WORKING MEMORY

Chapter 5

Learning Objective Topics

• What is working memory?
• Tripartite Model of WM (Baddeley & Hitch, 1974)
  • Phonological Loop
  • Visuospatial Sketchpad
  • Central Executive
• Brain Processes that support Working Memory
Definition of WM

- Temporary maintenance or storage of information during cognitive processing
- Juggling metaphor
- Engle (2002): WM = STM + controlled attention
- “attention-limited workbench of memory”

One or two processes?

- Question: Is working memory a unitary process?
  - Or is it divided into two separate processes?

- What do we need to tell if it is a unitary process?
Separate Working Memory Systems?
• Draw this 3 x 7 grid in your notes:

<p>| | | | | | | |</p>
<table>
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• I will show you letters in the boxes.
  • If you remember the letter and location put it in the correct location
  • If you just remember the location, put a check there
  • If you just remember the letter write it on the side

Separate WM Systems?
Remember what the letters are, and where the letters are
Separate WM Systems?

<table>
<thead>
<tr>
<th>X</th>
<th>C</th>
<th>O</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>W</td>
<td>R</td>
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</table>

Separate WM Systems?
**Answer**

<table>
<thead>
<tr>
<th></th>
<th>X</th>
<th>C</th>
<th>O</th>
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<tbody>
<tr>
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<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>W</td>
<td>R</td>
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</table>

**Directions**

Remember what the letters are, and where the letters are.
<table>
<thead>
<tr>
<th>B</th>
<th>I</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>F</td>
<td>E</td>
</tr>
<tr>
<td>A</td>
<td>L</td>
<td></td>
</tr>
</tbody>
</table>

**Distracter**

```
. . . .
. . . .
. . . .
. . . .
. . . .
```
### Write your answer

```
B   I   Q
```

### Answer

```
B   I   Q
M   F   E
A   L
```
**Directions**

Remember what the letters are, and where the letters are

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**Separate WM Systems?**

<table>
<thead>
<tr>
<th>Z</th>
<th>T</th>
<th>P</th>
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<tr>
<td>V</td>
<td>L</td>
<td>K</td>
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<td>J</td>
<td>R</td>
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Distracter

Count backwards from 100 by 7s
100…93…etc

Separate WM Systems?
**Answer**

<table>
<thead>
<tr>
<th></th>
<th>Z</th>
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<tr>
<td>J</td>
<td>R</td>
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**Separate WM Systems?**

- **Spatial distractor:** affects memory for location more than memory for letter.
- **Verbal distractor:** affects memory for letter more than memory for spatial location.
Spatial distractor: affects memory for location more than memory for letter

Verbal distractor: affects memory for letter more than memory for spatial location

** Is this a double dissociation??? Why? **
Group Thought Experiment

- Imagine that you are working with patients with brain damage and you want to see which areas of the brain are related to these two systems.
- What kind of tests would you do?
- What would you need to see to give you a double dissociation indicating two separate working memory systems? (verbal and spatial)

Separate WM Systems?

P.V.
- extensive LH stroke covering non-verbal language regions
- impaired verbal short-term memory
- intact spatial short-term memory

E.L.D.
- right-sided hemisphere stroke to anterior temporal lobe
- impaired spatial short-term memory (gorski) span, with intact verbal span
Is WM unitary or non-unitary?

NON-UNITARY (separate verbal and spatial components)

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Baddeley & Hitch (1974)

Baddeley's working memory model

- Phonological loop
  - Storage (passive)
  - Rehearsal (active)

- Central executive

- Visuospatial sketch pad
  - Visual information
  - Spatial information

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Phonological Loop

- Phonological Store
  - Can retain speech-based information for about 2 seconds without rehearsal
  - Then will decay unless you engage the . . .

- Articulatory Control Process
  - Refreshes info from phonological store (offset decay)
  - Sub-vocal rehearsal
    - Translates visual info into speech-based code
    - See a picture of a tree and say “tree”

Phonological loop is specialized for language:

- Word Length Effect
- Articulatory Suppression
- Phonological Similarity Effect
When I finish, write down these words in the same order as I say them in

Potato, pencil, computer, magazine, fireplace, avalanche, toothpaste

The Phonological Loop

- Word length effect:
  - Verbal span decreases with number of syllables per word
The Phonological Loop

- When children are learning to talk, they talk slower than adults
- Kids can remember more words as their speech rate increases

Articulatory Suppression Effect

Partner Experiment

- Partner 1: Say a list of numbers
- Partner 2: Listen, then repeat the word “the”
- Partner 1: After some time ask Partner 1 to recall
- Which part of the phonological loop does this interfere with?
### Phonological Similarity Effect

Write down these words in the same order as I say them in

Cook, look, hook, book, nook, rook

- What happened? Why?
- Phonological similarity effect.
- Which part of the phonological loop does this interfere with?

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Baddeley & Hitch (1974)

Baddeley's working memory model

Forward or reversed R?
Forward or reversed R?

R

Forward or reversed R?

9
How were you deciding?

Representations in Visuo-Spatial Working Memory

_May support mental imagery, with images being in analogue format_

Stimulus set:

Forward or Reversed?

- Normal
- Reversed

Reaction Time

Orientation

0 90 180 270 360

R P O A D P R
B 6 9 4 9 6 B
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Baddeley & Hitch (1974)

Phonological loop
  Storage (passive)
  Rehearsal (active)

Central executive

Visuospatial sketch pad
  Visual information
  Spatial information

Baddeley's working memory model
The Central Executive Controls the two “slave systems”

Central Executive/Cognitive Control helps us with:

- Controlled action (as opposed to automatic)
- Planning for the future
- Central to most cognitive functions
  - Working Memory
  - Attention
  - Language
  - Generating and Maintaining Goals
  - Contributes to unique aspects of human behavior (underlies our notions of consciousness, will, agency).

- How may it function in the Stroop task?
Random Generation Task

Task: Generate a random series of letters, at a rate of one letter per second.

*Each time I clap, think about a different letter.*

Make sure it’s totally random and not in any specific order.
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Brain Bases of the Phonological Loop

Patient K.F.:

• the temporo-parietal junction is necessary for verbal working memory

But which part of working memory?

• rehearsal (articulatory control process) or
• storage (phonological store)
Brain Bases of the Phonological Loop

Task 1: Short-term memory for letters
(Phonological Storage & Rehearsal)
X…T…R…W…N…H…2sec delay…R?

Task 2: Rhyming judgment for letters
(Rhyme with “B”?)
(Phonological Rehearsal Only)
X…T…R…W…N…H…

What subtractions would you do to figure out what parts of the brain are important for storage vs. rehearsal?

Task 3: Shape Similarity
(Control Task; matches e?)
(No phonological storage or rehearsal; but controls for visual stimulus, button press, etc)
ﬁ…g…c…a…e

Brain Bases of the Storage

Task 1: Phonological Storage & Rehearsal

Task 2: Phonological Rehearsal Only

= Storage Regions

Activity in the Supramarginal gyrus (part of tempo-parietal junction)
Brain Bases of the Rehearsal

**Task 2**: Phonological Rehearsal Only

**Task 3**: No phonological storage or rehearsal; but controls for visual stimulus, button press, etc

= Rehearsal Areas

Activity in Broca’s Area

Brain Bases of the Phonological Loop

Network of regions implicated in neuroimaging studies of verbal Working Memory

Note: there are some question marks!

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Fig. 2. The Multiple-Component Model (Baddeley, 1996). Panel A illustrates the main structural and processing components of the Multiple-Component Model, adapted from (Baddeley, 1996). Panel B illustrates a cognitive, but fairly widely accepted, mapping of the Multiple-Component Model onto the brain. Regions are color coded to correspond to the model components shown in panel A. Images modified from Sylva’s Fundamentals of Human Neural Structure, S. Mark Williams, Streser Associates, Inc. Sunderland MA.
Visiuspatial Sketchpad

• What is visuospatial rehearsal?

• May be similar to the brain areas you use for selective attention

“selective attention” is thought to result from differences in the prefrontal cortex

(Reinke et al., 1994)
Central Executive

- Prefrontal cortex

- Often *perseverate* (repeat things)
- Have reduced ability to inhibit ongoing or automatic behavior
  - For example: Stroop
- Utilization behavior: can’t resist picking up and manipulating objects

Neural mechanisms of cognitive control

- Prefrontal cortex

- Patients with frontal damage can also be *inactive*
- Reduced ability to generate goals based on internal cues, or to initiate behavior
- Reliant on external cues to influence behavior
- Will often sit motionless and speechless
Frontal Lobe Case Study

What did you notice about Bill?
How does this fit with what you know about the frontal lobes?
Neural mechanisms of cognitive control

- How do you alter the degree of control?

  - You pay closer attention to the road if you’re driving while it’s raining as compared to while it’s sunny.

  - You pay even closer attention if it’s raining and dark out, than if it’s raining but light out.

  - By modulating the strength of the activity from the pre-frontal cortex
Neural mechanisms of cognitive control: Anterior Cingulate

• The anterior cingulate may modulate the prefrontal cortex activity
• The anterior cingulate may be important for error detection, or for conflict monitoring