Human Reaction and Prediction of Cognitive Performance

module2

human performance:

- cognitive
- ergonomic

cognitive

- Cognitive abilities are brain-based skills we need to carry out any task from the simplest to the most complex.
- They have more to do with the mechanisms of how we learn, remember, problem-solve, and pay attention, rather than with any actual knowledge.
- For instance, answering the telephone involves perception (hearing the ring tone), decision taking (answering or not), motor skill (lifting the receiver), language skills (talking and understanding language), social skills (interpreting tone of voice and interacting properly with another human being).

- Norman and Draper spoke of the “gulf of execution/evaluation,” which explains how users can be left bewildered (and not perform very well) when an interactive system does not offer certain actions or does not result in a state as expected by the user.
- The mismatch between the user’s mental model and the task model employed by the interactive system creates the “gulf.” On the other hand, when the task model and interface structure of the interactive system maps well to the expected mental model of the user, the task performance will be very fluid.

- two types of memory in the human cognitive system: the short term and the long term.
- The short-term memory is also sometimes known as the working memory, in the sense that it contains (changing) memory elements meaningful for the task at hand (or chunks).
- Humans are known to remember about eight chunks of memory lasting only a very short amount of time This means that an interface cannot rely on the human’s short-term memory beyond this capacity for fast operation

- Retrieving information from the long-term memory is a difficult and relatively time-consuming task.
- Therefore, if an interactive system (e.g., targeted even for experts) requires expert-level knowledge, it needs to be displayed so as to at least elicit “recognition” (among a number of options) of it rather than completely relying on recall from scratch.

Predictive Performance Assessment

- *GOMS* Many important cognitive activities have been analyzed in terms of their typical approximate process time, e.g., for single-chunk retrieval from the short-term memory, encoding (memorizing) of information into the long-term memory, responding to a visual stimulus and interpreting its content, etc
- GOMS (Goals, Operators, Methods, and Selection

Predictive models

- Provide a way of evaluating products or designs without directly involving users.
- Less expensive than user testing.
- Usefulness limited to systems with predictable tasks - e.g., telephone answering systems, mobiles, cell phones, etc.
- Based on expert error-free behavior.

GOMS

- Goals – what the user wants to achieve eg. find a website.
- Operators - the cognitive processes & physical actions needed to attain goals, eg. decide which search engine to use.
- Methods - the procedures to accomplish the goals, eg. drag mouse over field, type in keywords, press the go button.
- Selection rules - decide which method to select when there is more than one.

Keystroke level model

- GOMS has also been developed to provide a quantitative model - the keystroke level model.
- The keystroke model allows predictions to be made about how long it takes an expert user to perform a task.

Response times for keystroke level operators (Card et al., 1983)

Operator	Description	Time (sec)
K	Pressing a single key or button Average skilled typist (55 wpm) Average non-skilled typist (40 wpm) Pressing shift or control key Typist unfamiliar with the keyboard	 0.22 0.28 0.08 1.20
P P1	Pointing with a mouse or other device on a display to select an object. This value is derived from Fitts' Law which is discussed below. Clicking the mouse or similar device	0.40 0.20
H	Bring 'home' hands on the keyboard or other device	0.40
M	Mentally prepare/respond	1.35
R(t)	The response time is counted only if it causes the user to wait.	t

Estimates of Time Taken for Typical Desktop Computer Operations from GOMS

TYPE OF OPERATION	TIME ESTIMATE
K: Keyboard input	Expert: 0.12 s Average: 0.20 s Novice: 1.2 s
T(*n*): Type *n* characters	280 × *n* ms
P: Point with mouse to something on the display	1100 ms
B: Press or release mouse button	100 ms
BB: Click a mouse button (press and release)	200 ms
H: Home hands, either to the keyboard or mouse	400 ms
M: Thinking what to do (mental operator)	1200 ms (can change)
W(*t*): Waiting for the system (to respond)	*t* ms

Source: Card, S. K., Moran, T. P., and Newell, A. The Model Human Processor: An Engineering

GOMS Models

GOMS Models: A Family of Engineering Models

GOMS Model Family as Simplified Cognitive Architectures

GOMS Models: A Family of Engineering Models

Definition of GOMS model:

An approach to describing the knowledge of procedures that a user must have in order to operate a system.

- Proposed by Card, Moran, & Newell (1983).

Goals - what goals can be accomplished with the system.

Operators - what basic actions can be performed.

Methods - what sequences of operators can be used to accomplish each goal.

Selection Rules - which method should be used to accomplish a goal.

GOMS is limited to describing procedural knowledge.

Interfaces have other aspects!

Family summarized here:

Keystroke-Level Model (KLM).

Critical-Path Method GOMS (CPM-GOMS).

Natural GOMS Language (NGOMSL)/Cognitive Complexity Theory.

Executable GOMS Language (GOMSL)/GLEAN.

GOMS Model Family as Simplified Cognitive Architectures

Simple Stage Model Architecture.
A sequence of stages, with characteristic times, produces behavior.
Keystroke-Level Model.

Elementary Human Performance Architecture.
Cognitive system executes a procedural knowledge representation.
A shared working memory for temporary task information.
Simple stage model for rest of activity.
Original CMN-GOMS, CCT, NGOMSL models.

Multiple Parallel Processor Architecture.
Perceptual, cognitive, motor processes run in parallel.
• E.g. Card, Moran, & Newell (1983) Model Human Processor.
CPM-GOMS model.
GOMSL/GLEAN.

The Keystroke-Level GOMS Model

The Keystroke-Level Model (KLM) Method

Operators and Times for the Keystroke-Level Model

Example: File Deletion in MacOS, Original Design, Experienced User

Example: Command Key File Deletion, Experienced User

Summary: The Keystroke-Level Model

The Keystroke-Level Model (KLM) Method

Adapted from Card, Moran, & Newell (1983)

1. Choose one or more representative task scenarios.
2. Have design specified to the point that keystroke-level actions can be listed.
3. List the keystroke-level actions (operators) involved in doing the task.
4. Insert mental operators for when user has to stop and think.
5. Look up the standard execution time to each operator.
6. Add up the execution times for the operators.
7. The total is the estimated time to complete the task.

Operators and Times for the Keystroke-Level Model

K - Keystroke (.12 - 1.2 sec; use .28 sec for ordinary user).

Pressing a key or button on the keyboard.
Different experience levels have different times.
Pressing SHIFT or CONTROL key is a separate keystroke.
Use type operator T(n) for a series of n Ks done as a unit.

P - Point with mouse to a target on the display.

Follows Fitts' law - use if possible.
Typically ranges from .8 to 1.5 sec, average (text editing) is 1.1 sec.

B - Press/release mouse button (.1 sec; click is .2).

Highly practiced, simple reaction.

H - Home hands to keyboard or mouse (.4 sec).

W - Wait for system response.

Only when user is idle because can not continue
Have to estimate from system behavior
Often essentially zero in modern systems

M - Mental act of thinking.

Represents pauses for routine activity (not problem-solving).
New users must often pause to remember or verify every step.
Experienced users pause and think only when logically necessary.
Estimates ranges from .6 to 1.35 sec; 1.2 sec is good single value.

Example: File Deletion in MacOS, Original Design, Experienced User

Assumptions:

Experienced user thinks of selecting and dragging an icon as a single operation.

Finding the to-be-deleted icon is still required, since it is different every time.

Moving icons to the trash can is highly practiced:

- The trash can does not have to be located, so finding the trash can is overlapped with pointing to it.
  - Finding the trash can is overlapped with pointing to it.
  - Verifying that the trash can has been hit is overlapped with pointing to it.
  - Final result (bulging can) is not checked since it is redundant with verifying that the can has been hit.

Pointing to the original window is overlapped with finding it.

General procedure

Find the file icon to be deleted and drag it to the trash can.

Operator sequence

1. initiate the deletion M
2. find the file icon M
3. point to file icon P
4. press and hold mouse button B
5. drag file icon to trash can icon P
6. release mouse button B
7. point to original window P

Total time = 3P + 2B + 2M = 5.9 sec

Example: Command Key File Deletion, Experienced User

Assumptions:
User operates both mouse and command key with right hand.
Right hand starts and ends on the mouse.

General procedure
Select the file icon to be deleted and hit a command key.

Operator sequence
1. initiate the deletion M
2. find the icon for the to-be-deleted file M
3. point to file icon P
4. click mouse button BB
5. move hand to keyboard H
6. hit command key KK
7. move hand back to mouse H

Total time = P + 2B + 2H + 2K + 2M = 5.06 sec
Only slightly faster, due to need to move the hand!