ADMINISTRIVIA

next week (March 18-22)
- I am away all week
- No office hours – if needed, schedule time with your TA by appointment
- If needed, contact me through piazza (which I will prioritize accessing, as I will have very limited connectivity)
- Izabelle will give lecture on Human Perception
- Prep Assignment 11 is due at regular time
- Workshop is on (more on this at end of class today)

MSIV: WORKPLAN RECOMMENDATION

To allow adequate time for all Parts A, B & C, we suggest the following workplan below. You have ~3 weeks for parts A/B. Part C overlaps with MS V.

By the end of the 1st week: Complete Step 1 and Step 9.
- Team discusses pilot results and finalizes modifications to the experiment protocol. Team also discusses the plan for the project video. Use workshop time to get feedback from the course staff on both these issues.

By the end of the 2nd week: Complete Step 2 and have Steps 3, 4, 5, 6 and 10 underway.
- Mix of group and individual work (consult milestone)
- Gist: Team discusses preliminary analysis of the full set of data and preliminary conclusions. But graphs, interpretation of, formulation of conclusions, etc. are written and presented individually in the experiment write up.
- Team and TA feedback should be solicited on the video data clips selected as well as those new clips that have been created from scratch to be part of the final project video.

By the end of the 3 week: Up to Step 6 completed and submitted, Steps 7, 8 and 10 underway.
- Brainstorm the components in Steps 7 & 8.
- Work on video, identify clips to use in MSV.
TODAY’S LEARNING GOALS

- a refresher on human info processing
  - knowledge from 344 on this topic is assumed
- introduce human motor processing
- theories of performance
  - empirical ‘laws’
    - actually, models of simple movements
  - examples
    - Fitts, Hicks, Power, Steering
- some implications for UI design

---

MODEL HUMAN PROCESSOR (MHP):
ONE MODEL FOR PERCEPTION → MEMORY → COGNITION
(BASED ON ANALOGY WITH THE PROCESSING AND STORAGE AREAS OF A COMPUTER)

- Based on empirical data
- Three interacting subsystems
  - perceptual, motor, cognitive
- Parameters
  - processors have cycle time ($T$) ~ 100-200 ms (more on next slide)
  - memories have capacity, decay time, & type (physical, acoustic, visual, semantic)
CHARACTERISTIC CYCLE TIMES

- each subsystem has a typical processing time

<table>
<thead>
<tr>
<th>subsystem</th>
<th>average</th>
<th>range</th>
</tr>
</thead>
<tbody>
<tr>
<td>perceptual</td>
<td>100 msec</td>
<td>50-200 msec</td>
</tr>
<tr>
<td>cognitive</td>
<td>70 msec</td>
<td>25-170 msec</td>
</tr>
<tr>
<td>motor</td>
<td>70 msec</td>
<td>30-100 msec</td>
</tr>
</tbody>
</table>

WHAT’S MISSING FROM MHP?

Long-term Memory (LTM)
Working Memory (WM)
Visual Image Store
Auditory Image Store

sensory buffers (Dia)

...you should be able to identify 4 things from 344!

PERCEPTION & ACTION SUBSYSTEMS

input (perception):
- visual subsystem for what we see (most studied)
- acoustic subsystem for what we hear
- haptic subsystem for what we feel

output (action):
- vocal (articulatory) subsystem for what we speak
- motor subsystem for how we move

subsystems may operate in parallel (theory):
- Reading and hearing (input)
- Voice and motor (output)

USER OUTPUT MODALITY: MOTOR CONTROL

- used in **lots of very different ways** such as
  - discrete control (buttons), e.g. keyboard, icon selection
  - continuous control (handles), e.g. steering, slider
- **limited** by speed, strength, coordination, flexibility, size, ...
- **neurally integrated** w/ haptic sense (reflexes)
- **muscle memory**: learning of spatial “home”
  - e.g., reaching for gearshift in car; position tells you what gear you’re in
  - e.g., adaptive menus can be problematic
**WHY IS MHP VALUABLE?**

- Provides one way to evaluate the usability of an interface – system designer can use the MHP to predict performance with respect to time it takes a person to complete a task *without* actually performing an experiment with real users.
- Can also build dynamic models of an interface.

  e.g., Key Stroke Level Modelling for predicting expert performance:
  
  http://en.wikipedia.org/wiki/Keystroke-Level_Model

---

**THEORIES OF PERFORMANCE**

---

**CONTEXT:**

THEORIES OF HUMAN PERFORMANCE

- **types of theories and models used in HCI:**
  - empirical laws
  - dynamic models
  - explanatory theories

  - *when look at low enough level (cognitive / motor), people are the same.*
  - *can predict performance*

  - *social: messy! hard to apply numbers.*
  - *but, perhaps richest insights to be gained...many tasks aren’t just about speed and error.*
**Empirical Law**

- Quantitative model that provides predictions
  - Derived from experiments (controlled studies)

- Examples:
  - Fitts' Law
  - Hick's Law
  - Power Law of Practice
  - Steering Law

---

**Fitts' Law**

*Paul Fitts, 1954*

\[ MT = a + b \log_2 \left( \frac{D}{W} + 1 \right) \]

Movement Time = Index of Difficulty (ID [bits])

Index of Performance (IP) = ID/MT (bits/s)
  - Sometimes called bandwidth or throughput

Task difficulty is analogous to information:
  - Execution time is interpreted as human rate of processing information

---

**Example: Pointing Device Evaluation**

Real task: Interacting with GUI's
  - Pointing is fundamental

Experimental task: Target acquisition
  - Abstract, elementary, essential

\[ D = \text{distance} \]
\[ W = \text{target width} \]

**First way to calculate IP:**

\[ IP = \frac{ID}{MT} \]

**How can we use Fitts’ Law?**

So what can we do with this information?

50 years of data

<table>
<thead>
<tr>
<th>Device</th>
<th>Study</th>
<th>IP (bits/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand</td>
<td>Fitts (1954)</td>
<td>10.6</td>
</tr>
<tr>
<td>Mouse</td>
<td>Card, English, &amp; Burr (1978)</td>
<td>10.4</td>
</tr>
<tr>
<td>Joystick</td>
<td>Card, English, &amp; Burr (1978)</td>
<td>5.0</td>
</tr>
<tr>
<td>Trackball</td>
<td>Epps (1986)</td>
<td>2.9</td>
</tr>
<tr>
<td>Touchpad</td>
<td>Epps (1986)</td>
<td>1.6</td>
</tr>
<tr>
<td>Eyetracker</td>
<td>Ware &amp; Mikaelian (1987)</td>
<td>13.7</td>
</tr>
</tbody>
</table>

Table Reference:


**Making Comparisons**

- what are some caveats / limitations of trying to make comparisons between devices using Fitts’ Law?

- **speed accuracy tradeoff normalization**: if input type A is faster than input type B, but A also yields more errors . . . which is really faster?
  - can normalize by calculating an *effective width*
    - *don’t need to know HOW to calculate, but should know why*

**What does Fitts’ Law really model?**

- target width
  - (a) velocity
  - (b) distance

**MT [secs] = a + b(ID)**

- second way to calculate IP
  - \[ b = \text{slope} \]
  - \[ IP = \frac{1}{b} \]

**ID [bits] = \log_2 \left( \frac{D}{W} + 1 \right)**
BEYOND POINTING: TRAJECTORY-BASED TASKS

FROM TARGETS TO TUNNELS...
1 goal to pass through:
\[ ID = \log_2\left(\frac{D}{W} + 1\right) \]
2 goals to pass through:
\[ ID = 2\log_2\left(\frac{D}{2W} + 1\right) \]
N goals to pass through:
\[ ID = N\log_2\left(\frac{D}{NW} + 1\right) \]
\( \infty \) goals to pass through:
\[ ID = \frac{D}{W \ln 2} \]

STEERING LAW (ACCOT-ZHAI, 1997)

fixed width tunnel:
\[ ID = \frac{D}{W}, \quad MT = a + b \frac{D}{W} \]
narrowing tunnel:
\[ ID = \int_0^\infty dx \frac{dx}{W(x)} \]
genral Steering Law:
\[ ID = \int ds \frac{ds}{W(s)} \]

SOME RESULTS (FROM ACCOT-ZHAI 1997)
RECAP

– steering law mathematically derived using Fitts’ Law and integral calculus (derivation not shown in these slides)
– then empirically proven (data from experiments with human subjects)
– MT is linearly related to the ID
  • slopes differ for the different tasks, i.e., different throughput

– work is a strong indicator of the robustness of Fitts’ law

USE THESE LAWS TO
PREDICT PERFORMANCE / JUSTIFY DESIGN

Q: Which law applies?
Q: Is the contribution to overall movement time likely to be the same for vertical and horizontal segments?

worksheet

USE THESE LAWS TO
PREDICT PERFORMANCE / JUSTIFY DESIGN

• which ‘Format’ menu bar option is likely to be the faster target to hit on average?

worksheet

• which would you predict to be easier to use (faster, less error prone) on average?
**Lots of Target Acquisition Work Loosely Based on Fitts’ Law**

**Example:**
Enhanced area cursors:  
[https://www.youtube.com/watch?v=Nci-EAZLOpg](https://www.youtube.com/watch?v=Nci-EAZLOpg)

[https://doi.org/10.1145/1866029.1866055](https://doi.org/10.1145/1866029.1866055)

---

**Hick’s Law**

- describes the time it takes for a user to **make a decision** as a function of the possible choices he or she has

- Original experiment:
  - up to 10 lamps with corresponding keys.
  - Lamps light up randomly every 5 seconds.
  - User must press key for lit up lamp
  - measure response time from 2 – 10 lamps

  - note: this is not about motor processing, but example of a relevant empirical law

---

**Example**

Given two scenarios for the 10 lamps/lines:
- A: where each line gets an equal number of calls
- B: where two lines are used heavily, getting 50% and 40% of the calls, with the other 10% divided evenly among the other eight lines

Which of these situations do you expect will be faster to react to?
- A:
- B:
LIMITATIONS OF APPLYING HICKS

• Sometimes applied to justifying menu design
  — but should do so cautiously!

• Useful ONLY for predicting quick, fairly mindless, option selections
  — over simplifies in many cases where other factors may be at play (e.g., search)

• e.g., What confounds occur trying to apply Hicks to an alphabetical vs. randomly ordered menu?

USE THESE LAWS TO PREDICT PERFORMANCE / JUSTIFY DESIGN

Compare the ‘swipe left to close’ interaction over ‘select the x to close’ interaction. Which do you think is better?

POWER LAW OF PRACTICE

• task time on nth trial follows a power law
  — \( T_n = T_1 n^{-a} \), where \( a = .4 \) (empirically determined)
  — i.e., you get faster the more times you do it! (until you become expert)
  — applies to skilled behavior (sensory & motor) -- is an example of the learning curve effect on performance
  — does not apply to knowledge acquisition or quality

• another way of stating: law states that the logarithm of the reaction time for a particular task decreases linearly with the logarithm of the number of practice trials taken
ON DECK

• More human abilities: visual processing

• Then human memory

• Workshops next two Fridays:
  – More 444 project videos
  – Work ahead: Use strategically to get feedback on direction for your project video and group presentation (long weekend before design competition, so no workshop Friday before)