Baddeley's Three Systems of Working Memory

By Dr. Cyndi McDaniel, Northern Kentucky University, adapted by Rob McEntarffer, Lincoln Public Schools

Concept: Many introductory textbooks are including the concept of "working memory" in the discussion of short-term memory. Working memory refers to a memory system that can store and use information needed for a specific task. For example, a person would use their working memory to drive to their friends' house. The directions to the house would be retained and used while information about how to drive, when to turn the wheel, how to shift is also being used. Alan Baddeley's research implies three components or systems of working memory that high school students find interesting and are easily understood in a quick classroom demonstration. The three systems are:

- Central executive: controls our attention and coordinates working memory for a specific task
- Phonological loop: stores and utilizes semantic (word) information
- Visuo-spatial sketchpad: stores and utilizes speech based information

Materials: None!

Instructions: Ask students to close their eyes. Instruct the students to mentally (not out loud) count the number of windows in their house. If a student asks what counts as a window, tell them they can use their own definition of window for purposes of this demonstration, since this is not crucial to success of the demonstration, or you can make a specific operational definition of "window" for the whole class to use. Tell the students to open their eyes when they are finished so you know they're done. When everyone is finished with that task, ask them to close their eyes again and to mentally count the words in this sentence:
"Please count the number of words in the sentence I just said" (you may need to repeat this sentence more than once:
As the students mentally count the words in that sentence, watch them closely to see if they are using their fingers to count. Again, ask them to open their eyes when they're finished. After all the students are done, ask them to raise their hands if they used their fingers to count the number of windows in their house. Few if any should have used their fingers on this memory task. Then ask how many used their fingers to count the number of words in the sentence. Most if not all of the students should raise their hands. You can then start a discussion asking the students to explain this difference. Why did they need to use their fingers to count the words but not the windows?

Discussion: The three systems Baddeley describes explain why we need to use our fingers on certain memory tasks. After the students offer some possible explanations, I explain the three systems to the class. I tell my students to think of the phonological loop and visuo-spatial sketchpad as tools in a tool box. We can use both tools simultaneously on a certain task, but we can't use one tool twice at the same time. When we're visualizing windows, we use the sketchpad to mentally walk through our house and look at each window. At the same time we use the phonological loop to count mentally, since numbers are verbal labels. Our central executive can use both those tools at the same time, so we don't need our fingers. But when we try to count the words in the sentence, we need our phonological loop to retain and repeat the sentence mentally. But we also need the phonological loop to count the words. Since we can't use the same tool (the phonological loop) twice at the same time, we need something else to keep track of the number of words: Our fingers! You can continue the discussion from this point by asking for other examples of these systems in action.

References:

Baddeley, A. (1992) Working Memory *Science*, 255, 556-559
Sternberg, Robert J and Wagner, Richard K. (1999) *Readings in Cognitive Psychology*, Harcourt Brace & Co.

Single Diagnostic Item for Baddeley's Three Systems of Working Memory
Big idea: Executive function/working memory
Misconceptions:
1) visual information is easier to process
2) visual/auditory/kinesthetic learning styles myth
3) long-term vs. short term memory influences the task
4) familiarity influences the task
5) "picturing" influences the task

Stem: Why do most people have to use their fingers when they count the words in the sentence, but they don't when they count the windows?
A) Windows are visual, and visual things are easy to process. (misconception 1)
B) Most people are visual learners. (misconception 2)
C) The windows are in long term memory, but the words are in short term memory. (misconception 3)
D) Familiarity - I'm more familiar with my windows than I am the words in that sentence, so that task is harder. (misconception =4)
E) I can picture the windows but I can't picture the words, and that has something to do with it. (misconception 5)
F) Working memory must process words and pictures differently. (right answer)

Attention and Encoding

Based on a concept and demonstration by Dr. Ludy Benjamin, Texas A&M University. Adapted by Rob McEntarffer, Lincoln Public Schools (Note: This demonstration also included with the Memory Unit Lesson Plan distributed by Teachers of Psychology in Secondary Schools (TOPSS), American Psychological Association)

Concept: This activity demonstrates the power of attention in the encoding process (as a step in the information-processing model of memory). Participating students will experience involuntary encoding into working and long-term memory.

Materials: None (white or chalk board is helpful).

Instructions:

1. Talk with the students about a VERY important and difficult assignment you are about to assign. Make sure that all students are focused on you and explain that you are about to give them an assignment that may be impossible to complete correctly. Tell them they will have to put all their effort into the assignment for any of them to even have a chance at completing the assignment successfully.
2. After you've made a "really big deal" out of the set-up above, write the number "107" on the board (or large piece of paper, etc.) Make sure all the students focus on the number. Ask them all to repeat the number aloud. Have the class chant the number two or three times all together. Then tell them it's time for them to hear their assignment: Instruct them to FORGET the number overnight.
3. Students will object and there will be some murmurings of discontent. Expand on the instructions and tell them they should all try hard to try to NOT remember the number by class time tomorrow, and that you will test them all tomorrow. You can ask the students make a prediction about the chances of their success.
4. The next day, ask all the students whether they remember the number or whether they successfully forgot. You can have students all write down the number privately and then write "107" on the board and have students check their responses. Almost all (probably all) the students will remember the number if they are responding honestly.
5. Discuss with the students why this was an impossible assignment. Students should be able to talk about the element of attention in this example of encoding: So much attention was devoted to the number 107 that the number was very likely the number would be encoded into working and long-term memory. Once the information was encoded in long-term memory, it was very likely to be recalled (and any "effort" to forget the number would further help encode it).

Discussion: Students remember this demonstration and the number "107" for a LONG time after this activity (years!). This powerful demonstration

<u>Single Diagnostic Item for Attention and Encoding</u>

<u>Big Idea:</u> The more attention we devote to a stimulus, the more likely it is to be encoded into working and long-term memory than other stimuli.

<u>Misconceptions:</u>

1. Memory is like video tape: all stimuli are encoded, but only some can be recalled.
2. Encoding only happens at an unconscious level and we can do little to affect what we encode into memory.
3. We are somehow more likely to encode small details that we barely attend to into long term memory.

4. Encoding is inherently unreliable, and we are unlikely to encode any stimuli into long term memory accurately.

Stem: You are walking behind a woman when suddenly someone rushes out from an alley and grabs the woman's purse. Which of the following statements best describes what parts of this event are encoded into your memory?

A. Everything about this event is stored in long term memory, but you may not recall most of the details. (misconception 1)

B. Many details of this event might be encoded into long term memory because of unconscious connections between details and our previous memories. (misconception 2)

C. We are likely to encode small details about the event, like the color of the purse, more accurately than the large details, like the gender of the attacker. (misconception 3)

D. Most of the details we encode about this event are likely to be inaccurate, constructed memories (misconception 4)

E. The details that we happened to notice most, like the sight of the attacker rushing by, are likely to be encoded. (possible correct answer)

F. Attention determines what will be encoded, so whatever details we most noticed will likely be encoded into long-term memory. (possible correct answer)

Newspaper Mind Reading Trick

Dr. Doug Bernstein originally presented this demonstration at the Nebraska Wesleyan Teaching High School Psychology Institute in Lincoln, NE. Adapted by Rob McEntarffer, Lincoln Public Schools

Concept: Involving students in the initial steps of the scientific method (specifically, hypothesis generation and experiment design) can be challenging. This demonstration is a highly engaging way to inspire students to want to figure out possible hypotheses for a seemingly inexplicable phenomenon.

Materials:

1. Prepared newspaper article: Cut out a long, single column newspaper article (preferably left and right margin justified). Cut the article at a line just below the headline. Turn this bottom part of the article upside down and tape the article on the back. Now the bottom line of the article should be upside down, and it should not be obvious from the front of the article that the article has been "doctored."
2. Card and sealed envelope: Write the bottom line of the article on a piece of paper and seal it in an envelope. Tape this envelope under a student's chair before the class arrives. Remember which seat the envelope is under.
3. Scissors.

Instructions:

1. After the class arrives, tell a fictional story about how you gained "psychic abilities." I used a fictional story of a minor car accident (e.g. "I bumped my head on the steering wheel, and ever since then I've been able to see the future!"). Tell the students you are going to prove your psychic ability to them.
2. Hold up the prepared article under the headline pinched between your finger and thumb (covering the tape on the back). Make sure you are standing far enough away from the students sitting at the front of the class so that they can't see that the bottom of the article is upside down.
3. Ask for a student volunteer.
4. Explain to the student volunteer and the class that you are going to move the scissors up and down the newspaper article. Ask the student volunteer to tell you when she/he wants to you cut the article.
5. Tell the student that, using your psychic ability, you are going to predict where she/he will tell you to cut.
6. Move the scissors slowly up and down the article. When the student volunteer says "cut," cut the article straight across (make sure you don't cut at an angle).
7. Let the bottom part of the article fall to the ground, and sneak the top of the article into your pocket.
8. Ask for another student volunteer to come pick up the article and read the top line (Note: the "top line" the student will read is actually the "bottom line" of the article since it was upside down).
9. Point at the student sitting in the chair where you taped the sealed envelope with the card. Ask that student to retrieve the envelope, open it, and read the card.
10. Point out that the lines are the same! (Triumphantly!)
11. Talk with the students about the phenomenon they just witnessed. The students will not believe that you have "psychic" powers, so have them generate a list of other possible

hypotheses, along with plans of how to test these hypotheses. You can extend this activity by preparing more articles and performing some of the tests the students design!

12. At the end of the activity, you need to choose whether or not to tell the students the solution to the "trick." They will want to know. I choose to let them think about it and wonder until the end of the semester. I tell them if anyone remembers to ask, I will reveal the solution at the end of the semester, but until then they should keep generating hypotheses and tests.

Discussion: This demonstration always captures students' attention and can be a powerful way to introduce the idea of hypothetical reasoning. Students will WANT to know how the trick is done and many students become passionate about generating and testing hypotheses. Teachers can extend this activity into a discussion about testing psychic phenomena in general, including a discussion of skeptics like James Randi and Michael Shermer in debunking psychic claims.

Single Diagnostic Item for Newspaper Mind Reading Trick

Big Idea: Multiple, carefully controlled trials need to be performed in order to test different hypotheses about unexplained phenomena.

Misconceptions:

1. The goal of experimentation is to prove hypotheses correct.
2. Single trials can test multiple hypotheses.
3. Common sense is adequate to test hypotheses.
4. Our perception about physical phenomena is most often accurate.

Stem: A person claiming to be psychic demonstrates his ability to find an underground source of water using a "dowsing rod." As a psychologist, which tests would you like to use to test hypotheses about how the water was found?

A. This psychic should have to find water several more times in order to prove the hypothesis that he is psychic correct (misconception 1)

B. The psychic should have to find water again under a condition that controls for all the other possible explanations, such as cheating, coincidence, non-verbal clues from the audience, etc. (misconception 2)

C. As a psychologist, I don't need to test this claim because common sense has already dis-proven the possibility of psychic abilities. (misconception 3)

D. I would want to look at a videotape of the psychic demonstration frame by frame in order to determine where the deception occurred. (misconception 4)

E. The psychic should be asked to find underground water several more times, but each time a different possible explanation would be tested (possible correct answer)

Transmission of Neural Impulses

I originally saw Charlie Blair-Broeker demonstrate this activity at the Texas A&M Institute for the Teaching of Psychology. Adapted by Rob McEntarffer, Lincoln Public Schools

Concept: This demonstration gets students involved in "measuring" the speed of neural impulses as they travel through parts of the body. The concept of neural transmission can feel theoretical and removed from students' experiences, and this demonstration makes them real in a physical, participatory way.

Materials:

1. Enough space for the class to stand and sit in a circle.
2. Stopwatch.

Instructions:

1. Talk with the class about the process of neural transmission (using diagrams, slides, animations, etc.)
2. Ask the class: How long does this process take? How would research go about measuring the speed of neural transmission? Discuss student ideas (these explanations usually involve attempts to measure the speed of an impulse traveling within a single neuron).
3. Tell the class that there is a way to demonstrate the relative speed of neural transmission right here in the classroom.
4. Ask everyone to stand up and form a circle, shoulder to shoulder.
5. Ask for a volunteer timekeeper to stand in the middle of the circle and use the stopwatch.
6. Ask everyone to put their right hand on the shoulder of the person next to them. Tell the class that you are going to squeeze the shoulder of the person in front of you and say "Start!" The timekeeper will then start the timer. The students should pass the "impulse" (shoulder squeeze) around the circle, and the person behind you says "stop!" as soon as her/his shoulder is squeezed.
7. Practice this a few times, recording the elapsed time.
8. Then ask the class what would happen if they could LENGTHEN the neural distance. They will eventually decide that it would take longer for the impulse to travel around the circle.
9. Tell them that we will now test their guess! Ask the class to sit down and grab the right ankle of the person next to them. (Ask any students wearing skirts to be careful!).
10. Discuss the difference in total neural length: the distance between the ankle and the brain is significantly longer than the distance between the shoulder and the brain.
11. Use the timekeeper and students to test several trials of passing the "impulse" around the circle. Record the times.
12. Examine the data with the students. The average time of the "ankle trials" will be significantly different from the average of the "shoulder trials". Review the reasons why there are differences between the data, and incorporate students' knowledge if the process of neural transmission.

Discussion: Teachers can extend this demonstration and discussion by actually computing neural speed. Students can find the average distance from ankle to brain and from shoulder to brain, and use this distance in a formula to determine "feet (or inches) per second" for the impulse.

<u>Single Diagnostic Item for Transmission of Neural Impulses</u>

<u>Big Idea:</u> Neural impulses take time to travel across distances within the body and the longer the distance, the more time it takes the impulse to travel.

Misconceptions:
1. Sensation and perception occur simultaneously.
2. Neural impulses travel so quickly that their speed cannot be measured.
3. We feel physical sensations as we see them.
4. The neural distances within the body are so similar that speed differences are negligible.
Stem: As a focusing exercise, a group of actors stands in a circle holding hands. One person in the circle will start the "impulse" by squeezing a neighbor's hand, who will squeeze the hand of the person next to them, and in this way the pulse travels around the circle. Which statement below best describes how the neural impulse travels during this exercise?
A. When the neurons in the actor's hand sense the squeeze, neurons in the brain fire immediately to squeeze her neighbor's hand. (misconception 1)
B. The neural impulses that travel from the actors' hands to their brain travel so quickly that the "travel time" cannot be measured. (misconception 2)
C. The moment an actor sees her or his hand being squeezed, the neural impulses from the hand reach the brain and cause the perception of the hand being squeezed. (misconception 3)
D. Since neural impulses travel so quickly, the distances between the actors' hands and brains are not an important variable in the overall speed of the imulse. (misconception 4)
E. The neural impulse starting with the hand squeeze takes a measurable time to travel up the actors' arms to their brain, and then again down their other arm to their other hand. (possible correct answer)

Smiling Operational Definition

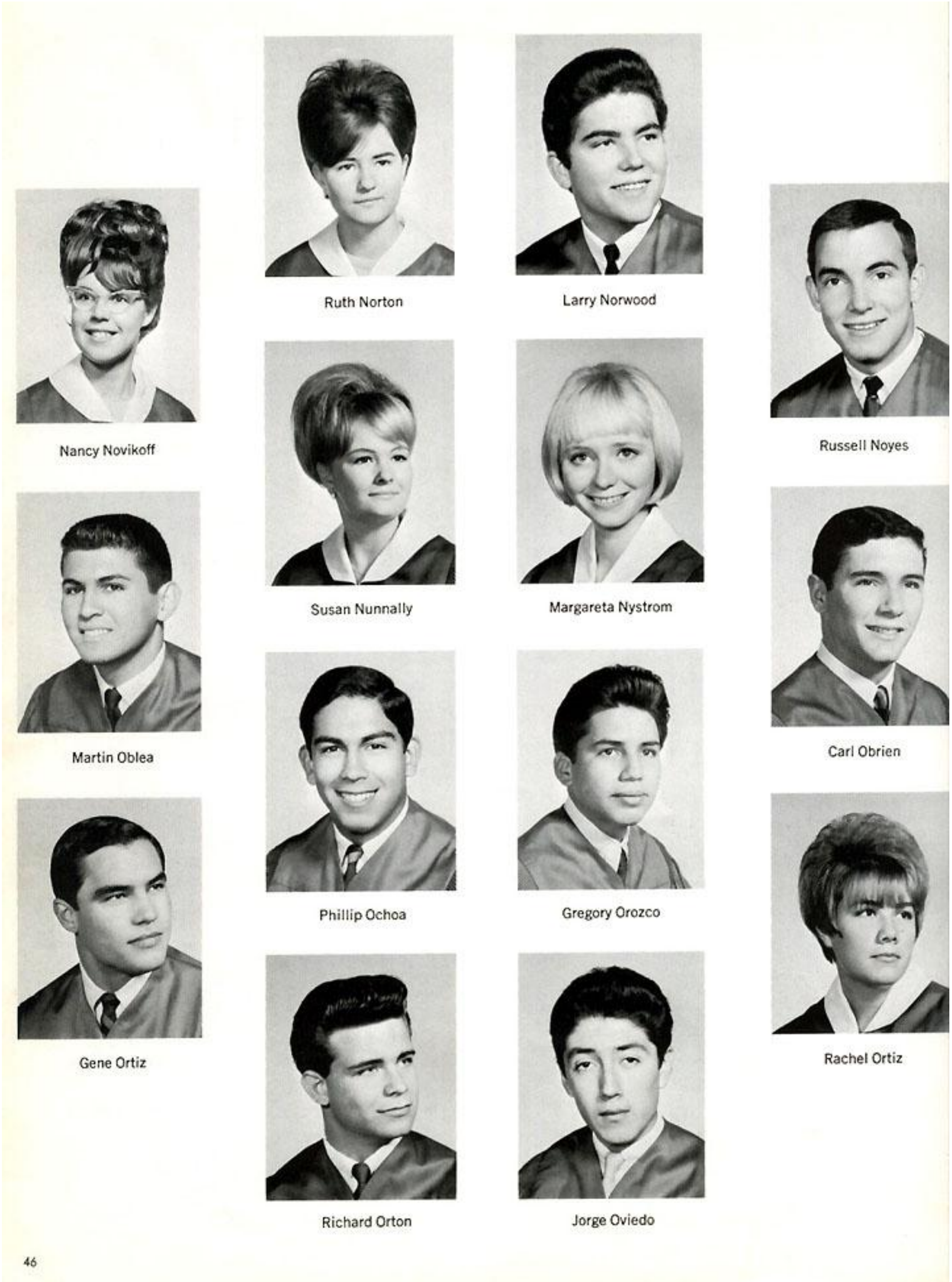
By Rob McEntarffer, Southeast High School, Lincoln, NE – rmcenta@lps.org
[note: I can't remember where I first heard of this activity – if you know the source, please tell me!]

Concept: Operational definitions are one of the trickiest concepts for my students to understand. This activity gets students involved in making operational definitions in the context of gathering data, and the results of the data gathering demonstrate the implications of operationally defining variables.

Materials: Several copies of the same yearbook.

Instructions: Ask students how they would test the hypothesis "Girls smile more than boys." After discussing some possible research methodologies, pass out the yearbooks to groups of students and tell them their goal is to use the yearbooks to test the hypothesis. Direct student groups to gather data about smiling rates in men and women in the yearbook. After the groups gather their data, let them share their results with the class. Students should quickly discover that each group's results depended on their unique operational definition of a "smile", and that in order to accurately test the hypothesis, "smile" needs to be operationally defined.

Discussion: The class could reach consensus on an operational definition for what counts as a "smile" and use this consensus definition to re-gather their data, which should demonstrate the value of a precise operational definition in consistent data gathering.



http://www.csupomona.edu/~rosenkrantz/santafeweb/yearbook/sfhs67_yearbook_pg46f.jpg

Single Diagnostic Item for Operational Definitions:

Big idea: Understanding operational definitions conceptually
Misconceptions:
1) operational definition = the dependent variable
2) operational definition = the hypothesis
3) operational definition = the independent variable
4) operational definition = a control against confounding variables
5) operational definition = a participant sample
6) operational definition = the population
7) operational definition = a statistical analysis procedure

Given the hypothesis: "Watching TV as a toddler leads to decreased ability to focus as an adult", which is the most likely operational definition?
A)ability to focus *(misconception 1)*
B) toddlers who watch TV have less ability to focus *(misconception 2)*
C) watching television *(misconception 3)*
D) a control group of toddlers who don't watch television *(misconception 4)*
E) a sample of toddlers, age 9-24 months *(misconception 5)*
F) all children defined as toddlers (age 9-24 months) *(misconception 6)*
G) comparing the means of the two groups to see if the hypothesis is correct (*misconception 7)*
H) timing how long an adult can attend to a problem solving task (one right answer)
I) using an observational checklist measuring ability to focus (one right answer)