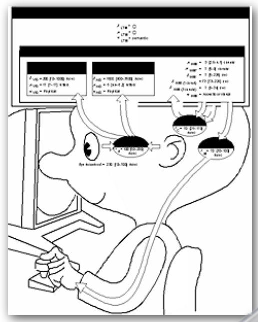
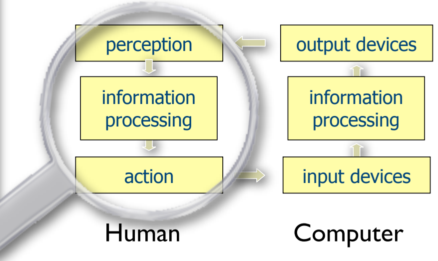
Human-Computer Interaction

Session 3:
The human user - Attention & Memory

Psychology of HCI (Card, Moran & Newell; 1983)



Two information processors coupled in goal-directed action.



Human Information Processor

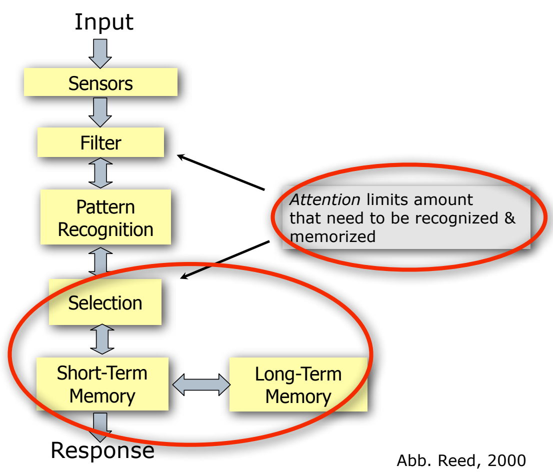
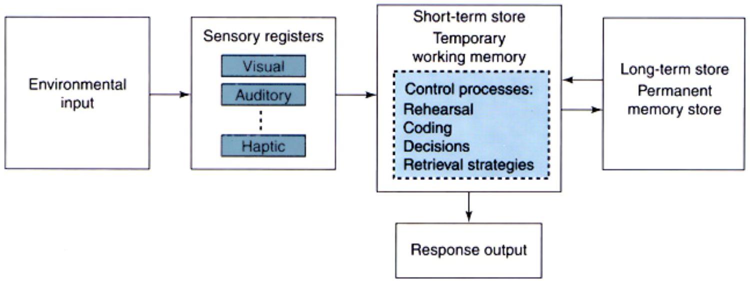


Abb. Reed, 2000

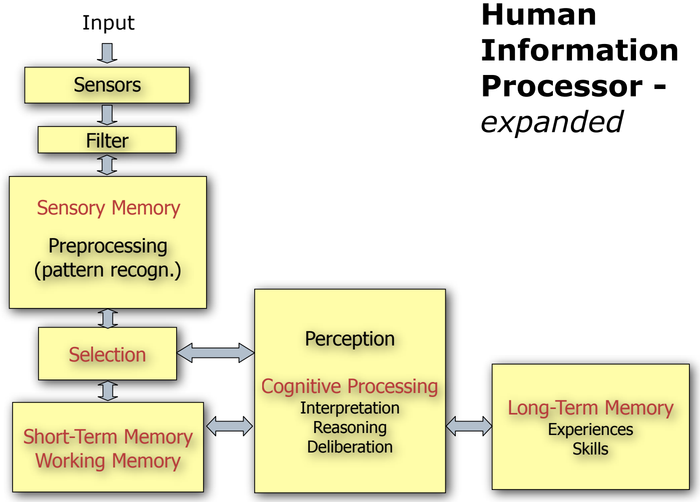
Standard model

Atkinson & Shiffrin (1968)



Standard theory of memory & information processing, aka. modal model

Human Information Processor - *expanded*



Sensory memory

Modality-specific buffers for received stimuli (Neisser, 1967)

Large capacities, but information lasts only short durations
- *iconic memory*: visual stimuli, *~250-400 msec*
- *echoic memory*: aural stimuli, *only little longer*
- *haptic memory*: tactile stimuli, *shorter*

FIFO: memories are washed out or masked by new information
- iconic memory: By the time ~4 items have been extracted, the remaining contents have been decayed
- decay rate depends on intensity, contrast, duration of the stimulus, as well as the following of another stimulus (masking)

Example: Reading your watch quickly, twice

Sensory memory

Sperling (1960)

Array of letters, presented for 50 milliseconds

X	M	R	J
C	K	P	R
V	F	L	B

Whole-report method („recall as much as possible")
- 4.5 letters on average, letters "fade away"

Part-report method („recall specific elements")
- tone (high, medium, low) *after* presentation to cue subjects to report a particular row
- Higher percentage of letters recalled, depending on delay of tone: 50ms: 9 (i.e. 3 per row) → 300ms: 6 → 1s: 4.5
- Explanation: People attend to and scan the row image in sensory memory, until it faded away

Short-term memory (STM)

A more durable "scratch-pad" for temporary recall

- ~20-30s, if not maintained (see below) or externalized
- rapid and reliable access: ~ 70ms

Very limited capacity

- Miller (1956): **7 ± 2 chunks**
- Cowan (2002): **4 ± 2 chunk**

Capacity limits can be overcome by chunking

- grouping of information into larger meaningful units
- found by looking for familiar pattern abstractions
- individual differences, e.g. chess masters vs. novices
- closure = successful formation and completion of chunks, also seen in everyday tasks that must be held in STM

STM limits - examples

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STM - maintenance

What happens if you need to keep information in memory longer than 30 seconds? To demonstrate, memorize the following phone number (presented one digit at a time):

STM - maintenance

What is the number?

857-9163

The number lasted in your short-term memory longer than 30 seconds. Needs to be maintained through continued rehearsal.

STM - maintenance rehearsal

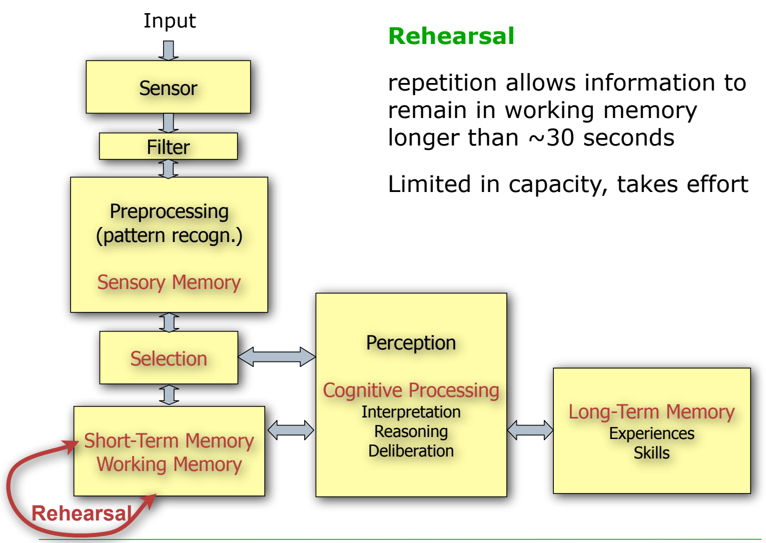
What happens if you can't use maintenance rehearsal?
To demonstrate, memorize a phone number BUT count backwards from 1,000 by sevens (i.e., 1014, 1007, 1000 …)

STM – maintenance rehearsal

What is the number?

628-5094

Without rehearsal, memory fades.



Rehearsal

repetition allows information to remain in working memory longer than ~30 seconds

Limited in capacity, takes effort

STM & working memory

Working memory

- place where basic cognitive operations are carried out (comprehension, decision-making, problem-solving,...)
- modality-dependent (e.g., rehearsal of language and sounds vs. inspection or rotation of mental images)

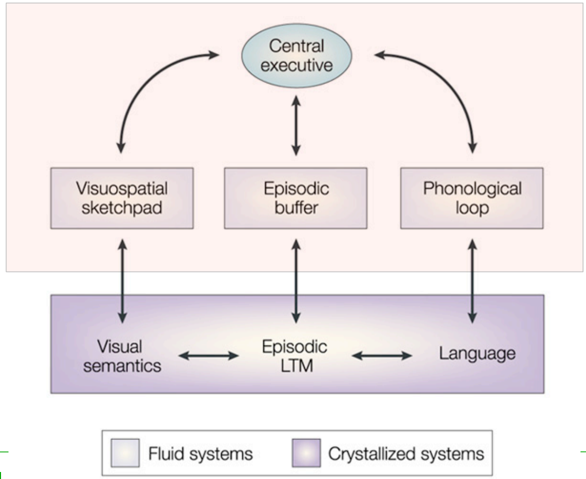
Content of STM defines context of cognitive processing

- Can faciliate or hinder efficient processing
- HCI: Beware of the context that is actively created by your system's feedback and functions, in which the user operates

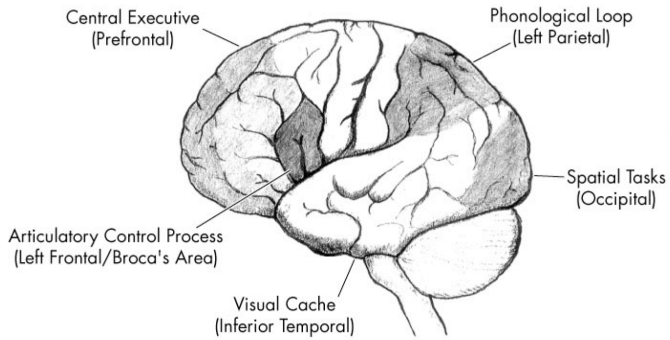
WM = STM + „central executive"

Working Memory

Baddeley (2000)



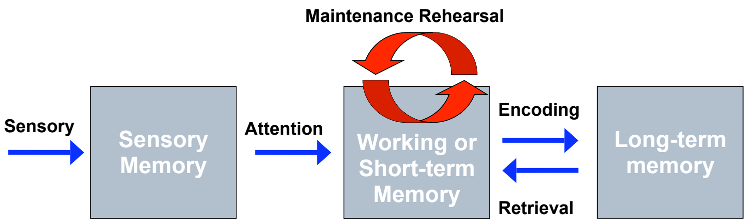
Brain regions involved in working memory



Groome (2006), Fig. 6.10

Long-Term Memory

Once information passed from sensory to working memory, it can be learned, i.e., encoded and stored in long-term memory



Long-term memory (LTM)

Repository for all our knowledge and experiences

- slow access (~1/10 second), slow decay, huge capacity
- Storage for …
  - facts, data, concepts, …
  - images, sounds, sents, …
  - situation, episodes, processes, …
  - connections, conclusions, insights, …
  - procedures, recipes, movements, …

Of big relevance for HCI

- combined knowledge about a system and the interaction - the basis of a user's mental model of the system
- distinguishes a novice from an expert user

LTM - different kinds

Stanford Encycl. of Phil.

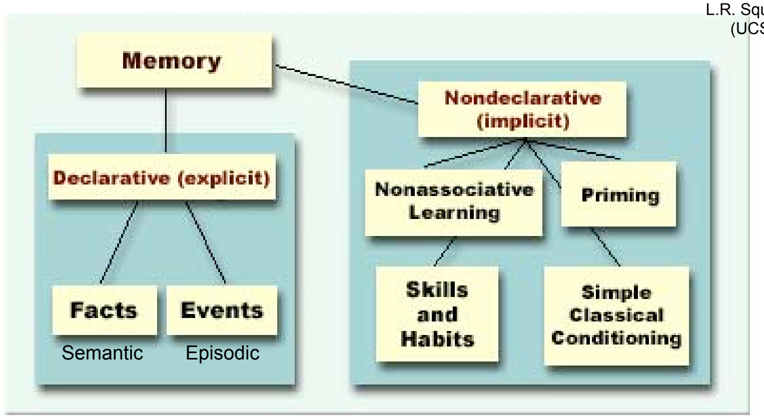
habit memory, procedural memory
- embodied skills such as typing, playing golf, using a knife and fork

propositional memory, semantic memory
- network of conceptual information underlying our world knowledge

recollective memory, episodic memory, personal memory
- experienced events and episodes, generic or specific, of more or less extended temporal periods

declarative memory = semantic + episodic memory
- vs. non-declarative forms of memory
- more controversial: 'explicit' vs. 'implicit' memory systems
  - a matter of how a memory is accessed (by subject or labeled)

L.R. Squire (UCSD)



Semantic vs. episodic memory

(Tulving, 1983)

Semantic Memory
- facts, concepts, meaning of words & things
- abstracted and generalized, not tied to place, time or event

Episodic Memory
- serial, biographical
- tied to explicit autobiographical events
- recall = subjective sense of "being there"

Distinction supported by neuropsychological evidence
- Frontal lobe patients and some amnesics have relatively intact semantic memory, but significantly impaired event memory

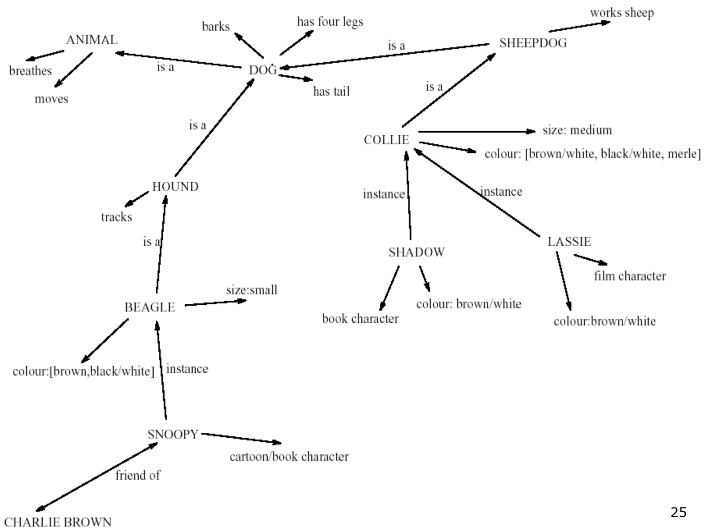
Semantic memory

Structure of semantic memory provides associative access
- follows relationships between entities of information
- supports inference

Semantic or associatve network (e.g., ACT-R)
- closeness of concepts represented by closeness in graph
- inheritance – child nodes inherit properties of parent nodes
- relationships between bits of information explicit
- supports inference through inheritance

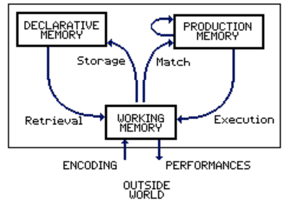
Learning of new information: embedding
- looking for associations with known facts or concepts
- the more associations are found, the better something is learned, anchored in our conceptual knowledge

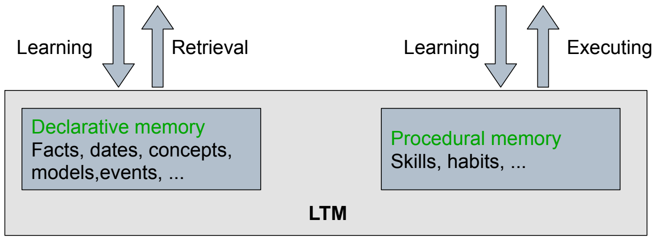
Associative or semantic network



Declarative vs. procedural memory

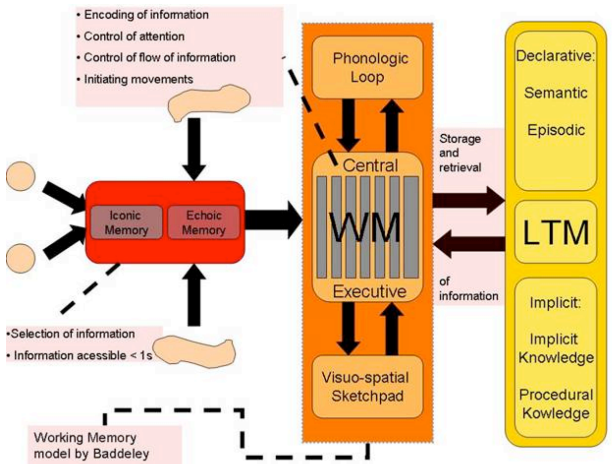
ACT* (Anderson, 1993)





Automatic sequences of keystrokes, menue selections, condition-action rules, etc.

Summary - memories



How is information memorized?

Rehearsal
- information moves from STM to LTM through repetition
- *„total time"* hypothesis: amount of information ~ rehearsal time

Distribution of practice
- optimized by spreading learning over time

Importance of structure, meaning, and familiarity
- information about objects is easier to remember
  - Faith Age Cold Tenet Quiet Logic idea Value Past Large
  - Boat Tree Cat Child Rug Plate Church Gun Flame Head
- information related to existing structures is more easily incorporated into memory (~embedding)

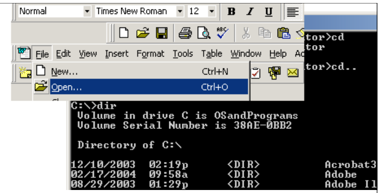
How is information forgotten ?

Decay
- information is lost gradually, but very slowly

Interference
- new information replaces old: *retroactive interference*
  - new tel. number masks old one
- old may interfere with new: *proactive inhibition*
  - find yourself driving to your old house

Note: memory is selective, affected by emotion – can subconsciously `choose' to forget

How is information retrieved?



Memory retrieval in HCI:

recall
- information must be retrieved from memory, without any hint (free recall)
- can be assisted by cues, e.g. categories, imagery (cued recall)

recognition
- present information „evokes" that it has been seen before, plus further useful knowledge
- less complex than recall - *information itself acts as a cue*
- frequent design goal

Retrieval is of unequal difficulty

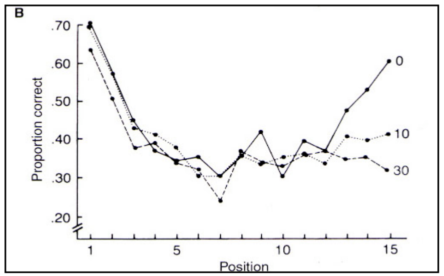
- **Free recall**
  ("Who are these persons?")
- **Cued recall**
  ("Last name starts with an M.")
- **Recognition**
  ("Whose last name is Fischer?")

H. Markowitsch, 2006

Free recall

(Glanzer & Cunitz, 1966)

Example: learning a word list and free recall
- More likely to remember words at the beginning (*Primacy effect*) and end of the list (*Recency effect*)



Evidence for LTM-STM
- Recency effects reflect limited STM capacity, ceases with time
- Primacy effects reflect transfer to LTM via rehearsal
- Primacy effect more robust than recency, less affected by interference or delay

Expert vs. novice users

Beginners: memorize and operate upon simple facts and rules (declarative), must build up a mental model of the system from the scratch

Experts: utilize declarative and procedural (implicit) knowledge, which they can often not explicate

How to support learning in HCI?

1. enable connections to existant knowledge
2. use metaphors to connect to known realms
3. build up knowledge step-by-step, support rehearsal
4. account for different types of learners (learning by reading, visualizing, verbalizing, doing)

Human Information Processor

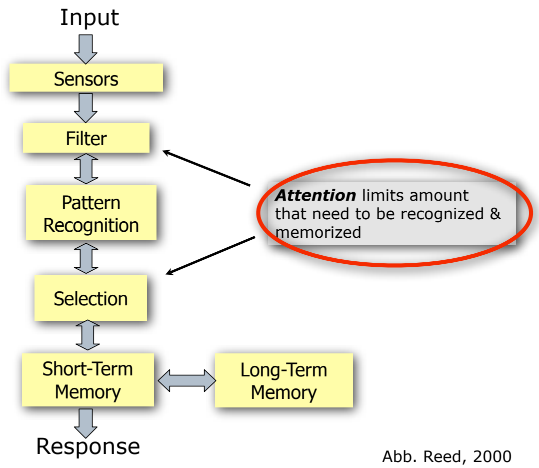


Abb. Reed, 2000

Attention

- Limited capacity of working memory restricts the amount of information we can take in and process at a time
- Brain actively focuses on and concentrates on a certain pieces of information
- With practice, some kinds of information require little to no effort (automatic) in becoming the focus of attention

Of huge importance in HCI:

- Attention should be focused on task not on interaction
- Minimize mental effort of using a system
- *Example: driving a car*

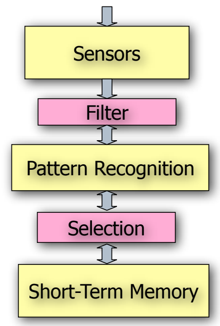
Attention

bottleneck theories

- *Filter theory*: attention determines what reaches recognition stage through filter
- *Late-selection model*: attention selects pre-processed pattern information for memory

capacity theories

- selection occurs everywhere
- depends on mental effort



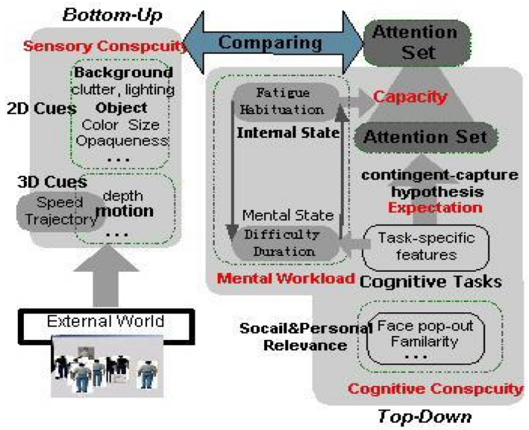
(cf. Reed. 2000)

Automatic skills are those that require little mental effort (*habituation*)

What are we attending to? (Green, 2004)

Affected by

1. Saliency/conspicuity: object's ability to grab attention
   - sensory conspicuity (physical properties)
   - cognitive conspicuity (relevance, e.g. faces pop-up)
2. Current mental workload, fatigue
3. Capacity
   - number of items you can attend to at a time
4. Expectations
   - Causes specific stimuli to gain more weigth than other
   - „Contingent-Capture Hypothesis" (Ward):
     expected items are part of attentional set, informing the person what is relevant and important in a scene
   - Main cause of inattentional blindness



(Gu, Stocker & Badler, 2005)

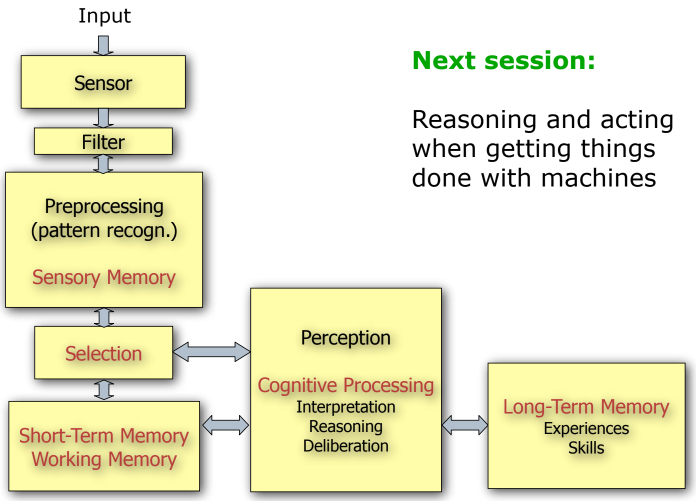
Change blindness

Change blindness

Change blindness

Gender effects

Task: Watch the yellow team playing basketball. Count how often the *yellow team* *dribbles* the ball AND how often it *passes* the ball.



Next session:

Reasoning and acting when getting things done with machines