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Presents

Course Title:

Basic Cognitive Processes

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Lecture 31: Memory - III

Working Memory

- Alan Baddeley reasoned that short - term memory processes must be dynamic and also consider of a number of components that can function separately.

- Acc. to this idea, the digit span task would be handled by one component while comprehending the paragraph would be handled by another component.

- The model Baddeley proposed was first described in a paper with Graham Hitch (Baddeley & Hitch, 1974) and, was later modified to explain new findings.
- In this model, the short - term memory component of memory is called *Working Memory*.
- ***Working Memory*** is defined as a limited capacity system for temporary storage & manipulation of information for complex tasks such as comprehension, learning and reasoning.

- From this definition we can see that working memory differs from short term memory in two ways:
  - STM is concerned mainly with *storing information* for a brief period of time, whereas working memory is concerned with the *manipulation of information* that occurs during complex cognition.
  - STM consists of a single component, whereas working memory consists of a *number of components*.

- Working memory accomplishes the manipulation of information through the action of three components: ***the phonological loop, the visuospatial sketch pad, & the central executive***.

- The **phonological loop** consists of two components: the phonological store, which has a limited capacity and holds information for only a few seconds; & the articulatory rehearsal process, which is responsible for rehearsal that can keep items in the phonological store from decaying. The phonological loop holds verbal and auditory information.

- The **visuospatial sketchpad** holds visual & spatial information.

- The **central executive** is where the major work of working mmemory occurs. The central executive pulls information from long - term memory and coordinates the activity of the phonological loop & visuospatial sketch pad by focusing on specific parts of a task and switching attention from one part to another.
    - One of the main tasks of the central executive is to decide on how to divide attention between tasks.

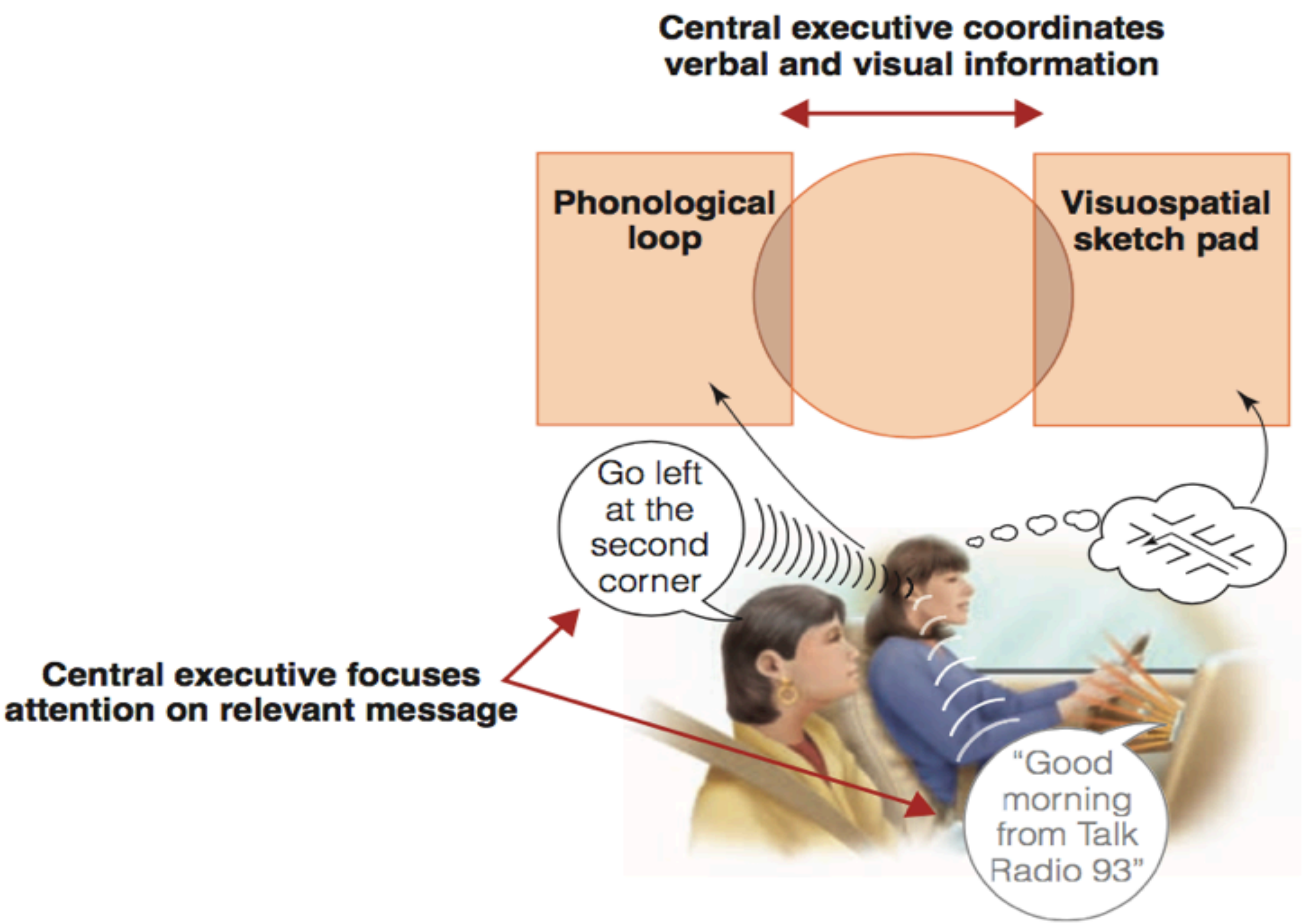


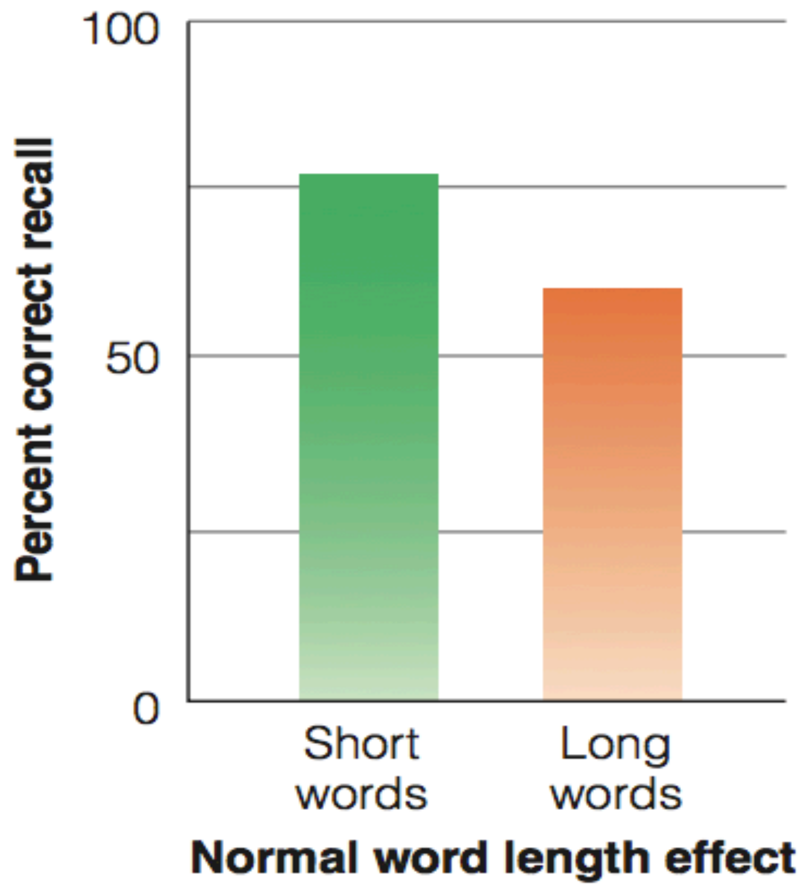
FIGURE 5.15 Tasks processed by the phonological loop (hearing directions; listening to the radio) and visuospatial sketch pad (visualizing the route) being coordinated by the central executive. The central executive also helps the person ignore the messages from the radio, so attention can be focused on hearing the directions.

Image: Goldstein (2010).Cognitive Psychology: Connecting Mind, research & Everyday Experience. *Wadsworth Publishing*. (Fig. 5.15, p. 132).

- **The Phonological Loop**
  - the *phonological similarity effect* is the confusion of letters or words that sound similar. remember Conrad's experiment.
  - the *word length effect* occurs when memory for lists of words is better for short words than for long words (Baddeley et al., 1984).

- *articulatory suppression* one way that the operation of the phonological loop has been studied is by determining what happens when its operation is disrupted. This occurs when a person is prevented from rehearsing items to be remembered by repeating an irrelevant sound, such as “the the the..” (Baddeley, 2000). the repetition of an irrelevant sound results in a phenomenon called **articulatory suppression** which reduces memory because speaking interferes with rehearsal.

- Baddeley & colleagues (1984) found that repeating “the the the..” not only reduces the ability to remember a list of words, but also eliminates the word length effect.



● **FIGURE 5.16** How word length affects memory, showing that recall is better for short words (Baddeley et al., 1984).

Image: Goldstein (2010).Cognitive Psychology: Connecting Mind, research & Everyday Experience. *Wadsworth Publishing*. (Fig. 5.16, p. 133).

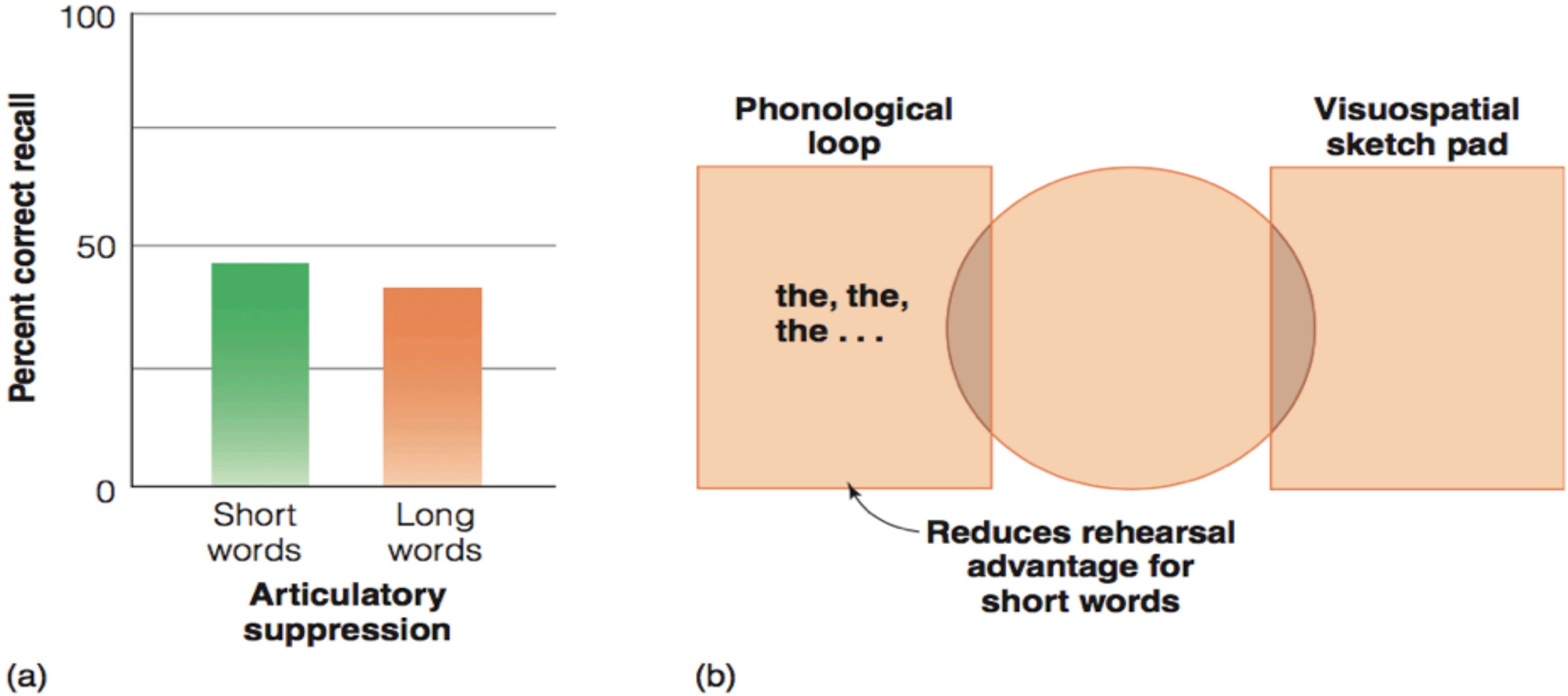


FIGURE 5.17 (a) Saying "the, the, the…" abolishes the word length effect, so there is little difference in performance for short words and long words (Baddeley et al., 1984). Saying "the, the, the…" causes this effect by reducing rehearsal in the phonological loop.

Articulatory suppression occurs when remembering the second list becomes harder because repeating "the, the, the…" overloads the phonological loop.

- Image: Goldstein (2010).Cognitive Psychology: Connecting Mind, research & Everyday Experience. *Wadsworth Publishing*. (Fig. 5.17, p. 134).

- **The Visuospatial Sketchpad:** handles visual & spatial information & is therefor involved in the process of visual imagery - the creation of visual images in the mind in the absence of a physical visual stimulus. The following demonstration illustrates an early visual imagery experiment by Shepard & Metzler (1971).

- When Shepard & Metzler measured participants' reaction time to decide whether pairs of objects were same or different, they obtained the relationship for objects (…figure) that were same or different. From this function it can be seen that when two shapes were separated by an orientation difference of 40 degrees, it took 2 seconds to decide that a pair was the same; but for a difference of 140 degrees, it took 4 seconds.

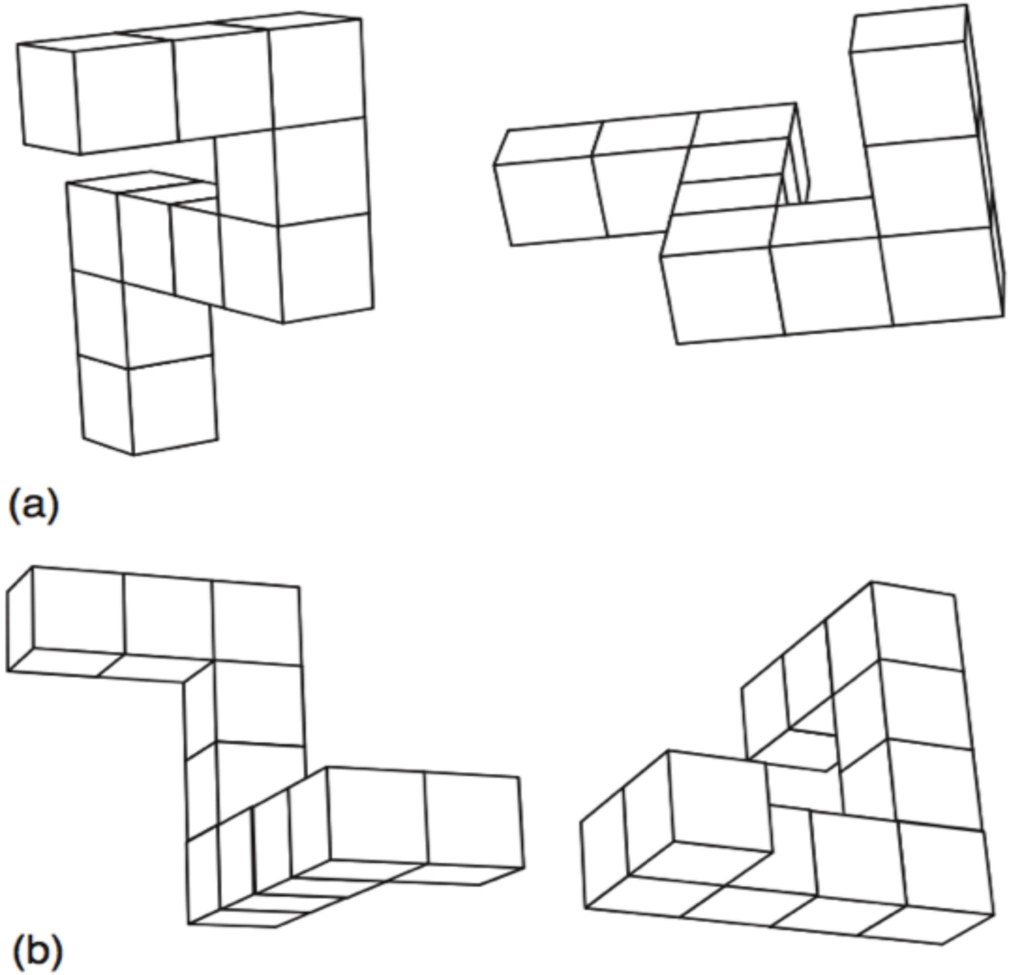


FIGURE 5.18 Stimuli for the "Comparing Objects" **demonstration.** (Source: R. N. Shepard & J. Metzler, "Mental Rotation of Three-Dimensional Objects," *Science, 171*, Figures 1a&b, 701–703. Copyright © 1971 American Association for the Advancement of Science. Reproduced with permission.)

Image: Goldstein (2010).Cognitive Psychology: Connecting Mind, research & Everyday Experience. *Wadsworth Publishing*. (Fig. 5.18, p. 134).

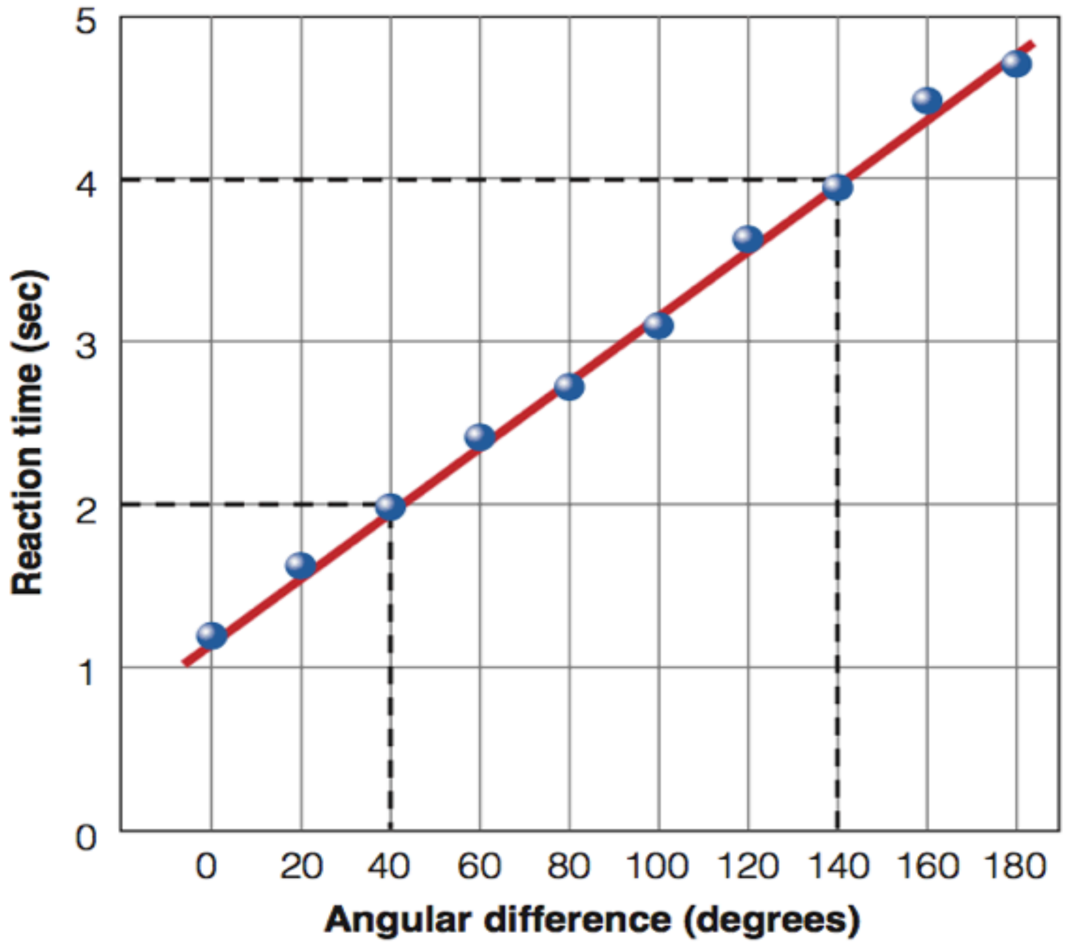


FIGURE 5.19 Results of Shepard and Metzler's (1971) mental rotation experiment. (Source: R. N. Shepard & J. Metzler, "Mental Rotation of Three-Dimensional Objects," *Science, 171*, Figure 2a, 701–703. Copyright © 1971 American Association for the Advancement of Science. Reproduced with permission.)

- Image: Goldstein (2010).Cognitive Psychology: Connecting Mind, research & Everyday Experience. *Wadsworth Publishing.* (Fig. 5.19, p. 135).

- Based on these findings, Shepard & Metzler concluded that participants were solving the problem by rotating the image of one of the objects in their mind, a phenomenon called **mental rotation.**

- Lee Brooks (1968) did some experiment in which he demonstrated how interference can affect the operation of the visuospatial sketch pad.

DEMONSTRATION Holding a Spatial Stimulus in the Mind

Task 1: Visualize the *F* in ● Figure 5.20. Then cover the F and while visualizing it in your mind, start at the upper left corner (the one marked with the *) and, moving around the outline of the F in a clockwise direction in your mind, point to “Out” in ● Figure 5.21 for an outside corner (like the one marked with the *), and “In” for an inside corner (like the one marked with the ●). Move your response down one level in Figure 5.21 for each new corner.

Image: Goldstein (2010).Cognitive Psychology: Connecting Mind, research & Everyday Experience. *Wadsworth Publishing*. (Demo, p. 135).

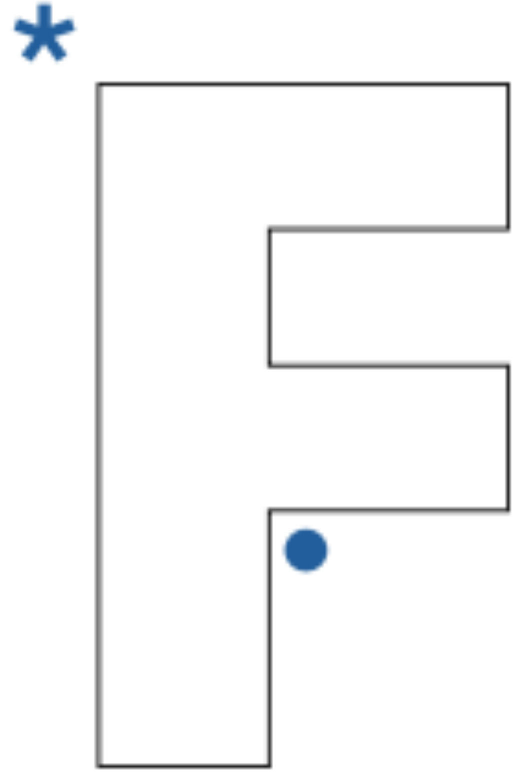


FIGURE 5.20 *F* stimulus for "Holding a Spatial Stimulus in the Mind" demonstration. (From Brooks, 1968.) The * indicates an outside corner, and the • indicates an inside corner.

Image: Goldstein (2010).Cognitive Psychology: Connecting Mind, research & Everyday Experience. *Wadsworth Publishing.* (Fig. 5.20, p. 135).

Task 2: Visualize the F again, but this time, as you move around the outline of the F in a clockwise direction in your mind, say "Out" if the corner is an outside corner or "In" if it is an inside corner.

Which was easier, *pointing* to "Out" or "In" or *saying* "Out" or "In"?

Image: Goldstein (2010).Cognitive Psychology: Connecting Mind, research & Everyday Experience. *Wadsworth Publishing*. (Demo, p. 135).

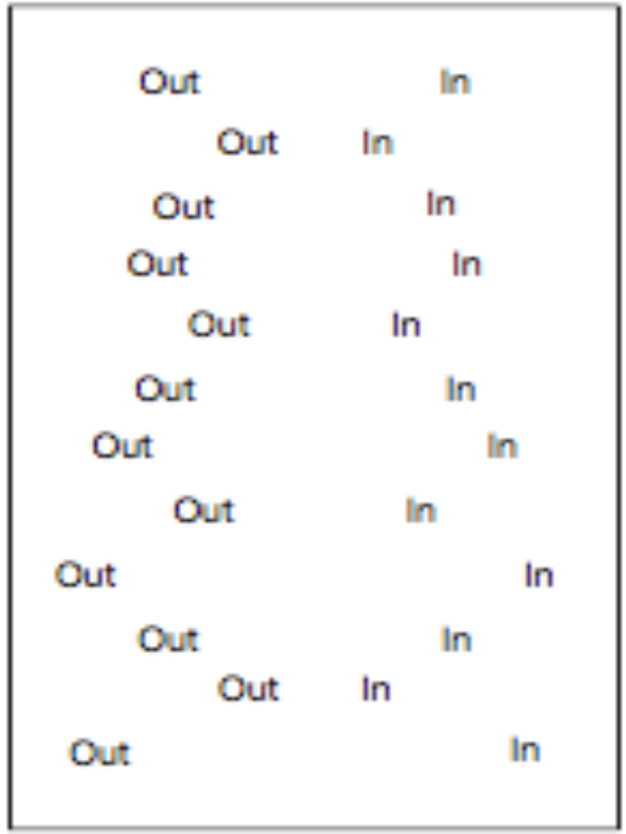


FIGURE 5.21 Response matrix for the "Holding a Spatial Stimulus in the Mind" demonstration. (From Brooks, 1968.)

Image: Goldstein (2010).Cognitive Psychology: Connecting Mind, research & Everyday Experience. *Wadsworth Publishing*. (Fig. 5.21, p. 135).

- Most people find that the pointing task is more difficult. The reason is that holding the image of the letter and pointing are both visuospatial tasks, so the visuospatial sketchpad becomes overloaded.

- In contrast, saying “out” or “in” is an articulatory task that is handled by the phonological loop, so speaking did not interfere with visualising the F.

- **The Central Executive** is the component that makes working memory “working” because it is the control centre of the working memory system. It’s mission is not to store information, but to coordinate how information is used by the phonological loop & visuospatial sketchpad (Baddeley, 1996).

- Baddeley describes the central executive as the *attention controller.* It determines how attention is focused on a specific task, how it is divided between two tasks & how it is switched between tasks.

- The central executive is therefore essential in situations as for e.g. when the person is attempting to simultaneously drive & use a cell phone. In this example, the executive would be controlg a phonological loop process (talking on the phone) & a sketchpad process (visualising landmarks & the layout of the streets; navigating the car).

- One of the ways the central executive has been studied is by assessing the behaviour of patients with brain damage. As we see, the frontal lobe plays a central role in working memory; therefore that patients with frontal lobe damage have problems controlling their attention. e.g. a typical example is **perseveration** i.e. repeatedly performing the same behaviour even if it is not achieving the desired goal.

- Consider for example, a problem that can be easily solved by following a rule, “Pick up the red object.” A person with frontal lobe damage might be responding correctly on each trial as long as the rule stays the same. However, when the rule is changed, (“ Now pick the blue object.”), the person continues following the old rule even when feedback that his or her action is incorrect is given.

- Another example of how the central executive controls attention is provided by situations in which a person is supposed t focus attention on “relevant” stimuli and ignore other, “irrelevant stimuli”.
- Some people are better at focussing attention than others.

- **The Episodic Buffer:** There are also some results that the model cannot explain. One of those things is that working memory can hold more than would be expected based on just the phonological loop or the visuospatial sketchpad. for e.g. people can remember long sentences consisting of as many as 15 - 20 words. The ability to do this is related to chunking, in which meaningful units are grouped together.

- Baddeley decided it was necessary to propose an additional component of working memory to address these abilities.

- This new component, i.e. **the episodic buffer** can store more information (thereby providing extra capacity) & is connected to LTM (thereby making interchange between working memory & LTM possible).

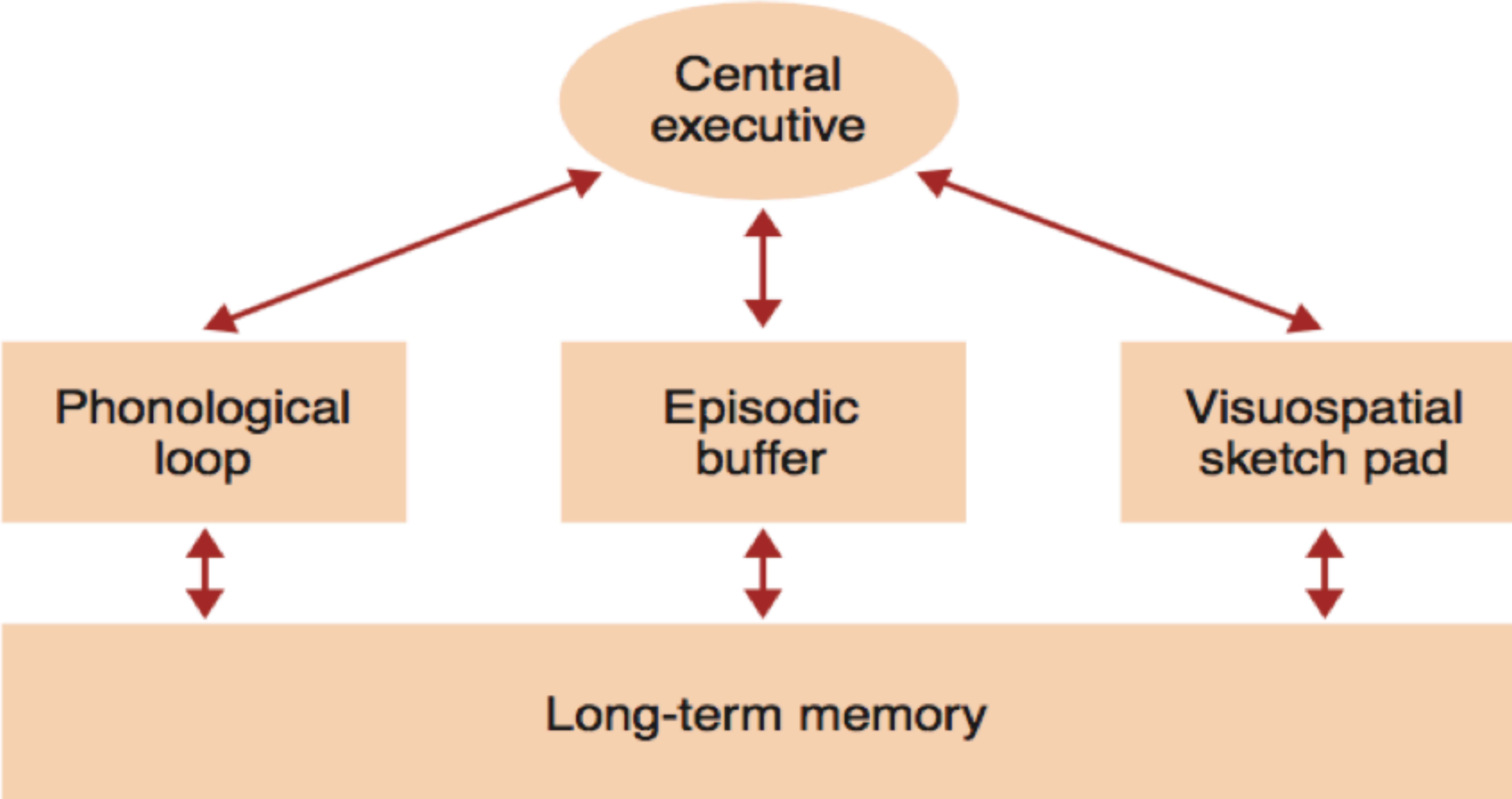


FIGURE 5.22 Baddeley's revised working memory model, which contains the original three components plus the episodic buffer.

Image: Goldstein (2010).Cognitive Psychology: Connecting Mind, research & Everyday Experience. *Wadsworth Publishing*. (Fig. 5.22, p. 137).

- Note that this model also shows that VSP & PL as connected to the LTM.

- The proposal of the episodic buffer represents another step in the evolution of Baddeley’s model, which has been stimulating research on working memory for more than 30 years since it was first proposed.

- The exact functioning of the episodic buffer, seems a little vague as it is very much a work in progress.

Working Memory & the Brain

- There are few methods that have been used to determine the connection between cognitive functioning & the brain:
  - analysis of behaviour after brain damage (lesion studies)
  - recording from single neurons (single cell recording)
  - recording electrical signals (EEG)
  - measuring brain activity (fMRI)

- the delayed response task: early research on the frontal lobe & memory was carried out in monkeys using the delayed response task, which required a monkey to hold information in working memory during a delay period (Goldman - Rakic, 1992).

- The monkey sees a food reward in one of two food wells; both wells are then covered, a screen is lowered, and then there a is a delay before which the screen is raised again.

- When the screen is raised, the monkey must remember which well had the food to uncover the well & then take the food well to obtain a reward.

- Monkeys can be trained to accomplish this task.

FIGURE 5.24 The delayed-response task being administered to a monkey.

Image: Goldstein (2010).Cognitive Psychology: Connecting Mind, research & Everyday Experience. *Wadsworth Publishing*. (Fig. 5.24, p. 138).

- However, when their prefrontal cortex is removed, their performance drops to the level of chance & they are correct only about 50% of the time.

- This result supports the idea that the PF is important for golding information for brief periods of time.

- **Brain activation in humans:**
  - The conclusion that many brain areas are involved in working memory has been confirmed by research using imaging techniques such as PET and fMRI to measure brain activity in humans. these studies show that as a person carries out a working memory task, activity occurs in the prefrontal cortex (Courtney et al., 1998).
  - The figure shows that other than areas in the frontal lobe; areas in the parietal lobe & the cerebellum are involved in working memory.

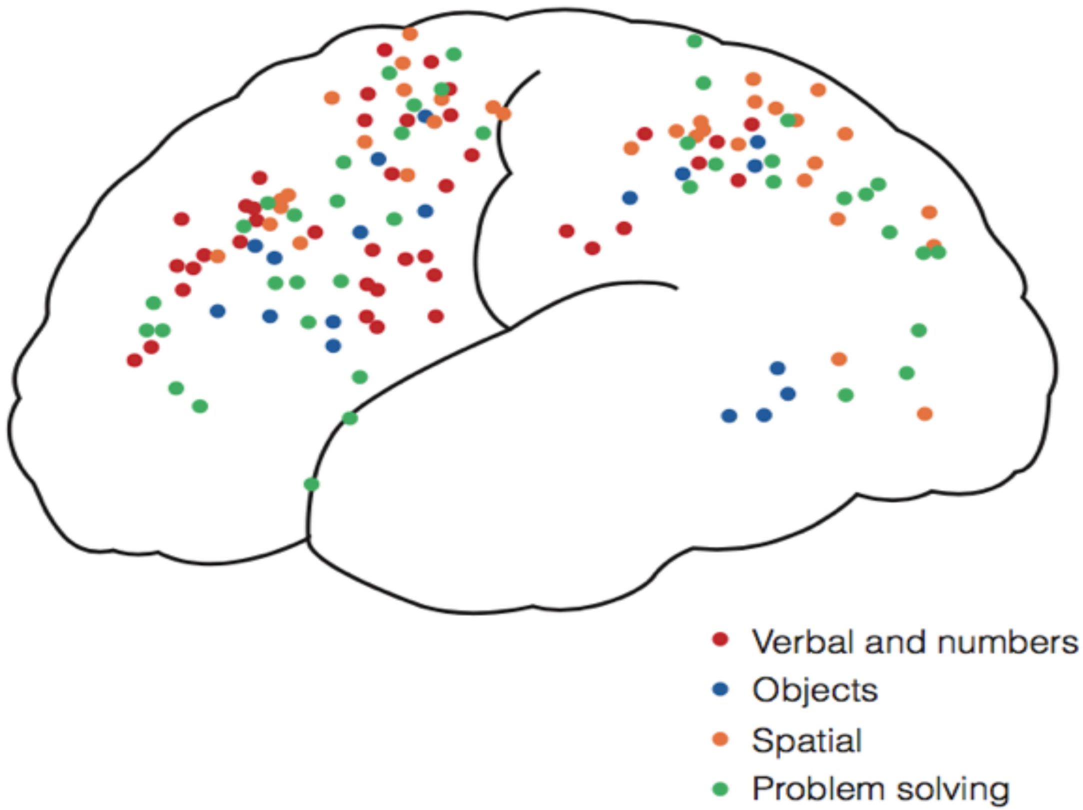


FIGURE 5.26 Some of the areas in the cortex that have been shown by brain imaging research to be involved in working memory. The colored dots represent the results of more than 60 experiments that tested working memory for words and numbers (red), objects (blue), spatial location (orange), and problem solving (green). (Source: R. Cabeza & L. Nyberg, "Imaging Cognition II: An Empirical Review of 275 PET and fMRI Studies," *Journal of Cognitive Neuroscience, 12*, 1–47, 2000.)

Image: Goldstein (2010).Cognitive Psychology: Connecting Mind, research & Everyday Experience. *Wadsworth Publishing*. (Fig. 5.26, p. 140).

- Vogel & cowokers (2005) did an experiment on the allocation of attention by measuring a component of the event related potential (ERP) in humans, recorded during a working memory task.

- The response they measured was related to encoding items in working memory, so a larger ERP response indicated that more space was used in working memory.

- Vogel & colleagues separated participants into two groups based on their performance on a test of working memory.
    - Participants in the high WM capacity group were able to hold a umber of items in the working memory; participants in the low WM capacity group were able to hold fewer items in the working memory.

- Bothe groups viewed the stimuli as shown in figure (); they first saw a cue indicating whether to direct their attention to the red rectangles on the left side or the red rectangles on the right rectangles on the right side of the displays that followed.

- they then saw a memory display for 1/10th of a second, followed by a brief blank screen & then a test display.

- On some trials, two red rectangles were presented on the left & right sides of the display, as shown in fig (); on the other trials two red rectangles & two blue rectangles were presented.

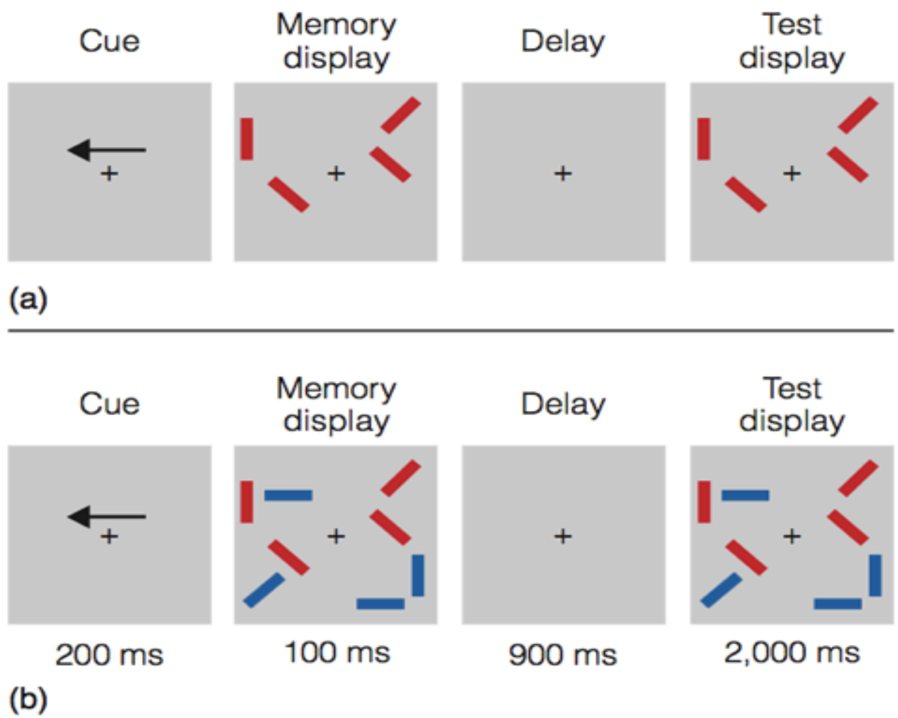


FIGURE 5.27 Sequence for the Vogel et. al (2005) task. The arrow in this example tells the participant to pay attention to the left side of the memory and test displays. The task is to indicate if the red rectangles on the attended side are the same or different in the two displays. (a) Display with two red rectangles on each side of the display. (b) Display with two blue rectangles added to each side. The participant is told to ignore the blue rectangles. (Source: Based on E. K. Vogel, A. W. McCollough, & M. G. Machizawa, "Neural Measures Reveal Individual Differences in Controlling Access to Working Memory," *Nature* 438, 500–503, 2005.)

Image: Goldstein (2010).Cognitive Psychology: Connecting Mind, research & Everyday Experience. *Wadsworth Publishing*. (Fig. 5.27, p. 140).

- The participant’s task was to respond to the test display by indicating whether the orientations of the red rectangles in the cued side of the test display was the same or different from the orientations of the red rectangles on the cued side of the memory display.

- the results show the size of the ERP response for both groups.

    - the left pair of bars show that the ERP response when just red rectangles were presented was similar for both groups of participants; however the right pair of bars indicate that adding blue rectangles had little effect on the response of the high capacity group; but it caused an increase in the response of the low capacity group.

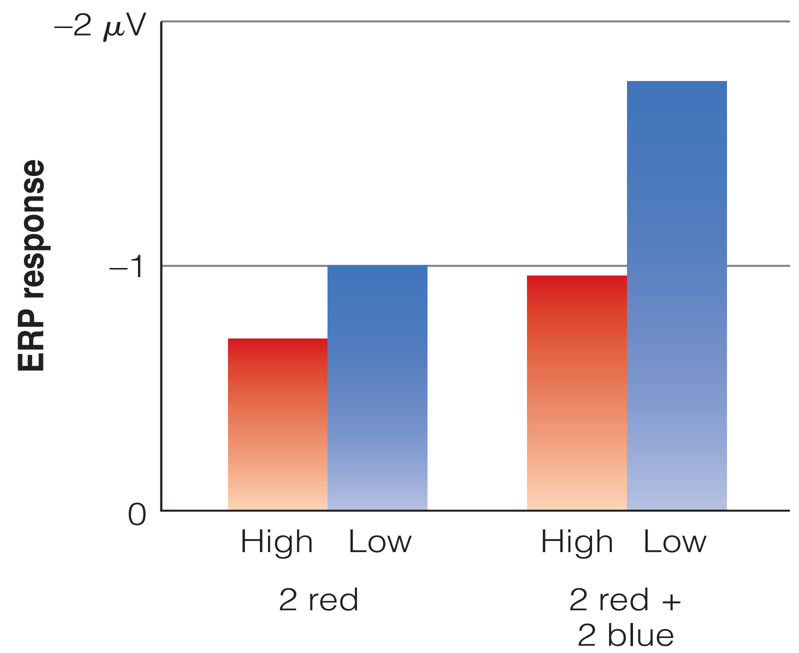


FIGURE 5.28 Results of the Vogel et al. (2005) experiment. The key finding is that performance is about the same for high- and low-capacity participants when only the red rectangles are present (left pair of bars), but although adding the two blue rectangles has little effect for the high-capacity participants, it causes an increase in the response for the low-capacity participants (right pair of bars). (Source: Based on E. K. Vogel, A. W. McCollough, & M. G. Machizawa, "Neural Measures Reveal Individual Differences in Controlling Access to Working Memory," *Nature 438,* 500–503, 2005.)

Image: Goldstein (2010).Cognitive Psychology: Connecting Mind, research & Everyday Experience. *Wadsworth Publishing*. (Fig. 5.28, p. 141).

- The fact that adding the two blue rectangles had little effect n the response of the high capacity group means that these participants were very efficient at ignoring the distracters, so the irrelevant blue stimuli did not take up any space in working memory. This means that the central executive was functioning well for these participants.

- The fact that adding the two blue rectangles caused a large increase in the response of the low capacity group means the these participants were not able to ignore the irrelevant blue stimuli, & the blue rectangles were therefore taking up space in working memory the central executive of these participants was not operating as efficiently as that of the high capacity group.

- Vogel & colleagues concluded that some people's central executives are better at allocating attention than others.

References

- Goldstein (2010).Cognitive Psychology: Connecting Mind, research & Everyday Experience. *Wadsworth Publishing.*