Human-Computer Interaction

Termin 3: The Human
Movement, Memory,
Attention, Thinking, Emotion

Movement

How does the way we move affect our interaction with computers? E.g. hitting a button in response to question

- time taken to respond to stimulus =
  reaction time + movement time
- movement time: dependent on age, fitness, etc.
- reaction time: dependent on stimulus type
  - visual ~ 200ms
  - auditory ~ 150 ms
  - pain ~ 700ms
  - combined ~ quickest response!
- decreasing reaction time decreases accuracy in the unskilled operator, but not in the skilled operator.

Movement

- movement time depends on difficulty of the movement
  - distance to target (*D*)
  - size of target (*S*)

- Fitts' Law describes the time taken to hit a screen target:

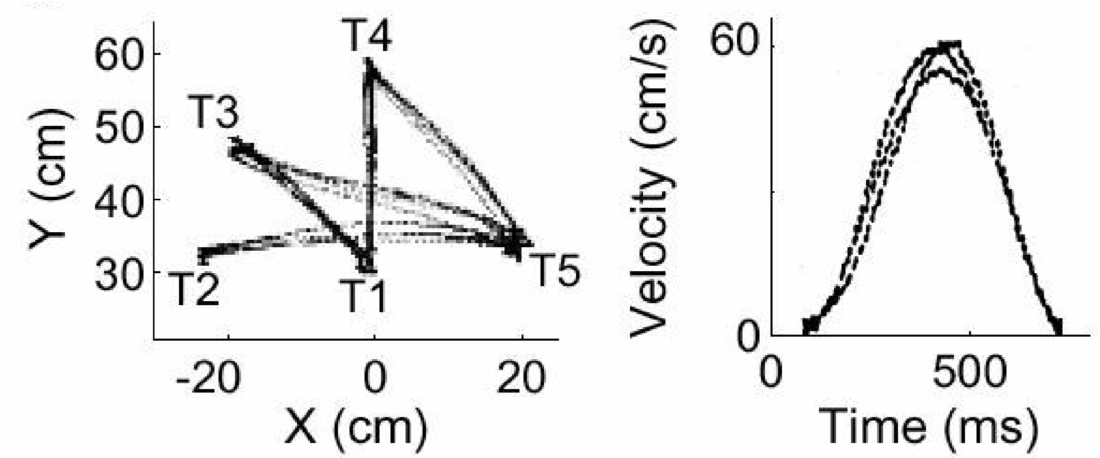
$$Mt = a + b \log_2(D/S + 1)$$

where: *a, b*: empirically determined constants, depend on person, pointing device, context, etc.

⇒ targets as large as possible, distances as small as possible!

Movement

- goal-directed hand movement consists of segments
  - linear or curved, bell-shaped velocity profiles
  - constant plane of movement in 3D
  - tend to have same movement time (*isochrony*)



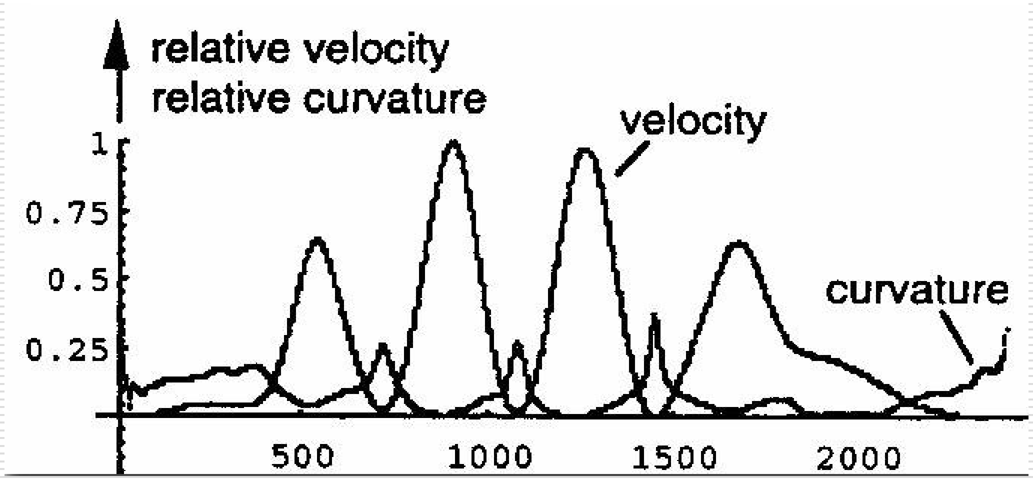
Uno, Kawato & Suzuki, 1989

Movement

- new segments start at maxima of curvature or change in plane of movement
- Law of 2/3 describes velocity at such points:

$$v(t) = k\ r(t)^{1/3} \leftrightarrow w(t) = k\ c(t)^{2/3}$$

where: *k*: constant for each segment



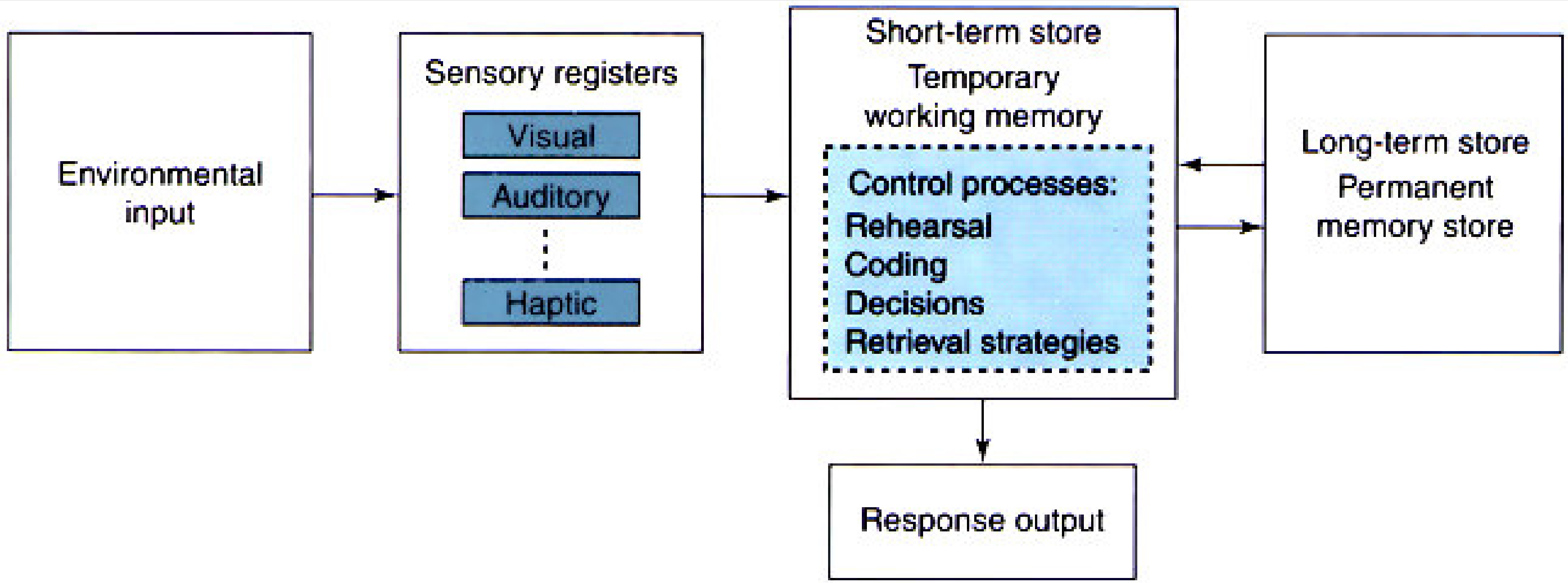
Hofmann & Hommel, 1997

→ hints for movement analysis, e.g., direct manipulations or gesture recognition in VR

Memory

- Sensory memory
- Short-term memory
- Long-term memory
- Semantic memory
- Episodic memory
- Working memory
- …

Atkinson & Shiffrin (1968): Multi-store model



Standard theory of memory & information processing, also “Modal model”

Sensory memory

- aka: buffers, store, registers, …
- modality specific buffers for stimuli received through senses (Neisser, 1967):
  - *iconic memory*: visual stimuli
  - *echoic memory*: aural stimuli
  - *haptic memory*: tactile stimuli
- examples
  - Move finger in front of eye, “sparkler” trail
  - stereo sound because we have brief ‘play-back’
- allow higher-level processes to select and access sensory information, especially when we need to be tuned to them

Sensory memory

- large capacities
- information lasts only short durations
  - iconic memory: ~250-400 msec
  - echoic memory: only little longer
- memories are "washed out" or "masked" (*decay*) or somehow displaced by new incoming information
  - iconic memory: By the time ~4 items have been extracted from the sensory memory, the remaining contents have been *decayed*
  - decay rate depends on intensity, contrast, duration of stimulus, following of another stimulus (*masking*)

Sensory memory

Sperling (1960):

- Presented an array of letters for 50 milliseconds

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

- *Whole-report method*: recall as much as possible
  - People recall 4.5 letters on average
  - Report that letters "fade away" before they can report them all
- *Part-report method*: only certain elements from array
  - Employs a tone (high, medium, low) to cue subjects to report a particular row
  - Recall a higher percentage of letters, depending on delay of tone: 50ms: 9 (i.e. 3 per row) → 300ms: 6 → 1s: 4.5
  - Attended to and scanned the row in sensory memory, until it faded away after 1 sec.

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
- limited capacity
  - Miller (1956): **7 ± 2 chunks**
  - Cowan (2002): **4 ± 2 chunk**
- overcome capacity limits by *chunking*
  - grouping info into larger meaningful units
  - *closure*: successful formation of chunks, also seen in everyday tasks held in STM
  - trying to find familiar pattern abstractions, individual differences, e.g., chess masters vs. novices

Examples

2123482278493202

0121 414 2626

FB-ITW-AC-IAIB-M

FBI-TWA-CIA-IBM

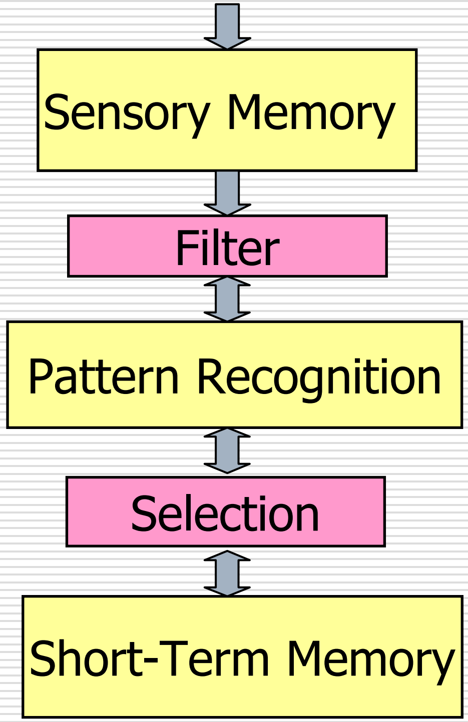
Exercise:

This is a task women against men!

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

Attention

- bottleneck theories
  - Filter theory: attention determines what info reaches pattern recognition stage through filter
  - Late-selection model: attention selects information for memory
- capacity theories
  - Selection can occur everywhere
  - depending on mental effort
- Automatic skills are those that require little mental effort



(cf. Reed. 2000)

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

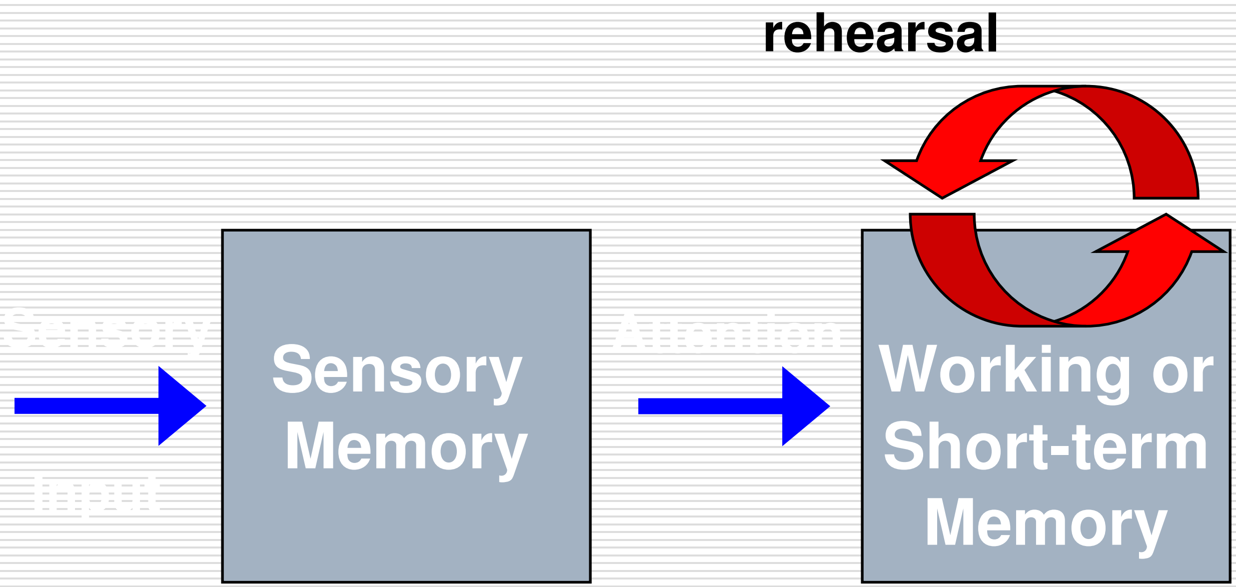
- what is the number?

857-9163

The number lasted in your short-term memory longer than 30 seconds. How were you able to remember the number?

STM - maintenance rehearsal

- *rehearsal*: Mental or verbal repetition of information allows information to remain in working memory longer than the usual 30 seconds



STM - maintenance rehearsal

- what happens if you can’t use maintenance rehearsal?
- to demonstrate, again memorize a phone number, BUT count backwards from 1,000 by sevens (i.e., 1014, 1007, 1000 … etc.)

STM – maintenance rehearsal

- what is the number?

628-5094

Without rehearsal, memory fades.

Working memory

- the place where basic cognitive operations are carried out (comprehension, decision making, problem solving, …)
- somehow related/identical to STM

But, how do we use the STM as working memory?

WM = STM + central executive

Baddley et al. (1974 - ongoing)

Central Executive

planning future actions, initiating transfer to & retrieval from LTM, decision processes, integrating information, *Controlled* attention

Phonological loop

maintain & manipulate speech- & sound-related info; contains a phonolog. store & rehearsal mechanism

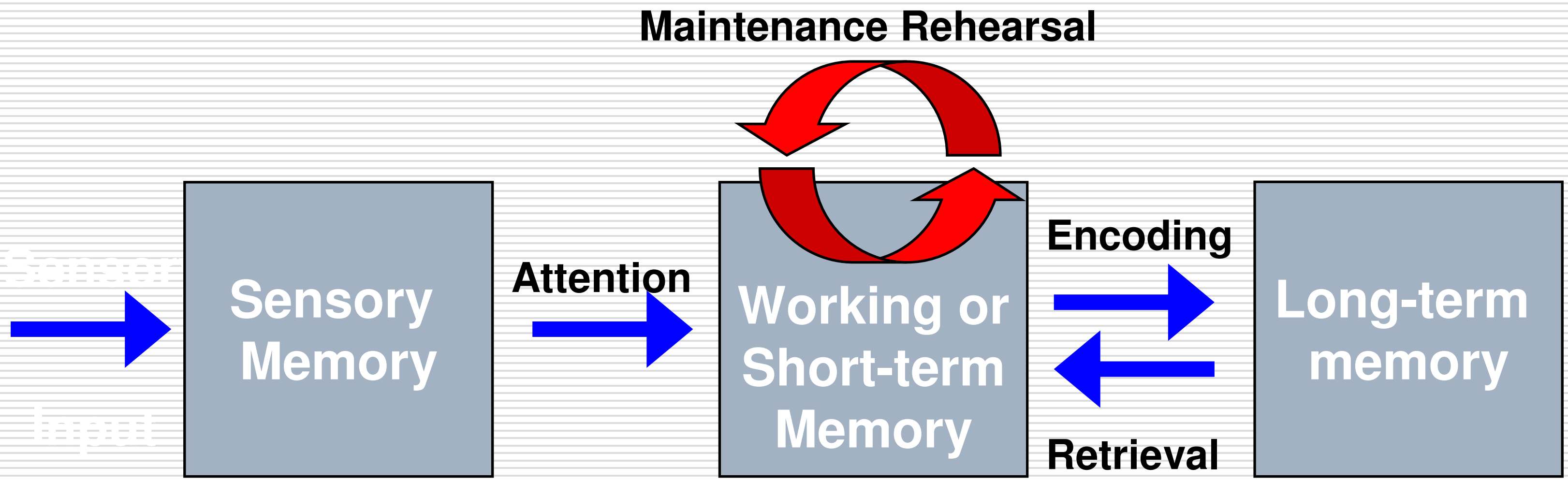
Visuospatial sketchpad

maintain & manipulate visual or spatial info

STM

Long-Term Memory

- Once information passed from sensory to working memory, it can be encoded into long-term memory



Long-term memory (LTM)

- Repository for all our knowledge
  - slow access ~ 1/10 second
  - slow decay, if any
  - huge or unlimited capacity

- Two types
  - episodic
  - semantic

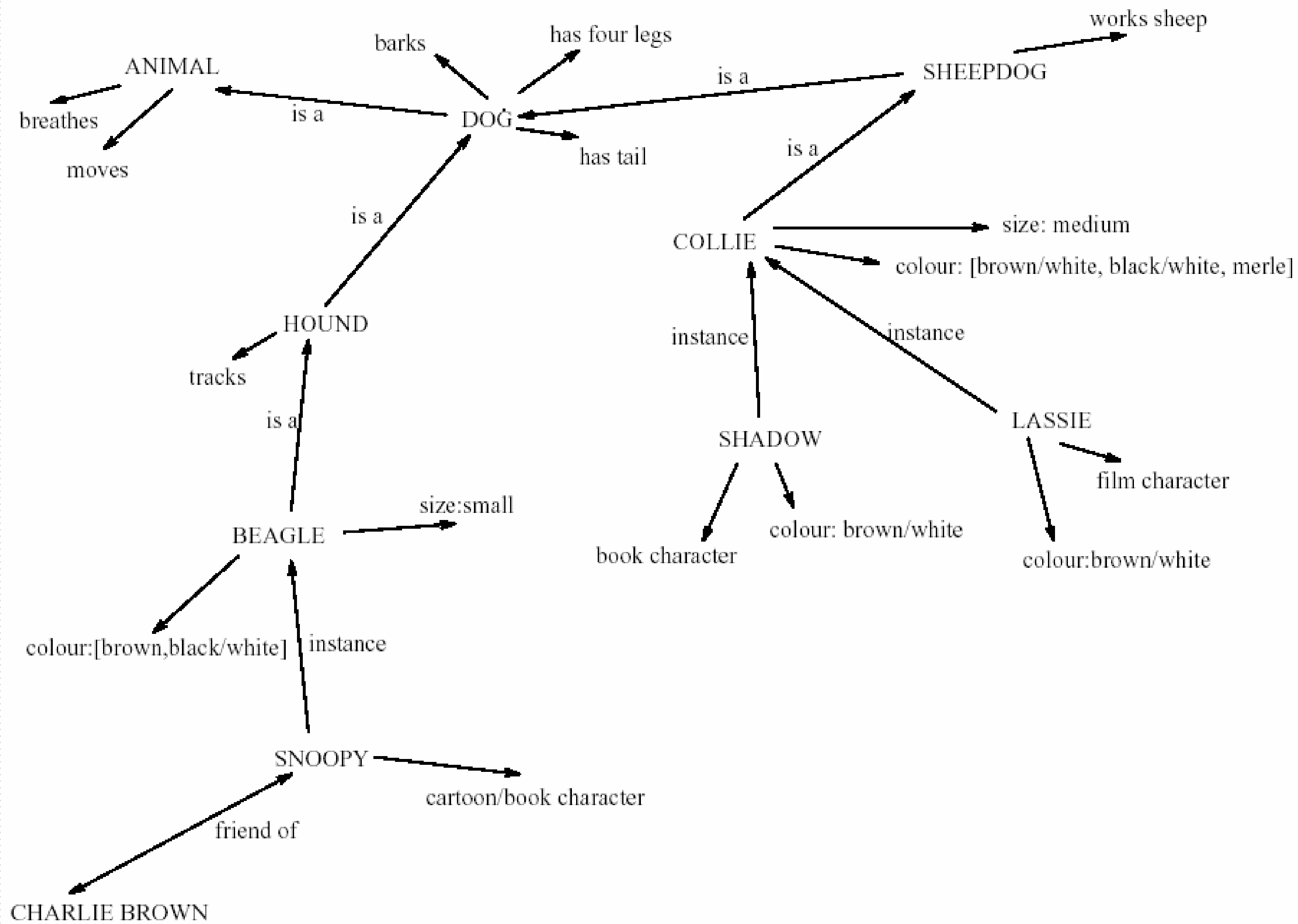
LTM - semantic & episodic memory

- Semantic Memory
  - structured memory of facts, concepts, skills, meaning of words and things
  - abstracted and generalized (not tied to specific place, time or event)
- Episodic Memory
  - serial, biographical memory of events
  - memory tied to explicit autobiographical events
  - subjective sense of “being there”
- Distinction supported by neuropsychological evidence
  - Frontal lobe patients and some amnesics have relatively intact semantic memories, but are significantly impaired in their memories of events.

Models of LTM

- Semantic memory structure
  - provides “associative” access to information
  - represents relationships between bits of information
  - supports inference
- Model: semantic network (e.g., ACT-R)
  - inheritance – child nodes inherit properties of parent nodes
  - relationships between bits of information explicit
  - supports inference through inheritance

Models of LTM - semantic network



Models of LTM – frames

- Information organized in data structures (*object-centred*)
- Slots in structure instantiated with values for instance of data
- Definitory values, default values, variable values
- Type–subtype relationships

DOG	**COLLIE**
Fixed legs: 4 Default diet: carniverous sound: bark Variable size: colour:	Fixed breed of: DOG type: sheepdog Default size: 65 cm Variable colour:

Models of LTM - scripts

- Model of stereotypical information required to interpret a *situation*
- Script has fixed structure → elements that can be instantiated with values for context

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*	Scenes:	*arriving at reception* *waiting in room* *examination* *paying*
Props:	*examination table* *medicine* *instruments*	Tracks:	*dog needs medicine* *dog needs operation*

Models of LTM - production rules

- Representation of *procedural* knowledge
- Condition/action rules

  if condition is matched

  then use rule to determine action.

IF dog is wagging tail
THEN pat dog

IF dog is growling
THEN run away

LTM - storage of information

- rehearsal
  - information moves from STM to LTM
- total time hypothesis
  - amount retained proportional to rehearsal time
- distribution of practice effect
  - optimized by spreading the learning over time
- structure, meaning and familiarity
  - information about objects 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 more easily incorporated into memory

LTM - forgetting

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

memory is selective …

… affected by emotion – can subconsciously `choose' to forget

LTM – information retrieval

recall

- information reproduced from memory
- can be assisted by cues, e.g. categories, imagery

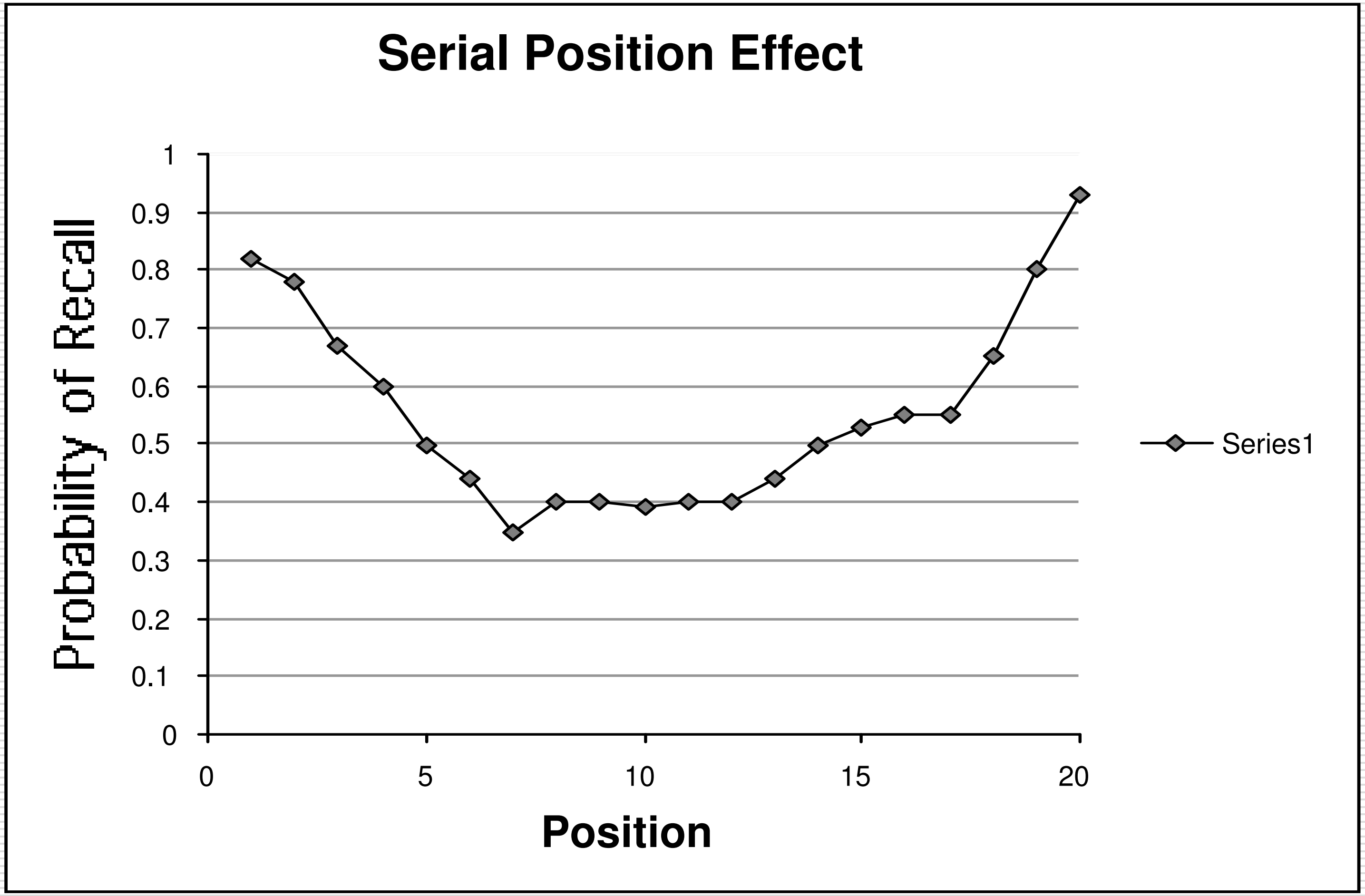
recognition

- present information gives knowledge that it has been seen before
- less complex than recall - information is provides as a cue

Retrieval

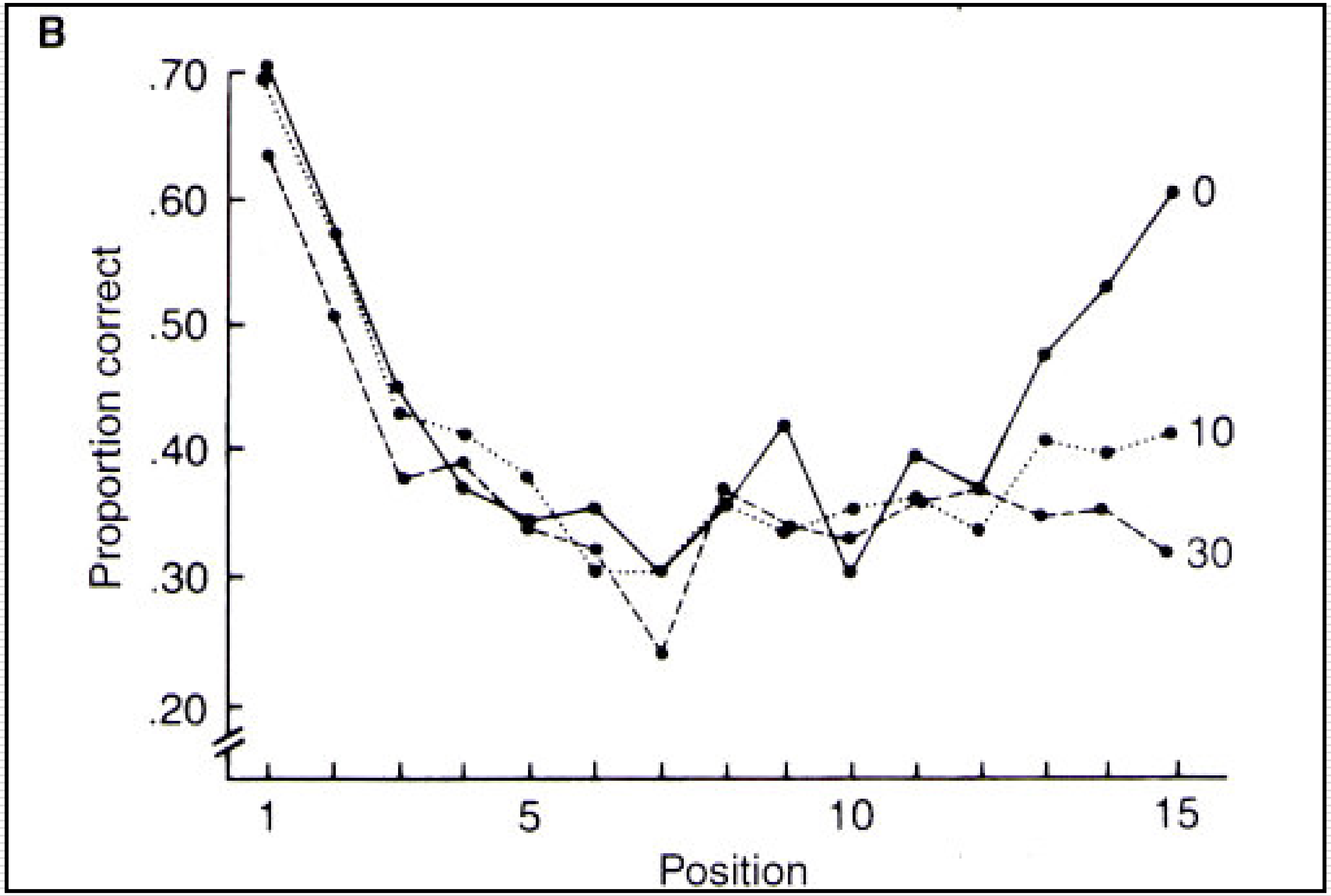
- Free recall list learning (Glanzer & Cunitz, 1966):
  - Subjects presented with a list of words (usually 15 to 20) auditorily
  - Results: Subjects were more likely to remember the words at the beginning (*Primacy*) and end of the list (*Recency*).
- Study provides evidence for the distinction between LTM and STM
  - Recency effects reflect limited STM capacity
  - Primacy effects reflect transfer to LTM via rehearsal
  - Primacy effect somewhat more robust than recency: less affected by interference

Recency and Primacy effects



Effect of delay

Delay & interference with another task wipe out the recency effect, but not the primacy effect.



Thinking

Reasoning

deduction, induction, abduction

Problem solving

Deductive Reasoning

- Deduction:
  - derive logically necessary conclusion from given premises

    e.g. If it is Friday then she will go to work
    It is Friday,
    therefore she will go to work.

- Logical conclusion not necessarily true:

    e.g. If it is raining then the ground is dry
    It is raining,
    therefore the ground is dry

  Correct, but true?

Deduction

- When truth and logical validity clash …

  e.g. Some people are babies

  Some babies cry

  Inference - Some people cry

  Invalid since we are not told that all people are babies.

- People bring world knowledge to bear

Inductive Reasoning

- Induction:
  - generalize from cases seen to cases unseen

    e.g. all elephants we have seen have trunks
    therefore all elephants have trunks

- Unreliable:
  - can only prove false not true (you never know)

  … but useful!

- Humans not good at using negative evidence

    e.g. Wason's cards

Wason's cards

7 **E** **4** **K**

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

Is this true?

How many cards do you need to turn over to find out?

…. and which cards?

Abductive reasoning

- reasoning from event to cause

  e.g. Sam drives fast when drunk.
  If I see Sam driving fast, assume drunk.

- Unreliable:
  - can lead to false explanations
  - generates hypotheses

Problem solving

- Process of finding solution to unfamiliar task using knowledge

- Problem space theory
  - problem space comprises problem states
  - problem solving involves generating states using legal operators
  - heuristics may be employed to select operators e.g. *means-ends analysis*
  - operates within human information processing system, i.e., suffers from STM limits etc.
  - largely applied in AI to problem solving, mostly in well-defined and well-understood areas, e.g. puzzles or chess, rather than knowledge intensive areas

Problem solving – analogy, skill

- analogical mapping
  - novel problems in new domain?
  - use knowledge of similar problem from similar domain
  - difficult if domains are semantically different

- skill acquisition
  - skilled activity characterized by *chunking*
  - a lot of information is chunked to optimize STM, e.g., see chess masters
  - conceptual rather than superficial grouping of problems
  - information is structured more effectively

Errors and mental models

Types of error

- slips
  - right intention, but failed to do it right
  - causes: poor physical skill, inattention, etc.
  - change to aspect of skilled behaviour can cause slip
- mistakes
  - wrong intention
  - cause: incorrect understanding of task or situation
  - humans create *mental models* to explain and predict behaviour, e.g., of computer system. If wrong model (different from actual system), errors can occur.

Emotion

- Various theories of how emotion works
  - James-Lange: emotion is our interpretation of a physiological response to a stimuli
  - Cannon: emotion is a psychological response to a stimuli
  - Schachter-Singer: emotion is the result of our evaluation of our physiological responses, in the light of the whole situation we are in
- Emotion clearly involves both cognitive and physical responses to stimuli

Emotion

- The biological response to physical stimuli is called *affect*
- Affect influences how we respond to situations
  - positive $\rightarrow$ facilitate problem solving
  - negative $\rightarrow$ 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)

- Implications for interface design
  - stress will increase the difficulty of problem solving
  - relaxed users will be more forgiving of shortcomings
  - aesthetically pleasing and rewarding interfaces will increase positive affect

Individual differences

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

Ask yourself:
will design decision exclude section of user population?

Psychology and the Design of Interactive System

- Some direct applications
  - e.g. blue acuity is poor
    $\Rightarrow$ blue should not be used for important detail

- However, correct application generally requires understanding of context in psychology, and an understanding of particular experimental conditions

- A lot of knowledge has been distilled in
  - guidelines
  - cognitive models
  - experimental and analytic evaluation techniques

we will get there…