Human processor, cognitive abilities and memory

Model Human Processor (1)

Very simple “model” of a **human interacting** with a computer

See Card, Moran and Newell 1983, and Dix Chapter 1

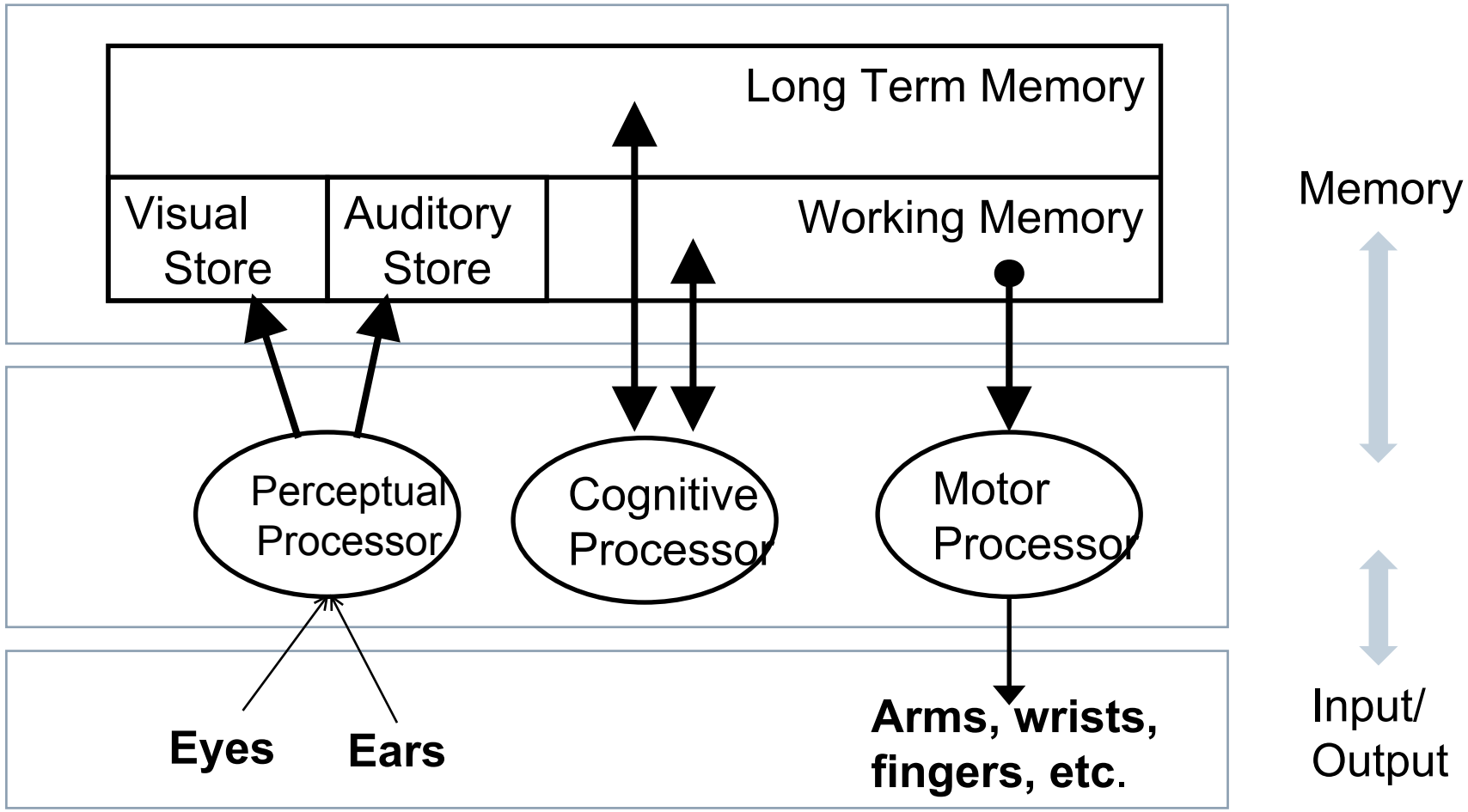
The model describes the human as **three sub-systems**

- **Perceptual system**
  (acquire input from the real world)
- **Motor system**
  (manipulate the real world)
- **Cognitive system**
  (connection between input and output, basic processing and memory)

Each subsystem includes:

- Processing
- Memory

Model Human Processor (2)



From Computer Science 498bpb, Psychology of HCI

Example : Visual Processor

https://www.youtube.com/watch?v=vJG698U2Mvo&ab_channel=DanielSimons

Model Human Processor (3)

The model can explain how long certain tasks will take

Examples for Reaction/processing time:

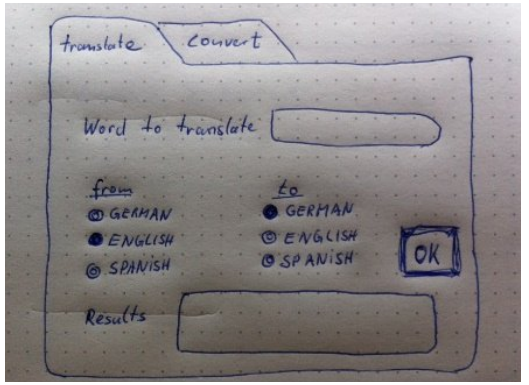
- Perception (stimulus); typical time: TP ~ 100ms
- Simple decision; typical time: TC ~ 70ms
- Minimal motion; typical time: TM ~ 70ms

Further example for complex motor action: see Fitts' law, KLM

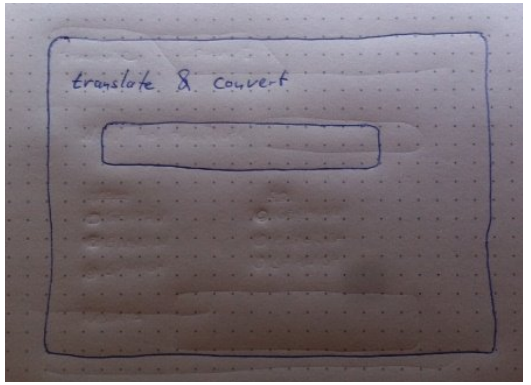
Model Human Processor (3)

Overall time for operation where there is a sequential processing

- Pressing a button when a light comes on ?
  - 240ms
  - T = TP + TC +TM
- Matching a symbol and then pressing one of the two buttons ?
  - 310ms (2TC because there is comparison and decision)
  - T = TP + 2TC + TM



vs.



Processing can also be “**parallel**”
(e.g., phoning while writing, talking while driving, …)

Movement

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 ~ 150ms
  - Pain ~ 700ms

- Interesting for programming games
- $t = \sqrt{\frac{2d}{9.81\ m/s^2}}$
  - d = distance in meters
  - t = reaction time

Human Information Processing

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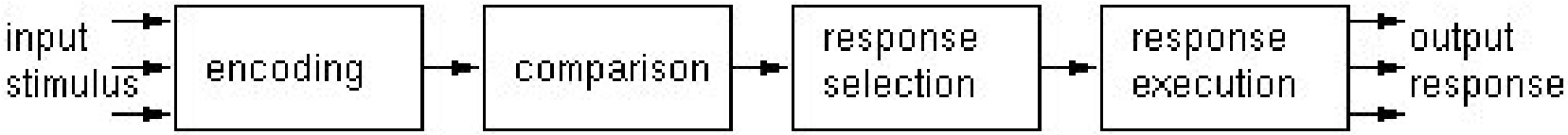
Sequential four-stage process



- Encode stimulus received from the environment into an internal representation
- Compare the encoded stimulus with stored / memorised representation
- Formulate / select a response to received and encoded stimulus
- Act on the stimulus and execute the response

Lindsay, P.H. and Norman, D.A. (1977). Human Information Processing: An Introduction to Psychology, 2nd edition. New York: Academic Press.
Source (text, image): http://web.cs.dal.ca/~jamie/teach/NickGibbins/psych.html

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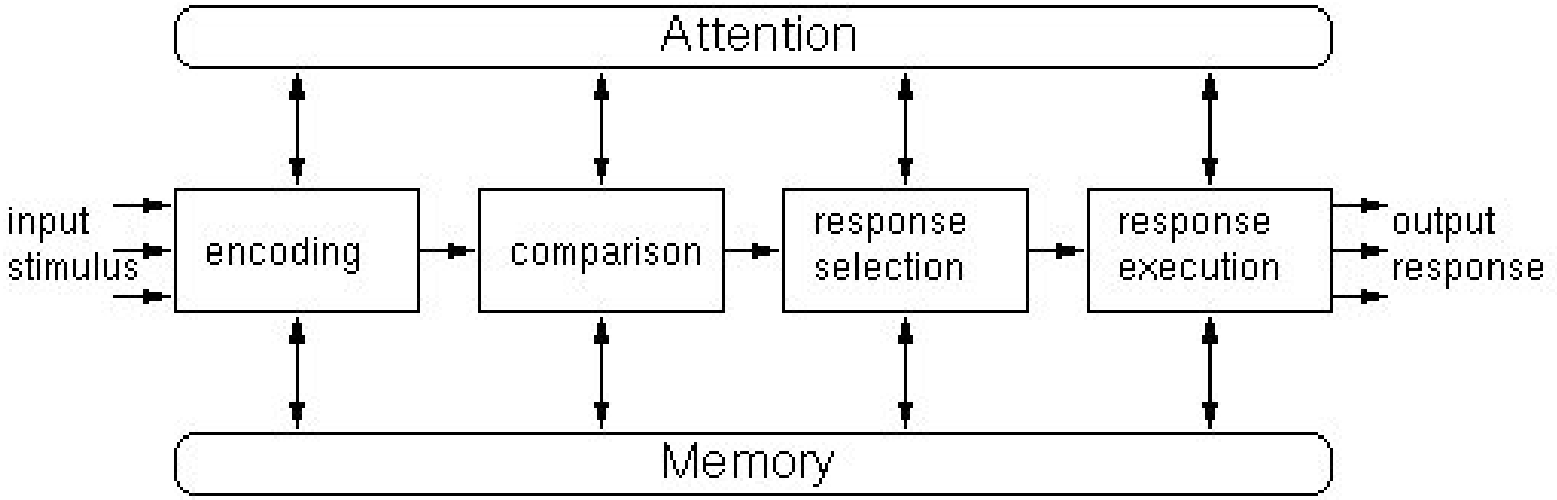
Extended four-stage process
Attention and memory are relevant in all 4 stages

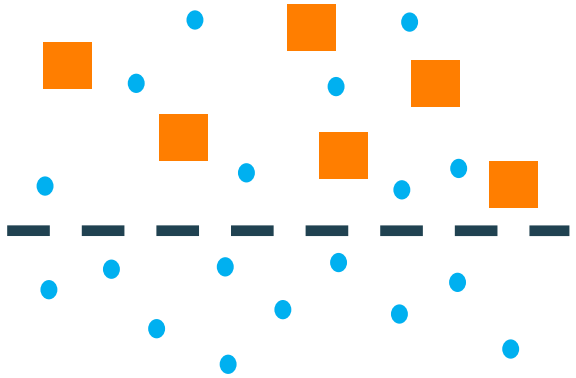


Barber, P (1988). Applied Cognitive Psychology. London: Methuen.
Source (text, image): http://web.cs.dal.ca/~jamie/teach/NickGibbins/psych.html

Excurse: Attention

Like a Filter?

- Attention acts as filter
- “Relevant” stimuli are accepted
- Others are filtered out



Like a Bottleneck?

- Attention as a limited resource
- The capacity is limited
- Only parts “get through”
- Coding is relevant

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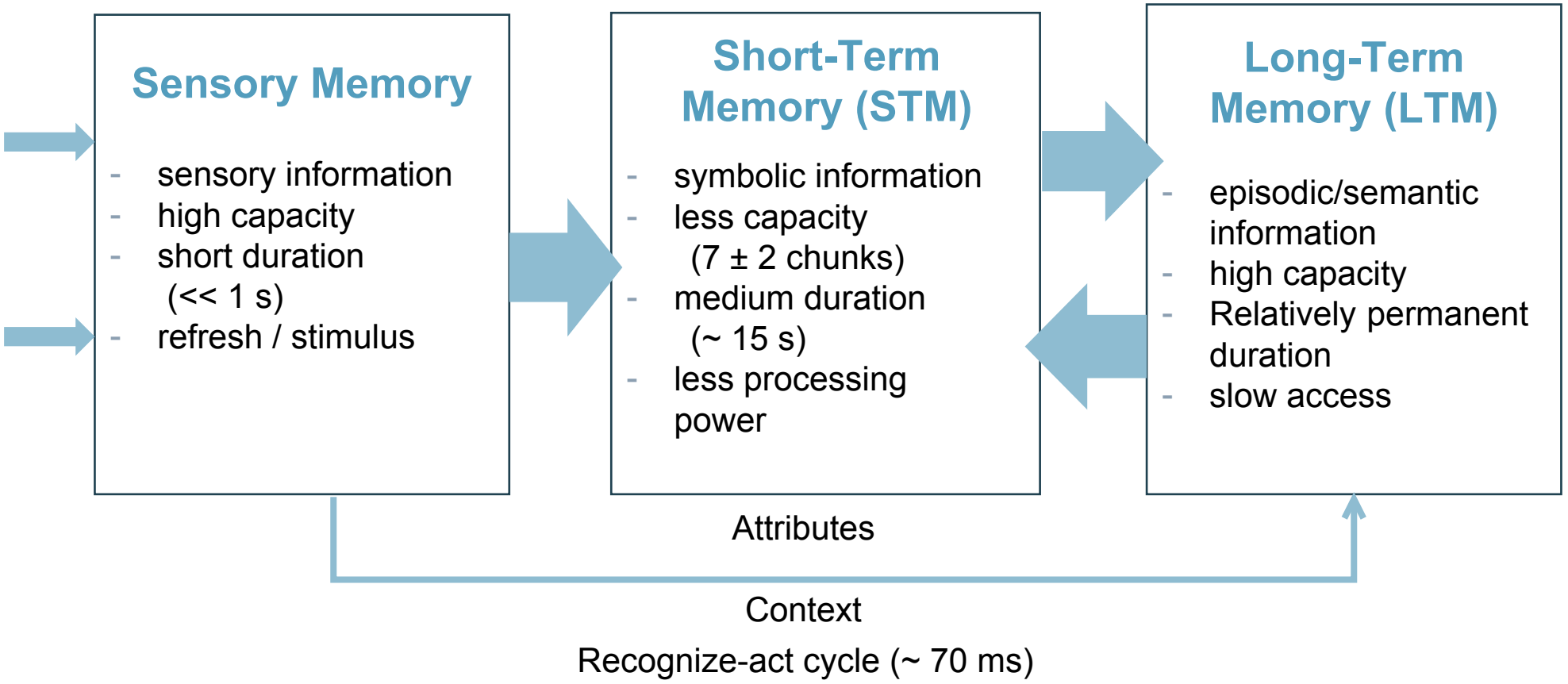
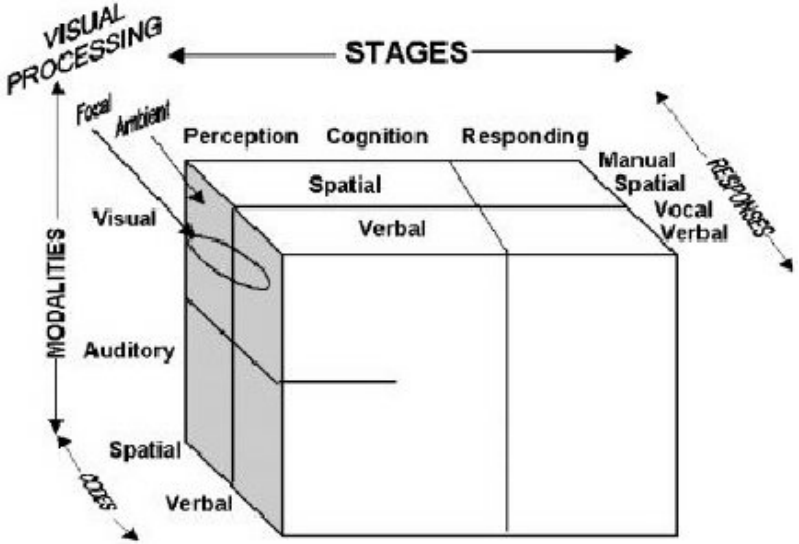
Multi-Store Model for visual and oral perception



Wickens 4 - Dimensional Multiple Resource Model

- **Four** important dimensions explain the variance in time-sharing performance
- Each dimension has **two discrete 'levels'**
- Two tasks that both demand one level of a given dimension (e.g., two tasks demanding visual perception) will **interfere** with each other more than two tasks that demand separate levels on the dimension

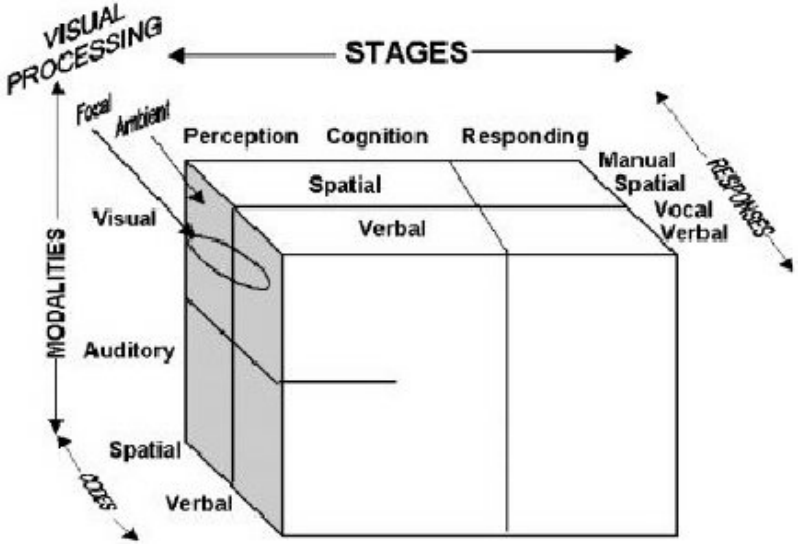


Source: Wickens, C. D.: Multiple resources and performance prediction. Theoretical Issues in Ergonomics Science. S.159–177, 2002.

Wickens 4 - Dimensional Multiple Resource Model

Four dimensions are:

- Processing stages
- Perceptual modalities
- Visual Channels
- Processing codes



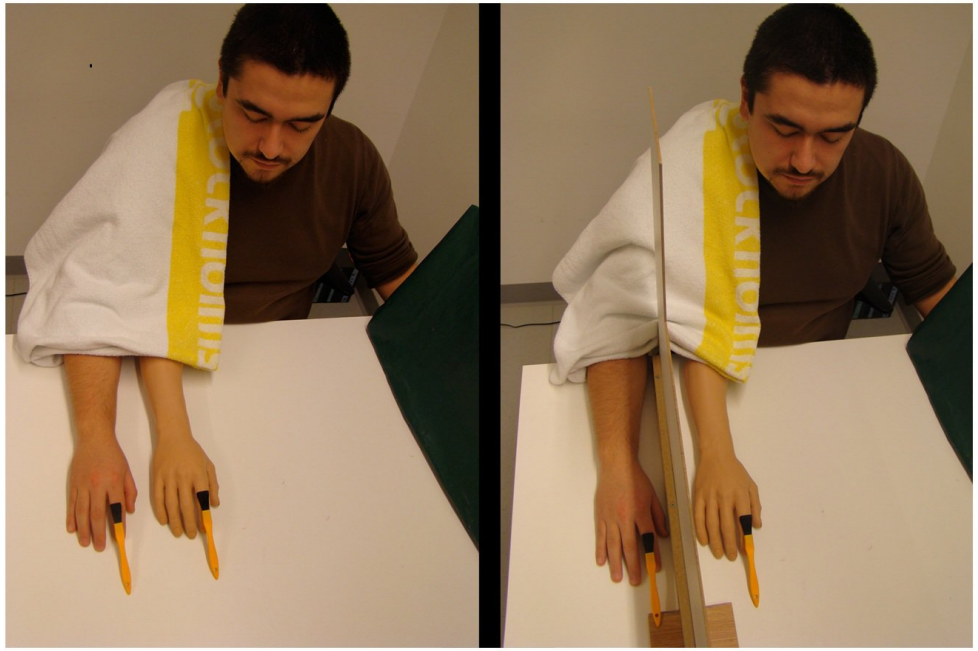
Source: Wickens, C. D.: Multiple resources and performance prediction. Theoretical Issues in Ergonomics Science. S.159–177, 2002.

Implications:

- Tasks that use different levels are
- easier to do than tasks that require “more” of one level
- Listening to 2 conversations?
- Searching a photo while listening?

Rubber-Hand illusion

Visual information overwrites proprioception



https://www.youtube.com/watch?v=sxwn1w7MJvk

Memory

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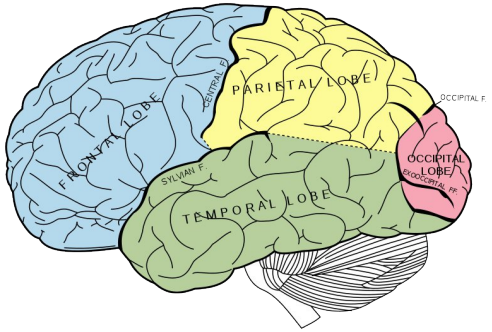
Involves encoding and recalling

- Knowledge and acting appropriately
- **We don't remember everything** – involves filtering and processing
- **Context** is important in affecting our memory
- We **recognize** things much better than being able to recall things
  - The rise of GUI over command-based interfaces
- Better at **remembering images** than words
  - The use of icons rather than names



Reproduction of a lithograph plate from Gray's Anatomy by Mysid (public domain)
https://en.wikipedia.org/wiki/File:Gray728.svg

https://en.wikipedia.org/wiki/File:Luna_Park_Melbourne_scenic_railway.jpg

Short-term memory (STM)

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Guideline: Do not overload and over strain your STM

- Use **known symbols**
- Notes, menus, lists (**WYSIWYG**)
- **Grouping**, chunks (complex super symbols)
- **Short**, closed actions

0110 1011 0111 1100
6B7C

www.mad.tf.fau.de
131.188.16.206

Guideline: Utilize STM properties

- Visualize **attributes** (icons, colors)
- Link illusion and keyword
- **Minimize distraction!**
- **Avoid inconsistent** similarity (e.g. get / set , delete / repeat)
- **Reduce Complexity**

Long-term memory (LTM)

- Context-based memory (associative links)
- Loss of access instead of erasing (forgetting)
- Duration depends on the intensity and the quality of memorizing
- Two types of LTM
  - **Episodic** : serial memory of events
  - **Semantic** : structured memory of facts, concepts, skills
- The following can train your LTM:
  - Learning by **repeated practicing**
  - **Active** learning (learning by doing)
  - **Rules** and **structures** increase the efficiency
  - Illustrate and **visualize** words

Motivation : Decision and long-term memory

Do dogs bark?

Do dogs breathe?

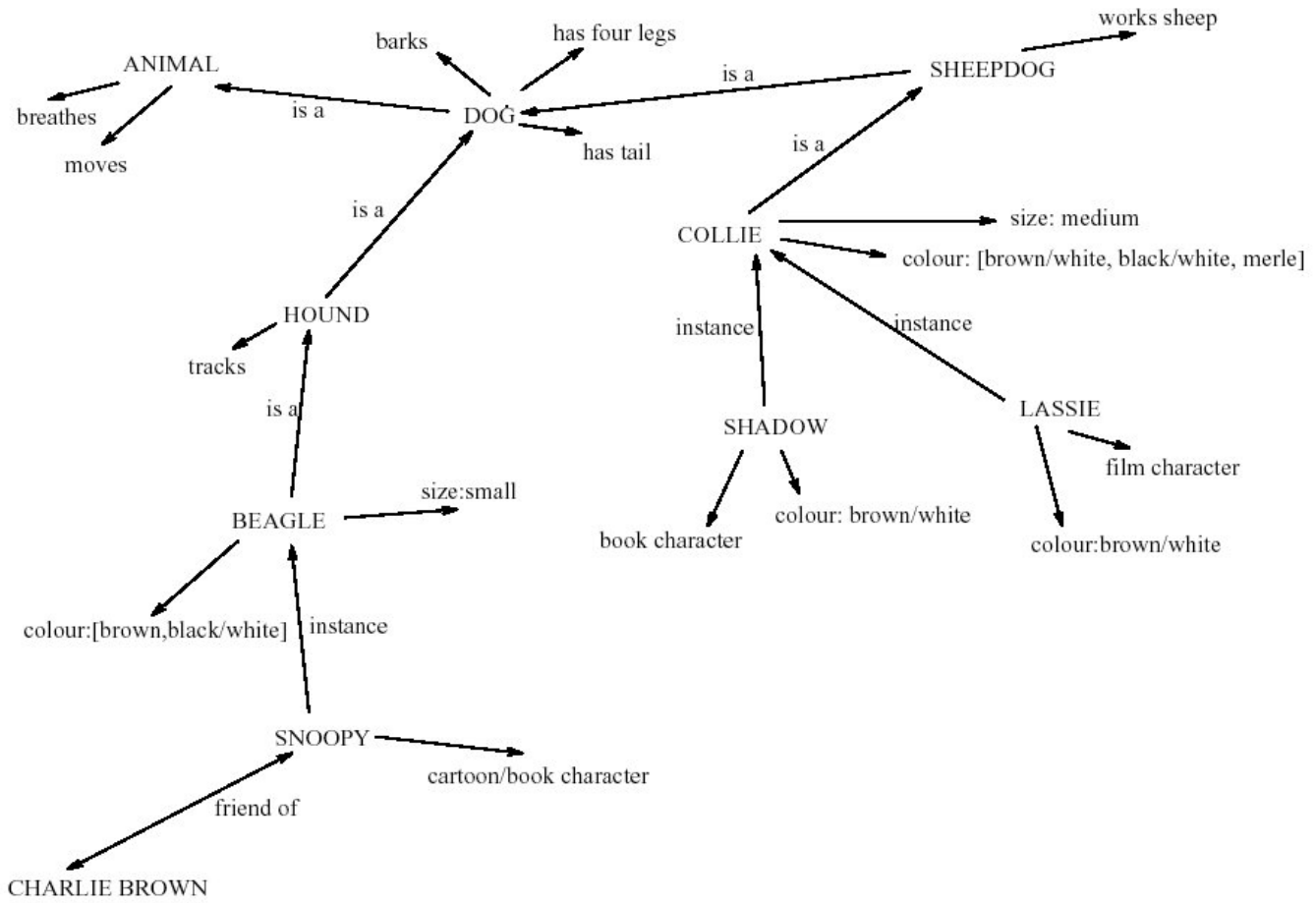
Yes | No

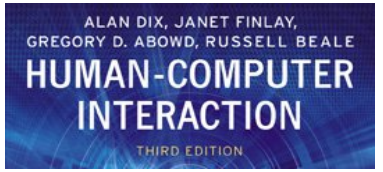
Yes | No

The second question takes longer to answer.

This indicates semantic coding.

LTM – semantic network





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 learning over time

Structure, meaning and familiarity

- Information easier to remember

LTM – Forgetting

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Decay

- Information is lost gradually but very slowly

Interference

- New information replaces old: retroactive interference
- Old may interfere with new: proactive inhibition

So may not forget at all memory is selective …

… affected by emotion – can be subconsciously ‘choose ’ to forget

Forgetting

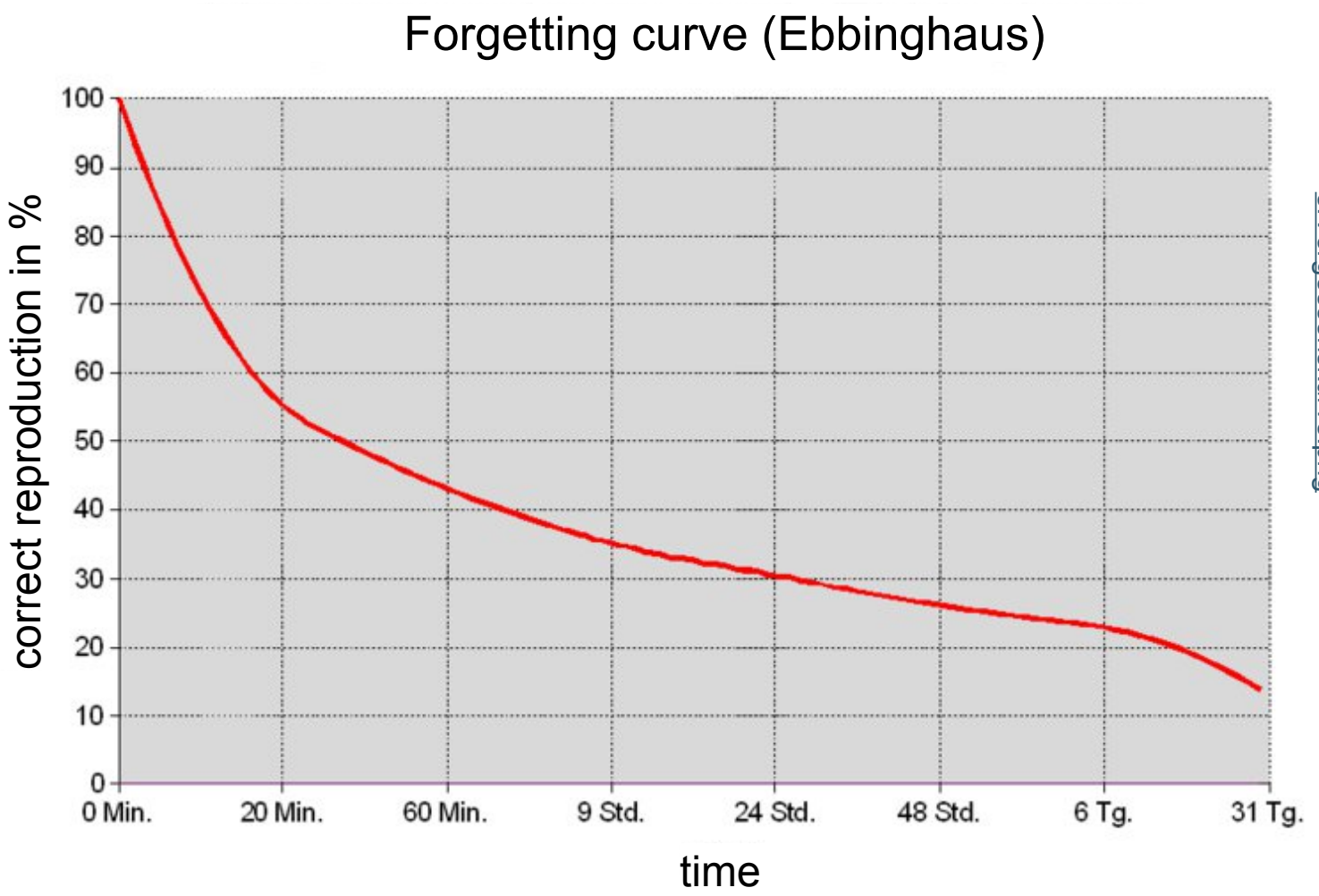


Image by Rdb (GFDL) https://commons.wikimedia.org/wiki/File:Vergessenskurve.png

LTM – Retrieval

Recall

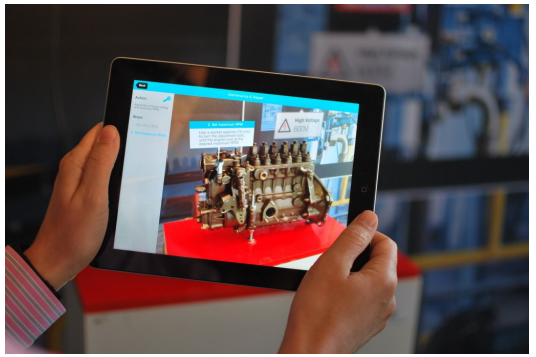
- Information reproduced from memory can be assisted by cues, e.g., categories, imagery

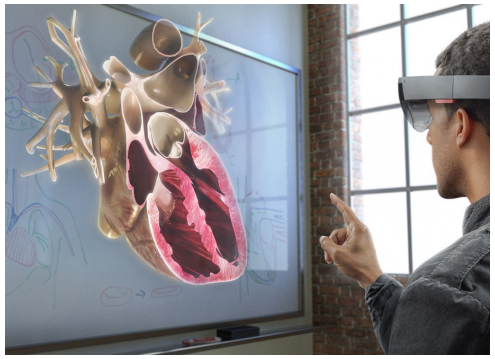
Recognition

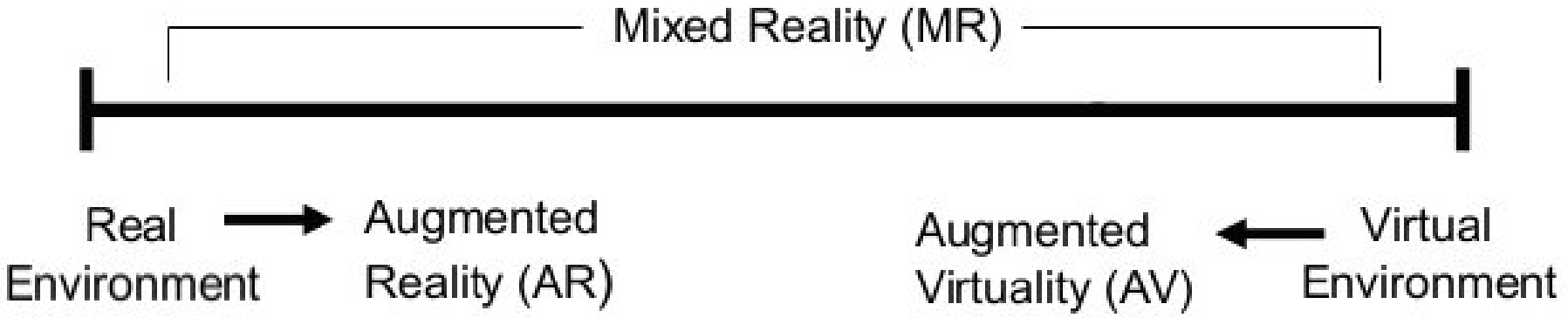
- Information gives knowledge that it has been seen before
- Less complex than recall - information is cue

Excurse: Modern Media

How does/can our learning process change?







The problem with the classic ‘7±2’

- George Miller’s theory of how much information people can remember
  (THE MAGICAL NUMBER SEVEN, PLUS OR MINUS TWO: SOME LIMITS ON OUR CAPACITY FOR PROCESSING INFORMATION, The Psychological Review, 1956, vol. 63, pp. 81-97)

- People’s immediate memory capacity is very limited

- In general, you can remember **5-9 chunks** – and chunks can be letters, numbers, words, sentences, images, …

Wrong application of theory

Many designers have been led to believe that this is a useful finding for interaction design

- 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?

- 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

Coding of Information

- Visual – image of a person
- Phonological – sound of a voice
- Semantic – meaning of what a person is saying
- Coding in Short Term Memory
- Sound is most efficient
- When users have to remember something in the application

Make it possible to code it phonological (e.g., password you can say)

Human Information Processing: Stroop Effect

Test:

- 3 groups of 6 words in different color
- Say color names of words as fast as you can
- Say done when finished
- Simple explanation: http://faculty.washington.edu/chudler/words.html
- An online version: http://faculty.washington.edu/chudler/java/ready.html

Interference:

- Strong clues in working memory
- Link to different chunks in LTM

Green
White
Yellow
Red
Black
Blue
White
Black
Yellow
Red
Blue

Paper
Fortune
Back
Homeland
Car
Paper
Homeland
Socker
Fortune
Back
Soccer

Blue
Green
Black
White
Red
Yellow
Red
White
White
Red
Yellow

Human Information Processing

Human Communication

- Inaccurate, full of assumptions, not complete & Short
- Structured information (forms, dialog boxes)
- Require confirmation

Thinking / Deciding

- Either broad and flat Or narrow and deep
- Limited number of alternatives
- Avoid frequent repetitions

Thank you for your attention