Understanding Users – Psychological and Cognitive Perspectives

COMP2044: Human-Computer Interaction (2024-2025)

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Overview

Objectives for today

- Mental Models, Gulf of Execution and Evaluation.
- Task Analysis.
- Predictive Cognitive Models:
  - MHP, GOMS, KLM-GOMS;
  - Fitts's Law.
- Throughout today's session consider - why and when we might use these models?

Frameworks for Understanding Users

Mental Models

- A mental model is what the user believes about the system at hand.
- When users interact with a system, they do so based on their understanding of how it works.
    - Interaction design needs to support the formation of a correct mental model.
- Each user will have a different mental model of a system.
    - Mental models are based on the user's prior experiences and knowledge.
    - For example, a mechanic and a layperson will have a different mental model of how a car works.

Gulf of Execution and Evaluation (Norman, 1986)

=discoverability

- Gulf of Execution - The gap between the user's goals and the system's functionality. =feedback
- Gulf of Evaluation - The gap between the system's output and the user's understanding of it.

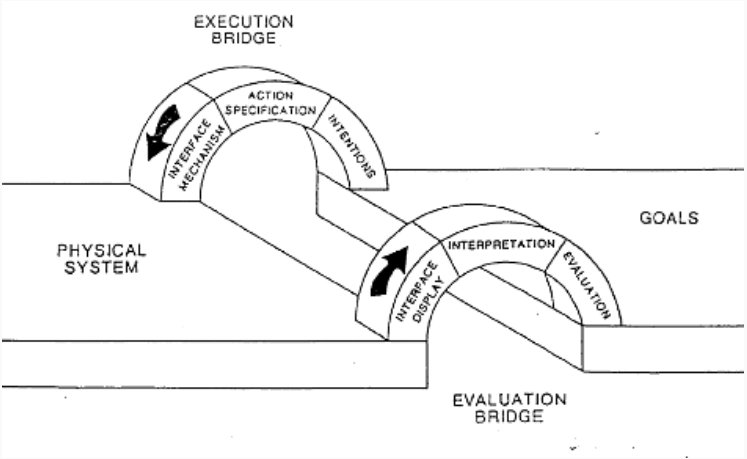


Figure 1: The Gulf of Execution and Evaluation from Norman's 1986 paper (Norman, 1986).

Task Analysis

What is Task Analysis?

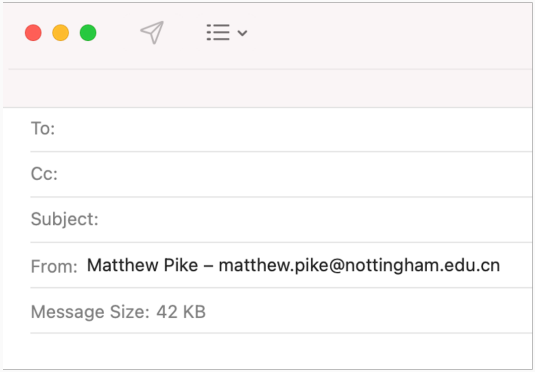
"Task analysis is the process of learning about ordinary users by observing them in action to understand in detail how they perform their tasks and achieve their intended goals."

Usability.gov

- Approaches include:
  - **Decomposition-based** - breaking down tasks into smaller sub-tasks. Order is important.
  - **Knowledge-based** - what users need to know about the objects and actions involved in a task, and how that knowledge is organised.
  - **Object-based** - identify the objects and actors that are used in a task and their relationships.
- Generally, we will: observe; collect data (actions, behaviours, resources, etc); and then organise them into a structured format.
- This process can be used to understand the user's approach to a task and how to design a system that supports the user. The user should be involved in the process.

Activity: Analyse the Task of Sending an Email

- In groups, analyse the task of sending an email.
  - What are the sub-tasks (or stages) involved?
  - Does the activity rely on any existing knowledge?
  - What are the objects and actors involved?



Hierarchical Task Analysis (HTA)

- HTAs produce a *hierarchy* of tasks and subtasks. In addition, plans describing the order and conditions of the tasks are included.
- Outputs can be diagrammatic or in ordered list.
- Consider the task of making a cup of tea. The HTA, in list format, might look like this:

- 0. make a cup of tea
  - 1. boil water;
  - 2. empty pot;
  - 3. add tea;
  - 4. add hot water;
  - 5. wait four or five minutes;
  - 6. pour tea.

- Plan 0. do 1:
  - at the same time, if the pot is full 2;
  - then 3 – 4;
  - after four or five minutes 5.

HTA: Making a Cup of Tea Example

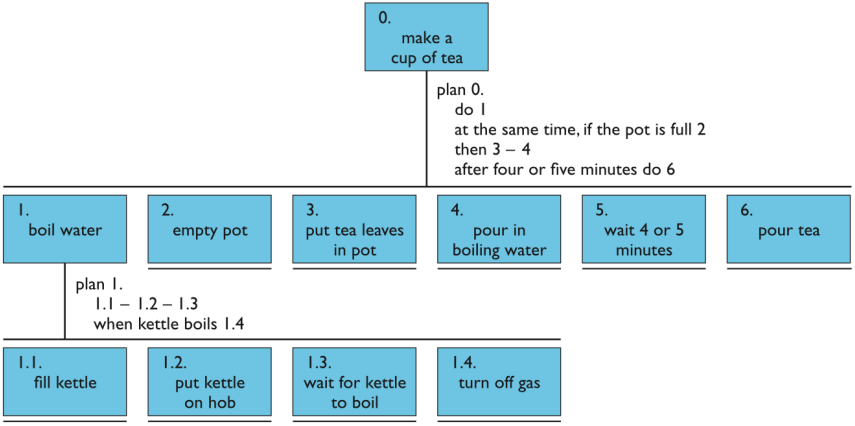


Figure 15.2 Hierarchical task analysis: making a cup of tea

Figure 2: An example of a diagram based HTA outlining the process of making a cup of tea. Figure is from Chapter 15 of the Human-computer interaction book (Dix, 2003)

User Modelling using Predictive Cognitive Models

- We saw how HTA could be used to perform task decomposition - but it was quite restrictive and doesn't deal with the wider cognitive and environmental aspects associated with interaction.
    - For example, what if the user is tired, or is interrupted?
- We might be able to get more sophisticated models by considering user's cognitive abilities and limitations.
- We'll look at how MHP, GOMS, KLM-GOMS and Fitts's Law provide predictors of user performance, which are grounded by empirical psychology findings.
- No 'user' required: Cost effective and quick. But, at what cost?

The Human Processor Model or Model Human Processor (MHP) (Card, 2018)

- A framework that describes the cognitive processes involved in HCI.
- MHP is comprised of three systems: Perception, Cognition, and Motor.
- Provides a systematic way to understand the limitations and capabilities of human cognition and behaviour.

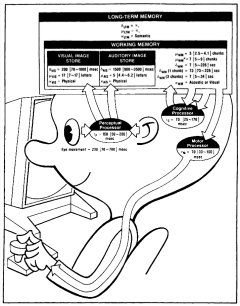


Figure 3: Components of the MHP include LTM, WM and associated subsystems. Each component has associated parameters and values that represent time in milliseconds or items in memory. Figure from Card (2018).

MHP Component Time and Memory Values

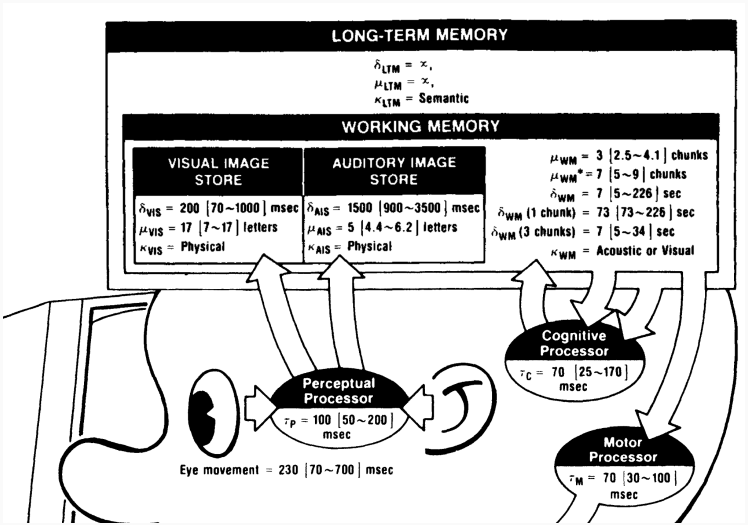


Figure 4: MHP Component Time and Memory Values. Figure from Card (2018).

MHP: Applications in HCI

- Predict the probability of a user remembering an item.
  - This can be used to calculate the efficacy of an interface for “mission critical” activities.
- Examples:
  - Predicting the time to complete a web form.
  - Modelling parallel tasks.

Parameter	Mean	Range
Eye movement time	230 ms	70-700 ms
Decay half-life of visual storage	200 ms	90-1000 ms
Visual Capacity	17 letters	9-17 letters
Decay half-life of auditory storage	1500 ms	90-3500 ms
Auditory Capacity	5 letters	4.4-6.2 letters
Perceptual processor cycle time	100 ms	50-200 ms
Cognitive processor cycle time	70 ms	25-170 ms
Motor processor cycle time	70 ms	30-100 ms
Effective WM capacity	7 chunks	5-9 chunks
Pure WM capacity	3 chunks	2.5-4.2 chunks
Decay half-life of WM	7 sec	5-226 sec
Decay half-life of 1 chunk WM	73 sec	73-226 sec
Decay half-life of 3 chunks WM	7 sec	5-34 sec

Table 1: MHP Component Time and Memory Values.

GOMS: Goals, Operators, Methods, and Selection Rules (Card, 2018)

- Proposed by Card, Moran and Newell. GOMS is an acronym for Goals, Operators, Methods, and Selection from Card (2018).
- Comprised of:
  - **Goals**: The user's intended goals, decomposed into sub-goals.
  - **Operators**: Cognitive and motor (physical) actions that are used to achieve the goals.
  - **Methods**: Different sequences of operators that can be used to achieve the goals.
  - **Selection Rules**: Rules for determining the method a user will choose based on specific circumstances.

Example: Deleting a File using GOMS

```
GOAL: DELETE-FILE
.   GOAL: SELECT-FILE
.   .   [select:  GOAL: KEYBOARD-TAB-METHOD
.   .             GOAL: MOUSE-METHOD]
.   .   VERIFY-SELECTION
.   GOAL: ISSUE-DELETE-COMMAND
.   .   [select*: GOAL: KEYBOARD-DELETE-METHOD
.   .             .   PRESS-DELETE
.   .             .   GOAL: CONFIRM-DELETE
.   .             GOAL: DROP-DOWN-MENU-METHOD
.   .             .   MOVE-MOUSE-OVER-FILE-ICON
.   .             .   CLICK-RIGHT-MOUSE-BUTTON
.   .             .   LOCATE-DELETE-COMMAND
.   .             .   MOVE-MOUSE-TO-DELETE-COMMAND
.   .             .   CLICK-LEFT-MOUSE-BUTTON
.   .             .   GOAL: CONFIRM-DELETE
.   .             GOAL: DRAG-AND-DROP-METHOD
.   .             .   MOVE-MOUSE-OVER-FILE-ICON
.   .             .   PRESS-LEFT-MOUSE-BUTTON
.   .             .   LOCATE-RECYCLING-BIN
.   .             .   MOVE-MOUSE-TO-RECYCLING-BIN
.   .             .   RELEASE-LEFT-MOUSE-BUTTON]
*Selection rule for GOAL: ISSUE-DELETE-COMMAND
  If hands are on keyboard, use KEYBOARD-DELETE-METHOD,
    else if Recycle bin is visible, use DRAG-AND-DROP-METHOD,
    else use DROP-DOWN-MENU-METHOD
```

- This is GOMS notation for deleting a file.
- You can see there are different ways of doing it:
  - First you have to choose which method you are going to use to select the file.
  - Then you have to choose which method of deleting.
- At the end there is an if statement which tries to determine which methods you will use, but ultimately, a user could choose any of them.
- You have to allow time (processing and action) to do all the sub-goals.

Activity: Lets take a step back. Why are we doing this?

Keystroke-Level Model (KLM) GOMS (KLM-GOMS) (Card et al., 1980)

- KLM is a simplified version of GOMS that focuses on the time it takes to perform a task.
- Predict performance times for common operations based on knowledge of human motor system.
- 7 basic operators:
  - **K** - keystroking - actually striking keys.
  - **P** - pointing, moving the mouse at a target.
  - **P1/B** - pressing a mouse button.
  - **H** - homing - switching the hand between mouse and keyboard.
  - **D** - drawing lines using the mouse.
  - **M** - mentally preparing for physical action.
  - **R** - system response (may be ignored for low-latency operations).

KLM-GOMS: Timing Values

Operator	Remarks	Time (s)
K	Press key	
	good typist (90 wpm)	0.12
	average typist (40 wpm)	0.28
	non-typist	1.20
B	Mouse button press down or up click	0.10
		0.20
P	Point with mouse	
	Specific movement	Fitts' law
	Average movement	1.10
H	Home hands to/from keyboard	0.40
D	Drawing	domain dependent
M	Mentally prepare	1.20
R	Response from system	measure

Table 2: KLM-GOMS Timing Values from (Card et al., 1980).

M-Operator: Mentally Prepare

- These are things that involve the user thinking about what to do and making decisions.
- E.g. task of sending a photo using WeChat:
  - User has to think about what has to be done.
  - Strategy decision – do they choose file from gallery and then share using WeChat or find file from within WeChat, or take the photo from within WeChat.
  - Remembering something – e.g. what sub-folder file is in.
  - Finding something on the screen – e.g. the paperclip or share symbol (or equivalent).
  - Verifying – making sure it is the right photo and the right recipient.

KLM-GOMS: Deleting a File Example

Drag to Recycle Bin

- Operator sequence:
  - Initiate the deletion (M).
  - Find the file icon (M).
  - Point to file icon (P).
  - Press and hold mouse button (B).
  - Drag file icon to wastebasket (P).
  - Release mouse button (B).
- Total predicted time:
  - = 2M + 2P + 2B
  - = 4.8 secs

Using the Keyboard Accelerator Key

- Operator sequence:
  - Initiate the deletion (M).
  - Find the file icon (M).
  - Point to the file icon (P).
  - Click – i.e., press and release mouse button (BB).
  - Move hand to keyboard (H).
  - Press ‘Apple’ and ‘Delete’ keys (KK).
  - Move hand back to mouse (H).
- Total predicted time:
  - = 1P + 2B +2K + 2M +2H
  - = 5.1 seconds

Fitt's Law (Fitts & Posner, 1967)

- Fitt's Law is a predictive model of human movement in HCI.
- Describes basic relationship between object / target characteristics and pointer movement and bundles together human motor action, perceptual resources, cognitive processing, etc.
- It is based on the idea that the time required to move to a target depends on the distance to the target and the size of the target.
- The model is based on empirical data and is widely used in HCI.

- The model is expressed as:
  - $MT = a + b \log_2(2D/W)$
  - Where:
    - MT is the movement time.
    - a and b are empirically derived constants.
    - D is the distance to the target.
    - W is the width of the target.

Activity: Fitt's Law in Practice

- https://fww.few.vu.nl/hci/interactive/fitts/

Conclusion

Summary

- We have seen how mental models can be used to understand user's understanding of a system.
- Task analysis can be used to understand the user's approach to a task and how to design a system that supports the user.
- We have seen how cognitive models can be used to predict user performance.
- Remember why and when we might use these models. They are not always appropriate.

Web Articles

- The Two UX Gulfs: Evaluation and Execution
  - https://www.nngroup.com/articles/two-ux-gulfs-evaluation-execution/
- Task Analysis
  - https://www.usability.gov/how-to-and-tools/methods/task-analysis.html
- Task Analysis: Support Users in Achieving Their Goals
  - https://www.nngroup.com/articles/task-analysis/
- Fitts's Law and Its Applications in UX
  - https://www.nngroup.com/articles/fitts-law/

References

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Dix, A. (2003). *Human-computer interaction*. Pearson Education.

Fitts, P. M., & Posner, M. I. (1967). *Human performance*.

Norman, D. (1986). User centered system design. *New Perspectives on Human-Computer Interaction*.