Sensory, short-term, and working memory

Paymon Hosseini

10/10/2007
Outline

• Review: memory is not monolithic
• Temporary memory systems
  – Evidence for short-term memory (STM)
  – Evidence for sensory memory
• How do temporary memory systems interact?
  – Atkinson-Shiffrin model of STM
  – Evidence against Atkinson-Shiffrin model
  – Baddeley-Hitch model of STM
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Memory is not monolithic

Secondary memory (LTM)
the knowledge of a former state of mind after it has already once dropped from consciousness

Primary memory (STM)
information remaining in consciousness after it has been perceived

Declarative (Explicit)
Facts
Events
Skills and Habits
Priming and Perceptual Learning
Simple Classical Conditioning
Emotional Responses
Skeletal Responses

Nondeclarative (Implicit)
Nonassociative Learning

Medial Temporal Lobe
Diencephalon
Striatum
Neocortex
Amygdala
Cerebellum
Reflex Pathways

Figure by MIT OpenCourseWare. Squire, 1996
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STM

Short-term memory (STM) refers to memory processes that retain information only temporarily, until information is either forgotten or becomes incorporated into a more stable, potentially permanent long-term store

- Memorize:
  773-562-5519
STM can be dissociated from LTM

- Capacity of short-term memory is limited
  - Miller, 1956
- Duration of short-term memory is brief
  - Peterson and Peterson, 1959
- Two storage mechanisms active in free recall
  - Glanzer and Cunitz, 1966
- Impact of neurological damage on STM
  - H.M.
  - K.F.
  - C.W.
Capacity

- Memorize a sequence of
  - digits
  - letters
  - words
  - Repeat in original order

Span: $7 \pm 2$ “chunks”

$8 \ 7 \ 3 \ 2 \ 5 \ 9 \ 4 \ 3 \ 5 \ 6$

$873 \ 259 \ 4356$

Capacity of STM is limited

Miller, 1956
**Duration**

<table>
<thead>
<tr>
<th>SEC.</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>…</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>CHJ</td>
<td>506</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

506  503  500  CHJ

Without attention and rehearsal, information is lost rapidly from STM

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Graph of experimental results showing that as the length of time and amount of interfering verbal information increased between a stated cue and time of recall, frequency of correct cue recall exponentially decreased.

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Peterson and Peterson, 1959
Serial position effect in free recall

Rehearsal facilitates maintenance of information in STM and transfer of information from STM to LTM

Glanzer and Cunitz, 1966; Atkinson et. al., 1971
A double dissociation between LTM and STM

H. M. - Bilateral removal of medial temporal lobe structures
K. F. - Left temporo-parietal lesion
C.W. - Hippocampal lesion

<table>
<thead>
<tr>
<th></th>
<th>LTM</th>
<th>STM</th>
</tr>
</thead>
<tbody>
<tr>
<td>H.M., C.W.</td>
<td>Cannot form new LTM</td>
<td>normal</td>
</tr>
<tr>
<td>K.F.</td>
<td>normal</td>
<td>digit span = 2</td>
</tr>
</tbody>
</table>

Short-term and long-term memory stores are distinct
Short-term memory summary

- Limited capacity
- Short duration
- Lost quickly without attention and rehearsal
- Rehearsal facilitates transfer of information from STM to LTM

7±2 chunks
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Sensory memory

A large-capacity but very temporary holding device that allows people to choose which elements, from all of the stimuli arriving through their senses, should be further processed and stored.

Modality specific stores

- visual → iconic store
- verbal → echoic store
- tactile → haptic store

George Sperling
Sensory memory

Given larger and larger matrices of letters, the ability to recall these letters maxes out at about 4.5 (averaged over 5 test participants).

Averbach & Sperling, 1961
Targeted Report Procedure

The partial report procedure is an improvement over the whole report procedure, but it does not solve the delay confound either.

Targeted report procedure:
• After the presentation of a 3X4 array, one letter is underlined.
• Participants report the underlined letter

- Very little loss due to time delay
- Memory capacity estimated to be at least 16-18 letters under optimal conditions

Capacity of iconic memory is large
Iconic memory is lost rapidly without attention
Performance does not drop to chance because of contributions from STM, which operates on a longer time scale than iconic memory.

Duration of iconic memory is roughly 200 ms.
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# Temporary memory systems summary

<table>
<thead>
<tr>
<th>Sensory memory</th>
<th>Short-term memory</th>
<th>LTM</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Large capacity</td>
<td>• Limited capacity</td>
<td></td>
</tr>
<tr>
<td>• Modality-specific stores</td>
<td>• Short duration</td>
<td></td>
</tr>
<tr>
<td>• Very brief duration</td>
<td>• Lost without attention and rehearsal</td>
<td></td>
</tr>
<tr>
<td>• Lost rapidly w/o attention</td>
<td>• Rehearsal facilitates transfer to LTM</td>
<td></td>
</tr>
</tbody>
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How can we combine this information into a coherent model of temporary memory systems?
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Atkinson-Shiffrin modal model

- **Sensory registers**
  - visual
  - auditory
  - haptic

  Unattended information is quickly lost

- **Input**

- **Short-term store**

  Unrehearsed information is quickly lost

  Rehearsal

- **Long-term store**

  Attention
Evaluating the Atkinson-Shiffrin model

- Evidence against a simple rehearsal-based transfer of information from STM to LTM
  - Craik and Lockhart, 1972
- Evidence against a unitary short-term store
  - Warrington and Shallice, 1972
Craik-Lockhart levels-of-processing model

<table>
<thead>
<tr>
<th>Speech</th>
<th>Each</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brush</td>
<td>Lush</td>
</tr>
<tr>
<td>Cheek</td>
<td>Teak</td>
</tr>
<tr>
<td>Flour</td>
<td>Sour</td>
</tr>
<tr>
<td>Honey</td>
<td>Funny</td>
</tr>
<tr>
<td>Glove</td>
<td>Shove</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

Is the word in capital letters?

Does the word rhyme with ____?

Would the word fit the sentence: “He met a ____ in the street”?

Is the word in capital letters?

Does the word rhyme with ____?

Would the word fit the sentence: “He met a ____ in the street”?
Evidence from Patient K.F. against a unitary STS

<table>
<thead>
<tr>
<th>Span</th>
<th>Visual</th>
<th>1-3 letter stimulus presented at 1Hz</th>
<th>Auditory</th>
<th>0,5,10,15 sec distraction</th>
</tr>
</thead>
</table>

Warrington et al., 1972

Presentation
Visual
Auditory

Warrington et al., 1972

Figure by MIT OpenCourseWare.
Two primary assumptions of the Atkinson-Shiffrin model are incorrect:

- Short-term store is not a unitary store
- Simple rehearsal cannot fully account for transfer of information from STM to LTM

Evidence against the modal model lead Baddeley and Hitch to propose a multi-component model of temporary memory capacities called “working memory”

STM:
- Memorize 773-562-5519 and then repeat it in the same order

Working memory
- Memorize 773-562-5519, sort it and repeat it from the largest to the smallest number
Baddeley-Hitch model

Working memory is the ability to maintain and manipulate information online to guide a goal-directed behavior.

- **Phonological Loop**
- **Central Executive**
- **Visuo-Spatial Sketchpad**

Baddeley-Hitch model is process (maintenance vs manipulation) and material (visual vs. verbal) specific

Baddeley, 2003
Visuospatial sketchpad and phonological loop are distinct
Visuospatial sketchpad and phonological loop are distinct

Dual-task evidence

<table>
<thead>
<tr>
<th>Visual</th>
<th>Verbal</th>
</tr>
</thead>
<tbody>
<tr>
<td>RG</td>
<td>RGX</td>
</tr>
<tr>
<td>RGXD</td>
<td></td>
</tr>
</tbody>
</table>

Neuropsychological evidence

K.F. has a normal visual span, but severely impaired verbal span

![Graph showing visual span and verbal span](https://www.sciencedirect.com)

Figure by MIT OpenCourseWare.

Logie et. al., 1990

Warrington et. al., 1972
Evidence for the phonological loop

- Phonological Loop
- Central Executive
- Visuo-Spatial Sketchpad
Phonological loop

Phonological store
holds phonological memory for a few seconds before it fades

Articulatory control process
refreshes the memory trace by retrieval and re-articulation

Auditory input

Phonological store

Articulatory control process

Visual input
Phonological store

Evidence from: Phonological similarity effect

Auditory input

Phonological store

Articulatory control process

Visual input

Baddeley, 1966
Articulatory control process

Evidence from:
Word length effect
Articulatory suppression effect

Baddeley, 1975
Visuo-spatial sketchpad

- Phonological Loop
- Central Executive
- Visuo-Spatial Sketchpad
Visuo-spatial sketchpad

Visual component
holds visual form and color information

Spatial component
holds spatial and movement information

Images removed due to copyright restrictions.

Baddeley, 2006
Della Sala, 1999
Central Executive

Phonological Loop

Central Executive

Visuo-Spatial Sketchpad
Major functions of the central executive include:

- Switching attention between tasks
- Planning sub-tasks to achieve a goal
- Selective attention and inhibition
- Updating and checking contents of working memory
Evidence for central executive

**Primary visual-spatial Material**

Text removed due to copyright restrictions.

Small sample:
"In the starting square put an A.
In the next square to the right put a B.
In the next square down put a C. ..."

**Primary verbal Material**

Text removed due to copyright restrictions.

Small sample:
"In the starting square put an A.
In the next square to the slow put a B.
In the next square good put a C. ..."

**Secondary tasks:**

- Spatial interference
  - finger tapping
- Verbal interference
  - say "go ... go ... go"
- Central interference
  - random number generation

Salway, 1999
Primary tasks

Spatial

Verbal

% Correct

Spatial interference

Verbal interference

Random generation

Salway, 1999
Anatomical localization of central executive

- Principal sulcus
- Arcuate sulcus
- Lateral sulcus
- Superior temporal sulcus
- Central sulcus
- Intraparietal sulcus
- Visual features
- Auditory features

Figures by MIT OpenCourseWare.
Student Report
Thank you!