

Cognitive Systems

Foundations of Information Processing
in Natural and Artificial Systems

Lecture 7

Human Memory:
sensory memory, short-term memory,
working memory, and long-term memory



Models of Human Memory

- (1) A general memory model
- (2) Sensory memory
- (3) Short-term memory
- (4) Working memory
- (5) Long-term memory

7.0

2

Definitions

- Memory
 - An individual's entire **mental store of information** and the **set of processes** that allow the recall and use of that information when needed
 - Learning → Memory → Future Behaviors
- Consciousness
 - Experience of one's own mental event in such a way that one can report on them to others
 - Consciousness = awareness

3

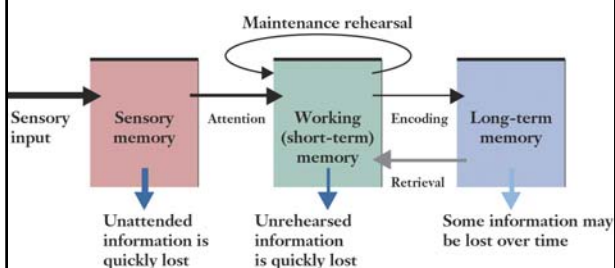
Models of Memory

- Information-processing model of the mind
 - Mind as processor of information
 - Memory refers to:
 - all information in a person's mind
 - the mind's capacity to store and retrieve that information
 - A general model of the mind
 - 'modal' model by Atkinson & Shiffrin 1968

4

Modal Model of the Mind

(Atkinson & Shiffrin 1968)



5

Sensory Memory

6

Sensory Memory

- Receives sensory input and holds it for a short period of time
- Forms automatically without attention or interpretation
- Unconscious to the person
- Separate sensory memory stores – one for each sensory system:
 - visual information: iconic memory
 - auditory information: echoic memory
 - haptic information: haptic memory
 - olfactory information, taste perception ...

7

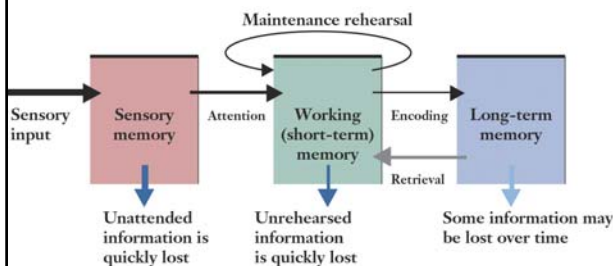
Duration of sensory memory

- Duration is on the order of one 1 second for visual and auditory information
 - Visual displays of number arrays are only completely available for a maximum of 1 second (Sperling 1960)
 - people can detect rhythmic patterns in a sound presented at a repetition rate of up to 2 seconds (Guttman & Julesz 1963)

8

Modal Model of the Mind

(Atkinson & Shiffrin 1968)



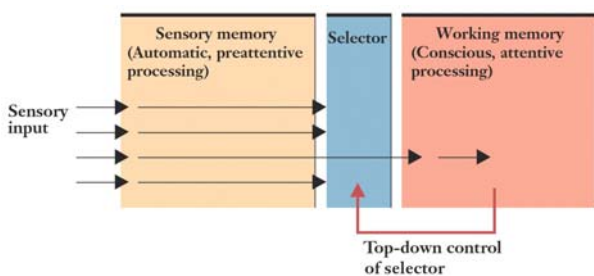
9

Attention

- Restricts flow of information
 - from sensory memory (large capacity)
 - to short-term memory (small capacity)
- Selection and filtering
 - contributes to the task at hand (top down)
 - Sensitive to possible danger (bottom up)
 - concentration on one source of input (listening, viewing)

10

Model of Attention



(Gray 2001)

11

Model of Attention

- Preattentive Processing
 - occurs at unconscious level
 - preliminary analysis of stimulus
- Attentive Processing
 - conscious
 - provides top-down control of selection criteria

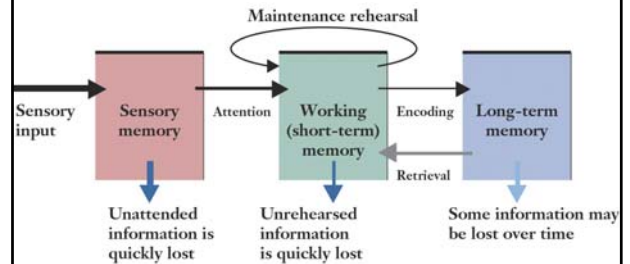
12

Short-term Memory

13

Modal Model of the Mind

(Atkinson & Shiffrin 1968)



14

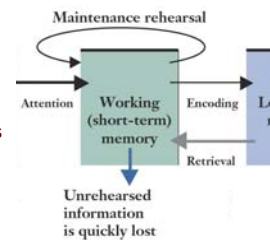
Short-Term Memory

- Conscious perceptions and thoughts plus rehearsal process(es)
- Function
 - Transient store of conscious information
 - Gateway to long-term memory
- Limited capacity
 - 7 +/- 2 (Miller 1956)
 - 4 (Cowan 2001)
- Short duration
 - approximately 30s

15

Short-Term Memory

- Information input
 - from sensory memory
 - immediate environment
 - from long-term memory
 - knowledge from previous experiences
- Information output
 - to long-term memory
 - encoding through rehearsal



16

Problems with the Modal Model

- Claim: sensory information is only used if it is attended to
- Counter example
 - unconscious priming of mental concepts
 - automatic and obligatory processing of stimuli

17

Priming

- The activation of information in memory by sensory input
- Activated information becomes more available
- Activation may not be experienced consciously but influences consciousness
- Activation can occur when the priming stimulus is not consciously perceived
- Example: ...

18

Tree with/without a Duck

(Eagle et al. 1966)



- Subjects got stimulus for 300ms on a screen
- They are aware of seeing the tree but not the duck
- When asked to draw a natural scene subsequently, they more frequently draw a scene having to do with ducks than did those who got the stimulus on the right

19

Automatic Processing of Stimuli

- Adaptive characteristic of the mind to perform routine task automatically
- Free conscious working memory for more creative purpose or emergencies
- Example:
Stroop (1935) interference effect

20

Stroop Interference Effect

	GREEN	RED	TRUCK
	RED	BLUE	TOP
	BLUE	GREEN	COUCH
	BLACK	BLACK	HAND
	BLUE	GREEN	COUCH
	RED	BLUE	TOP
	GREEN	BLACK	TRUCK
	BLACK	RED	TOP
	RED	BLUE	COUCH
	BLUE	GREEN	HAND

(a)

(b)

(c)

(d)

21

Problems with the Modal Model II

- Claim: rehearsal is essential for encoding in long-term memory
- Counter Example
 - the way of dealing with information in working memory is more important for storage in long-term memory than rehearsal
- 'Levels of processing model' (Craik & Lockhart 1972)
 - 'depth' of processing
 - semantic links to existing knowledge

22

Working Memory

23

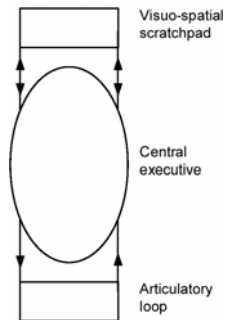
Working Memory

- Multiple interacting components
- STM as a *workplace* not only a gateway
 - CPU Analogy
 - conscious / active processing of information
- Working Memory supports:
 - perceiving
 - feeling
 - comparing
 - computing
 - reasoning
 - ...

24

Working Memory (Baddeley 1986)

- **Articulatory loop**
 - verbal information
- **Visuo-spatial sketchpad**
 - visual and spatial information
- **Central executive**
 - control
 - attention
 - transfer from/to sensory memory and long-term memory
- Simultaneous performance of two tasks is better if each involve a different part of working memory



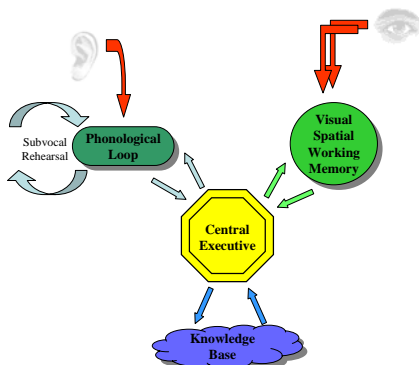
25

Working Memory

- **Phonological Loop**
 - rehearsal necessary to retain information
 - unrehearsed items fade quickly (within ~2s)
 - verbal information retained via subvocal repetition
- **Visuo-spatial sketchpad**
 - visual and spatial information
 - mental images (see next but one lecture)

26

Baddeley's Working Memory Model



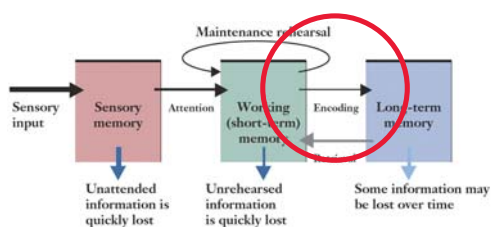
27

Baddeley's Working Memory Model

- Information can enter one or more sub-components of the working memory either from the sensory input or from LTM
- Working memory plays the role of transferring information from sensory input to long-term memory
 - particularly in the learning of novel information

28

Encoding in Long-term Memory



29

Encoding

- **Deliberate**
 - memorization
- **Automatic**
 - occurs as a side effect of interest devoted to certain information due to special interest

30

Rehearsal vs. Encoding

- Rehearsal / maintenance
 - process to hold information in working memory for a period of time
- Encoding
 - transfer of information to LTM
- Important
 - activities that are effective for maintenance are not necessarily effective for encoding
 - duration and repetition in working memory has no effect in later recall

31

'Levels of Processing' Theory

(Craik & Lockhart 1972)

- For an item to be remembered
 - process at a series of encoding levels
 - visual appearance of the word on the page
 - sound of the word when pronounced
 - meaning of that word and its relationship to other experiences
- Memory trace will be more durable as the levels of encoding increase in depth
- Processing of encoding material richly and elaborately in terms of prior experience leads to a more durable and retrievable memory trace

32

Effective Encoding Strategies

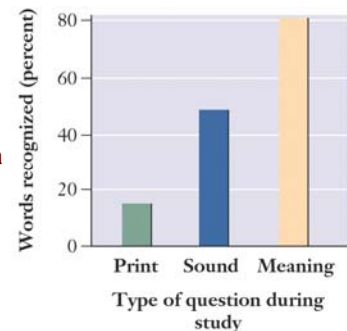
- Elaboration (elaborative rehearsal)
 - unconscious memorization
 - interest
 - deep thoughts
 - rich contexts
 - connection of information to those stored in LTM
 - understanding

33

Elaboration

(Craik & Tulving 1975)

- Subjects presented with a long list of words
- For each word a question has been asked that requires a different form of thought
- Example:
 - word: WORD
 - question: is it in capital letters?



34

Effective Encoding Strategies

- Organization
 - as a means of elaboration
 - items need to be thought about to organize them
 - reveal / create links among items that would otherwise be perceived as separate

35

Effective Encoding Strategies

- Organization
 - chunking (Miller 1956)
 - reduction of number of separate items
 - decrease of the number of items to be remembered
 - more meaning for each item
 - increase of amount of information associated with each item
 - advantage for both maintaining information in working memory and for encoding into LTM
 - example:
 - 7 physiological systems: SACRED MANOR (consonants)
 - skeletal / circulatory / respiratory / digestive / muscular / nervous / reproductive
 - 7 systems chunked into 2 meaningful words

36

Effective Encoding Strategies

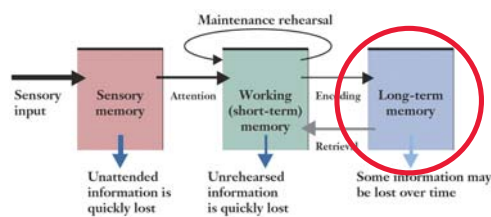
- Organization
 - hierarchical structure (formation of categories)
- Visualization
 - images to supplement other information
 - provides second memory trace
 - provides a means of elaboration and chunking
 - e.g. meaning of a word as image
 - chunking of separate items of information into a scene

37

Long-term Memory

38

Encoding in Long-term Memory



39

Long-Term Memory

- Stored representation of all that is known
- Information remains dormant until they are called into working memory
- Corresponds to everyday notion of memory
- Passive repository of information
- Large / unlimited capacity
- Duration: long (up to a lifetime)

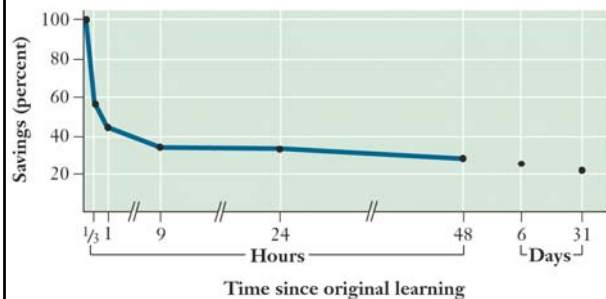
40

Retrieval from Long-term Memory

- Decay over time (decay theory)
 - ability to retrieve an item from LTM declines over time
 - Availability of information at some time point depends on:
 - rate of decline
 - depth of initial encoding
 - circumstances under which the information is retrieved

41

Forgetting Curve (Nonsense Syllables)



(Ebbinghaus 1885/1913)

42

Retrieval from Long-term Memory

- Retrieval-cue theory (mental associations as basis for retrieval)
 - associations and memory retrieval cues
 - 2 concepts are associated when thinking of one tends to evoke the other from LTM
 - ability to retrieve information depends on the availability of appropriate cues (reminders)
 - importance of organization of information
 - categories act as retrieval cues

43

Retrieval from Long-term Memory

- Retrieval-cue theory
 - principle of association by contiguity
 - concepts are associated because their referents have occurred together in previous sensory experience
 - example: napkin and plate (seen together)
 - accounts for the ability to bring quickly to mind the properties of an object when its name is heard
 - example: apple – red/round/sweet/... etc.
 - properties and object have been experienced together beforehand

44

Retrieval from Long-term Memory

- Retrieval-cue theory
 - principle of similarity
 - concepts are associated because they share some common properties (irregardless if they have been experienced together or not)
 - example: apple and fire engine (red color)
 - gives the ability to quickly generate a list of items from memory that are red, with names that start with A, etc.

45

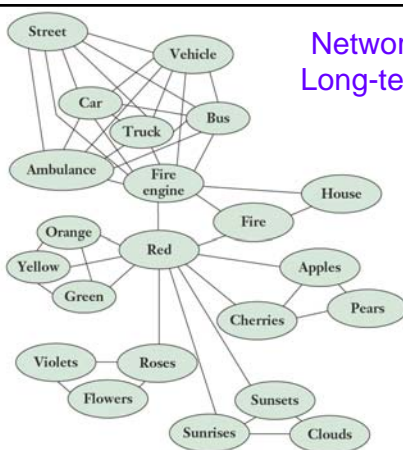
Network Model of Long-term Memory Organization

(Collins & Loftus 1975)

- Long-term memory as large network of mental concepts linked by associations (pointers)
- Spreading activation model
- Strength of association (distance) determines the speed at which one concept speeds up the ability to recall or recognize the other
- Connecting links between concepts in memory provided by common properties

46

Network Model of Long-term Memory



47

Retrieval through Spreading Activation

- Spreading activation model
 - activation of any one concept initiates a spreading of activity to nearby concepts and primes them so that they are more retrievable than they were before
 - spreading activation declines with distance
 - closer concepts receive more priming than those further away

48

The Constructive Aspect of Memory

- Retrieval from memory is not simply a readout of the original information but a *construction* built and rebuilt from various sources
- Remembering is
 - active
 - inferential and adaptive
 - guided by general knowledge and intuition about the world
 - cued by the present environment

49

Construction: Encoding and Retrieval

- Encoding
 - only part of the information dealt with in working memory is encoded into LTM
- Retrieval:
 - encoded pieces of knowledge are supplemented by logic and general knowledge
 - includes what *must* have happened
 - with repeated retrieval, it becomes harder to distinguish between the actual encoding and what was added later
 - *distortions* due to the constructive aspect of memory

50

Distortions in Memory

- 'False' memory construction due to pre-existing beliefs
 - schemas (Bartlett 1932)
 - generalized mental concepts
 - highlights the role of general knowledge or beliefs in more specific memories
 - concepts that involves spatial or temporal relationships between individual objects
 - example: schema of living room
 - tendency to remember the actual information being more like the standard schema than it really was
 - gaps in the particular is filled with information from schemas

51

Distortions in Memory

- Pre-existing beliefs
 - scripts (Schank & Abelson 1977)
 - schema that involves the organization of events in time
 - example: birthday party
 - suggestions and imagination
 - effects of events that occur after the to-be-remembered event was encoded
 - example: in court
 - manner of questioning affects the memories that are generated

52

Distortions in Memory

- Suggestions and imagination (cont'd)
 - eyewitness testimony (Loftus & Palmer 1974)
 - question: "how fast were the cars going when they ...
 - *hit* each other?"
 - *smashed into* each other?"
 - second version elicited estimates of faster speed and broken glass
 - causes: source confusion (Mitchell & Johnson 2000)
 - source: first hand experience / through others / imagination
 - Mind organizes information in a meaningful way but obscures the ties between each items and its original source

53

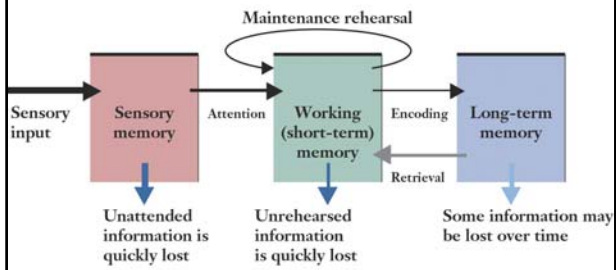
To Sum up: Multiple Memory Systems

- Describing the entire range of phenomena classified as memory
- Memory refers to all effects of prior experience on subsequent behavior
- Memory involves both conscious and unconscious mental processes

54

Modal Model of the Mind

(Atkinson & Shiffrin 1968)



55

Next week

• Memory and Reasoning

- problem solving
- mental models
- analogical representations
- preferences

6.7

56