perceptual, Cognitive, and Motor systems - Includes rules - Accounts for memory
Seven-Stage Model	Tasks and interactions including human and world/system	- Accounts for cognitive processes and decision making - Helps identify breakdowns

For next week

- No reading assignment
- Exercise on Wednesday will cover material from today's lecture as well as readings for today