HUMAN-COMPUTER INTERACTION THIRD EDITION
DIX FINLAY ABOWD BEALE

chapter 1

the human

Overview

- Memory
  - Sensory memory
  - Short-term memory
  - Long-term memory
- Problem solving
- Emotions
- Individual differences

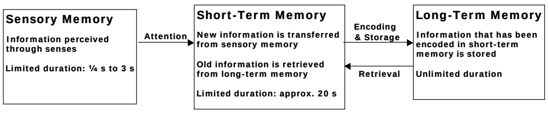
Memory

- Memory is the process involved in retaining, retrieving and using information about stimuli, images, events, ideas, and skills after the original information is no longer present.
- Q: What do you use memory for?

Why memory?

- Computers are expected to make our work more efficient
- If computer systems tax people's minds, the effects can be counter-productive
- If we understand memory processes, we can identify ways to minimise the memory requirements and cognitive load
  - which are essential for creating usable systems.

Stage model of memory



Sensory Memory

Information perceived through senses

Limited duration: ¼ s to 3 s

Attention

Short-Term Memory

New information is transferred from sensory memory

Old information is retrieved from long-term memory

Limited duration: approx. 20 s

Encoding & Storage

Retrieval

Long-Term Memory

Information that has been encoded in short-term memory is stored

Unlimited duration

Sensory memory

- Buffers for stimuli received through senses
  - iconic memory: visual stimuli 0.3sec
  - echoic memory: aural stimuli 2sec
  - haptic memory: tactile stimuli
- Examples
  - “sparkler” trail
  - stereo sound
- Continuously overwritten
- Sensory memory is passed into short-term memory by attention

Sensory memory

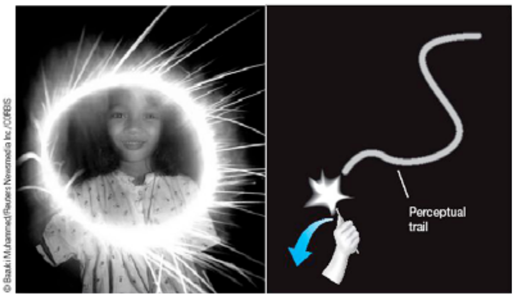


Image from Goldstein, p. 142

Short-term memory (STM)

- memory of the just present:
  - content from sensory memory and LTM.
- information is retained in automatically
- info is retrieved without effort

- scratch-pad for temporary recall
  - rapid access ~ 70ms
  - rapid decay ~ 0.2s
  - duration ~ 20s

- visual and auditory channels

- “flush” when finished with a task
- or, move into long-term memory via rehearsal

Capacity of STM - chunking

- Miller (1956) demonstrated that humans generally have the capacity to store 7 ± 2 items of information in STM.
  - Item: a number, a face, a word, or any unit.
  - Chunk – collection of similar items
- Through chunking the capacity of STM can be is expanded:
  - limited capacity: 7± 2 chunks

Examples

212348278493202

0121 414 2626 852 111 9665 323 1989

HEC ATR ANU PTH ETR EET

THE CAT RAN UP THE TREE

STM and Design (DOs)

- the limitations of STM has caused the necessity of organizing commands into menus
- systems should not force the user to remember more than a small amount of information

- design messages, alerts, and warnings to be minimally disruptive.

- allowing closure:
  - the completion of a task that requires items stored in STM but not committed to LTM (dialling a new number, logging into a system)

- structuring of menus and screens
- consistent short keys
- helpful pictures on buttons
- colour coding

STM and Design (DONTs)

- Wrong application of Miller’s finding:
  - Present only 7 options on a menu
  - Display only 7 icons on a tool bar
  - Have no more than 7 bullets in a list
  - Place only 7 items on a pull down menu
  - Place only 7 tabs on the top of a website page

– But this is wrong? Why?

http://www.id-book.com/chapter3.htm

Why?

- Inappropriate application of the theory
- People can scan lists of bullets, tabs, menu items till they see the one they want
- They don't have to recall them from memory having only briefly heard or seen them

- Sometimes a small number of items is good design
- But it depends on task and available screen estate

Long-term memory (LTM)

- memory for the past
- information is retained through rehearsal
- information is retrieved with effort

- longer access time approx 0.1 seconds
- very slow decay rate (years)

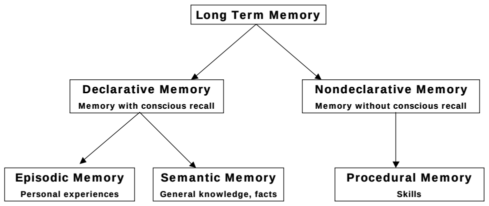
- huge, if not unlimited capacity
- difficulty: in organisation – getting material in and out.

Long-term memory (cont)

memory for the past

- memory for arbitrary things
  - rote learning, e.g. alphabet, the multiplication table
- memory for meaningful relationships
  - meaningful structure can organise what may seem arbitrary
- memory through explanation
  - understanding
  - mental models

Long-term memory - types



Long-term memory (cont)

- Declarative memory
  - stores facts and events
  - standard textbook learning
  - pair: stimulus – response
  - can be put into words
- Procedural memory
  - skills and procedures
  - "how to" knowledge
  - difficult to verbalise
  - very durable

Long-term memory (cont)

Semantic memory

- structured record of facts, concepts and skills
- storage requires rehearsal
- semantic memory structure
  - provides access to information
  - represents relationships between bits of information
  - supports inference

Episodic memory

- autobiographical memories
- explicit memory of events
- narratives, includes time, space and emotions
- easy to store
- serial

Semantic LTM derived from episodic LTM

LTM – semantic memory structures

- Semantic networks
  - memories are represented as nodes
  - inheritance – child nodes inherit properties of parent nodes
  - relationships between bits of information explicit
  - supports inference through inheritance
  - static storage of information
- Schema theory
  - explains constructive encoding of input and reconstruction of storage memories: new knowledge is interpreted within the context of existing schema.
  - Frames
    - extend semantic nets to include complex classes with different types of attributes: fixed, default, variable
  - Scripts
    - allow to infer information for interpreting a situation

LTM - semantic network

Models of LTM - Frames

- Information organized in data structures
- Slots in structure instantiated with values
- Type–subtype relationships

DOG

Fixed
  legs: 4
Default
  diet: carniverous
  sound: bark
Variable
  size:
  colour

COLLIE

Fixed
  breed of: DOG
  type: sheepdog
Default
  size: 65 cm
Variable
  colour

Models of LTM - Scripts

- Model of stereotypical information required to interpret situation
- Scripts allow us to infer information when presented with partial details of a situation

Script for a visit to the vet

Entry conditions:	*dog ill* *vet open* *owner has money*	Roles:	*vet examines* *diagnoses* *treats* *owner brings dog in* *pays* *takes dog out*
Result:	*dog better* *owner poorer* *vet richer*		
Props:	*examination table* *medicine* *instruments*	Scenes:	*arriving at reception* *waiting in room* *examination* *paying*
		Tracks:	*dog needs medicine* *dog needs operation*

Schemata and user expertise

Schemata research into learning addresses novice versus expert performance

- experts have schemas that guide perception and problem-solving which novices do not have.
  - computer experts lean more quickly to use new computer-based systems than novices
- users will have an easier time learning to use a system if it relies on familiar design schemata.
- Implications for design:
- design of HCI systems should consider the subjects' background because this may significantly impact on their performance.

Long-term memory processes

- Storage
- Forgetting
- Information retrieval

LTM - Storage of information

- storage improved by
  - repeated exposure to a stimulus
  - rehearsal of a stimulus
  - structure, meaning and familiarity
- rehearsal
  - information moves from STM to LTM

Theories

- total time hypothesis
  - amount retained proportional to rehearsal time
- distribution of practice effect
  - optimized by spreading learning over time

LTM - Forgetting

Theories

1. decay
   - information is lost gradually but very slowly
2. interference: disruption of learning
   - proactive interference - the disruptive effect of the prior learning on the recall of new information. For example, after receiving a phone number, the old one may interfere.
   - retroactive interference - the disruptive effect of new learning on the recall of old information. For example, the learning of new students' names interferes with a teachers recall of names learnt in previous classes
3. undesired memory is held back from awareness (emotions)
   - suppression - conscious forgetting
   - repression – unconscious forgetting

LTM – information retrieval

1. Recognition: presentation of the information provides the knowledge that the information has been seen before
   - just double check that we've seen it before (familiarity).
   - ex. multiple choice, True/False on exams, recognizing someone you know
2. Recall: information reproduced from memory can be assisted by cues.
   - child, red, plane, dog, friend, cold, tree, big, angry
   - ex. fill-in-the-blank on exams, coming up with the name for person you recognized
   - tip-of-the-tongue phenomenon

Which information retrieval process is more complex?

Recall is more complex because it involves a search of memory and then the comparison process once something is found. Recognition involves only the process of comparing what is perceived now with the information stored in memory

Cognitive load

Cognitive load

- Load on working memory during problem solving, i.e. the more things to be learned in a short amount of time, the more difficult is to process information in working memory.

Cognitive load theory

- Optimum learning occurs in humans when the load of working memory is kept to minimum to best facilitate changes in LTM.
- A schema is a mental model that makes it easier for users to recall an item. Schemas can serve as the basis for "chunks" because they provide a meaningful method for grouping information.

External cognition

Memory can be:

- internal: “knowledge in the head”
- external: “knowledge in the world”

External representations

- verbal: notes, reminders, diaries, to-do lists, post-its
- diagrammatic: maps, diagrams, graph.

Placing knowledge in-the-world eliminates the need for the user to store knowledge in-the-head

- Computational offloading: external representations help reduce the cognitive load required to solve the tasks

LTM and Design

- Use *familiar* design schemata to make learning easier:
  - consistency with standards - using common keyboard and shortcuts for their common purpose, i.e. ctrl-C for copying.
  - dialogue boxes with familiar options, layout, and commands
  - familiar positioning of menu bars, placement of specific menus within the bar, and organization of menu items within a menu
- Provide structure
  - group activities which form a meaningful cluster
- Know your users, e.g. expert vs. novices.
- Facilitate recognition rather then requiring recall
  - using GUIs (instead of an input prompt)
  - file management systems should allow for recall and recognition

Thinking: Problem Solving

Problem solving

Process of finding solutions to unfamiliar task using knowledge
Problem space theory
- problem state: situations encountered while solving the pb.
  - initial state: the problem solving starts
  - goal state: solutions to the problem
  - impossible state: failure of problem solving
- problem space: the set of all such states for a given pb.
- operators: transformations of problem states
- pb. solving: search for identifying the sequence of operators that allows the transition from the initial state to the goal state.

Tower of Hanoi

- This problem involves a set of three rings of different sizes that can be placed on three different pegs:

- The goal of this puzzle is start with the rings arranged as shown above, and to move them all to this configuration:

- problem space: the set of all possible configurations of rings on the pegs
- operators: only the top ring on a peg can be moved, and it may only be placed on a larger ring, or on an empty peg.

http://www.rci.rutgers.edu/~cfs/472_html/AI_SEARCH/ProbRed.html

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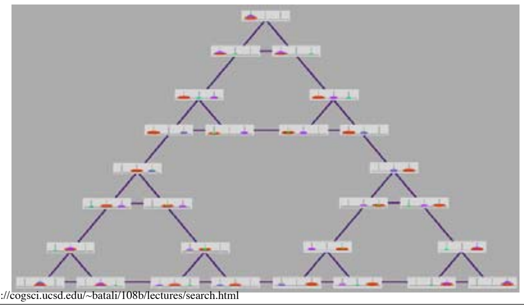
Tower of Hanoi

- What is the minimum number of steps required to solve the problem?



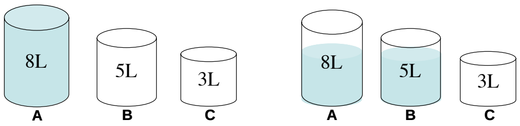
http://cogsci.ucsd.edu/~batali/108b/lectures/search.html

Heuristics

Principles used in making decisions when all possibilities cannot be fully explored
Heuristics are employed to select operators:
- difference-reduction method
- means-ends analysis

Difference-Reduction Method

Attempts to select the operators which will resolve the difference between the current state and the goal state.



Answer: A>B, 2:B>C, 3:C>A, 4:B>C, 5:A>B, 6:B>C, 7:C>A

Obs.: similarity to the goal is a good heuristic, but in step 4: B>C which is crucial, it does not apply.
At such critical steps, 50% the time, subjects deviated in favour of moves that appear closer to the goal.

http://www.it.bton.ac.uk/staff/rng/teaching/notes/ProbSolvMethods.html

Design Implications

- Any ideas?

- Task should be designed so that progression towards the goal at each step is obvious
- Task steps which appear to move away from the goal may present problems for new users, and will require careful support.

Means-ends analysis

- Comparison between the present state and the goal state, detecting the difference between them and searching for actions to reduce it.

Steps:

1. Note the difference between the current state and the goal state
2. Create an achievable intermediate state (subgoal) that will reduce this difference
3. Select and apply a suitable operator to move to the intermediate state.

Ex. Viewing a file
  - Subgoal1: finding the file
    - Subsubgoal1.1: run directory listing
  - Subgoal2: browsing the file
    - Subsubgoal2.1: run browsing

http://www.it.bton.ac.uk/staff/rng/teaching/notes/ProbSolvMethods.html

Design implications

- Means-ends analysis is mentally taxing when the user needs to keep track of a number of embedded subgoals
  - as intermediate goals must be kept in mind, there is a danger of the user forgetting where in the task they are.
  - subgoals should be kept to a minimum, and assistance in remembering where the user is should be given.

Ex. Hierarchical menu selection enables the user
  - to traverse the goal and subgoal states up and down
  - to access menu options from numerous points during the interactions
  - to reduce the memory load by keeping track of goal states and prompting the user for input appropriate to each subgoal.

http://www.it.bton.ac.uk/staff/rng/teaching/notes/ProbSolvMethods.html

Analogy in problem solving

Known solution to one problem is used to guide the development of a solution to another problem.

Ex. doctor treating a malignant tumour, needs to blast it with high intensity rays which may also destroy the healthy tissue surrounding the tumour. If he lessen the rays' intensity, the tumour will remain. How does he destroy the tumour?

A: He fires low intensity rays from different directions converging on the tumour. The healthy tissue receives harmless low intensity rays while the tumour receives the rays combined, making a high-intensity dose.

- Only 10% reached the solution without the help of an analogous story vs. 80% with the help.
- A general is attaching a fortress but he can't send all people together since the road are minded to explode if large numbers of people cross them. He splits them into small groups and sends them on separate roads.

http://www.it.bton.ac.uk/staff/rng/teaching/notes/ProbSolvMethods.html

Metaphors

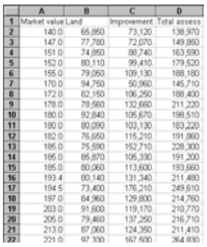
- Metaphor represents a system object as if it were another type of object
- Purpose: leverages our knowledge of familiar, concrete object to understand abstract computer and task concepts.
- Problem – metaphor portrays inaccurate/naïve conceptual model of the system
- Metaphors in interface design have limitations
  - overly literal: unnecessary fidelity, excessive interactions, unnecessary restrictions
  - does not match user's task and/or thinking

- Ex. desktop metaphor: the manipulation of files resembles the physical manipulation on an office desk.
- Can you think of an example of metaphor for the internet?

http://pages.cpsc.ucalgary.ca/~saul/hci_topics/topics/representations.html

Metaphors

Pervade excellent interfaces



	A	B	C	D
1	Market value	Land	Improvement	Total assess
2	140.0	65,850	73,120	138,970
3	147.0	77,780	72,070	149,850
4	151.0	74,850	88,740	163,590
5	152.0	80,110	99,410	179,520
6	155.0	79,050	109,130	188,180
7	170.0	94,750	50,960	145,710
8	172.0	82,150	106,250	188,400
9	178.0	78,560	132,660	211,220
10	180.0	92,840	105,670	198,510
11	180.0	80,090	103,130	183,220
12	182.0	76,650	115,210	191,860
13	185.0	75,590	152,710	228,300
14	185.0	85,870	105,330	191,200
15	185.0	80,060	113,600	193,660
16	193.4	80,140	131,340	211,480
17	194.5	73,400	176,210	249,610
18	197.0	84,960	129,800	214,760
19	203.0	91,600	119,170	210,770
20	205.0	79,460	137,250	216,710
21	213.0	87,060	124,350	211,410
22	221.0	97,330	167,500	264,830

spreadsheet (actuary sheet)

games (literal world)

http://pages.cpsc.ucalgary.ca/~saul/hci_topics/topics/representations.html

Metaphors and Design

Things to watch for:
- Use metaphors that matches user's conceptual task
  - desktop metaphor for office workers
  - paintbrush metaphor for artists
- Given a choice, choose the metaphor close to the way the system works
- Ensure emotional tone is appropriate to users
  - eg file deletion metaphors
    - trashcan
    - black hole
    - paper shredder
    - pit bull terrier
    - nuclear disposal unit…

http://pages.cpsc.ucalgary.ca/~saul/hci_topics/topics/representations.html

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Emotions

Emotion

- The biological response to physical stimuli is called *affect*
- Affect influences how we respond to situations
  - positive → creative problem solving
  - negative → narrow thinking

> “Negative affect can make it harder to do even easy tasks; positive affect can make it easier to do difficult tasks”
>
> (Donald Norman)

Emotion

Theories
- James-Lange
  - emotion is our interpretation of a physiological response to a stimuli
  - Ex. “I am afraid because I perspire”
- Cannon-Bard
  - emotion is a psychological response to a stimuli
  - Ex. “I see a spider. I am afraid. I begin to perspire.”
- Schacter-Singer two factor theory of emotion:
    - physiological arousal
    - cognition
  - emotion is the cognitive interpretation of a physiological response in a particular situation
  - Ex. pounding heart will be interpreted as excitement if we are in a competition and fear if we find ourselves under attack.

Emotion and Design

- aesthetically pleasing and rewarding interfaces will increase positive affect
- stress will increase the difficulty of problem solving, i.e. relaxed users will be more forgiving of shortcomings in design
- what emotions will induce:

a well organized website with a professional, "clean look and feel", with intuitive navigation and task-oriented functionality	perception of credibility, security, trust and ease of use
a software application that is task-centric, contains "just in time" features and performs robustly	improved user satisfaction, perceived software quality and product appeal
a product that carries aesthetic value and performs elegantly	perception of improved performance, pleasure, and deep attachment

http://experiencedynamics.blogs.com/site_search_usability/2004/08/design_and_emot.html

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Individual differences

- long term
  - sex, physical and intellectual abilities
- short term
  - effect of stress or fatigue
- changing
  - age, expertise

Implications for design:
will design decision exclude section of user population?