Immediate Memory

I. Context
II. History
   (changing views of immediate memory)
III. Proposed Properties of Immediate Memory
   A. Capacity
   B. Forgetting
   C. Coding
   D. Retrieval

Context

Immediate Memory refers to the general idea of a memory system dedicated to the storage of the recent past. It includes ideas such as:
Short-term storage (STS)
Short-term memory (STM)
Working memory

1. Context

Atkinson and Shiffrin Model

Input → Sensory Store → Short-Term Store (Control Processes: rehearsal, coding, retrieval strategies) → Long-Term Store → Response Output
II. History

William James (1890, pp. 646-647)
primary memory (immediate) vs. secondary memory (long-term)

"An object which is recollected, in the proper sense of that term, is one which has been absent from consciousness altogether, and now revives anew. It is brought back, recalled, fished up, so to speak, from a reservoir in which, with countless other objects, it lay buried and lost from view. But an object of primary memory is not thus brought back; it never was lost; its date was never cut off in consciousness from that of the immediately present moment. In fact it comes to us as belonging to the rearward portion of the present space of time, and not to the genuine past."

II. History (cont.)

Freud (1856-1939)
Hierarchical architecture of human consciousness:
conscious mind
preconscious
unconscious mind

The "magic slate" as a metaphor for memory
(Note on the Mystic Writing Pad, 1925)

II. History (cont)

Atkinson & Shiffrin (1968)
Short-term storage buffer model

External Input

Sensory Register

Rehearsal Buffer

Lost from STS

Long-Term Store
II. History (cont)

Buffer as a “push down stack”

Input  
Buffer  
Lost

II. History (cont)

Working Memory (Baddeley, 1986)

Central Executive  
(limited capacity)

Phonological Loop  
phonological store  
articulatory control  
(short-term buffer)

Visuo-spatial Sketchpad  
(visual imagery)


Central Executive  
(limited capacity)

Phonological Loop  
phonological store  
articulatory control

Episodic Buffer  
(multimodal code)

Visuo-spatial Sketchpad  
(visual imagery)

Language  
Episodic  
Long Term Memory  
Visual  
Semantics
II. History (cont)


Three component framework of working memory (Oberauer, 2006, 2009)

1. Nodes activated in LTM
2. A small number (4) of items temporarily bound to a mental space.
3. A single focus of attention

III. Proposed Properties of Immediate Memory

A. Limited Capacity
1) digit span task
2) Miller (1956)
The magical number 7 +/- 2 digit span tasks categorization tasks (how many tones, etc) judgments task
A. Limited Capacity (cont)

3) Chunking and Memory Span
(Ericsson, 1980)

male student practiced digit span task
1 hour of practice a day, 3-5 days a week
Total of 20 months practice (230 hours)

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Ericsson (1980) results

![Graph showing digit span increasing from 7 to 80 over practice](image)

Conclusion: Exceptional memories: Made not born
(Ericsson, 2003)

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Expert Memory (from an interview with memory champion Nelson Dellis, 2012)

Here’s how Dellis tackles numbers:

12481460360928379862433574 ...

He’ll memorize seven digits at a time, using the "person-action-object" method. Start by splitting the seven digits:

124-68-14

Ahead of time, he’s stored 999 people in his head, each associated with an action and an object. In Dellis’ mind, 124 is Michael Jordan doing something with a basketball; 68 is Stephen Hawking, whose action is rolling in a wheelchair; and 14 is a hockey player whose object is a hockey stick.

So, 124-68-14 is Michael Jordan rolling in a wheelchair while swinging a hockey stick...
A. Limited Capacity (continued)

4) The Magical Number 4 (Cowan, 2000, Oberauer, 2006)
   Compound STM limit (7 +/- 2)
   (measured by digit span)
   includes contributions from:
   
   Sensory Storage,
   LTM (chunking)
   
   Pure STM capacity limit (4 +/- 1)
   measured under conditions that prevent contributions from other sources.
   e.g., Sperling’s whole report, measures of chunk size, measures with un-rehearsable material (long phrases)

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A. Limited Capacity (continued)

5. Visual Working Memory Capacity

Focal Cross | Stimulus Set | Visual Mask | Test Set

“The capacity of visual working memory is limited to no more than four items (Šveg, 2011, p. 48).”

“Visual working memory capacity is limited on at least three dimensions: the number of objects, the number of features per object, and the precision of memory for each feature" (Oberauer & Eichenberger, 2013, p. 1212).”

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A. Limited Capacity (continued)

6. Time limit (rather than a number of items limit)
   For Example, Baddeley’s: Phonological loop

- The capacity limit is apparent because information in the loop decays (in a matter of seconds).
- It must be refreshed through rehearsal
- It is impossible to rehearse a lengthy series of items before decay creates a loss of information.
Memory Span and Word Length
Baddeley, Thomson, & Buchanan (1975)

<table>
<thead>
<tr>
<th>List 1</th>
<th>List 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>lice</td>
<td>abundant</td>
</tr>
<tr>
<td>mink</td>
<td>approval</td>
</tr>
<tr>
<td>pain</td>
<td>foreigner</td>
</tr>
<tr>
<td>pint</td>
<td>paragraph</td>
</tr>
<tr>
<td>rose</td>
<td>sympathy</td>
</tr>
</tbody>
</table>

Lists of short words are easier to remember than lists of long words.
Baddeley’s Interpretation: Greater Memory span for shorter words because shorter words are easier to rehearse before they decay.

Is working memory limited by time?
Jalbert, Neath, Bireta, & Surprenant (2011)

Word-length effect disappears when you control for orthographic neighborhood size (short words with more similar neighbors are easy to remember, perhaps because similar words help you reconstruct other list items.).

Memory for long phrases (a demonstration).

Conclusion – Working memory is not time limited.

III. Proposes Properties of Immediate Memory (cont)

B. Forgetting from Immediate Memory

Two hypotheses:
- decay: information fades with time
- interference: new information interferes with old

Waugh & Norman (1965)
- probe-digit task: 27485667 beep 5 ?
- 43259412567 beep 9 ?
- two rates of presentation: 1/sec vs. 4/sec
C. Forgetting from Immediate Memory (cont)

Waugh & Norman’s Results

<table>
<thead>
<tr>
<th>Probability of Recall</th>
<th>Number of Interfering Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 per sec</td>
<td>0.2</td>
</tr>
<tr>
<td>4 per sec</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Decay or Interference?

Lewandowsky, Duncan, & Brown (2004)
- Participants performed a serial recall task on short list of letters (H, J, M, Q, R, V)
- Recall was paced to create different retention intervals:
  - fast: 400 msec/item (6x400 = 2.4 sec)
  - med: 800 msec/item (6x800 = 4.8 sec)
  - slow: 1600 msec/item (6x1600 = 9.6 sec)
- During recall, participants performed an articulatory suppression task to prevent rehearsal (repeated the word “super”).

Decay or Interference?

Predictions from two models:

Decay: [Graph]
Interference: [Graph]
Lewandowsky et al (2004) results:
Which model is supported?

III. Proposes Properties of Immediate Memory (cont)

C. Coding in STS
1) phonological coding
Conrad (1964)

Experiment 1
Presented letters aurally, immediately after each letter, participants were asked to write down the letter.

Experiment 2
Presented 6 letters visually, then participants were asked to write the list (memory span task).

Results: Correlation between errors made on the listening and memory tasks was $r = .64$.

Confusion matrix for auditory task

<table>
<thead>
<tr>
<th>Stimulus Letter</th>
<th>B</th>
<th>C</th>
<th>P</th>
<th>T</th>
<th>V</th>
<th>F</th>
<th>M</th>
<th>N</th>
<th>S</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>-</td>
<td>171</td>
<td>75</td>
<td>84</td>
<td>148</td>
<td>2</td>
<td>11</td>
<td>10</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>C</td>
<td>32</td>
<td>-</td>
<td>35</td>
<td>42</td>
<td>29</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>P</td>
<td>162</td>
<td>358</td>
<td>-</td>
<td>505</td>
<td>91</td>
<td>11</td>
<td>31</td>
<td>23</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>T</td>
<td>142</td>
<td>232</td>
<td>281</td>
<td>-</td>
<td>50</td>
<td>14</td>
<td>11</td>
<td>8</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>V</td>
<td>122</td>
<td>61</td>
<td>34</td>
<td>22</td>
<td>-</td>
<td>8</td>
<td>11</td>
<td>1</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>F</td>
<td>6</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>-</td>
<td>13</td>
<td>8</td>
<td>336</td>
<td>238</td>
</tr>
<tr>
<td>M</td>
<td>10</td>
<td>14</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>22</td>
<td>-</td>
<td>334</td>
<td>21</td>
<td>9</td>
</tr>
<tr>
<td>N</td>
<td>13</td>
<td>21</td>
<td>6</td>
<td>9</td>
<td>20</td>
<td>32</td>
<td>512</td>
<td>-</td>
<td>38</td>
<td>14</td>
</tr>
<tr>
<td>S</td>
<td>2</td>
<td>18</td>
<td>2</td>
<td>7</td>
<td>3</td>
<td>488</td>
<td>23</td>
<td>11</td>
<td>-</td>
<td>391</td>
</tr>
<tr>
<td>X</td>
<td>1</td>
<td>6</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>245</td>
<td>2</td>
<td>1</td>
<td>184</td>
<td>-</td>
</tr>
</tbody>
</table>
Confusion matrix for Short-term memory task - visual presentation.

<table>
<thead>
<tr>
<th>Stimulus Letter</th>
<th>B</th>
<th>C</th>
<th>P</th>
<th>T</th>
<th>V</th>
<th>F</th>
<th>M</th>
<th>N</th>
<th>S</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>18</td>
<td>62</td>
<td>5</td>
<td>18</td>
<td>12</td>
<td>9</td>
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</tr>
<tr>
<td>C</td>
<td>13</td>
<td>27</td>
<td>18</td>
<td>55</td>
<td>15</td>
<td>3</td>
<td>12</td>
<td>35</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>102</td>
<td>18</td>
<td>24</td>
<td>40</td>
<td>15</td>
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<td>8</td>
<td>7</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>50</td>
<td>46</td>
<td>20</td>
<td>14</td>
<td>11</td>
<td>7</td>
<td>8</td>
<td>7</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>V</td>
<td>56</td>
<td>32</td>
<td>14</td>
<td>21</td>
<td>15</td>
<td>11</td>
<td>11</td>
<td>7</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>F</td>
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<td>14</td>
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<td>31</td>
<td>12</td>
<td>13</td>
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<td>5</td>
</tr>
<tr>
<td>M</td>
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<td>6</td>
<td>5</td>
<td>20</td>
<td>16</td>
<td>-</td>
<td>123</td>
<td>16</td>
<td>16</td>
<td>5</td>
</tr>
<tr>
<td>N</td>
<td>11</td>
<td>7</td>
<td>5</td>
<td>1</td>
<td>19</td>
<td>28</td>
<td>165</td>
<td>-</td>
<td>22</td>
<td>5</td>
</tr>
<tr>
<td>S</td>
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<td>11</td>
<td>2</td>
<td>9</td>
<td>37</td>
<td>4</td>
<td>12</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>3</td>
<td>7</td>
<td>2</td>
<td>11</td>
<td>12</td>
<td>30</td>
<td>16</td>
<td>11</td>
<td>59</td>
<td>-</td>
</tr>
</tbody>
</table>

B. Coding in Immediate Memory (cont)

1) phonological coding (cont)
   b) Schweickert, et al. (1990)
   GZDBPV
   MJYFHRK

   Phonologically similar list are more difficult to remember.

B. Coding in Immediate Memory (cont)

2) Visual Coding
   Shepard’s Mental Rotation Task
   Shepard & Metzler (1971)
Shepard & Metzler (1971) results

Rotation time related to distance rotated
Demonstrates visual coding in working memory

3) Phonological and Spatial Coding in Working Memory (PET research)

Smith & Jonides (1977) pet scans of subjects performing working memory tasks.

Verbal Memory

- L M
- R D

500 msec 200 msec 3000 msec 1500 msec

Spatial Memory

- +
- *
- *
- *

Smith & Jonides (1977) cont.

Phonological Store: posterior parietal (left lateralized)
Phonological Rehearsal: Broca’s area, premotor and supplementary motor area (left lateralized)
Smith & Jonides (1977) cont.

Spatial Store: posterior parietal (right lateralized)

Spatial Rehearsal: premotor area (right lateralized)

III. Proposes Properties of Immediate Memory (cont)

D. Retrieval from STS (Sternberg, 1966)

Task:
list 1,9,4,3 (size = 4)
test 4 (positive)
or 2 (negative)
list 2, 7, 1, 4, 9, 0 (size=6)
test 9 (positive)
or 3 (negative)

D. Retrieval from Immediate Memory (Sternberg, 1966, cont)

Questions:
1) Is the search serial or parallel?
2) Is it terminating or exhaustive?
3) What is searched (coding)?
Serial or Parallel Search?

Serial Search

STS Buffer

4

1 9 4 3

“yes”

Prediction: reaction time should increase with list length.

Serial or Parallel Search?

Parallel Search

STS Buffer

4

1

9

4

3

“yes”

Prediction: Reaction time should stay the same across list length

Serial or Parallel Search?

Results:

Mean Reaction Time (msec)

Memory Set Size

Conclusion: Search is serial
**Is the search exhaustive or self terminating?**

STS Buffer

4

1 9 4 3

"yes"

Prediction: If it is terminating, RT on **yes** trials should be faster than RT on **no** trials

---

**Is the search exhaustive or self terminating?**

Results:

Mean Reaction Time (msec)

<table>
<thead>
<tr>
<th>Memory Set Size</th>
<th>Positive</th>
<th>Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>600</td>
<td></td>
</tr>
</tbody>
</table>

Conclusion: Search is exhaustive

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**What is searched (coding)?**

STS Buffer

intact

4

1 9 4 3

"yes"

STS Buffer

degraded

1 9 4 3

"yes"

Prediction: If search is done with a copy of the input, then a degraded input should yield a steeper slope than an intact input.
D. Retrieval from STS (Sternberg, 1966, cont)

Results:

<table>
<thead>
<tr>
<th>Memory Set Size</th>
<th>Degraded</th>
<th>Intact</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>400</td>
<td>500</td>
</tr>
<tr>
<td>2</td>
<td>500</td>
<td>600</td>
</tr>
<tr>
<td>3</td>
<td>600</td>
<td>700</td>
</tr>
<tr>
<td>4</td>
<td>700</td>
<td>800</td>
</tr>
</tbody>
</table>

Conclusion: Search is carried out with a "named" input.

D. Retrieval from STS (Sternberg, 1966, cont)

Summary:
- serial
- exhaustive
- named (phonological) code of list

Conclusions on Immediate Memory

A. Immediate Memory plays a central role in information processing
B. Numerous theories have proposed a separate Immediate Memory systems.
C. Common properties of the system include
   1) limited capacity
   2) loss of information resulting from interference
   3) phonological and/or visual coding
   4) items must be retrieved in a serial-exhaustive fashion.