HCI Lecture 3

Human capabilities: Memory and learning

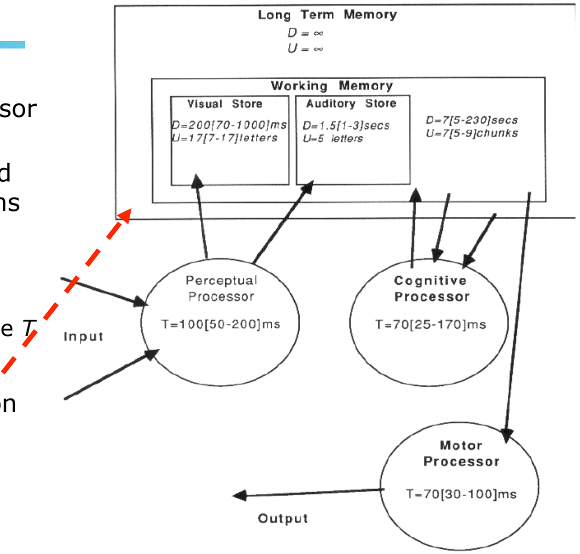
Hiroshi Shimodaira

Key points:

- Long term memory
  - organised as networks, schemas, frames
- Short term memory
  - what are the limits?
- Learning rates
- Learnability

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 memory stores

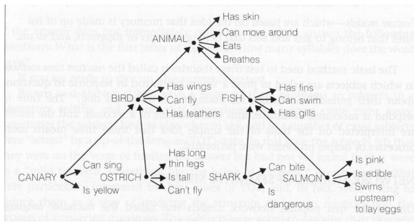


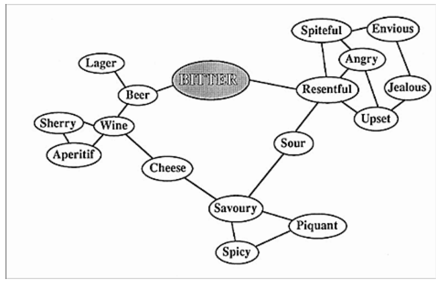
Long term memory

- Long Term Memory (LTM)
  - Infinite capacity and decay time?
    - Not everything is stored (what is filtering process?)
    - Not everything stored can be retrieved (what is recall process?)
    - Not everything recalled is correct (what is interference process?)
- Different kinds of memory may be distinguished:
  - **Declarative**, knowledge of facts:
    - **Episodic**: *what* happened, *where and when*
    - **Semantic**: factual information, general knowledge independent of context
  - **Procedural**: *how-to-do-it* knowledge
    - Usually implicit, hard to put in words (hence 'non-declarative') e.g. how to ride a bicycle

Declarative memory models

- **Semantic nets:** memory is organised by links expressing strength or type of relationships between nodes
  - May be hierarchical

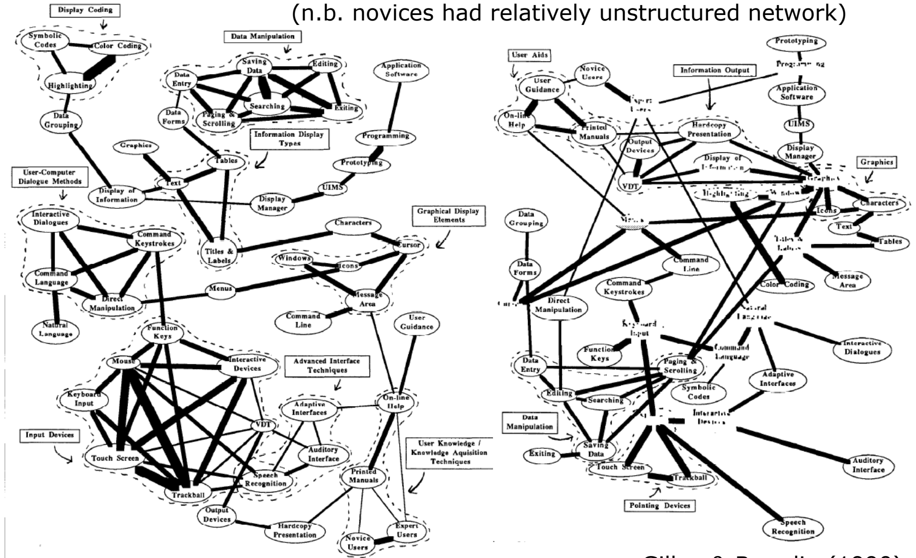




- Can generate representation of people's knowledge by asking them to rank relatedness of item pairs, then generate and prune network (e.g. Pathfinder algorithm)

Human factors specialists Software developers

(n.b. novices had relatively unstructured network)



Gillan & Breedin (1990)

Declarative memory models

- **Schemas:** pre-exisiting knowledge structures that shape our memory of new inputs
  - Can improve recall but also cause memory biases
- The schema concept has been formalised as:
  - **Frames:** knowledge is organised into data structures with fixed, default and variable slots or attributes (c.f. OOP)
  - **Scripts:** stereotypical knowledge about situations that allows interpretation of partial descriptions or cues
    - E.g. "We went to that restaurant you recommended. The food arrived quickly. We left about nine." *Did they eat the food? Did they pay? Were there tables in the restaurant?*
- Note interaction with episodic memory
  - Schemas may develop as abstractions of specific experiences
  - Our memory of specific experiences may be shaped by schema

Procedural memory

- **'How to do it'**
- Often modelled in HCI as **production rules***:*
- Set of rules in the form: *if* **condition** *then* **action**
  - **Conditions:** e.g. user goals (and subgoals) and current STM contents
  - **Actions:** what to do (and update to goals)

Condition	Action
GOAL: DELETE	[POSITION CURSOR] [PRESS DELETE]

- A more realistic example:

```
(TARGET-IS-LOCATED-BEGIN-MOVING-MOUSE
IF
((GOAL DO MENU TASK)
 (STEP VISUAL-SEARCH)
 (WM TARGET-TEXT IS ?T)
 (VISUAL ?TARGET-OBJECT LABEL ?T)
 (WM CURSOR IS ?CURSOR-OBJECT)
 (MOTOR MANUAL PROCESSOR FREE))
THEN
((DELDB (STEP VISUAL-SEARCH))
 (ADDDB (STEP MAKE RESPONSE))
 (SEND-TO-MOTOR MANUAL PERFORM PLY MOUSE
      RIGHT ZERO-ORDER-CONTROL ?CURSOR-OBJECT ?TARGET-OBJECT)))
```


Procedural memory

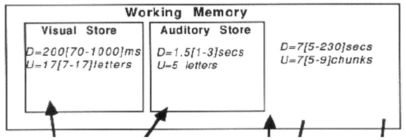
- Using production rule description:
  - Complexity of interaction task can be estimated from number of production rules needed to describe it.
  - Time to learn a task can be estimated by how many production rules transfer to it from previous tasks
  - Cognitive load can be estimated by how much working memory the conditions assume
- Note this does not imply these rules are consciously understood

Long term memory

- Important constraint is ability to ***retrieve*** information
  - Semantic nets imply easier if have cues that are near links to the target
  - Schemas imply easier if target is part of coherent structure
- Have a much larger capacity for recognition than recall
  - Hence menus vs. command interfaces
  - But scanning also takes time, or may have many more items than can be realistically scanned
    - Need to recall where to look for the item to recognise
    - Important to support partial recall (e.g. part of file name)
    - Important to support contextual recall (e.g. when file created)

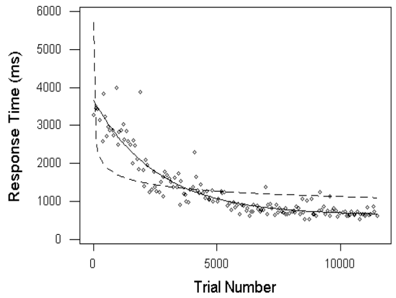
Short term memory (STM)

- Capacity of STM
  7±2 chunks of information.
- cf. **Working Memory**
  - \`Registers' of the Cognitive Processor
    - Data from perceptual sub-systems
    - Activated 'chunks' of LTM
  - 'Cognitive load' of task is how much we have to keep "in mind"
  - Attention bottleneck
  - Limited capacity – but what is the limit?



Learning

- **Power law of Practice**:
  - Reaction time: $T_n = T_1 n^{-a}$ a = 0.4[0.2 -- 0.6]
  - I.e. improvement is rapid at first, and slows later
  - Has been found in a wide variety of tasks (pressing button sequences, reading inverted text, mental arithmetic, manufacturing, writing books…)
- However Heathcote et al. (2000) show individual data in a variety of tasks is actually better described as exponential:
  - $T_n = T_1 e^{-an}$
  - Implies constant relative learning rate



Learning curve

Learning

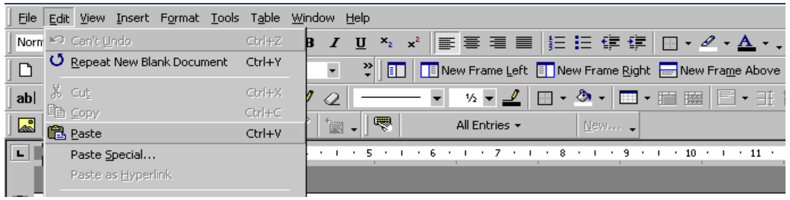
- An alternative framework to the acquisition of 'production rules' is the reinforcement learning approach
- Assume an agent is interacting with a world that can be described as a Markov Decision Process
  - World contains set of states S
  - In each state s the agent can take one of a set of actions A(s)
  - Given action a in state s, will have transition to state s' with probability P(s,s',a)
  - Also have expected reward on the transition R(s,s',a)

  - The problem for the agent is to find a *policy π* for taking the right action in a given state to maximise the expected future reward
- Ignoring (for now) the various AI algorithms for solving this problem, we can use it as a framework for understanding what makes interfaces more or less learnable

Learnability (Dix #1)

Predictability — determinism and operation visibility

- System behaviour is observably deterministic:
  - Easier to learn if *P(s,s',a)=1,* i.e. the same action in the same state has the same consequence
  - Also important that user can see that the state has changed as a result of the action (within reasonable delay)
  - Markov property: transition does not depend on history (how current state was reached); hence reduced memory load?
- operation visibility:
  - *user knows the available actions (e.g. use logical constraints)*



Learnability (Dix #2)

Synthesisability: the user can assess effect of past actions

- Specifically, they can assess if the outcome is better or worse than expected (are they making progress towards the goal?)
- Immediate vs. eventual honesty
  - Supervised learning provides explicit feedback at each step
    - Advantages of WYSIWYG
  - Difficult learning situations involve long chains of states and actions before any reward is received

Learnability (Dix #3)

Familiarity: match the interface to users' expectations:

- Facilitate *guessing*:
  - Suggested that users when guessing will generally pick the action that (superficially) most resembles the goal. Hence should:
  1. Make the possible actions salient and distinct, keep number small
  2. Use identity cues between actions and goals as much as possible
  3. Don't require long sequences of choices
  4. Have one or less obscure actions
  5. Enable undo.
  - Users learn better from exploring, but may be reluctant to explore

Learnability (Dix #3)

Familiarity: match the interface to users' expectations:

- Use terms consistent with everyday usage?
- Problem that agreement can be low, e.g. Furnas et al:
  - find only 10-20% of users generate same command name as an 'armchair' designer.
  - User-preferred names overlap by only 15-35%.
  - Up to 15 aliases still covers only 60-80%.

- Exploit natural *affordances*

Affordances

- **Affordance**: a relation between agent, object and task
  - We don't normally see the world in terms of coloured surfaces in space
  - We directly perceive the potential for interaction

  "If a terrestrial surface is nearly horizontal (instead of slanted), nearly flat (instead of convex or concave), and sufficiently extended (relative to the size of the animal) and if its substance is rigid (relative to the weight of the animal), then the surface affords support…"

  J.J. Gibson (1979) The Ecological Approach to Perception

- "If a door handle needs a sign, then its design is faulty"

  D. Norman, *The Psychology of Everyday Things*

Affordances & HCI

- Doors are 'surface artifacts': what you can perceive is all that exists (though bad design might confuse these properties)
  - E.g. physical file – can see if open, size, type of content
- Computers are `internal artifacts': they have complex internal states that determine their function but are not visible
- This information needs to be transformed into a surface representation for the user:
  - Opportunity: can choose the representation best suited to the user without the physical constraints of surface artifacts
  - Problem: it is up to the designer to decide what will be visible; and this requires expert knowledge of both the artifact and the user
  - E.g. what might the user need or want to know about the computer file?

Learnability (Dix #4)

Consistency — likeness in input/output behaviour arising from similar situations or task objectives

- Make the state *s* recognisable to facilitate choice of correct action based on previous experience
- challenge (and danger): consistency is not self-contained
  - consistency within screens
  - consistency within applications
  - consistency within desktop
  - . . .
- Examples: consistent patterns in layout; same short-cut keys for similar action; same placement for recurrent menu options
  - *Always place the Quit command as the last item in the leftmost menu*
- Well-learnt actions can become 'habits': the state evokes a particular action even when it is not appropriate for the goal
  - E.g. confirmation dialogues

Learnability (Dix #5)

Generalizability — extending specific interaction knowledge to new situations

- Implies learning capability that abstracts from specific states and actions to recognise similarities and consistent patterns

- UI standards and guidelines can assist/enforce generalizability
  - *applications should offer the Cut/Copy/Paste operations whenever possible*
  - *Users should generalise from cutting text, cutting images, etc. to cutting files*

Learning in the computer

- Learning algorithms are increasingly being used to allow the computer to adapt to us, rather than vice versa
  - E.g. applying reinforcement learning for spoken dialogue managers to learn optimal action for every situation
  - See http://homepages.inf.ed.ac.uk/olemon/

	Utterance	Feature
S	How can I help you?	Open initiative initial question
U	I'm looking for a cheap chinese restaurant.	User initiative
S	Would you like something central?	Intention recognition
U	Yes.	
S	The Dragon Way is an affordable cantonese restaurant located on Main Street **[displayed on map]**.	Multimodal presentation
S	Are you happy with those options?	
U	Yes, and I also want a double room.	
S	Would you like something expensive, cheap, or reasonably priced?	Intention recognition

References

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Heathcote, A., Brown, S.D. & Mewhort, D.J.K. (2000). The Power Law repealed: The case for an exponential law of practice. *Psychonomic Bulletin and Review,7*, 185-207.

Furnas, G.W., Landauer, T.K., Gomez, L.M. and Dumais, S.T. (1987) The vocabulary problem in human-system communication. Communications of the ACM, 30(11):964-971.

- See also:

Dix et. al. sections 1.3, chapter 7.