CS160: User Interface Design

Human Information Processing (KLM, GOMS, Fitts' law) 03/03/10

Berkeley
UNIVERSITY OF CALIFORNIA

http://www.youtube.com/watch?v=WHxQU4RhyLk

Most heavily used features directly mapped (volume, play/pause)
Circular movements mapped to linear operations

Individual Programming Assignment 4 (due Mar 3)

Assignment: Low Fidelity Prototype

Due Mar 15

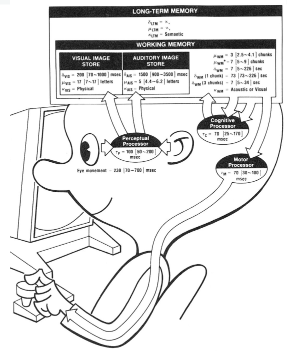
Identify project mission statement

Create low-fidelity prototype that supports 3 tasks
- 1 easy, 1 moderate, 1 difficult task

Create a video prototype showing (cameras next class)
- How it supports the 3 tasks
- Context in which is will be used (back story)
- Must include narration

Test the prototype with target users
- No one from this class
- Not your friends

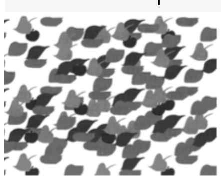
Review: Human Info Processor

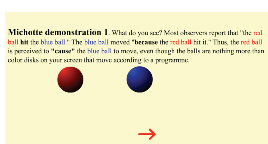


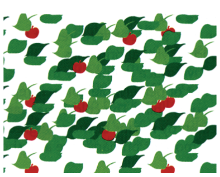
5 Parts
- Perceptual
- Cognitive
- Motor (will discuss today)
- Working memory
- Long-term memory

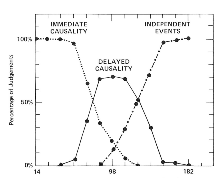
Unified model
- Probably inaccurate
- Predicts perf. well
- Very influential

Review: Pop-Out and Causality





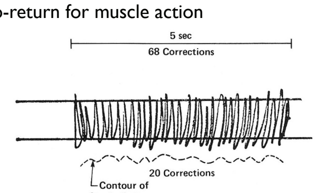




Motor Processor

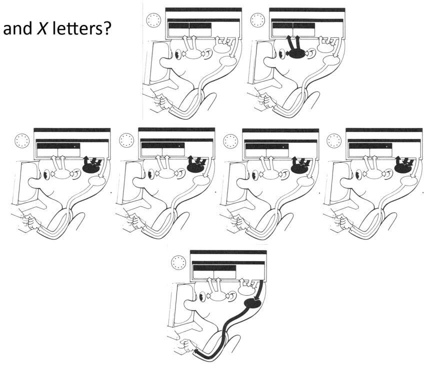
Receive input from the cognitive processor

Execute motor programs
- Pianist: up to 16 finger movements per second
- Point of no-return for muscle action



Recognize-Act Cycle

Are *Q* and *X* letters?



Recognize-Act Cycle

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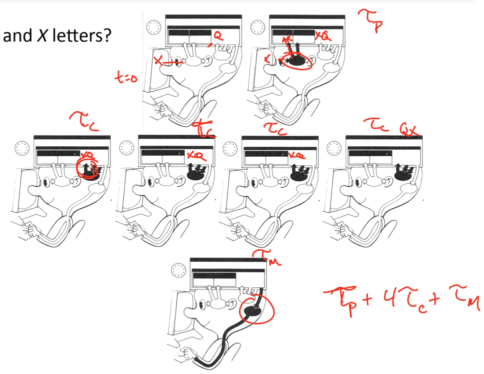


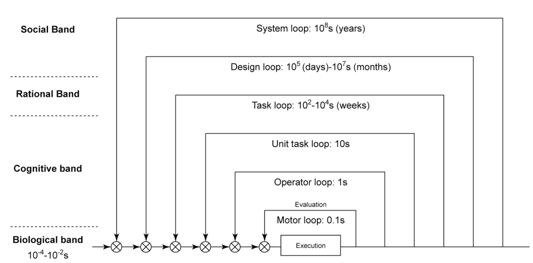
Cognitive Processor

Page 70 of Card Moran and Newell

Clocks starts when 2nd letter is flashed
Move letter x into visual store WM — T_p
Recognize the symbol as codes — +T_c
Classify the codes as letters — +T_c
Match the fact that they are both letters — +T_c
Initiate motor response — +T_c
Process motor command — +T_m
Approx 450 (180-980) ms

Human Interaction Loops

(Newell)



Principles of Operation

Interface should respect limits of human performance
- Preattentive features pop-out
- Events within cycle time fuse together
- Causality

Recognize-Act Cycle of the cognitive processor
- On each cycle contents in WM initiate cognitive actions
- Cognitive 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
  - Two strong cues in working memory
  - Link to different chunks in long term memory

Topics

- Memory
- Decision Making and Learning
- Fitts' Law
- GOMS and KLM

Memory

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…

Schedule
Paper
Page
Back
Change
Home

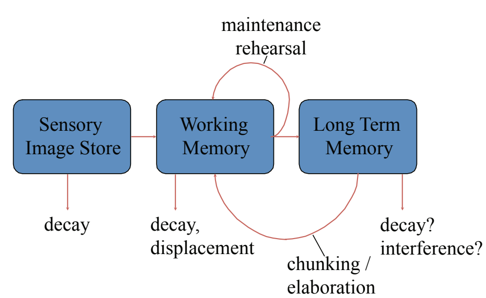
Simple Experiment

Do it again

Say "done" when finished

Blue
Red
Black
White
Green
Yellow

Stage Theory



Stage Theory

Working memory is small
Temporary storage
decay
displacement

Maintenance rehearsal
Rote repetition
Not enough to learn information well

LTM and Elaboration

Recodes information

Organize (chunking)

Relate new material to already learned material

Link to existing knowledge, categories

Attach meaning
Make a story

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

Interference model of forgetting
One item reduces ability to retrieve another
Proactive interference (3)
Earlier learning reduces ability to retrieve later info.
Retroactive interference (3 & 2)
Later learning reduces the ability to retrieve earlier info.

Recognition over Recall

Recall
Info reproduced from memory

Recognition
Presentation of info helps retrieve info (helps remember it was seen before)
Easier because of cues to retrieval

We want to design UIs that rely on recognition!

Recall

Recognition

Grouchy
Sneezy
Smiley
Sleepy
Pop
Grumpy
Cheerful
Dopey
Bashful
Wheezy
Doc
Lazy
Happy
Nifty

Recognition

Grouchy
Sneezy
Smiley
Sleepy
Pop
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Wheezy
Doc
Lazy
Happy
Nifty

Facilitating Retrieval: Cues

Any stimulus that improves retrieval

- Example: giving hints
- Other examples in software?
  - icons, labels, menu names, etc.

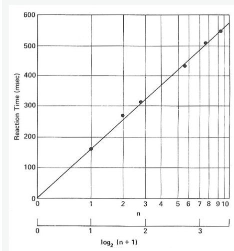
Anything related to

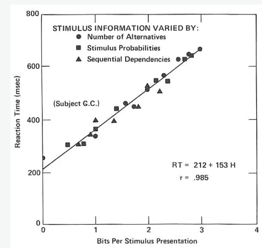
- Item or situation where it was learned

Decision Making and Learning

Hick's Law

Cost of taking a decision: $T = a + b\log_2(n+1)$





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

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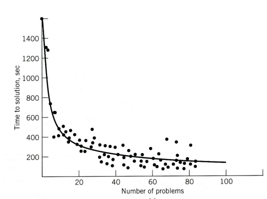
You get faster the more times you do it!



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

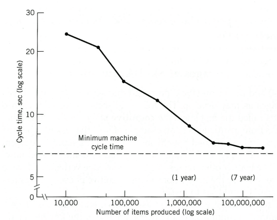
You get faster the more times you do it!

Applies to skilled behavior (sensory & motor)

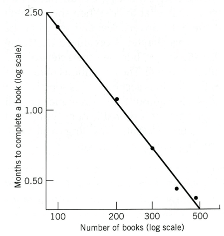
Does not apply to

Knowledge acquisition

Improving quality



Manual skills



Writing books

Stages of skill acquisition

Example: Using a manual transmission

Cognitive

Verbal representation of knowledge

Associative

Proceduralization

Form of chunking

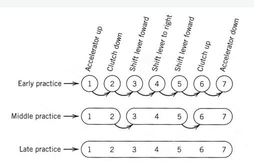
Autonomous

More and more automated

Faster and faster

No cognitive involvement

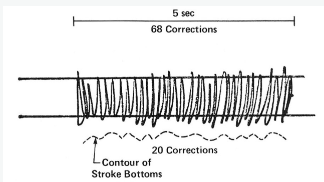
Difficult to describe what to do

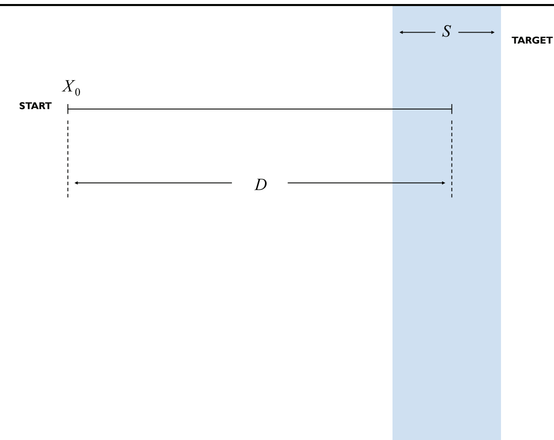


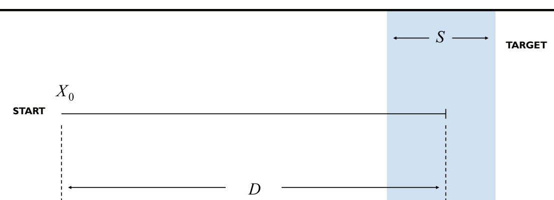
Fitts' Law

Motor Processor

- Receive input from the cognitive processor
- Execute motor programs
  - Pianist: up to 16 finger movements per second
  - Point of no-return for muscle action







- Hand movement based on series of microcorrections
  - X_i = remaining distance after ith move
  - Relative movement accuracy remains constant ➔ $\frac{X_i}{X_{i-1}} = \varepsilon$

Fitts' Law

$$T = a + b\log_2(D/S + 1)$$

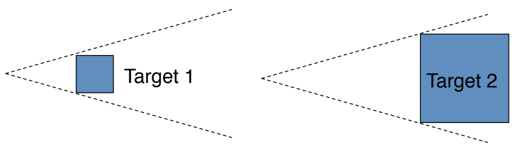
a, b	= constants (empirically derived)
D	= distance
S	= size

ID is Index of Difficulty = $\log_2(D/S+1)$

- Models well-rehearsed selection task
- T increases as the ***distance*** to the target increases
- T decreases as the ***size*** of the target increases

Considers Distance and Target Size

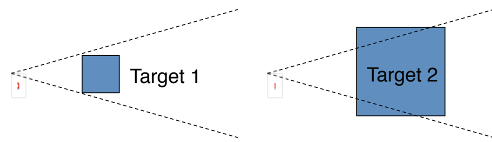
$$T = a + b\log_2(D/S+1)$$



Same ID → Same Difficulty

Considers Distance and Target Size

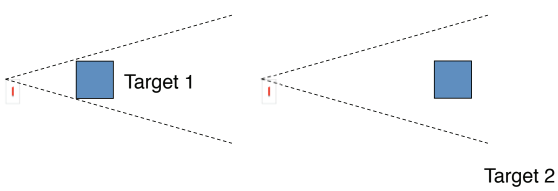
$$T = a + b\log_2(D/S+1)$$



Smaller ID → Easier

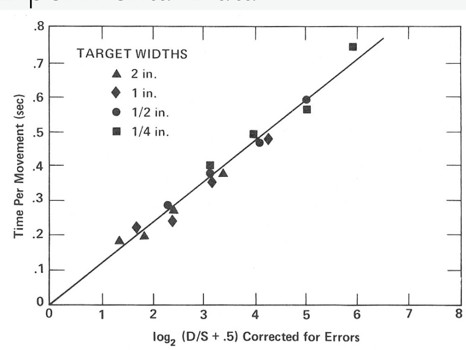
Considers Distance and Target Size

$$T = a + b\log_2(D/S+1)$$

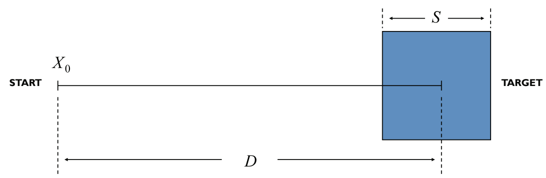


Larger ID → Harder

Experimental Data

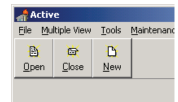


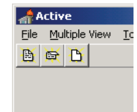
Extend Fitts' Law to 2D Targets?



Toolbar Example

Microsoft Toolbars offer the user the option of displaying a label below each tool. Name at least one reason why labeled tools can be accessed faster. (Assume, for this, that the user knows the tool.)

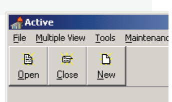


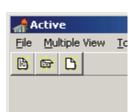


Toolbar Example

1. The label becomes part of the target. The target is therefore bigger. Bigger targets, all else being equal, can always be acccessed faster, by Fitts' Law

2. When labels are not used, the tool icons crowd together





Tool Matrix Example

You have a palette of tools in a graphics application that consists of a matrix of 16x16-pixel icons laid out as a 2x8 array that lies along the left-hand edge of the screen. Without moving the array from the left-hand side of the screen or changing the size of the icons, what steps can you take to decrease the time necessary to access the average tool?

Tool Matrix Example

1. Change the array to 1x16, so all the tools lie along the edge of the screen.
2. Ensure that the user can click on the very first row of pixels along the edge of the screen to select a tool. There should be no buffer zone.

GOMS and KLM

GOMS (Card et al.)

Describe the user behavior in term of

Goals

Edit manuscript, locate line

Operators

Elementary perceptual, motor or cognitive acts

Methods

Procedure for using operators to accomplish goals

Selection rules

Used if several methods are available for a given goal

Family of methods

KLM, CMN-GOMS, NGOMSL, CPM-GOMS

Quick Example

Goal (the big picture)

Go from hotel to the airport

Operators (or subgoals)?

Walk, take bus, take taxi, rent car, take train

Methods (or specific actions)

locate bus stop; wait for bus; get on the bus;...

Selection rules (choosing among methods)?

Example: Walking is cheaper, but tiring and slow

Example: Taking a bus is complicated abroad

GOMS Output

Execution time

Add up times from operators/methods

Assumes **experts** (mastered the tasks)

Error free behavior

Very good rank ordering

Absolute accuracy ~10-20%

Using GOMS Analysis

Check that frequent goals can be achieved quickly

Making operator hierarchy is often the value

Functionality coverage & consistency

Does UI contain needed functions?

Consistency: are similar tasks performed similarly?

Operator sequence

In what order are individual operations done?

How to do GOMS Analysis

Generate task description

Pick high-level user **Goal**

Write **Operators** for reaching Goal - may invoke subgoals

Write **Methods** for each Operator

This is recursive

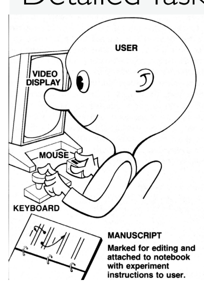
Stops when methods are reached

Evaluate description of task

Apply results to UI

Iterate!

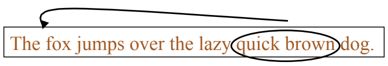
Detailed Task Description



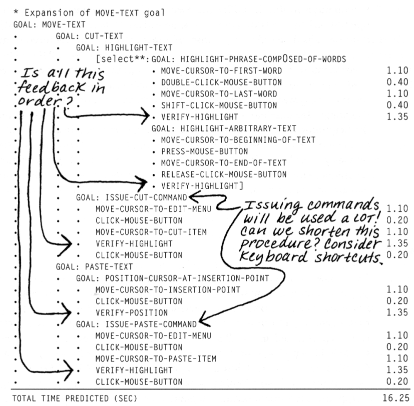

```
GOAL: EDIT-MANUSCRIPT
.   GOAL: EDIT-UNIT-TASK            repeat until no more unit tasks
.   .   GOAL: ACQUIRE-UNIT-TASK
.   .   .   GET-NEXT-PAGE           if at end of manuscript page
.   .   .   GET-NEXT-TASK
.   .   GOAL: EXECUTE-UNIT-TASK
.   .   .   GOAL: LOCATE-LINE
.   .   .   .   [select:  USE-QS-METHOD
                          USE-LF-METHOD]
.   .   .   GOAL: MODIFY-TEXT
.   .   .   .   [select:  USE-S-COMMAND
                          USE-M-COMMAND]
.   .   .   .   VERIFY-EDIT .
```

GOMS Example II

Using a text editor edit the following text as shown



Goals and sub-goals?
Operators?
Methods?
Selection rules?



```
* Expansion of MOVE-TEXT goal
GOAL: MOVE-TEXT
.       GOAL: CUT-TEXT
.       .   GOAL: HIGHLIGHT-TEXT
.       .   .   [select**:GOAL: HIGHLIGHT-PHRASE-COMPOSED-OF-WORDS
.       .   .       . MOVE-CURSOR-TO-FIRST-WORD                1.10
.       .   .       . DOUBLE-CLICK-MOUSE-BUTTON                0.40
.       .   .       . MOVE-CURSOR-TO-LAST-WORD                 1.10
.       .   .       . SHIFT-CLICK-MOUSE-BUTTON                 0.40
.       .   .       . VERIFY-HIGHLIGHT                         1.35
.       .   .       GOAL: HIGHLIGHT-ARBITRARY-TEXT
.       .   .       . MOVE-CURSOR-TO-BEGINNING-OF-TEXT
.       .   .       . PRESS-MOUSE-BUTTON
.       .   .       . MOVE-CURSOR-TO-END-OF-TEXT
.       .   .       . RELEASE-CLICK-MOUSE-BUTTON
.       .   .       . VERIFY-HIGHLIGHT]
.       .   GOAL: ISSUE-CUT-COMMAND
.       .   .   MOVE-CURSOR-TO-EDIT-MENU                       1.10
.       .   .   CLICK-MOUSE-BUTTON                             0.20
.       .   .   MOVE-CURSOR-TO-CUT-ITEM                        1.10
.       .   .   VERIFY-HIGHLIGHT                               1.35
.       .   .   CLICK-MOUSE-BUTTON                             0.20
.       GOAL: PASTE-TEXT
.       .   GOAL: POSITION-CURSOR-AT-INSERTION-POINT
.       .   .   MOVE-CURSOR-TO-INSERTION-POINT                 1.10
.       .   .   CLICK-MOUSE-BUTTON                             0.20
.       .   .   VERIFY-POSITION                                1.35
.       .   GOAL: ISSUE-PASTE-COMMAND
.       .   .   MOVE-CURSOR-TO-EDIT-MENU                       1.10
.       .   .   CLICK-MOUSE-BUTTON                             0.20
.       .   .   MOVE-CURSOR-TO-PASTE-ITEM                      1.10
.       .   .   VERIFY-HIGHLIGHT                               1.35
.       .   .   CLICK-MOUSE-BUTTON                             0.20
TOTAL TIME PREDICTED (SEC)                                     16.25
```

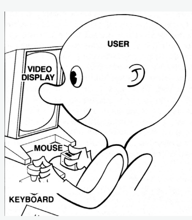
Is all this feedback in order?

Issuing commands will be used a lot! Can we shorten this procedure? Consider keyboard shortcuts.

Keystroke Level Model (KLM)

Describe the task using the following operators:

K: pressing a key or a pressing (or releasing) a button
t_K = 0.08 - 1.2s (0.2 good rule of thumb)
P: pointing
t_P = 1.1s (without button press)
H: Homing (switching device)
t_H = 0.4s
D(*n*,*l*): Drawing segmented lines
t_D = 0.9*n + .16*l
M: Mentally prepare
t_M = 1.35s
R(*t*): system response time
t_R = t



KLM Heuristic Rules (Raskin's)

0: Insert M
In front of all K
In front of all P's selecting a command (not in front of P's ending command)

1: Remove M between *fully anticipated* operators
PMK → PK

2: if a string of MKs belong to *cognitive unit* delete all M but first
4564.23: MKMKMKMKMKMKMK → MKKKKKKK

3: if K is a *redundant terminator* then delete M in front of it
↵↵: MKMK → MKK

4a: if K terminates a constant length string (command name) delete the M in front of it
cd↵: MKMKMK → MKKK

4b: if K terminates a variable length string (parameter) keep the M in front of it
cd class↵: MKKKMKKKKKMK → MKKKMKKKKKMK

Using KLM

Encode using all physical operator (K, P, H, D(*n*,*l*), R(*t*))

Apply Raskin's KLM rules [0-4]

Transform R followed by an M

If $t \leq t_M$: R(t) → R(*0*)

If $t_M < t$: R(t) → R(t - t_M)

Compute the total time by simply adding all time