MEMORY

STORES OF MEMORY

A. What is memory?

B. Stores of memory
   a) Sensory memory
   b) Short-term/Working memory (STM/WM)
   c) Long-term memory (LTM)

C. Memory disorders: Some case studies

D. In search of the neurobiology of memory

WHAT IS MEMORY ?

Memory as... *(Tulving, 2000)*

- a hypothetical store, in which info is held ?
- the total information within that 'store' ?
- a specific memory-related property of that info ? (e.g. 'trace strength')
- the process of retrieval of that information ?
- one's phenomenal awareness of remembering ?
- a neurocognitive capacity to encode, store, and retrieve ?

WHAT IS MEMORY ?

Memory is the conscious or nonconscious *process* by which we encode, store, and retrieve information

- *Encode:* coding once perceived → memory trace formation
- *Store:* keeping memory trace within some mental organization
  - ➥ *Must be inferred from observable, measurable responses (e.g., memory test performance..)*
- *Retrieve:* calling back the memory trace

STORES OF MEMORY

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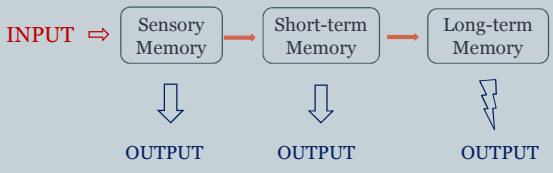
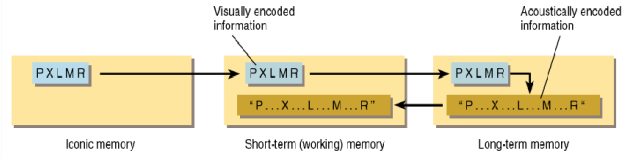
CANONICAL MODEL OF MEMORY SYSTEMS

Old model:



STORES OF MEMORY



From: Carlson et al. (2007) Psychology: The Science of Behavior, Allyn & Bacon

STORES OF MEMORY

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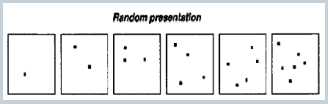
SENSORY MEMORY

Each sense feeds in information to the sensory memory, where they leave a very brief trace...

- in vision → iconic (sensory) memory
- in audition → echoic (sensory) memory
- in smell → olfactory (sensory) memory
- in touch → haptic (sensory) memory
  - tactile *(sense of touch)*
  - kinesthetic *(sense of muscles, body movement)*
- in taste → gustatory (sensory) memory

SENSORY MEMORY: Iconic

Averbach (1963):



Task: «How many dots?»

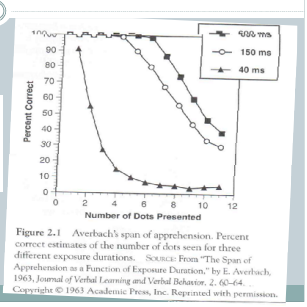


Figure 2.1 Averbach's span of apprehension. Percent correct estimates of the number of dots seen for three different exposure durations. SOURCE: From "The Span of Apprehension as a Function of Exposure Duration," by E. Averbach, 1963, *Journal of Verbal Learning and Verbal Behavior, 2*, 60–64. Copyright © 1963 Academic Press, Inc. Reprinted with permission.

SENSORY MEMORY: Iconic

Sperling (1960): First major study of sensory memory…

A. «whole report method» *(→ 'immediate memory')*

Stimulus display
(50 msec)

F C H D
J R P O
D N B A

SENSORY MEMORY: Iconic

Sperling (1960): First major study of sensory memory…

B. «partial report method» *(→ 'sensory memory')*

Stimulus display
(50 msec)

Tone

F C H D ← High pitch
J R P O ← Medium pitch
D N B A ← Low pitch

Check-out:

https://www.youtube.com/watch?v=GkZNHe49GcA

https://www.youtube.com/watch?v=ACddnsfgJ7I

SENSORY MEMORY: Iconic

Main finding:

- 3-4 letters/numbers w/ whole report
- 9-12 letters/numbers w/ partial report
- delaying probe tone w/ partial report techn. by
  - 0 sec. (0)
  - 150 ms (.15)
  - 500 ms (.50) → major loss of info
  - 1 sec (1.0)→ regressing to ~ 4 items (i.e. whole-report performance)

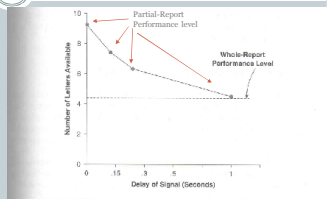


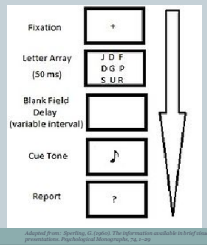
Figure 3.2 Estimated Number of Letters Available Across Delays Exceeding to 1 Second Under Conditions of Partial Report

SOURCE: From Sperling, G., "The information available in brief visual presentations," in *Psychological Monographs*, © copyright © 1960, American Psychological Association. Reprinted with permission.

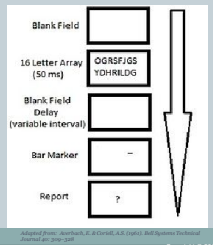
From: M. B. Howes «Human Memory»

SENSORY MEMORY: Iconic

Sperling (1960):



Averbach & Coriell (1961)



Adapted from: Sperling, G. (1960). The information available in brief visual presentations. *Psychological Monographs*, *74*, 1–29.

Adapted from: Averbach, E. & Coriell, A.S. (1961). Bell Systems Technical Journal pp. 309–328

SENSORY MEMORY: Iconic

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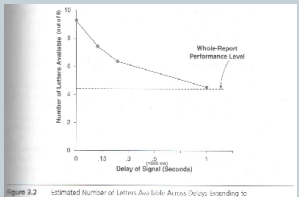

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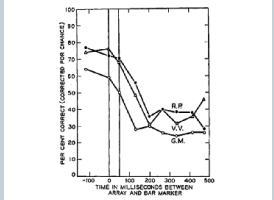


Fig. 4 — Results of memory experiment; "R.P.," "V.V." and "G.M." identify the three subjects participating.

Adapted from: Averbach, E. & Coriell, A.S. (1961). Bell Systems Technical Journal pp. 309–328

SENSORY MEMORY: Iconic

Sperling's main findings: Whole report condition

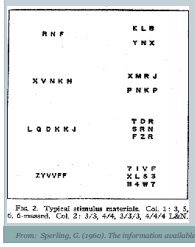


FIG. 2. Typical stimulus materials. Col. 1: 3, 5, 6, 6-missed. Col. 2: 3/3, 4/4, 3/3/3, 4/4/4 L2KN.

About **4-5 items** correctly reported,

- ★ **regardless of type of layout (n*m matrix) !**
- ★ **regardless of exposure duration !**
  (15, 50, 150 or 500 ms)

From: Sperling, G. (1960). The information available in brief visual presentations. Psychological Monographs, 74, 1–29

Ch 1 – 16

SENSORY MEMORY: Iconic

QUESTION: Is SM pre-categorical/retinal *or* post-categorical/post-retinal?

«report back numbers»

K	3	8	T
2	O	X	5
B	1	Q	4
9	Z	6	A

√

Merikle (1980)

«report back red letters» (after-image?)

K	V	P	T
M	O	X	U
B	L	Q	S
T	Z	W	A

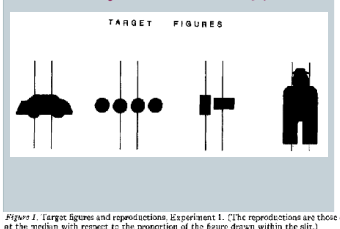
√

Banks & Barber (1977)

Ch 1 – 17

SENSORY MEMORY: Iconic

McCloskey & Watkins (1978):



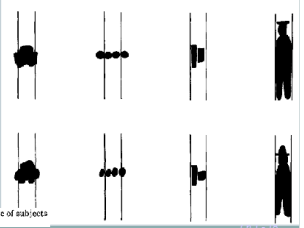
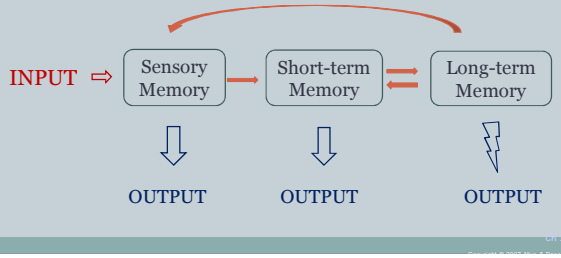


FIGURE 1. Target figures and reproductions. Experiment 1. (The reproductions are those of subjects at the median with respect to the proportion of the figure drawn within the slit.)

From: McCloskey & Watkins (1978). The Seeing-More-Than-Is-There Phenomenon: Implications for the Locus of Iconic Storage. JEP: HPP, 4, 553-564.

Ch 1 – 18

CANONICAL MODEL OF MEMORY SYSTEMS



SENSORY MEMORY

Main characteristics of sensory memory:

- no encoding (b/c too short for any encoding engagement) BUT
- high instant storage capacity BUT
- very short retention duration
  - for iconic SM: ca. 250-300 msec
  - for echoic SM: ca. 4 sec
  - for haptic SM: ca. 1.3 sec

  → Forgetting/loss seems to be a loss from consciousness, not necessarily a full erasure...
- retrieval is effortless

SENSORY MEMORY: Chimps vs. Humans

Check-out:

https://www.youtube.com/watch?v=fzUyX5kezb0

2013 TED talk in Kyoto by Dr. Matsusawa

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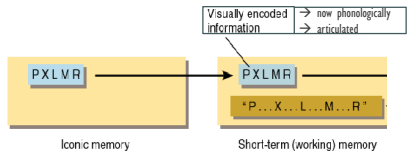
SHORT-TERM MEMORY



Adapted from Carlson et al. (2007) Psychology: The Science of Behavior. Allyn & Bacon

SHORT-TERM MEMORY

Peterson & Peterson (1959): First major study of STM

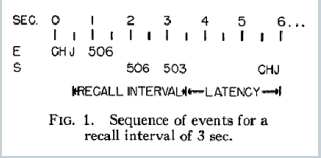


FIG. 1. Sequence of events for a recall interval of 3 sec.

Procedure:

trigram *(3-consonant nonsense syllable)*

⇩

retention interval without (w/o) rehearsal --> 0, 3, 6, 9, 12, 15, or 18 sec

⇩

back reporting of trigram

From: Peterson & Peterson (1959). Short-term retention of individual verbal items. Journal of Experimental Psychology, 58, 193–198

L J V

372

(count backwards by 3)

SHORT-TERM MEMORY

Peterson & Peterson (1959): First major study of 'short-term memory'

Findings:

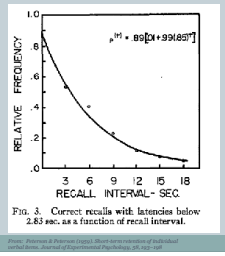
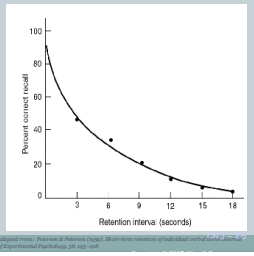


FIG. 3. Correct recalls with latencies below 2.83 sec. as a function of recall interval.



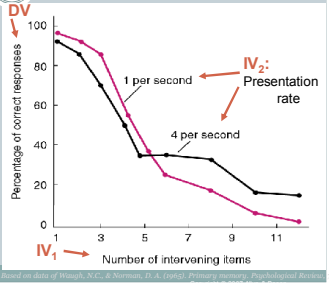
SHORT-TERM MEMORY: FORGETTING

Waugh & Norman (1965):

Forgetting due to decay or interference?

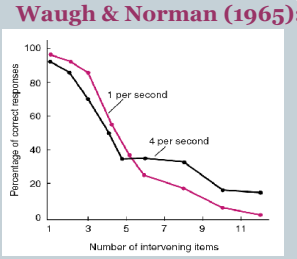
3
7
5
6
2
3 ← **probe** to recall by which digit «3» was followed in the just preceding list..
? ← correct answer: «7»

no. of intervening digits (e.g. four) btw target & probe



SHORT-TERM MEMORY: FORGETTING

Waugh & Norman (1965):



Decay
(=mere passage of time)
or
Interference
(→ displacement)?

Based on data of Waugh, N.C., & Norman, D. A. (1965). Primary memory. Psychological Review, 72, 89-104.

A WORKING MEMORY MEMORY

Baddeley's model of working memory:

Baddeley & Hitch (1974) WM model

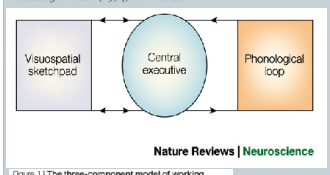


Figure 1 | **The three-component model of working memory.** This model, proposed by Baddeley and Hitch[36], comprises a control system, the central executive, and two storage systems, the visuospatial sketchpad and the phonological loop.

Baddeley's (2000) updated WM model w/ episodic buffer

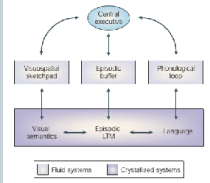
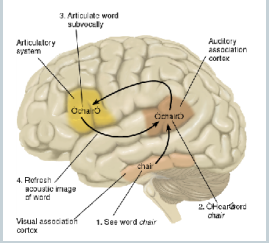


Figure 5 | **The multi-component working memory revision.** The dark purple areas represent long term or crystallized knowledge. The episodic buffer provides an interface between the sub-systems of working memory and long term memory (LTM)[125].

Baddeley & Hitch (1974) WM model. From: Baddeley (2003). Working memory: Looking backward and forward. Nature Reviews. Neuroscience, doi:10.1038/nrn1201

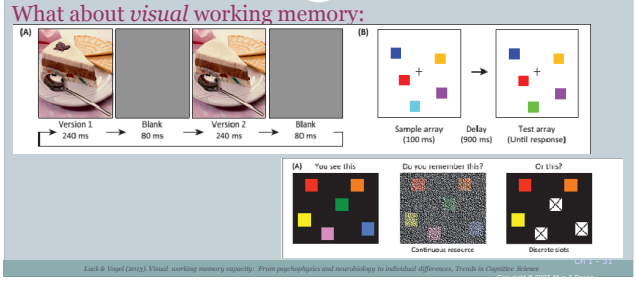
VARIETIES OF STM/WM: Phonological



Carlson et al. (2007) Psychology: The Science of Behavior. Allyn & Bacon

VARIETIES OF STM/WM: Visual

What about *visual* working memory:

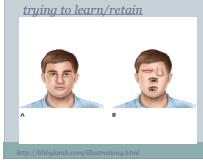


Luck & Vogel (2013). Visual working memory capacity: From psychophysics and neurobiology to individual differences, Trends in Cognitive Science

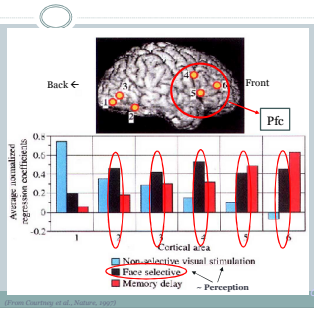
PREFRONTAL CORTEX & WM

Courtney et al. 1997 study:

- ***Perception:***
  looking at faces (A) vs. scrambled faces (B, «non-selective visual stimulation»)
- ***Memory:***
  trying to learn/retain



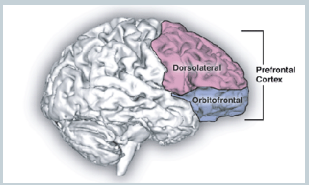
http://libbylamb.com/illustrations/html



(From Courtney et al., Nature, 1997)

PREFRONTAL CORTEX & WM

The prefrontal cortex (Pfc) as the central executive:



for demos see:

http://www.gocognitive.net/sites/default/files/stm.v1.0.a_1_0.swf

& compare with: http://www.youtube.com/watch?v=VPKmcT4IZDk

STM TESTS ~ Phonological Loop

Simple span tasks: *«Report in their correct order..»*

- Simple digit span: '7 8 4 5 2 4 6' → ?
- Simple letter span: 'Q G J H K R' → ?
- Simple word span: 'hut cake bush chair bold tone' → ?
- Peterson & Peterson type of tasks w/ nonsense (or normal) items

DEMO:
http://www.gocognitive.net/sites/default/files/stm.v1.0.a_1_0.swf

WM TESTS ~ Phonological Loop

Operation span task:

7 + 2 = ? «9»
9 – 5 = ? «4»
3 – 3 = ? «0»
1 + 3 = ? «4»
6 – 4 = ? «2»

DEMO:
http://www.gocognitive.net/sites/default/files/stm.v1.0.a_1_0.swf

→ report back in order: «9» «4» «0» «4» «2»

WM TESTS ~ Phonological Loop

n-Back tasks: *«Report when you notice a repetition..»*

- **with digits:** 7 8 4 5 (4) 6 9 2 (9) ... ← **2-back**
- **with letters:** K T X Q (T) C L V R (L) ... ← **3-back**
- **with words, syllables ....**

STM TESTS ~ Visuospatial Sketchpad

Simple visual span tasks:

- Object span task:

DEMO:
http://www.gocognitive.net/sites/default/files/stm.v1.0.a_1_0.swf

STM TESTS ~ Visuospatial Sketchpad

Simple visual span tasks:

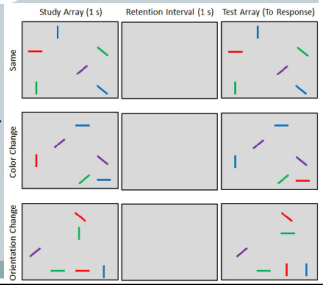
- Spatial span task:

DEMO:
http://www.cambridgebrainsciences.com/browse/memory/test/spatial-span-ladder

STM TESTS ~ Visuospatial Sketchpad

Simple visual span tasks:

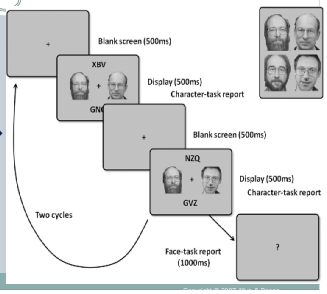
- Change detection task →



STM TESTS ~ Visuospatial Sketchpad

Simple visual span tasks:

- Change detection task →



SHORT-TERM/WORKING MEMORY

Main characteristics of (verbal) working memory:

- ✓ encoding in the form of «rote rehearsal» *(e.g., 7 2 3 9 → «seven-two-three-nine», i.e. mere repetition)*
- ✓ typical WM storage capacity/span = 7 +/- 2 items (or chunks) (Miller, 1956)
- ✓ quite short retention duration (ca. 10-20 sec)
  - «forgetting/loss» mostly in the form of 'displacement'
- ✓ retrieval is slightly effortful

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METAPHORS FOR LTM

Memory as ..?

http://blog.paperblanks.com/2012/03/notebooks-wax-tablets/

Cover page of Douwe Draaisma's «Metaphors of Memory: A History of Ideas about the Mind

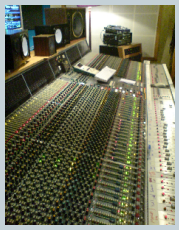
http://thememorynetwork.net/category/exchanges/metaphors-of-memory/

METAPHORS FOR LTM

Memory as ..?

http://www.soundrecordinghistory.net/history-of-sound-recording/history-of-dictaphone/

http://www.northwick.eu/Pages/gramophone.aspx



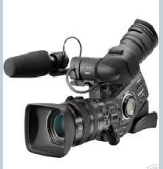
http://www.soundrecordinghistory.net/history-of-sound-recording/history-of-dictaphone/

http://www.brainpickings.org/2012/03/07/memory/

METAPHORS FOR LTM

Memory as ..?

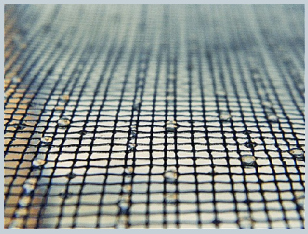
http://sounds.bl.uk/Sound-recording-history/Equipment/029M-UNCAT060XXXX-0001V0



http://rushforideals.com/blog/tips-to-buy-latest-video-recorders-online/

http://publicradiotulsa.org/post/keep-your-subway-map-handy-its-return-trip-new-york-happy-new-year-edition-all

METAPHORS FOR LTM

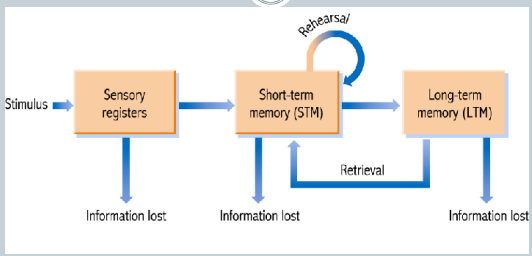


Memory as a 'sticky net':

The more you collect, the more will stick on it… The tightness of the net is flexible, depending on your attention, past experience etc.

(Metaphor by Lance Jones, I don't even know who he is but I like this metaphor…)

CANONICAL MODEL OF MEMORY SYSTEMS



From: Kowalski & Westen (2004) Psychology, Wiley & Sons, Inc.

LTM: REHEARSAL AIDS DURING ENCODING

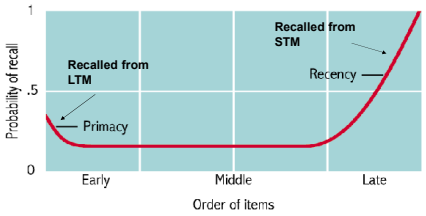
(Figure adapted from Rundus, 1971)

Item presented	Rehearsal
1. Reaction	Reaction, reaction, reaction, reaction
2. Hoof	Hoof, reaction, hoof, reaction
3. Blessing	Blessing, hoof, reaction
4. Research	Research, reaction, hoof, research
5. Candy	Candy, hoof, research, reaction
6. Hardship	Hardship, hoof, hardship, hoof
7. Kindness	Kindness, candy, hardship, hoof
8. Nonsense	Nonsense, kindness, candy, hardships
.	.
.	.
.	.
20. Cellar	Cellar, alcohol, misery, cellar

for demo of false memory in ltm see:
http://www.gocognitive.net/demo/memory-lists-roediger-mcdermott-1995

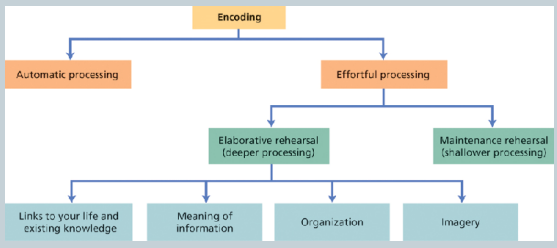
From: Kowalski & Westen (2004) Psychology, Wiley & Sons, Inc.

LTM: THE SERIAL POSITION CURVE



(Figure adapted from Atkinson & Shriffrin, 1968)

LTM: REHEARSAL AIDS DURING ENCODING



LTM: REHEARSAL AIDS DURING ENCODING

Is frequent exposure enough? No!

Nickerson & Adams (1979)

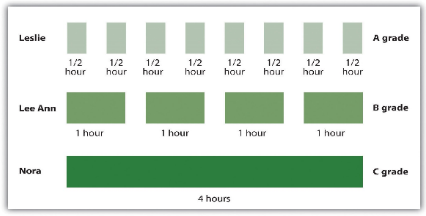
→ study on free recall and recognition memory for a «1 cent»

Free recall test:

Recognition test:

LTM: REHEARSAL AIDS DURING ENCODING

Encoding tasks (IV): massed vs. spaced encoding/learning



http://catalog.flatworldknowledge.com/bookhub/127?e=stangor-ch08_s02

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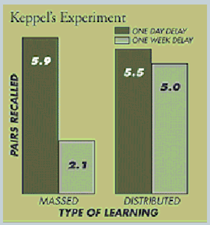
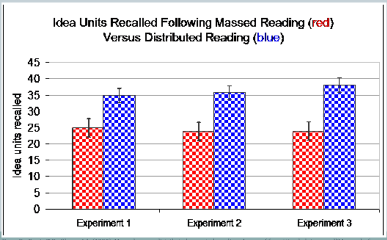
LTM: REHEARSAL AIDS DURING ENCODING

Encoding tasks (IV): massed vs. spaced encoding/learning



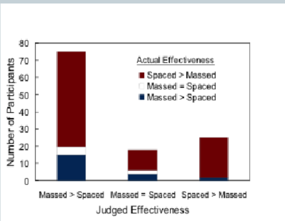


Keppel, G. (1964). Journal of Verbal Learning and Verbal Memory

Krug, D.; Davis, T.B.; Glover, J.A. (1990). Massed versus distributed repeated reading: A case of forgetting helping recall? Journal of Educational Psychology, 82, 366–71.

LTM: REHEARSAL AIDS DURING ENCODING

Massed vs. spaced encoding/learning: What people believe to be effective?



N. Kornell & R. A. Bjork (2008a), Psychological Science, 19, 585-592

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LTM: REHEARSAL AIDS DURING ENCODING

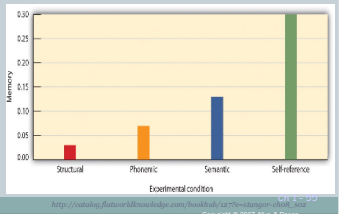
Encoding tasks (IV):

a) **structural** ('written with small or large letters?')

b) **phonemic** ('does it rhyme with x?')

c) **semantic** ('synonym of x?')

d) **self-reference** ('does it describe you?')

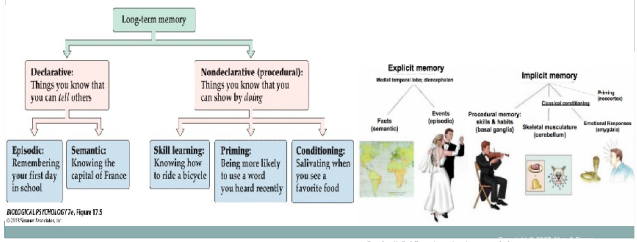


LTM: FEASTS OF ENCODING

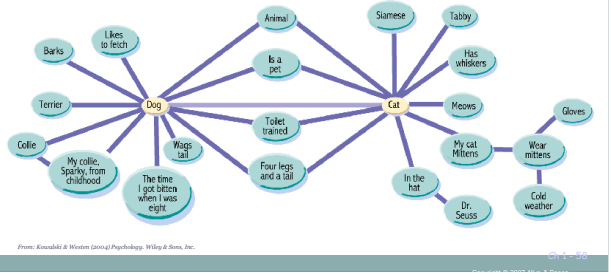
The «method of loci»: wonders of making use of visual/pictorial stimuli…

http://www.youtube.com/watch?v=V8S8V9VEFyI

LTM: OVERVIEW



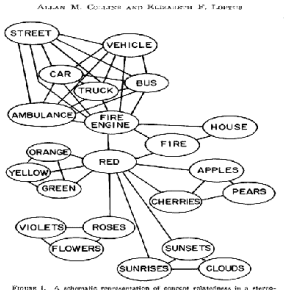
LTM: SEMANTIC MEMORY ('THE KNOWLEDGE STORAGE')



From: Kowalski & Westen (2004) Psychology. Wiley & Sons, Inc.

LTM: SEMANTIC MEMORY ('THE KNOWLEDGE STORAGE')

Collins & Loftus (1975) Model:



LTM: SEMANTIC MEMORY

A priming task demo:

http://www.u.arizona.edu/~kforster/priming/index.htm

LTM: IMPLICIT MEMORY

Implicit (LTM) memory test:

press SPACE BAR once you have identified the word

http://www.gocognitive.net/demo/implict-memory-test-dot-clearing

LTM: EPISODIC MEMORY

Anything that is remembered together with some aspect of the time and/or place when or where it was experienced is an episodic type of memory.

(Semantic memory, on the other hand, is a memory of 'facts'/associations that are completely devoid of any temporal or spatial contextual experience.)

Example:

- ***You watch a film and notice at one point that you had watched that film before...***
  - *Option A. - You know for sure that you had watched the film, you remember the film but you do not have any conscious recollection of the time or place or circumstances when you watched that film ← SEMANTIC MEMORY of the film*
  - *Option B - You not only know that you know the film but you remember when or where or with whom you watched it ← EPISODIC MEMORY*

LTM: EPISODIC MEMORY & FORGETTING

The Ebbinghaus forgetting curve

- *drops off rapidly at first but then levels off...*

BUT what is forgetting ?

- is it loss of information?
- is it loss of access to information?

↳ *evidence from implicit memory*

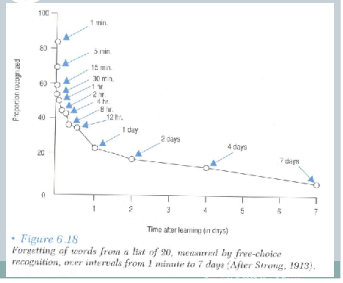
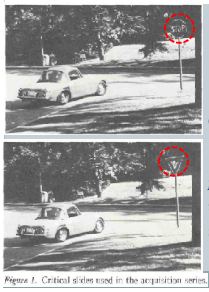


Figure 6.18
Forgetting of words from a list of 90, measured by free-choice recognition, over intervals from 1 minute to 7 days (After Strong, 1913).

LTM: MEMORY AS RE/CONSTRUCTION



Loftus, Miller, & Burns (1978)

Question at retrieval:

«Did another car pass the red Datsun while I stopped at the yield sign?»

«Implanted False Memory» (Loftus, 1995)

'Since the 1990s, when DNA testing was first introduced into the courtroom, researchers have reported that 73% of the 239 convictions overturned through DNA testing were solely based on mistaken eyewitness testimony.'

How could so many eyewitnesses be wrong?

SEE: *https://www.youtube.com/watch?v=PQr_LJuYzbA*

Figure 1. Critical slides used in the acquisition series.

LONG-TERM MEMORY

Main characteristics of long-term memory:

- ✓ encoding style & method is extremely critical w/r/t (with regard to) LTM
- ✓ LTM storage capacity/span = infinite ? *(based on evidence from amnesics and implicit memory performance, also see Bahrick et al., 1976)*
- ✓ long retention duration (hours, even days, even years...)
  - ↳«forgetting/loss» in the form of 'inaccessibility' ('blocking', 'interference') or 'reconstr.'
- ✓ retrieval can be quick, easy & organized OR slow, effortful & spread out in time..

STORES OF MEMORY

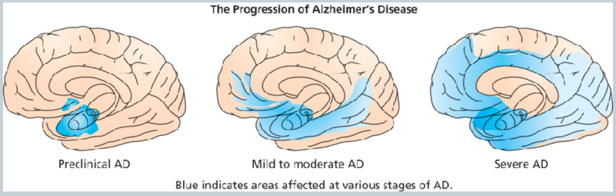
A. What is memory?

B. Stores of memory
   a) Sensory memory
   b) Short-term/Working memory
   c) Long-term memory

C. Memory disorders: Some case studies

D. In search of the neurobiology of memory

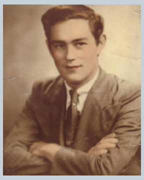
ALZHEIMER'S DISEASE

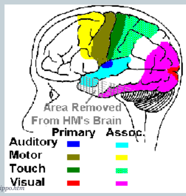


From: Passer & Smith (2007) Psychology: The Science of Mind and Behavior. McGraw-Hill Co, Inc.

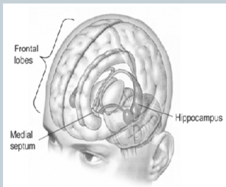
MEMORY DISORDERS: SOME CASE STUDIES

Henry Gustav Molaison aka H. M. (1926 – 2008): *A severe case of antegrograde amnesia with some retrograde amnesia*





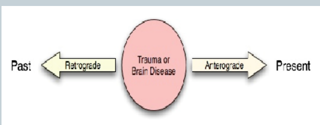
From: http://www.indiana.edu/~p1013447/dictionary/memhippo.htm

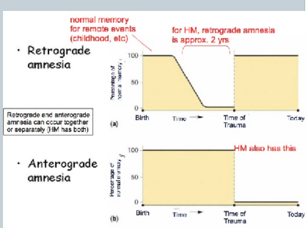


From: http://en.wikipedia.org/wiki/Henry_Molaison

VIDEO: http://www.pbs.org/wgbh/nova/body/how-memory-works.html

LTM: Anterograde vs. retrograde amnesia

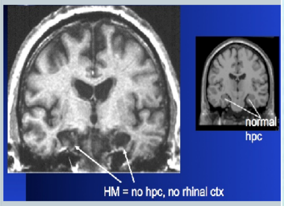


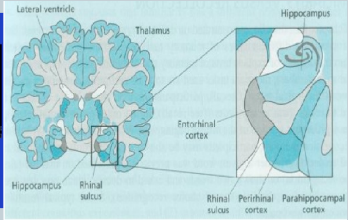


From: http://sccpsy101.com/home/chapter-5/section-3/

From: http://mikeclaffey.com/psyc170/notes/notes-memory.html

LTM: Anterograde vs. retrograde amnesia





From: http://mikeclaffey.com/psyc170/notes/notes-memory.html

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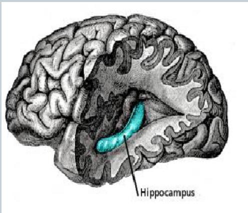
MEMORY DISORDERS: SOME CASE STUDIES

Kent Cochrane aka K. C. (1951 – 2014):

Figure 1 K.C., a man who lost his episodic memory as a result of traumatic brain injury in 1981, photographed in 1986 when he was 35 years of age.



From: http://en.wikipedia.org/wiki/Kent_Cochrane

From: Tulving (2002), Episodic memory: From mind to brain. Annual Rev. Psycholog., 53, 1-25.

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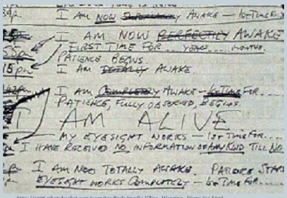
MEMORY DISORDERS: SOME CASE STUDIES

Clive Wearing (1938 –): *A case of complete antegrograde AND retrograde amnesia…*

http://jirirezac.photoshelter.com/image/I0000sC7TjfxBnAE



http://s276.photobucket.com/user/tazdizzle/media/Clive_Wearing_Diary.jpg.html

Video: http://www.youtube.com/watch?v=Vwigmktix2Y

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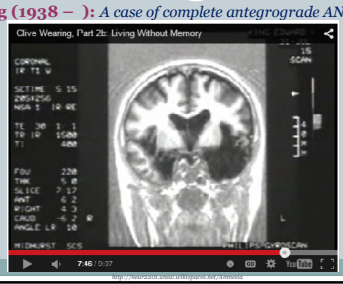
MEMORY DISORDERS: SOME CASE STUDIES

Clive Wearing (1938 –): *A case of complete antegrograde AND retrograde amnesia…*



MEMORY

A. What is memory?

B. Stores of memory
   a) Sensory memory
   b) Short-term/Working memory
   c) Long-term memory

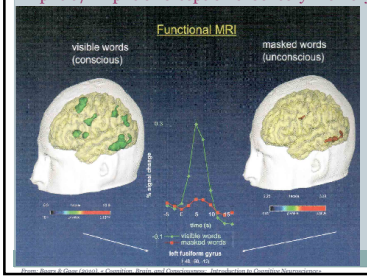
C. Memory disorders: Some case studies

D. In search of the neurobiology of memory

VIDEO: http://www.scientificamerican.com/article/memory-brain-tour-video/

IN SEARCH OF THE NEUROBIOLOGY OF MEMORY

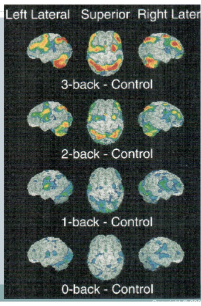
Explicit / Implicit Perception & Sensory Memory:



IN SEARCH OF THE NEUROBIOLOGY OF MEMORY

Working Memory:

FIGURE 2.11 Brain activity increases with the Work Memory load. Brain imaging using fMRI shows dramatic increa in the amount of cortex involved in the n-back task, as n rises fro to 3. In the 0-back condition, subjects only need to name the vis slide. On these brain images, brighter colors signal higher level activity. *Source*: Smith and Jonides, 1997, Figure 10.



From: Baars & Gage (2010). « Cognition, Brain, and Consciousness: Introduction to Cognitive Neuroscience»

IN SEARCH OF THE NEUROBIOLOGY OF MEMORY

Visual WM – A combined model

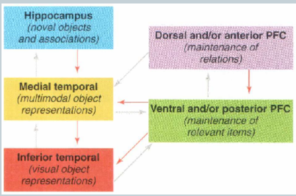
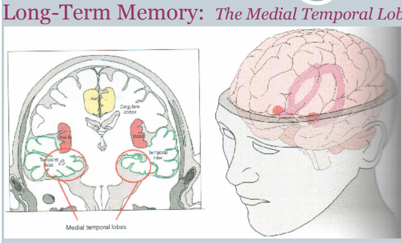


FIGURE 9.29

From: Baars & Gage (2010). « Cognition, Brain, and Consciousness: Introduction to Cognitive Neuroscience»

IN SEARCH OF THE NEUROBIOLOGY OF MEMORY

Long-Term Memory: *The Medial Temporal Lobe (MTL) & Subcortext (hippo, amygdala, & enthorhinal cortext)*



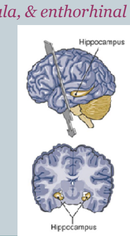
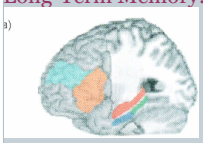


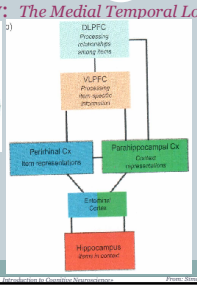
FIGURE 9.1

From: Baars & Gage (2010). « Cognition, Brain, and Consciousness: Introduction to Cognitive Neuroscience»

IN SEARCH OF THE NEUROBIOLOGY OF MEMORY

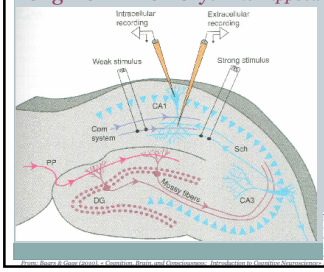
Long-Term Memory: *The Medial Temporal Lobe (MTL) & Subcortext (hippo, amygdala, & enthorhinal cortext)*





IN SEARCH OF THE NEUROBIOLOGY OF MEMORY

Long-Term Memory: *The Hippocampus & Episodic Memory*



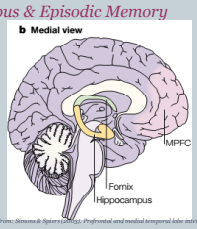
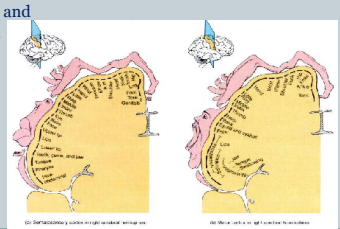


FIGURE 9.15 Single-cell recording in hippocampus. A schematic of single cell recording and stimulation either inside of hippocampal neurons or outside. An electrode placed outside of a neuron can pick up electrical field potentials, which are similar to EEG but much more localized. Electrical field potentials often reflect the activity of small populations of neurons, as opposed to the axonal or dendritic potential of a single neuron. Notice that a very similar technique can be used to stimulate

IN SEARCH OF THE NEUROBIOLOGY OF MEMORY

Wilder Penfield (1891 - 1976)

- neurosurgeon; discovered the motor and sensory 'homonculus' in the brain →



IN SEARCH OF THE NEUROBIOLOGY OF MEMORY

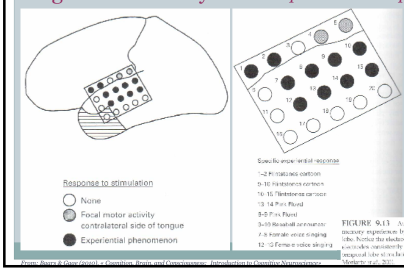
When delivering slight electrical stimulation to various parts of the brain during surgery, he discovered flashbacks of sensations, and in very few occasions, sth like recall of past events, most long-lost...

> *'The patient then said something about 'street corner'. The surgeon asked him 'Where?' and he replied 'South Bend, Indiana, corner of Jacob and Washington'. When asked to explain, he said he seemed to be looking at himself - at a younger age.*
>
> *(Penfield, 1955, p.52)*

- *QUESTION: Real memories or generated experiences w/ accompanying memory-like feeling?*
- *NOTE: Out of 1132 patients, only 40 instances (24 auditory, 19 visual, only 12 full-blown 'memories'*

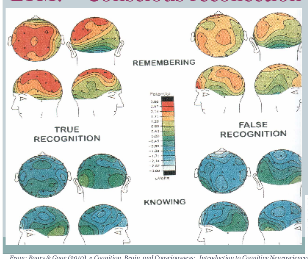
IN SEARCH OF THE NEUROBIOLOGY OF MEMORY

Long-Term Memory: *The Temporal Lobe & Episodic Memory*



IN SEARCH OF THE NEUROBIOLOGY OF MEMORY

LTM: «Conscious recollection» vs. «familiarity», true vs. false



IN SEARCH OF THE NEUROBIOLOGY OF MEMORY

LTM: The Dorsolateral & Ventrolateral Prefrontal Cortex:

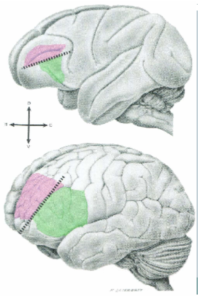
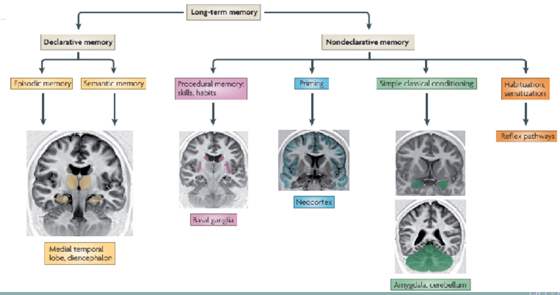


FIGURE 9.25 The prefrontal cortex in monkeys (top) and humans (bottom). The most common division is between upper and lower halves of the prefrontal cortex (PFC), called the dorsolateral prefrontal cortex (DL-PFC) for the light purple region, and the ventrolateral prefrontal cortex (VL-PFC) for the light green area. Also notice the orientation cross, pointing to dorsal (upper), ventral (lower), rostral (toward the nose in humans), and caudal (toward the back of the head in humans). *Source:* Ranganath, 2006.

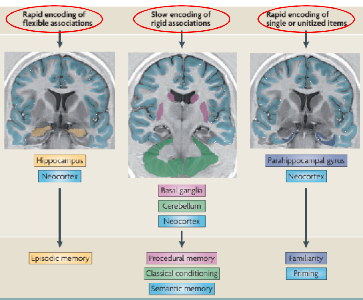
From: Baars & Gage (2010). « Cognition, Brain, and Consciousness: Introduction to Cognitive Neuroscience»

LTM: OVERVIEW



From: Henke (2010). A model of memory systems based on processing modes rather than consciousness.. Nature Reviews Neuroscience.

LTM: OVERVIEW



From: Henke (2010). A model of memory systems based on processing modes rather than consciousness.. Nature Reviews Neuroscience.

IN SEARCH OF THE NEUROBIOLOGY OF MEMORY

VIDEO:

http://www.scientificamerican.com/article/memory-brain-tour-video/