HCI Lecture 4:

Human capabilities: Cognitive processing

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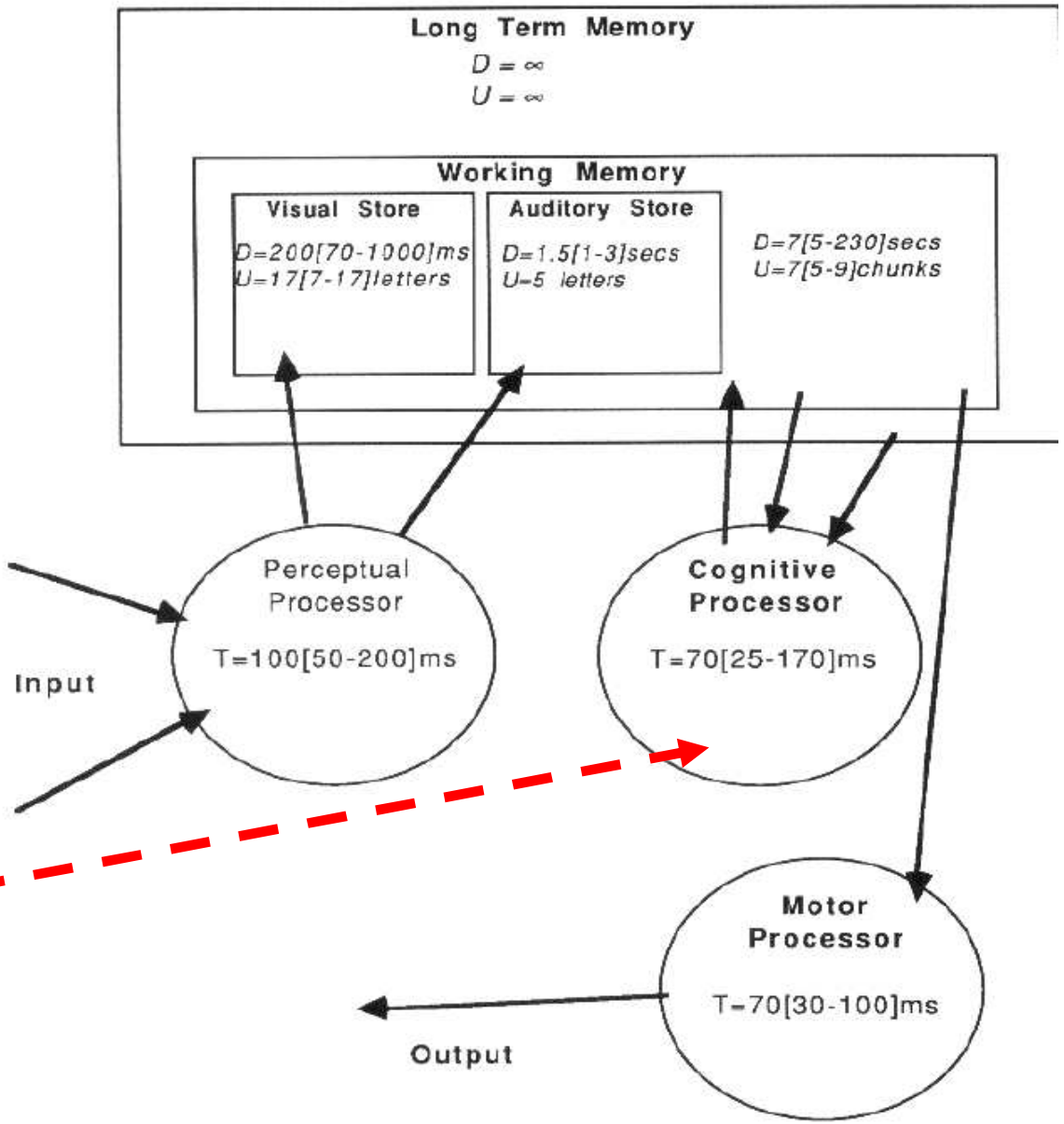
Key points:

- Reducing cognitive load
- Deciding: Hick-Hyman law
- Reasoning
- Metaphors
- Mental models

Human constraints

- Model Human Processor (MHP)
- Perceptual, Motor and Cognitive sub-systems characterised by:
  - Storage capacity *U*
  - Decay time *D*
  - Processor cycle time *T*
- We will focus today on the cognitive processor



Cognitive processor

- 'Cognitive processing' is involved when:
  - The correct action is not obviously signalled by the system
  - We don't have a memorised rule that applies for the current situation and current goal (we lack "procedularised" knowledge)
- Consequently we need to do some form of problem solving
  - Extrapolating from knowledge we do have (interaction with memory systems)
  - May be very simple, e.g. making a decision
  - Logical reasoning might supply the answer
  - Reasoning by analogy or metaphor is powerful and natural
  - Mental models can be used to predict outcomes

Simple decision making

- Hick-Hyman law

$T = a + b \log_2(n+1)$

T=time to make a decision, n=number of options

a, b are constants that depend on the display, response mode etc.

- As for Fitt's law, it is justified by analogy to information theory: decision time is linearly related to entropy
- Example: What is relative time to select from one menu of eight items vs. two menus of four items?

Simple decision making

- Hick-Hyman law

$T = a + b \log_2(n+1)$

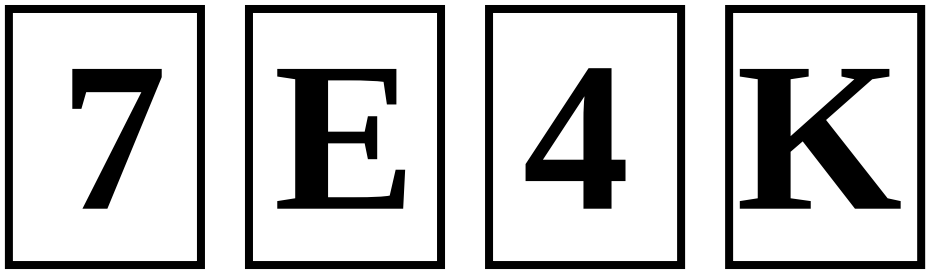
T=time to make a decision, n=number of options

a, b are constants that depend on the display, response mode etc.

- N.B. apparent advantage of broad shallow menus applies only if the list is logically ordered (e.g. alphabetical)
- For unfamiliar random order list, decision time is linear with *n*.
- For most real applications, there is some natural or conventional partition which designers/users can exploit
  - Problems if they differ in what is considered 'obvious' partition…

Logical reasoning

If a card has a vowel on one side it has an even number on the other



- How few cards can you turn over to confirm this rule? Which ones?

- Humans are not very reliable at logical reasoning

Confirmation fallacy

- We tend to look for or notice evidence that confirms our hypotheses, rather than check for contradictions:
  - 1989 British Midland air-crash:
    - engine failure causes severe vibration and fumes;
    - crew shut down right engine;
    - vibration and fumes reduce;
    - on approach to landing, increase thrust to left engine, which fails completely, no time to restart right engine.

- Computer may be used to aid logical reasoning, e.g., in medical diagnosis systems prompting checks for counter-indications
- However, confirmation bias can be made worse by automation, e.g., ignoring road signs while following satnav instructions

Metaphor

- A powerful (but risky) method in design is to exploit the human tendency to reason by metaphor, i.e. "X is like Y"
- This is a very natural mode of thought for humans
- Examples
  - Word processing vs. typewriter
  - The 'desk top'

  Domain: "Can I change the arrangement of my documents?"

  Semantic: "What is the wastebasket for?"

  Syntax: "What is the procedure for throwing a document away?"

  Lexical: "How do I perform the action of throwing a document away?"; "How do I open a folder?"
  - Spreadsheets

Metaphor

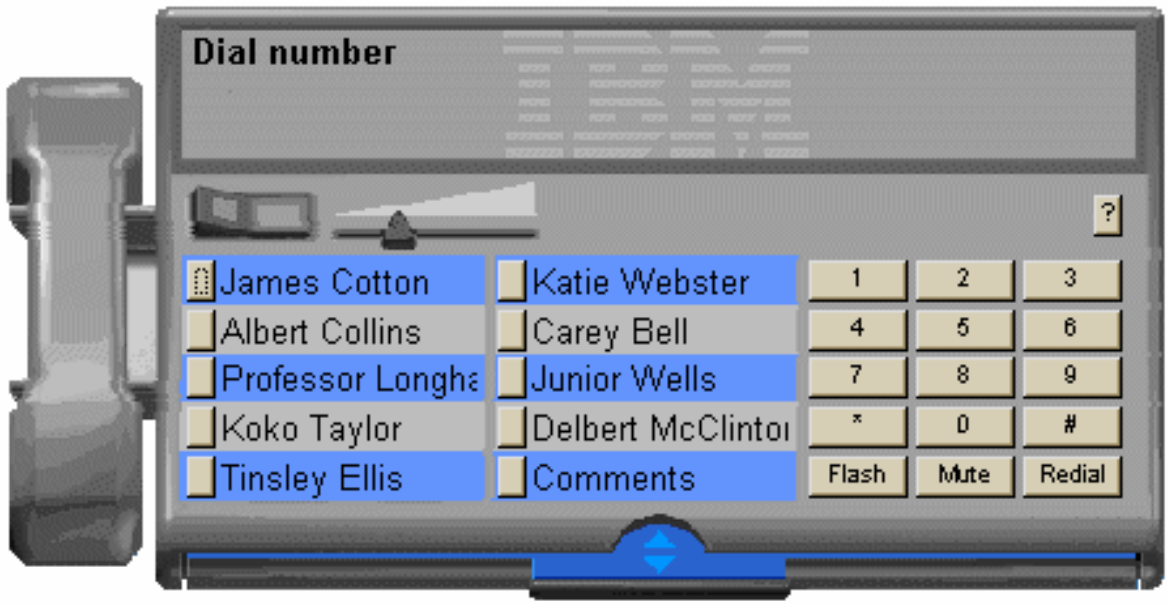
- Ledger sheet analogy proposed in 1979 (http://www.bricklin.com)
- Extends from metaphor by adding interactivity and computation

Learning and Metaphor

- Exploiting existing knowledge for learning
  - Need entity resemblance to prompt appropriate metaphor
  - Need relational resemblance to support correct mapping
- Users prefer 'learning by doing' or ('learning by observing')
  - Metaphor provides obvious clues for systematic investigation
- Mismatches prompt investigation and learning
  - Correspondences, non-correspondence and indeterminate correspondence

- But can lead to very poor design…

Metaphor



IBM RealPhone: How do you make a call?

http://homepage.mac.com/bradster/iarchitect/target.htm

Metaphor

- A metaphor can have a big impact so should be carefully considered:
  - How much structure does it provide?
  - How much is really relevant to the problem?
  - Is it easy to represent?
  - How extensible is it?
- Problems:
  - Breaking conventional or cultural rules
  - Constrain designers in the problem space
  - Conflict with design principles
  - Forces user into one mode of understanding
  - May transfer over bad design
  - May limit imagination for new conceptual model

Mental models

- Affordances (previous lecture) are directly perceivable and easily recognised opportunities for action
- More complex actions require some knowledge or understanding of how the artifact functions
- We form a mental model of the function, which we use to predict the likely result of our actions, and hence choose what to do for a desired outcome:
  - Example: You walk into a cold house where the heating is off, and want to heat it as fast as possible. After switching the heating on, would you also turn up the thermostat setting?

Mental models

- Craik, 1943

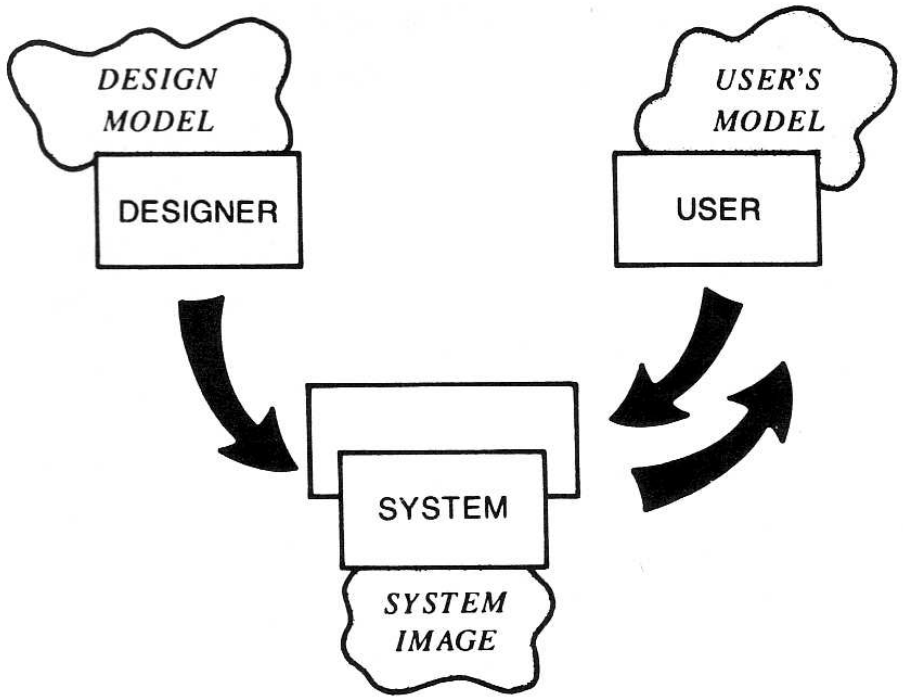
"If the organism carries a 'small-scale model' of external reality and its own possible actions within its head, it is able to try out various alternatives, conclude which is the best of them, react to future situations before they arise, utilise the knowledge of past events in dealing with the present and future, and in every way to react in a much fuller, safer and more competent manner to emergencies which face it."

- Card and Moran, 1986

"The user's model…allows the user to predict what the system will do if certain commands are executed, to predict the state of the system after the commands are executed, to plan methods for novel tasks, and to deal with odd error situations…"

Mental model

- In design, this is often called a ‘conceptual model’: the model the designer wants/expects the user to have in their head
- The user’s mental model should come to resemble the designer’s mental model through the visible system image



Example

- Write down your own mental model of how a cash machine (ATM) works
- Answer the following:
  - What happens to prevent you taking out more than the limit by using several machines in turn?
  - What information is on the card itself, and how is it used?
  - Why are there pauses between steps, and why are they duration they are?
  - What happens to the card while in the machine?
  - Do you count the money? Why or why not?
- Now ask two other people the same questions and compare your mental models.

Based on Payne, S. (1991) A descriptive study of mental models. Behaviour and Information Technology 10, 3-21

Conceptual models

A more formal approach within the design cycle is to establish a *conceptual* model of the interaction system

This system description should specify:

- the (user-level) **concepts** to be created and manipulated, which map to:
  - Objects: including both agents and passive objects
  - Actions: which can be initiated by agents (need task allocation)
- the **relationships** between concepts:
  - Conceptual relations, typically taxonomic, e.g. classification (X is a Z) or hierarchical (Y is a part of X), or ordered (action A must occur before action B)
  - Communicative relations, how information/data passes between objects/agents or one thing affecting another

Example (sketch)

ONLINE LIBRARY

metaphor information is organised as a physical card catalogue

concepts *item*, *book*, periodical, *issue*, *DVD*, *shelf-mark*, *user account*, *librarian*, . . .

object relationships a book is a type of item; periodicals contain issues

mappings *item* corresponds to a physical object; *shelf-mark* to its physical location

actions *issue item*, *return item*, *search item*

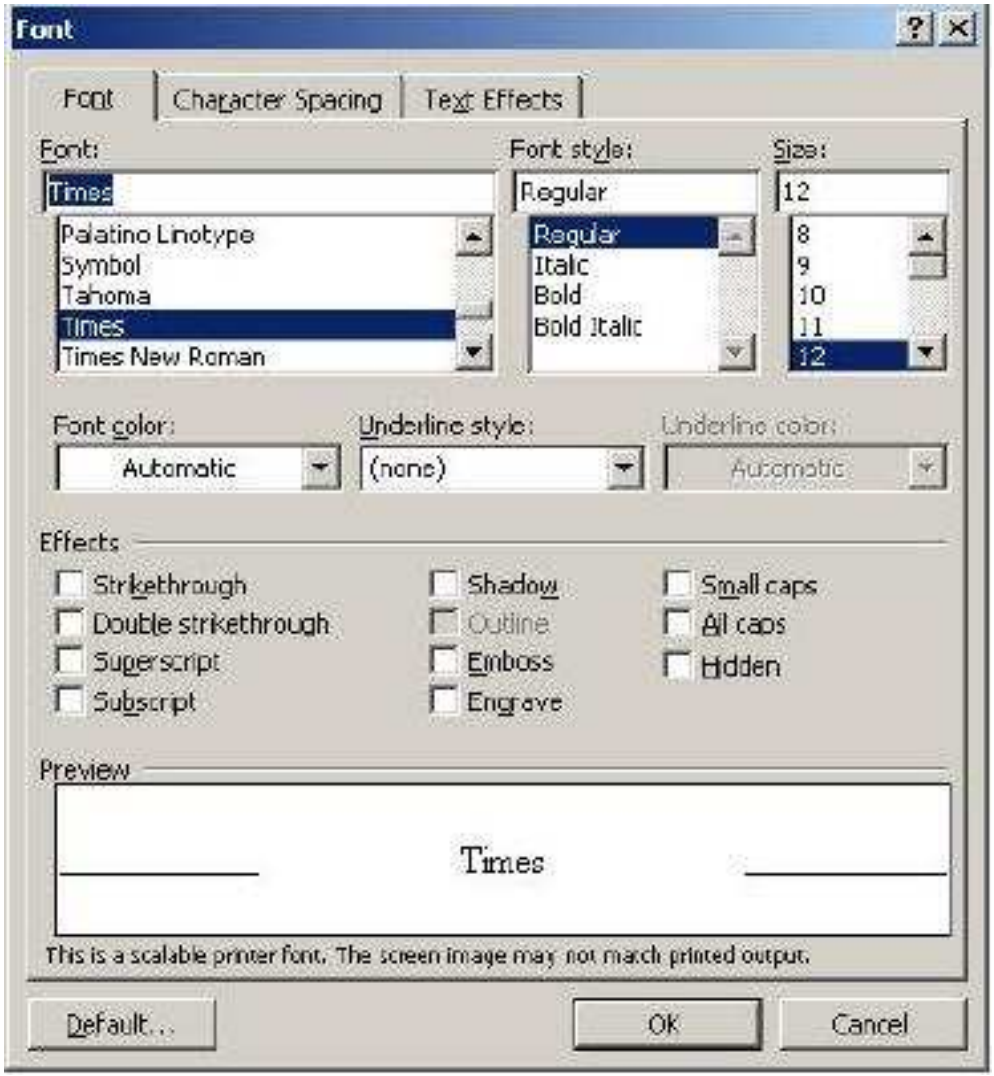
action relationships issue before return for same item; for different items, in parallel, . . .

data flow new items added by librarian typing data

Deriving conceptual models

- To determine the objects, actions and relationships one approach is to try to elicit the user's declarative knowledge about the task through interview
- Or may be able to draw on established conventions or use existing documentation
- From these list objects and actions (roughly nouns and verbs), then sort into taxonomies
- Method of 'laddering':
  - Start with seed item: *type faces*
  - Move around taxonomy using prompts:
    - Move down: *can you give examples of type faces?*
    - Move across: *alternative ways to change text appearance?*
    - Move up: *what do Verdana and Helvetica have in common?*
- More formalised, this is a process of Task Analysis (next lecture)
- Example application is menu layout

Applied to menu layout



Conceptual models

- A conceptual model
  - is a starting point for interaction design
  - should help the user "figure it out": the user should have (or should acquire through interaction) the same model as the designer
  - Lets design team establish a set of common terms they all understand and agree upon (a standard **lexicon** for the project)

See Johnson and Henderson (2002) for more motivation and methodology.

- As described so far is a static model of the system; want to add to this a dynamic, task-oriented description of *performance*

References/Further Reading

- Dix et al., 3rd ed: section 1.4 & 7

- J. Johnson and A. Henderson (2002) Conceptual models: begin by designing what to design. Interactions 9(1):25--32, 2002.
- H. Sharp, Y. Rogers & J. Preece (2007) Interaction Design. John Wiley & Sons, Chichester. (See also www.id-book.com)
- D.A. Norman (1986) Cognitive Engineering. In *User Centered System Design*, pages 31-61. Lawrence Erlbaum Association, 1986