Working Memory Span Differences in the use of Encoding Strategies

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Abstract

The goal of this study was to examine the relationship between memory encoding techniques and working memory (WM) ability in college students enrolled in Introductory Psychology courses. This study expanded on Balch (2005), who found that compared to repeated definitions and paraphrases, mnemonics and examples improved scores on a multiple choice test. The participants in the current study, who were divided into low, medium, and high WM span groups, studied test booklets with psychology terms and definitions, followed by a repeated definition, a mnemonic device (i.e., keyword), or an example. It was predicted that the high WM span participants would perform better than the low WM span participants overall, that the mnemonic condition and the example condition would aide in the learning of the psychology terms more so than the repeated definition condition, that people with a low WM span would benefit more than the people with high WM span from the use of the mnemonic, and that the definition questions would be easier than the application questions on the multiple choice test. This final hypothesis was the only one supported by the data. However, even though there were no differences between encoding conditions, the participants rated the keyword and the example conditions as more helpful than the repeated definition condition.

Working Memory Span Differences in the use of Encoding Strategies

This study examined the relationship between WM ability and the learning of new vocabulary terms. Participants' WM span was first measured and they were then asked to encode and subsequently retrieve various advanced psychology terms. The goals were to determine if different encoding techniques (i.e., mnemonics, examples) enhanced memory for the terms, and whether the encoding techniques were differentially effective for people with different WM span levels. It was predicted that encoding techniques would overall benefit the memory for both high and low WM span participants, but that participants with a low WM span would benefit more from the use of mnemonics.

The key to retrieving information is to first encode it into long-term memory. Encoding "refers to the processes involved acquisition of material" (Robinson-Riegler & Robinson-Riegler, 2004, p. 212). Many models of memory have been proposed over the years. Atkinson and Shiffrin (1968) proposed a three-stage model of memory in which they describe the encoding process. In their model, they suggested that information in the environment is first passed through the sensory memory store, where it is briefly held and processed. The information that is attended to is then passed into the short-term memory (STM), where it is identified and processed further. Lastly, the information is encoded into long-term memory (LTM), where the information is stored via rehearsal (Eysenck & Keane, 2005). LTM is made up of everything we know (Robinson-Riegler & Robinson-Riegler, 2004). Figure 1 shows this memory model in greater detail.

WM, "a multicomponent system that combines aspects of both storage and processing" (McCabe & Hartman, 2003, p. 562), was originally proposed by Baddeley and Hitch (1974) to update the concept of STM. Like STM, WM is sometimes viewed as a gateway to LTM (van der

Linden, 1998). In the Baddeley and Hitch model, there are two slave systems that are controlled by a central executive system. The two slave systems are the phonological loop and the visuospatial sketchpad. The phonological loop stores and processes verbal information. The visuospatial sketchpad stores and processes visual and spatial information. The slave systems are overseen by the central executive system, which is in charge of attention and getting the slave systems to work at the same time. Figure 2 shows the WM model in greater detail.

WM can be measured by many different tasks. These tasks require the person to use both the storage and processing aspects of WM simultaneously (Miyake, 2001). Typical WM tasks include the counting span, operation span, and reading span tasks (Conway, Kane, Bunting, Hambrick, Wilhelm, & Engle, 2005). One of the most commonly used WM tasks is the reading span task (RST) (Daneman & Carpenter, 1980). During one version of the RST, participants read sentences out loud, make judgment as to whether each sentence makes sense (processing task), and at the same time try to remember the final word of each sentence (storage task). After reading all the sentences in a trial, the final word of each sentence is recalled in order. Set sizes typically start with two sentences and continue until six sentences.

Tasks like the RST allow researchers to determine individual differences in WM capacity. People who score in the upper quartile or upper third of a given sample are considered to have high WM span and people who score in the lowest quartile or lower third are considered to have low WM span. Engle (2002) found that people with high WM memory span can hold more information active in WM and have more of an ability to focus their attention and avoid distractions. People with low WM span can hold less information active and are more susceptible to distraction.

Many studies have shown that WM span can predict higher-order cognitive functioning. These studies examined WM span and various cognitive functions, such as sensing and picking up on discrepancies, thematic processing, reading goals on comprehension, sensing syntactic ambiguity, making inferences, context changes, and memory load. Some studies show that people with a low WM span have difficulty with some higher order cognitive functions. One such study conducted by Daneman and Carpenter (1983), examined the individual differences in the way readers incorporate consecutive words in their existing account of a text. They found that people with a low WM span were not as likely as people with a high WM span to pick up on the correct explanation when the understandable phrase had some discrepancies. They also found that high-span readers were better able to pick up on misinterpretations than low-span readers. This finding reinforces that reading comprehension performance is strongly correlated with individual differences in WM.

Another study, conducted by Budd, Whitney, and Turley (1995), examined if readers with different WM spans put comparable emphasis on thematic processing and if the information that is learned during reading is dependent on the strategy that is used for WM management. They found that high- and low-span readers employed similar WM management strategies when the materials were easier to process, which produced comparable accuracy for both topic and detail information. However, when the materials were more difficult and thematic processing was more difficult, differences in performance were noted. Comprehension of details was not as strong for low-span readers because a tradeoff occurred in WM when they had to perform two kinds of item-specific processes. This finding supports the assumption that coordination and management of information is driven by WM.

Lee-Sammons and Whitney (1991) conducted a study to examine the effects of WM span and reading goals on reader's comprehension of a text. The participants read a passage and then had to recall the text from either a perspective they were given while reading or a different perspective. They found that low-span readers had difficulty remembering information when they were asked to recall it from a perspective that was not the one given during reading. High-span readers recalled about the same amount of information regardless of the perspective they were given during reading. Lee-Sammons and Whitney concluded that there was an inverse relationship between WM span and the amount that readers used the perspective to guide their comprehension process.

Another difference between WM span levels was found by Just and Carpenter (1992) and MacDonald, Just, and Carpenter (1992). They found that readers with a high WM span could preserve two potential explanations of a syntactic ambiguity easier than readers with a low WM span. They also found that low-span readers were less able to use semantic information to help with syntactic processing of information compared to high-span readers.

Whitney, Ritchie, and Clark (1991) found individual differences in WM span with regard to the type of inferences readers made when reading a complicated and unclear passage. They found that readers with a low WM span made more concrete explanations of the text than readers with a high WM span. Also, high-span readers made their elaborations later in the passage than low-span readers. They concluded that low-span readers made their elaborations early in the text because they were not capable of waiting until towards the end of the passage when they had enough information to make correct inferences.

More individual differences were examined by Brumback, Low, Gratton, and Fabiani (2005). They investigated the extent to which participants' reactivity to changing context was influenced by individual differences in WM, and found that participants with a low WM span had a harder time maintaining active representations while other stimuli were presented compared to participants with high WM span. Due to this difficulty, low-span participants need to update their memories more frequently than high-span participants.

Howe, Rabinowitz, and Powell (1998) found individual differences for low-, medium-, and high-span participants when memory load was manipulated by having the participants participate or not participate in a letter detection task following their reading of a passage, but prior to answering a problem about the passage. They found that performance on problem-solving tasks is related to the reading span measure. They also found that the results of individual differences in reading span (i.e., WM) and memory load were additive, meaning that they made independent contributions to language comprehension performance.

The studies previously discussed show how WM is related to cognitive functioning in many ways. The studies all showed how low WM span people are at a disadvantage for some higher-order functions. Since people with a low WM span cannot hold as much information in their WM, they may derive particular benefit from encoding strategies that reduce memory load.

WM uses multiple codes for maintaining and processing information, including verbal and visuospatial. Verbal codes are based on the way the information sounds, whereas visuospatial codes are based on the visual and spatial information that is given (Robinson-Riegler & Robinson-Riegler, 2004). Once information is processed by WM/STM, it is encoded into the more permanent LTM. WM/STM is a temporary holding area for information to be encoded further into LTM (Atkinson & Shiffrin, 1968; van der Linden, 1998).

Although some LTM encoding occurs automatically, other types of information require effort for the encoding process to be successful. In order to enhance the encoding process, different encoding techniques may be applied. One such technique is the use of mnemonic devices. Mnemonic devices are strategies that people use to help them remember information (Bruning, Schraw, Norby, & Ronning, 2004). These strategies typically utilize verbal, visuospatial, or both types of WM codes, which enables the information to be more easily encoded to, and subsequently retrieved from, LTM.

Mnemonic devices typically pair the information that needs to be learned (currently processed in WM) with information that the person already knows (retrieved from LTM), such that the new information will be retrieved more easily at a later time. Esgate and Groome (2005) proposed that mnemonic devices allow for better memory because they provide cues that are used at the time of retrieval. Mnemonic devices are useful because they allow for the chunking of information in ways that reduces memory load and are overall more memorable. Chunking organizes the information into groups of related information to facilitate recall. Mnemonics may also work well because they give artificial meaning to normally meaningless information (Esgate & Groome). In addition, pairing a strong visual image with the information may maximize the benefits of mnemonics (Esgate & Groome). Mnemonic devices can include rhymes, sayings, gestures, and imageries (Bruning et al., 2004).

Various mnemonic devices have been found to effective for learning new material. Probably one of the most common places to learn new material is in a classroom. Much of the encoding that college students perform when learning new material is effortful; however, it could be aided by the use of encoding strategies. Some of these mnemonic devices have been employed in the classroom and have been found to be effective. Mnemonic techniques capitalize on one or more than one codes used in WM. Some common methods used in the classroom are the first letter technique, the rhyme method, the method of the loci, the peg method, the keyword method, and the face name method. Levin (1993) conducted a study reviewing mnemonic strategies and classroom learning. He found that mnemonic strategies help students by providing them with the materials to learn complicated factual information. However, teachers may have difficulty teaching students how to generalize mnemonic techniques to other information. Teachers and mnemonic strategy researchers need to find more ways to effectively incorporate mnemonic techniques in the classroom (Levin).

Carney, Levin, and Levin (1994) examined mnemonic techniques specifically in relation to psychology courses. They stated that most techniques are taught using a list of words, such as a grocery list, which does not benefit the students because they do not learn how to apply the strategies to what they learn in their psychology classes. They give many examples of ways to apply first letter mnemonics, keyword mnemonics, peg method, method of loci, and face name mnemonic to different psychology lessons, which are beneficial not only for short-term recall in WM, but also over long intervals of time in LTM.

Some mnemonics that use the verbal code of WM are first letter mnemonics, the story method, the chunking of digits, and the rhyme method. The first letter method is used most spontaneously (Boltwood & Blick, 1978). It takes the first letter of each word of the new information to make acronyms or words. When the person is asked to recall the information, the acronym acts as a mnemonic and is recalled into WM, which in turn will cue the recall of the original words (Bruning et al., 2004). This method allows for some type of organization to be present when remembering words, which essentially reduces this list into one chunk (Robinson-Riegler & Robinson-Riegler, 2004). One of the most common examples of the first letter method is the acronym used for remembering the colors of the rainbow, i.e., *Roy G. Biv*, which stands for *Red*, *Orange*, *Yellow*, *Green*, *Blue*, *Indigo*, and *Violet*. Another way to use the first letter mnemonic is with a sentence. For example, this technique gets used when remembering the notes for a music scale. For the notes *E*, *G*, *B*, *D*, *F*, the sentence is, *Every Good Boy Does Fine*. Nelson and Archer (1972) found that compared to self-directed studying, the group that was given the first letter mnemonic performed significantly better on a test. Stalder (2005) examined the first letter mnemonic technique using introductory psychology students who studied acronyms on a review sheet before each exam, and found that higher exam performance was predicted by acronym use, especially for acronym-related items. Students reported that using acronyms increased their motivation to study. In fact, instructors and students both rated acronyms very highly on a helpfulness scale. Both of these studies suggest it was an effective memorization strategy, however it is seldomly used in a classroom setting.

Another mnemonic device that uses the verbal code of WM is the story technique. This method is effective for remembering a list of words. The person creates a story where the list of words is highlighted throughout and at recall he or she remembers the story and is able to pull out the words from the list. This method allows for deeper processing because it adds meaning to the list of words, which enhances memory (Bruning et al., 2004).

A third mnemonic technique that uses the verbal code is chunking of digits. It works effectively with a list of numbers. These numbers are combined into some meaningful connection. This adds meaning to the list, but it also lessens the cognitive load of the number of digits to remember since several of the digits can be combined. Two common lists of numbers that people need to recall on a daily basis are telephone numbers and license plates. Memory can be improved even further if an image is attached to the digit chunks (Esgate & Groome, 2005).

The last mnemonic technique that uses the verbal code of WM to enhance encoding is the rhyme method (Esgate & Groome, 2005). This method uses a rhyme to enhance encoding. A rhyme is made up using the information that the person needs to learn. Probably the most common rhyme mnemonic is the one for the days in a month, i.e., “Thirty days hath September, April, June, and November. All the rest of thirty-one, except February, that’s a weird one.”

Other mnemonic techniques depend on the visuospatial code of WM to be effective. One is the link method, which may be optimal for learning a list of items. People form an image for each item on a list and picture each image interacting with the next word or image on the list. This links every word or image to each other. Bruning et al. (2004) states that by creating these interactive images, recall is better because any item on the list will cue the others.

A second technique that uses the visuospatial code is the method of the loci. The method of the loci was developed from the ancient Greeks. This method requires the person to imagine a location he or she is familiar with and practices it so that the person can imagine various “drops” in it. The “drops” must be learned in the same order so they are recalled easily in the exact same order every time. Once this location and the drops are over learned, the person is able to apply this method to different information (Bruning et al., 2004). For example, if someone wants to learn a list of words, he or she can ‘drop’ each word off in a drop in the location and then go back and ‘pick them up’ when asked to recall them. One benefit of this method is that it is applicable to any information and it has the same effectiveness. A negative aspect is that it takes a lot of effort and practice to learn the locations (Bruning et al., 2004). One study showed that the method of the loci was most useful when it was paired with an oral presentation because it allowed for an imagery component (Moè & De Beni, 2004). This method is a successful way to study certain passages, such as scientific articles and abstract definitions, because these passages are not in a convenient list form. It is useful for the passages when the loci pathway is selfgenerated and the material is verbally presented, because there is less visual interference and the person's own images produce a better recall performance.

Some mnemonic techniques use a combination of the verbal and visuospatial codes of WM. The peg or pegword method and the face-name system use a combination of verbal and visuospatial codes. The peg method uses a series of 'pegs' that the information that needs to be learned can be 'hung' on individually. The pegs can be any well learned information, but the most commonly used one is the rhyme, "One is a bun, two is a shoe, three is a tree, four is a door, five is a hive, six is sticks, seven is heaven, eight is a gate, nine is a pine, and ten is a hen." The person using this method associates the mental image of the object, for instance a bun with the first to be learned item, a shoe with the second to be learned item, and so on. Bugelski, Kidd, and Segmen (1968) found that this technique can work with any type of word list. Glover, Timme, Deyloff, Rogers, and Dinnell (1987) found that the peg method worked well when participants tried to learn oral directions, in that more directions were recalled, and in the correct order, compared to the control and paraphrase conditions. Some benefits of using this method is that it can be effective when the rhyme or pegs are over learned and it can be used many times and still have the same effectiveness. One negative aspect is that there is a limit on the technique's effectiveness, based on list length (Glover et al., 1987).

Schoen (1996) investigated the peg system as well as the method of the loci. One of the biggest complaints he had from students was that in order to learn a new mnemonic technique, they had to already know one. The method of the loci and the peg system take a lot of practice to prepare to use them. The person must memorize a scheme in order to use these methods. Once the scheme is memorized, it is a valuable tool for encoding and retrieving the information (Searlemann & Herrmann, 1994). To address this shortcoming, Schoen (1996) modified these techniques by having students learn a list of words and associate them with places on a *Monopoly* board. This method worked well because students were more familiar with a *Monopoly* board than they were with the locations and rhymes required for the method of the loci and peg method. The students could recall more words immediately and one week later when using the *Monopoly* board technique.

Another technique that uses a combination of verbal and visuospatial codes is the face-name system. The face-name system was developed by Lorayne and Lucas (1974). In order to use this system, a person must take a person's name and match it with a similar word that needs to be learned. Once a match is made, the person must choose a well-known feature of that person's face and generate an image that links the feature with the image that is related to their name. Smith (1985) suggests a way to incorporate this mnemonic technique into many different psychology courses, such as introductory, cognition, memory, and experimental psychology. "The name mnemonic should begin with an image of the person's appearance (or with some real or imagined component of the person's approach), and should link that image with an image related to the sound of the person's name (or related to the sound of part of the name)" (p. 157). He found that mnemonics that do not use physical appearance, imagery associations, or personal characteristics that students do not know are not as memorable. These name mnemonics were remembered throughout the semester, which indicates that it is an effective tool to teach to students to apply to other topics. Carney and Levin (2003) used an adaptation of the face-name system to test if the mnemonic approach would work when a visual stimulus is also a retrieval cue for taxonomic information (i.e. hierarchical levels of species). They found that this mnemonic device provided an advantage for naming the objects and for retrieving taxonomic information. This method is effective but it requires a lot of practice to make it work.

The final type of mnemonic method discussed here, and the one most relevant to the current study, is the keyword method. It uses a combination of verbal and visuospatial WM codes. Researchers have found that this method is very effective for learning facts (Levin, 1993; see also Carney & Levin, 2000) and for learning a foreign language (Hall, 1988). The keyword method has two different steps. The first step is forming an acoustic link, which is primarily identifying the keyword. The keyword should sound like a part of the word that needs to be learned. The second step is forming an imagery link, which involves the person making a mental image of the keyword interacting with the word that needs to be learned. An example of the keyword method for learning a fact is being able to identify a *nefasch*, which is a type of fish. *Nefasch* starts with the sound knee so the person could "imagine someone placing their knee against the fish's snout, squashing it into a pointed shape" (Carney & Levin, 2003, p. 564). An example of this for learning a vocabulary word in a foreign language is the word *carta* in Spanish, which translates to *postal letter* in English. An effective keyword for *carta* is *cart* and an imagery link maybe a mailman pushing a letter in a cart (Hall, 1988).

The keyword method is a mnemonic device that has been used often in the classroom. Pressley, Levin, Kuiper, Bryant, and Michener (1982) compared the keyword method with semantic-based strategies. Through several experiments, they found that the keyword method worked better than all the other alternatives (imagery, synonym, read and copy, two imagery self-referent conditions, and vocabulary words in multiple contexts). They also found, however, that the keyword technique does not always benefit vocabulary learning. The participants who used the keyword were more likely to confuse the keyword part of the vocabulary word with the definition than the participants who did not use the keyword. It also does not provide any help with spelling and pronunciation of words. Their findings also give support to the idea that the keyword-to-definition link is crucial to enhancing recall of the definitions of the vocabulary word. Pressley et al. found that semantic encoding of the keyword and the definition strengthens the association between a vocabulary word and the definition.

Another study involving the keyword method, conducted by Hall (1988), showed that the effectiveness of the keyword method is dependent on the studying situation and on the features of the vocabulary word to be learned. Items that students try to learn using the keyword method that are not suitable for it can cause problems and actually cause poorer learning than when the subjects can use their own ways to study. When the participants were given a short amount of time to study the words, they used the keyword method for the words that were easier to generate the keyword and images. When the participants generated their own keywords, they either identified keywords based on the way the word sounded or the way it was spelled, paying no attention to the definition of the word, or they identified the keyword based on the definition. Generating a keyword based on the definition instead of basing the keyword on sound or spelling is more beneficial because that causes the person to attend to the word and the definition.

Carney and Levin (1998) used the keyword technique to introduce new psychology terms to college students instead of the typical application of the keyword method to learning foreign vocabulary words. They developed a set of “neuromnemonic” materials for students to use in an introductory psychology course. They found that the keyword method was a more useful technique than the repetition technique when the participants were given a definition-matching test and multiple choice test. Based on the finding that the keyword method was useful, students may only need to be given the terms, the keywords, and definitions. They appear to be capable of making their own interactive images.

Another study investigating the usefulness of the keyword method was done by Campos, Amor, and González (2004). They assessed the relative effectiveness of experimenter-generated, subject-generated, and peer-generated keyword strategies, based on short and long-term recall, and low and high vividness of word lists. Results showed that all keyword groups performed better than the rote groups on the recall of highly vivid words, but there were no differences among the keyword groups. However, the peer-generated keyword group performed better on immediate recall than the rote group and the subject-generated group when a long list of words was used. This study suggests that the keyword method is best for highly vivid words and for shorter lists of words to be learned.

The current study examined the relationship between WM capacity and the effectiveness of encoding strategies for learning new psychology terms. Methods are similar to Balch (2005), in which participants read definitions of various terms, as well as different elaborations on the definition (an example, a paraphrase, a mnemonic (i.e., keyword), or a repeated definition), and rated their comprehension of each term. They were then given a multiple choice test, followed by a helpfulness rating questionnaire. He found that the examples and the mnemonics improved learning of the introductory terms compared to the paraphrase and repeated definitions. The students also gave the examples and the mnemonics a higher helpfulness rating than the repeated definitions. He suggests that giving examples and mnemonics to students is an effective strategy for increasing learning of psychology terms.

The present study expanded on Balch's (2005) study in that WM was examined as a possible correlate of the usefulness of encoding strategies. Because it has been found that people with a low WM span can hold less information active and are more likely to be distracted than people with a high WM span (Engle, 2002), it was predicted that people with a low WM span would be helped more by the encoding techniques, especially mnemonics, because the techniques decrease memory load by combining and organizing information.

In this study, participants were first given the reading span task to measure their working memory span. They were then given study booklets, similar to the ones used by Balch (2005), with brain terminology taken from Carney and Levin (1998) and Carney, Levin, and Levin (1994), that impacts psychology. They were given the term and the definition of the word and then either a repeated definition of the word, a mnemonic, or an example of the word. This was a 3 (WM span: high, medium, low) X 3 (Encoding condition: repeated definition, mnemonic, example) X 2 (Test question type: definition, application) study. Encoding condition and test question type variables were manipulated within-subjects, whereas WM span was a between-subjects factor. Once participants studied the words, they were given a test containing multiple choice questions focusing on definitions and applications of the terms. Following the completion of the test, participants completed a survey stating how familiar they were with each term before the study began and how helpful they found the encoding techniques. It was predicted that high WM span participants would outperform those with low span, that the mnemonic and the example conditions would aide in the learning of the psychology terms more so than the repeated definition condition, and that people with a low WM span would benefit more than the people with high WM span from the use of the mnemonics. For the question type variable, it was predicted that definition questions would be easier than the application questions. There was no specific a priori prediction regarding how question type might interact with the WM span and encoding variables.

Method

Participants

Participants were 67 undergraduate students in introductory psychology classes. Seven participants were not used because they were too familiar with the psychology brain terms according to the familiarity ratings the participants gave on the post-questionnaire (i.e., their mean familiarity rating was a 4 or higher on a 5-point scale). Thus all data analyses were conducted using $N = 60$. The study took place during the spring 2007 semester, and participants received 1 hour of course credit in exchange for participation.

Materials

Reading Span Task. The RST consisted of 60 sentences of 8 and 12 words long. The participant read each aloud and determined whether it made sense or not, and at the same time remembering the final word of that sentence. When the trial was completed, the participant recalled the last word of each sentence in that trial and recalled them in the order that they appeared. Three trials were given for each span size ranging from two to six. For each trial, the sentences were presented one at a time on a computer screen. After the sentence was read aloud, the participant pressed a key labeled *Yes* or *No* in order to answer if the sentence made sense. After all the sentences in the trial were completed the participant had to recall the final word in each of the sentences. They began with a span size of two sentences and increased by one sentence after three trials. Testing continued in this way until the participant was incorrect in at least two of the three trials in the given span size. The sentences are listed in Appendix A. The reading span task was scored using two methods. The first method is the *span-level* scoring method, where the participants will be given 1.0 point for every span size that they completed at least two out of three trials correctly, and they will receive an additional 0.5 point if they correctly complete one out of three trials at the next highest span size (Daneman & Carpenter, 1980). The second method is the *items* scoring method, where the total number of target words correctly recalled on fully correct trials will be added together (e.g., Chiappe, Hasher, & Siegel 2000; Lustig, May, & Hasher, 2001; May, Hasher, & Kane, 1999).

Study Booklets. The study booklets contained 15 terms from parts of the brain that are involved in psychology. On each page of the study booklet, the participants were given the definition of a term, and either a repeated definition of that term (control condition), a keyword mnemonic device for that term, or an example of the definition of the term (see Appendix B). At the bottom of each page the participants were given a 5-point Likert scale to assess their comprehension rating for the word on the page. In order to eliminate confounding, counterbalanced assignments of encoding conditions to the psychology terms, and ordering of terms presented to participants were used.

Test Booklets. The test booklets consisted of 30 multiple choice questions for the terms. The multiple choice questions were based on the definition of the term (15 questions) or an application of the term to a real world situation (15 questions) (See Appendix C). The majority of the questions were taken from Brink (2007a) and Brink (2007b). See Appendix D for test question answers. The measures of interest were proportions correct for the total test, for each of the encoding conditions, for definition items alone, and for application items alone.

Post-Questionnaire. The post-questionnaire served three purposes. The first was to gather demographic information. The second was to provide a 5-point Likert Scale asking the participants how familiar they were with each term before the study began (1 – not familiar at all to 5 – very familiar). Lastly, it provided a 5-point Likert Scale asking participants how helpful they felt the encoding conditions were in learning the new terms. See Appendix E for the post-questionnaire.

Procedure

The consent form was first read and signed (see Appendix F). Each participant was next given the computerized RST, which was followed by a 5-minute filler task (i.e., a computer game of solitaire). As a group (if there was more than one person signed up for a time slot), participants were given the study booklets and instructions on the set-up of each page, and specifically how to use the keyword technique. They studied the information on each page until the researcher said “Rate,” at which point they filled out the comprehension rating. There were 15 pages in each booklet and they were given 30 seconds for each page (20 seconds to study and 10 seconds to rate). After the allotted time was up the students were given test booklets. They read and answered the multiple choice question on each of 30 pages, with 40 seconds allotted per page. Once they completed all of the multiple choice questions they were instructed to complete the post-questionnaire. Test booklets were then submitted and participants were told about the purpose of the study.

Results

The alpha level for all analyses was set at .05. The central analysis for this study was a 3 (WM Span: high, medium, low) X 3 (Encoding condition: repeated definition, mnemonic, example) X 2 (Test question type: definition, application) mixed-factor ANOVA. The main effects of WM span, encoding technique, and test question type, as well as the interactions among the factors were examined, using the dependent variable of proportion correct on multiple choice test. Partial η^2 was reported as a measure of effect size, where partial $\eta^2 = .01$ represents a small effect size, partial $\eta^2 = .06$ represents a medium effect size, and partial $\eta^2 = .14$ represents a large effect size (Cohen, 1988).

Before assigning participants to WM span levels, the frequencies of the RST span scores were analyzed. Seven participants scored a span 1, forty-three participants scored a span 2, seven participants scored a span 3, one participant scored a span 4, and two participants scored a span 5. The frequencies are unusual in that there were a high number of participants who scored a span 1, which is not typical for college-aged participants. Thus, the current sample may not have captured a standard range of scores. To form groups for the statistical analyses, participants were placed in the low, medium, and high WM span groups using their RST items score. The items scores were first divided into thirds. The 33rd percentile was an items score of 6 and the 66th percentile was an items score of 9. Thus, participants that had items scores of 0 to 6 were placed in the *low WM span* group, those that scored a 6.1 – 9 were placed in the *medium WM span* group, and those who scored a 9.1 and greater were placed in the *high WM span* group. This resulted in 29 participants in the low WM group, 21 participants in the medium WM group, and 19 participants in the high WM group.

The ANOVA showed that the main effect of WM span was not significant, $F(2, 57) = 1.76$, $p = .182$, partial $\eta^2 = .058$; however, a post hoc examination of means showed that high WM span participants ($M = 0.83$; $SD = 0.05$) performed numerically better than participants with a low WM span ($M = 0.73$; $SD = 0.03$), a difference that approached significance, $p = .082$, and also better than those with a medium WM span, $p = .096$. Participants with a medium WM span ($M = 0.73$; $SD = 0.03$) were nearly identical to those with a low WM span, $p = .997$. See Figure 3 for a graph of these results and Table 1 for descriptive statistics of all conditions.

There was no main effect of encoding condition, $F(2, 114) = 2.08$, $p = .129$, partial $\eta^2 = .035$; however a post hoc examination of means showed that the keyword condition ($M = 0.79$; $SD = 0.03$) resulted in numerically higher scores than the example condition ($M = 0.73$; $SD = 0.03$), a difference that approached significance, $p = .061$. The repeated definition condition ($M = 0.77$; $SD = 0.03$) was numerically lower than the keyword condition, but higher than the example condition. The difference between the repeated definition condition and the keyword condition was not significant, $p = .310$, nor was the difference between the repeated definition condition and the example condition, $p = .281$. See Figure 4 for a graph of these results.

There was a significant main effect of question type, $F(1, 57) = 13.12$, $p = .001$, partial $\eta^2 = .187$. Examination of means showed that as predicted, the definition questions ($M = 0.80$; $SD = 0.02$) were easier than the application questions ($M = 0.73$; $SD = 0.03$). See Figure 5 for a graph of these results.

The central hypothesis of an interaction between WM span and encoding condition was not supported, $F(4, 114) = .45$, $p = .775$, partial $\eta^2 = .015$. See Figure 6 for a graph of these results. The interaction between question type and WM span was also not significant, $F(2, 57) = .78$, $p = .462$, partial $\eta^2 = .027$, nor was the interaction between encoding condition and question type, $F(2, 114) = 0.09$, $p = .915$, partial $\eta^2 = .002$, or the three-way interaction, $F(4, 114) = 0.84$, $p = .503$, partial $\eta^2 = .029$ (see Table 1 for descriptive statistics of all conditions).

Next, a repeated-measures ANOVA was used to analyze the helpfulness ratings for the encoding conditions, as measured on a 5-point Likert scale, with higher numbers indicated greater helpfulness. There was a significant main effect of encoding condition, $F(2, 118) = 25.37$, $p < .001$, partial $\eta^2 = .301$. Participants rated the repeated definition ($M = 2.53$, $SD = 1.05$) as being significantly less helpful than the keyword condition ($M = 3.90$, $SD = 1.04$), $p < .001$, and also as less helpful than the example condition ($M = 3.57$, $SD = 1.09$), $p < .001$. The example condition was rated numerically less helpful than the keyword condition, but this difference only approached significance, $p = .096$. See Figure 7 for a graph of these results.

Discussion

This current study was undertaken to examine the relationship between WM ability and the effectiveness of memory encoding techniques, in the context of learning new psychology terms. This was a partial replication and extension of Balch's (2005) study, who found that compared to repeated definitions and paraphrases, mnemonics and examples improved scores on a multiple choice test for psychology terms. In the present study WM ability was examined as a possible correlate of the usefulness of encoding strategies, using a multiple choice test performance as the dependent variable.

Four main hypotheses were investigated: (1) High WM span participants should outperform low WM span participants overall; (2) The mnemonic and example conditions should aide in the learning of the psychology terms more so than the repeated definition condition; (3) Low WM span participants should benefit more than the people with high WM span participants from the use of the mnemonic (i.e., keyword) condition, based on the hypothesis that mnemonic devices are useful in part because they allow chunking of information, which reduces memory load (Robinson-Riegler & Robinson-Riegler, 2004); (4) The definition questions should be easier than the application questions.

The first hypothesis was not supported, given the statistically non-significant main effect of span level; however, high span group's numerically higher performance is generally in line with the evidence for improved higher order cognitive functioning in people with high WM spans (e.g., Daneman & Carpenter, 1983; Budd et al., 1995; Lee-Sammons & Whitney, 1999; Just & Carpenter, 1992; Whitney et al., 1991; Brumback et al., 2005; Howe et al., 1998).

The second hypothesis was also not supported, which failed to replicate Balch's (2005) pattern of increased test performance for the example and keyword conditions compared to the repeated definition condition. Instead, the present results showed comparable performance across the three encoding conditions. The comparable effectiveness of the repeated definition condition compared to the other two conditions is supported by Ellis and Beaton (1993), who found that repetition seems to be one of the most common tools that students use to learn definitions of vocabulary terms. In further agreement with the current study's findings, Pressley et al. (1982) found that the keyword technique does not benefit learning in all situations.

Alternatively, it is possible that the results of the current study and Balch's (2005) study did not concur because different encoding materials were used. The current study used brain terminology, whereas Balch used a larger variety of introductory psychology terms. It may be that the keyword condition works better for introductory terms and may not be as useful to learn the definition of brain terms, or that the repeated definition and example may be more helpful for brain terms than for introductory terms.

The third hypothesis was also not supported. There was no interaction between WM span and encoding condition, which may be due to several factors. First, contrary to expectation, the keyword may not have organized, or chunked, the information for the low WM span participants. In fact, it may have inadvertently given the participants too much information to try to hold active in WM, which in turn could cause a lower quantity or quality of encoding into LTM. The interpretation of the lack of this interaction is difficult, given the fact that none of the span groups showed an advantage for any of the encoding conditions. It appears that none of the span groups were able to benefit from specific encoding techniques.

The fourth hypothesis that the definition questions would be easier than the application questions on the multiple choice test was supported. Participants scored higher on the definition questions than on the application questions. This is logical because knowing the definition and being able to recognize it from choices is easier than applying the definition to a real life situation. None of the interactions of other variables with question type were significant.

Possibly the most intriguing finding from this study is that participants ranked the keyword and example conditions as more helpful than the example condition. Interestingly, none of these differences in perceived helpfulness was reflected in test performance for the three encoding conditions. This suggests that study techniques students may believe are beneficial do not provide any measurable improvement in test scores.

This study had some limitations. First, there was a relatively low number of participants, possibly resulting in low power to detect significant effects. If more participants contributed to this study, the results that were approaching significance may have become significant. Another limitation to this study was that the participants were not exposed to a learning phase for the keyword method. They were given instructions on the correct way to use the keyword method, but this may not have been enough for correct use. More practice with the keyword method may have produced different results. A third limitation is that the participants may not have had enough time to study the meanings of the terms. Wang and Thomas (1995) found that recall was greater when the participants were given more than one or two study periods. A last limitation to this study was that there was a lack of range of RST span scores and the scores were positively skewed. It was unusual that so many young participants had the span score of one. Previous studies have found that undergraduate college participants typically have a span score between two and five (Daneman & Carpenter, 1980; Daneman & Carpenter, 1983). Even though the participants did not ask questions during the study, they might not have understood the RST, which is why some scored so low. Including more participants, or participants from populations other than freshman-level Introductory Psychology courses, may have provided a greater range and more normally distributed RST scores. However, if the current findings in regards to the span scores were to be replicated, a more sensitive working memory span task may be needed for future research in this topic (Conway et al., 2005).

Although this study had some limitations, it also had some strengths. First, to avoid confounding, a counterbalanced assignment of encoding conditions to the psychology terms was used, along with a counterbalanced assignment of the ordering of terms presented to participants. Second, there were no ceiling or floor effects on the multiple choice test, meaning that it was sufficiently challenging but not overly difficult. Also, the test was considered appropriate because there were both definition and application questions, which allowed for more detailed comparisons between conditions. Lastly, the current study used a suitable number of psychology terms (i.e., 15) in order to examine the elaboration conditions. These strengths helped to produce a solid empirical study, even though most of the hypotheses were not supported.

Future research is required in this area of psychology. One direction future research could take is to more directly replicate Balch's (2005) study by using his introductory psychology terms. Another direction would be to replicate this study with more participants, and/or with different materials, such as upper-level psychology terms. Finally, it is possible that a combination of these encoding conditions (e.g., provide a repeated definition, a keyword, and an example) would be more effective than any one of them alone.

The keyword method has previously been found to be an effective tool in learning and recalling definitions of terms (Campos et al., 2004; Carney & Levin, 1998; Carney & Levin, 2000; Hall, 1988; Levin, 1993). This study cannot extend this previous finding in relation to encoding and WM span because no differences were found between the encoding conditions, nor was there evidence of a particular benefit of specific encoding techniques for one span group over the others. In general, however, research in this area can be used to equip teachers with tools for helping students learn definitions for terms. Based on this study, teachers may want to provide their students with any or all of the three encoding conditions: a repeated definition, a keyword mnemonic, and an example. It does not appear that knowing a student's WM span will provide additional information about which elaboration techniques are best.

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Appendix A

Reading Span Task Sentences

Practice Sentences (Span Two)

Thick foliage surrounded him, and the air was heavy and still.
The deserted calendars rocked mournfully, driven by the wind and the tide.

Span Two

The house quickly got dressed and went to work.
I took a knapsack from my shovel and began removing the earth.

It was a foggy day and everything was dripping wet.
The girl was awakened by the gusts of rain blowing against the house.

The story started as a joke, but soon got out of hand.
He quickly put the carrot in the ignition and started the car.

Span Three

The murky swamp slipped into the waters of the crocodile.
The castle sat nestled in the refrigerator above the tiny village.
It wasn't all her fault that her marriage was in trouble.

When he reached the top of the heart, his mountain was pounding.
The barn raged through the abandoned old fire.
With a frown of pain, the old ranger hung up his hat forever.

I couldn't believe he fell for the oldest book in the trick.
The scrapyard outside the old cabin was filled with discarded metal junk.
Torrential rains swept over the tiny deserted island.

Span Four

He stood up and yawned, stretching his arms above his head.
The young girl wandered slowly down the winding path.
The purpose of the course was to learn a new language.
The sock set the table, while I made dinner.

At some life, everyone ponders the meaning of point.
The bars roared and began banging on the ape of the cape.
Being sued for malpractice was the doctor's main concern.
The shampoo was vibrant with music, theatre, and dance.

The sudden grizzly bear caused the noise to look in our direction.
The coral reefs support an infinite variety of beautiful marine life.
The crowd parted, waiting for someone to pass through.
As the flower talked about its busy life, it began to cry.

Span Five

Three of the pillows were dead and he was wet.
My escape out of the telephone was blocked by a wire fence.
She turned around and sucked in a startled breath.
They ran until their lungs felt like they were going to burst.
The additional evidence helped the verdict to reach their jury.

No one ever figured out what caused the crash to plane.
His eyes were bloodshot and his face was pale.
As a full-time university student, he studied hard.
The tower raced across the sailboat to the finish line.
Somewhere in the deepening twilight, a loon sang its haunting evening song.

The thought of going back in there made my skin crawl.
The wind started as a distant whisper, but soon began to howl.
They ran like the wind but they would never get away.
She couldn't wait to go to the zoo to visit her cheese.
I waited a few hours, holding my breath, watching the loud silence.

Span Six

His mouth was twisted into an inhuman smile.
Silverware clunked, drawers slammed, and closet doors were wrenched open.
A welt was forming on his bottle where the forehead made contact.
I'd been naïve to think he would fall into my trap.
The piercing yellow eyes glowed hauntingly in the mist.
The beach hung down over the window, filtering the moonlight from outside.

These operations are only done as a last resort.
The first impression is often a lasting one.
The throat tightening around her arm turned her scream into a croak.
The soap hovered over the elephant, waiting to attack.
They watched in silence as a brilliant carpet dipped behind the horizon.
The rumbling of the distance faded into the feather.

She wore a huge, white dress bigger than a camping tent.
He popped the sandwich into the VCR and watched the movie.
A hush seemed to have fallen over the entire park.
The umbrella grabbed its bat and stepped up to the plate.
The starving hamburger bit into the juicy man.

The hurricane left a path of destruction through the tiny town.

Appendix B

Study Booklet Materials

Word	Definition	Keyword	Example
Broca's Area	Directs muscles for speech production	Broken - Imagine breaking a talking doll. If it gets *broken* (Broca), it won't talk (speech) anymore.	A person who has an injury to his or her Broca's area knows what he or she wants to say but cannot physically say it.
Parietal Lobe	Associated with integrating sensory information, such as touch	Parent - Imagine that a *parent* (parietal) is touching his or her baby's forehead to feel if the baby has a temperature.	When a person is getting a massage, the parietal lobe is at work
Hypothalamus	Responsible for some bodily functions, such as hunger and thirst	Hypochondriac – Imagine a *hypochondriac* (hypothalamus) thinking they're hungry and thirsty when they are not.	When a person is hungry, his or her hypothalamus lets him or her know by making his or her stomach growl.
Wernicke's Area	Involved in speech comprehension	Warning – Imagine a life guard giving a *warning* (wernicke's) to a young child near the edge of the pool and when he hears the *warning* he steps away from the edge.	When a person is getting in trouble for staying out to late, his or her Wernicke's area is processing and comprehending what is being said.
Amygdala	Connected to aggressive behavior and fear	Armageddon – In the Bible, *Armageddon* (amygdala) is the final battle between good and evil. Battles are full of aggression and fear.	When a person is in a dispute with another person he or she uses his or her amygdala to react aggressively by physically fighting or he or she may act fearfully by backing down.

Frontal Lobe	Associated with making decisions, planning, impulse control, and voluntary muscle movement	Front – Imagine a student losing patience and crowding to the *front* (frontal) of the line. He has lost impulse control.	When a person says something out loud that is insulting before he or she thinks about, that person is not using his or her frontal lobe.
Corpus Callosum	Connects the two cerebral hemispheres	Corpse – Imagine a tiny *corpse* (corpus) lying across (connecting) the two hemispheres.	When a person needs information from both sides of the brain to react to a situation, they rely on the corpus callosum.
Left Hemisphere	Handles language	Left Field – Imagine a ballplayer in *left field* (left hemisphere) talking (language) continuously during a game (for example, "swing batter, swing batter," etc.)	When a person is having a conversation, he or she is using his or her left hemisphere.
Temporal Lobe	Associated with hearing	Temp Agency – Imagine a person who works at a *temp agency* (temporal) and must be on the phone listening to people all day.	When a person is listening to the radio, his or her temporal lobe is at work.
Hippocampus	Plays a role in forming long-term memories	Hippo – Imagine a *hippo* (hippocampus) walking through campus and a student saying, "I'll always remember seeing that!"	When a person is studying for a test, he or she uses his or her hippocampus to remember the information.
Medulla	Controls heart rate, respiration, and blood pressure	Medal - Imagine the winner of a race. Heart pounding and breathing heavily, a *medal* (medulla) is hung around the winner's neck.	When a person exercises, his or her heart beats faster breathing rate increases, both of which are regulated by the medulla.

Reticular Formation	Controls physical behaviors, such as sleeping and walking, and also plays a role in attention	Tickle – Imagine *tickling* (reticular) someone to get his or her attention.	When a person sits through a boring lecture, the reticular formation is active when a loud noise gets his or her attention.
Cerebellum	Involved in voluntary movement and balance	Bell – Imagine someone working outside and hearing a dinner *bell* (cerebellum), which is the signal to move to the dinner table as quickly as possible without losing his or her balance.	When a person gets up and walks from the kitchen to the dining room without losing his or her balance, his or her cerebellum is functioning properly.
Thalamus	Considered the relay station for incoming information	Thermos – Imagine a relay race. The first runner hands a *thermos* (thalamus), instead of a baton, to the next runner.	Before a person can react to visual and auditory information, it must first pass through the thalamus.
Occipital Lobe	Associated with vision	Octopus – Imagine an *octopus* (occipital) wearing glasses because it cannot see well.	When a person is viewing a silent movie, he or she must rely on his or her occipital lobe.

Appendix C

Test Questions

1. The part of the brain that controls heartbeat and breathing is called the:
    a. cerebellum.
    b. medulla.
    c. amygdala.
    d. thalamus.
2. Which region of the brain plays a role in arousing your attention when someone nearby mentions your name?
    a. reticular formation
    b. cerebellum
    c. amygdala
    d. medulla
3. Which brain structure relays information from the eyes to the visual cortex?
    a. thalamus
    b. amygdala
    c. medulla
    d. cerebellum
4. Which of the following is the component of the limbic system that plays an essential role in the formation of long term memories?
    a. hypothalamus
    b. thalamus
    c. hippocampus

d. medulla

5. A brain tumor caused extensive damage to Mr. Thorndike's hypothalamus. It is most likely that he may have problems with:
   a. visual perception.
   b. muscular coordination.
   c. perception of hunger.
   d. language comprehension.
6. Which lobes of the brain receive the input that enables you to feel someone scratching you back?
   a. parietal
   b. temporal
   c. occipital
   d. frontal
7. The surgical removal of a large tumor from Dane's occipital lobe resulted in extensive loss of brain tissue. Dane is most likely to suffer some loss of:
   a. muscular coordination.
   b. pain sensations.
   c. speaking ability.
   d. visual perception.
8. Auditory stimulation is first processed in the __________ lobes.
   a. occipital
   b. temporal
   c. frontal

d. parietal

9. The part of the cerebral cortex that directs the muscle movements involved in speech is known as:

    a. Wernicke's area.

    b. Broca's area.

    c. the hypothalamus.

    d. the reticular formation.

10. The corpus callosum is a wide band of axon fibers that:

    a. enables the left hemisphere to control the right side of the body.

    b. controls the glands and muscles of the internal organs.

    c. transmits information between the cerebral hemispheres.

    d. directs the muscle movements involved in speech.

11. After suffering an accidental brain injury, Kira has difficulty walking in a smooth and coordinated manner. It is most probable that she has suffered damage to her:

    a. amygdala.

    b. reticular formation.

    c. cerebellum.

    d. corpus callosum.

12. The structure that regulates hunger is called the:

    a. thalamus.

    b. amygdala.

    c. hippocampus.

    d. hypothalamus.

13. Which portion of the cerebral cortex is most directly involved in making plans and formulating decisions?
    a. frontal lobes
    b. occipital lobes
    c. temporal lobes
    d. parietal lobes
14. Dr. Frankenstein made a mistake during neurosurgery on his monster. After the operation, the monster “saw” with his ears and “heard” with his eyes. It is likely that Dr. Frankenstein “rewired” neural connections in the monter’s:
    a. hypothalamus.
    b. cerebellum.
    c. amygdala.
    d. thalamus.
15. The visual cortex is located in the:
    a. temporal lobe.
    b. occipital lobe.
    c. frontal lobe.
    d. parietal lobe.
16. Following a nail gun wound to his head, Jack became more uninhibited, irritable, dishonest, and profane. It is likely that his personality change was the result of injury to his:
    a. parietal lobe.
    b. temporal lobe.
    c. occipital lobe.

d. frontal lobe.

17. Which of the following is typically controlled by the left hemisphere?

    a. spatial reasoning

    b. perception of shapes

    c. language

    d. perceptual skills

18. Your life would most immediately threatened if you suffered destruction of the:

    a. medulla

    b. amygdala

    c. hippocampus

    d. thalamus

19. Which neural center plays a central role in emotion as such as aggression and fear?

    a. amygdala

    b. thalamus

    c. cerebellum

    d. medulla

20. Which network in the brainstem plays an important role in controlling attention?

    a. hypothalamus

    b. cerebellum

    c. reticular formation

    d. medulla

21. A loss of physical coordination and balance is most likely to result from damage to the:

    a. hypothalamus.

b. cerebellum.

c. corpus callosum.

d. amygdala.

22. After a sky-diving accident, Laurie was unable to make sense of other people's speech. It is likely that her cortex was damaged in:

a. corpus callosum.

b. Broca's area.

c. hippocampus.

d. Wernicke's area.

23. If Professor Kosiba lesions the amygdala of a laboratory rat, it is most likely that the rat will become:

a. hungry.

b. heightened attention.

c. physically uncoordinated.

d. less aggressive.

24. Alana suffered a brain disease that destroyed major portions of her temporal lobes. Alana is most likely to suffer some loss of:

a. auditory perception.

b. hunger and thirst.

c. touch sensations.

d. muscular coordination.

25. After she suffered a stroke, Mrs. Jacobitz had so much difficulty speaking that she had to communicate by writing. This suggests that her cortex was damaged in:

a. the occipital lobe.

b. Broca's area.

c. corpus callosum.

d. Wernicke's area.

26. Mr. Hill had a procedure in which an area of the brain is surgically cut so that the two hemispheres are unable to communicate with each other. The area of the brain that was cut was the:

a. hippocampus.

b. cerebellum.

c. corpus callosum.

d. thalamus.

27. The sensory cortex that detects touch is located in the __________ lobes.

a. parietal

b. temporal

c. frontal

d. occipital

28. Sarah suffers from amnesia, where she has a loss of memory ability. Doctors would diagnose her with damage to her:

a. hypothalamus.

b. cerebellum.

c. amygdala.

d. hippocampus.

29. Jamie is walking through campus while talking on her cell phone. Throughout her conversation, her ___________ is controlling her language.

    a. occipital lobe
    b. left hemisphere
    c. reticular formation
    d. cerebellum

30. The part of the left temporal lobe that is involved in understanding language is known as:

    a. Broca's area
    b. the amygdala
    c. Wernicke's area
    d. the hippocampus.

Appendix D

Test Answers

1. b
2. a
3. a
4. c
5. c
6. a
7. d
8. b
9. b
10. c
11. c
12. d
13. a
14. d
15. b
16. d
17. c
18. a
19. a
20. c
21. b
22. d
23. d
24. a
25. b
26. c
27. a
28. d
29. b
30. c

Appendix E

Post-Questionnaire

Sex: _________ College Year: ________ GPA: _________ Major: ___________

Please rate how familiar you were with the psychology brain terms before you participated in this study.

1. Broca's Area

Not Familiar				Very Familiar
1	2	3	4	5

2. Parietal Lobe

Not Familiar				Very Familiar
1	2	3	4	5

3. Hypothalamus

Not Familiar				Very Familiar
1	2	3	4	5

4. Wernicke's Area

Not Familiar				Very Familiar
1	2	3	4	5

5. Amygdala

Not Familiar				Very Familiar
1	2	3	4	5

6. Frontal Lobe

Not Familiar				Very Familiar
1	2	3	4	5

7. Corpus Callosum

Not Familiar				Very Familiar
1	2	3	4	5

8. Left Hemisphere

Not Familiar				Very Familiar
1	2	3	4	5

9. Temporal Lobes

Not Familiar				Very Familiar
1	2	3	4	5

10. Hippocampus

Not Familiar				Very Familiar
1	2	3	4	5

11. Medulla

Not Familiar				Very Familiar
1	2	3	4	5

12. Reticular Formation

Not Familiar				Very Familiar
1	2	3	4	5

13. Cerebellum

Not Familiar Very Familiar

1 2 3 4 5

14. Thalamus

Not Familiar Very Familiar

1 2 3 4 5

15. Occipital Lobe

Not Familiar Very Familiar

1 2 3 4 5

Please rate how helpful you feel the repeated definition, keyword, and example were in completing the multiple choice test, compared to how you might have done if you studied only the definition.

1. Helpfulness of the Repeated Definition

Not Helpful Very Helpful

1 2 3 4 5

2. Helpfulness of the Keyword

Not Helpful Very Helpful

1 2 3 4 5

3. Helpfulness of the Example

Not Helpful Very Helpful

1 2 3 4 5

Appendix F

Informed Consent Form

Working Memory Span Differences in the use of Encoding Strategies

Investigator: Lyndley Dmitsak, dmitsakl@marietta.edu

Advisor: Dr. Jennifer McCabe, Jennifer.McCabe@marietta.edu

The purpose of this research is to examine the relationship between memory encoding techniques and working memory ability. Undergraduate students will participate in this study that will examine individual differences in working memory and the use of mnemonics and other elaboration strategies to learn new material. This study has been approved by the Marietta College Human Subjects Committee.

This study will take approximately one hour, during you will be given a computerized reading span task, followed by a study booklet and a multiple choice test. The risks associated with your participation in this study should be no greater than those associated with normal daily activity. This study will help us learn more about the relationship between working memory and encoding techniques. The terms presented in this study are some of the most important to psychology because they help us understand how the brain works. By participating in this study you will gain knowledge of these terms, which may help you in your psychology courses. You will gain an understanding of how knowledge is gathered in psychological research and you will be given one hour course credit in exchange for your participation.

Your privacy will be protected at all times. You will be given a number and that number will be associated with the answers you give. Your name will not be used. All of the data collected will be used for research purposes and will not be used for any other reason.

Participation in this study is completely voluntary. If you refuse to participate, there will be no penalty. You can withdrawal from the study at any time without being penalized.

If you have any questions or concerns about research subjects' rights, you can contact Dr. Jennifer McCabe, Marietta College Human Subjects Committee Chair, 740-373-7894, Jennifer.McCabe@marietta.edu.

I HAVE READ THE INFORMED CONSENT FORM, ASKED QUESTIONS, AND AM PREPARED TO PARTICIPATE IN THIS STUDY.

____ ____________________

Participants Signature Date

____

Participants Name

Table 1

Means (Standard Deviations) for Multiple Choice Test Performance (Proportion Correct) for the WM Span, Elaboration Condition, and Question Type Conditions

		Definition Questions			Application Questions		
WM Span	*n*	RD	KW	EX	RD	KW	EX
Low	29	.76 (.23)	.79 (.20)	.77 (.27)	.70 (.20)	.71 (.17)	.64 (.31)
Medium	21	.75 (.25)	.81 (.18)	.73 (.26)	.67 (.25)	.70 (.27)	.70 (.24)
High	10	.90 (.11)	.86 (.16)	.78 (.24)	.82 (.26)	.88 (.10)	.74 (.27)

Figure Captions

Figure 1. Atkinson and Shiffrin's (1968) working memory model.

Figure 2. The traditional model of working memory by Baddeley and Hitch (1974).

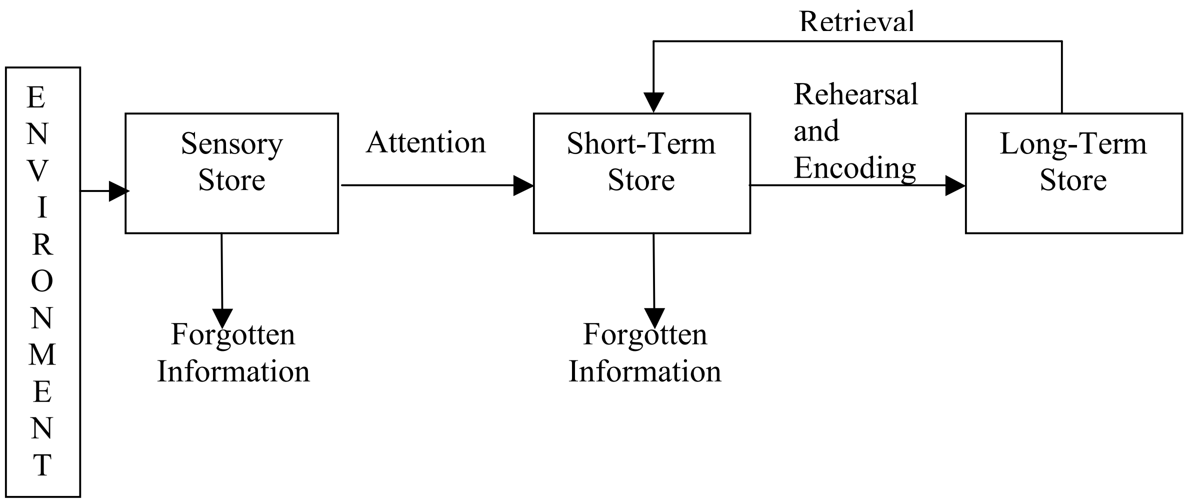
Figure 3. A graph of the main effect of WM span, using the dependent variable of proportion correct on the multiple choice test. Bars represent standard errors.

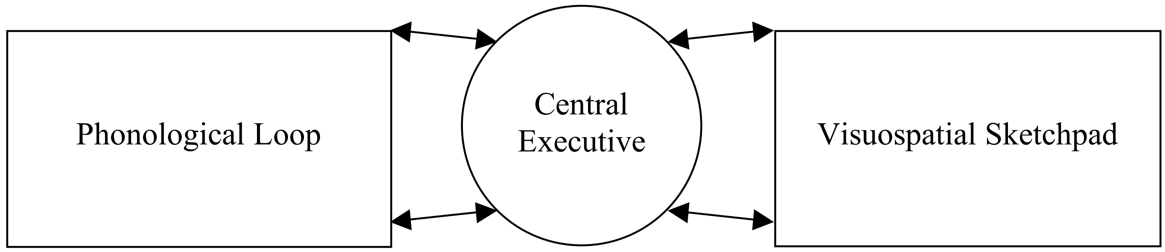
Figure 4. A graph of the main effect of encoding condition, using the dependent variable of proportion correct on the multiple choice test. Bars represent standard errors.

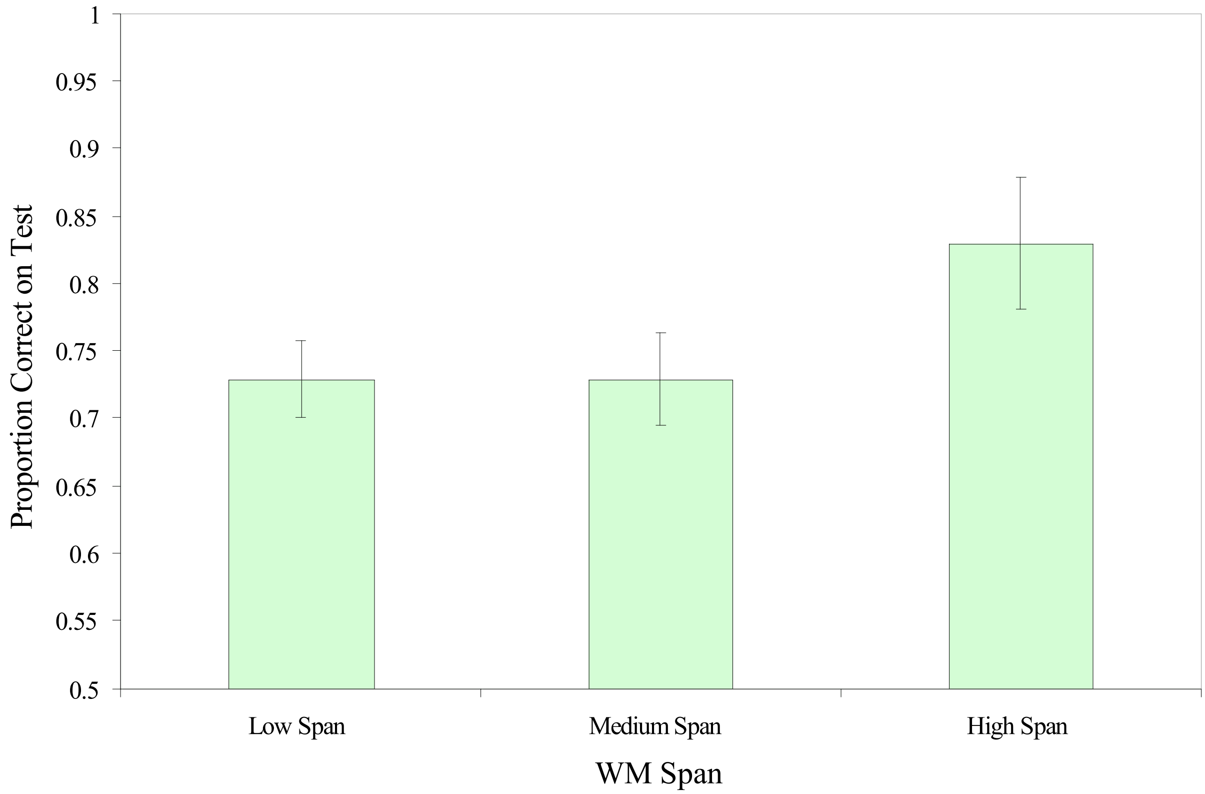
Figure 5. A graph of the main effect of question type, using the dependent variable of proportion correct on the multiple choice test. Bars represent standard errors.

Figure 6. A graph of the lack of interaction between WM span and encoding condition, using the dependent variable of proportion correct on the multiple choice test. Bars represent standard errors.

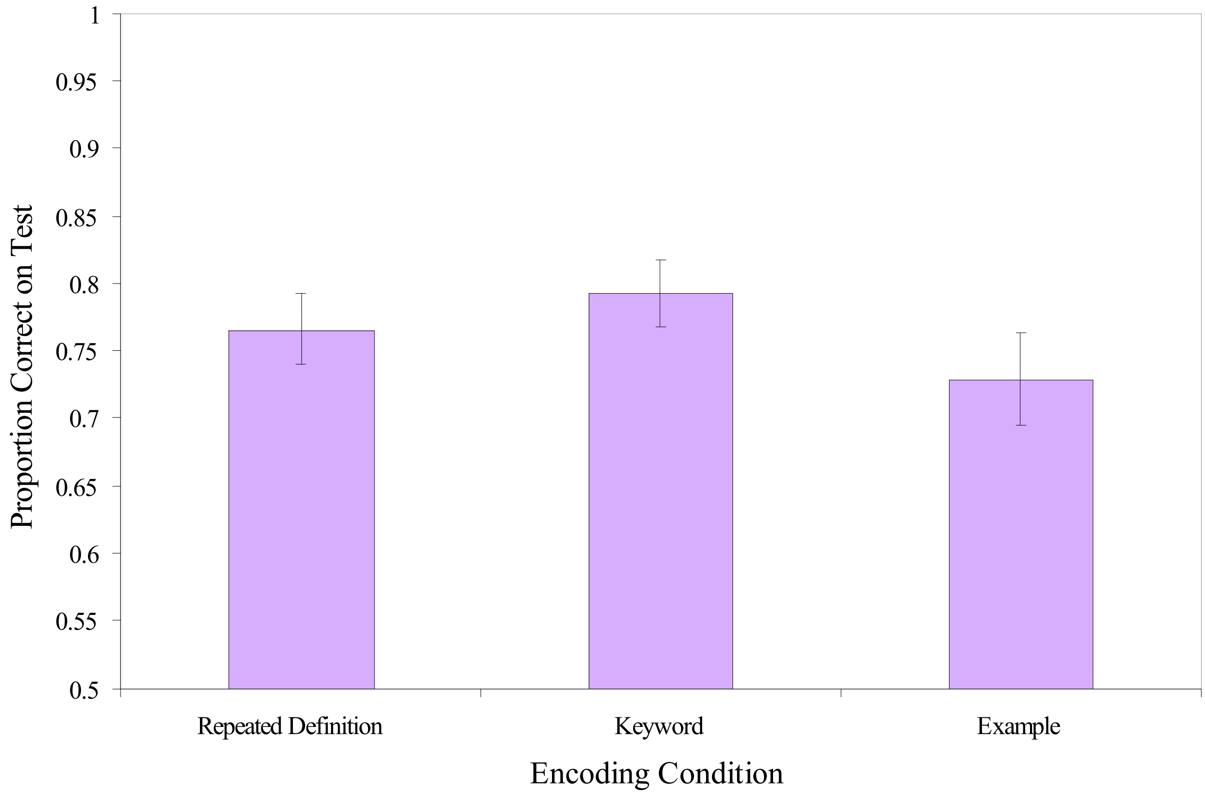
Figure 7. A graph of the perceived helpfulness ratings for the three en conditions, using a 5-point Likert scale. Bars represent standard errors.

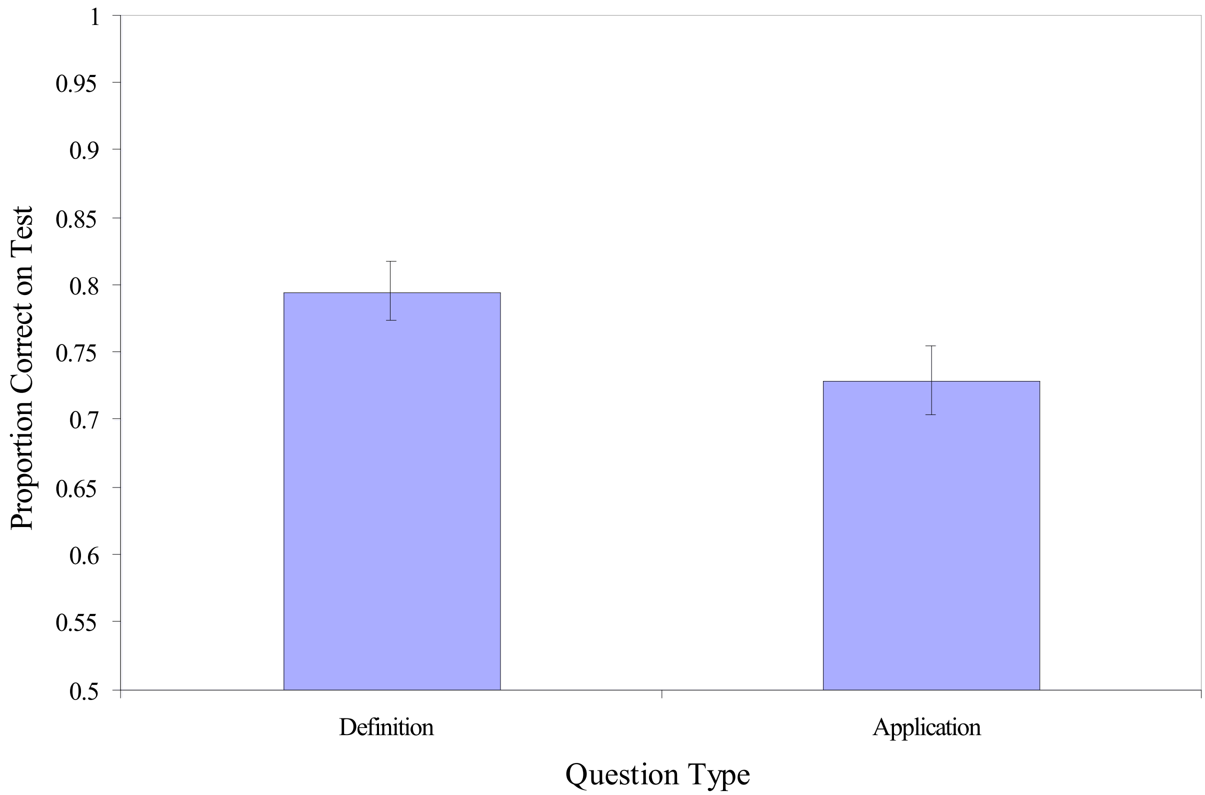

Retrieval
E N V I R O N M E N T
Sensory Store
Attention
Short-Term Store
Rehearsal and Encoding
Long-Term Store
Forgotten Information
Forgotten Information

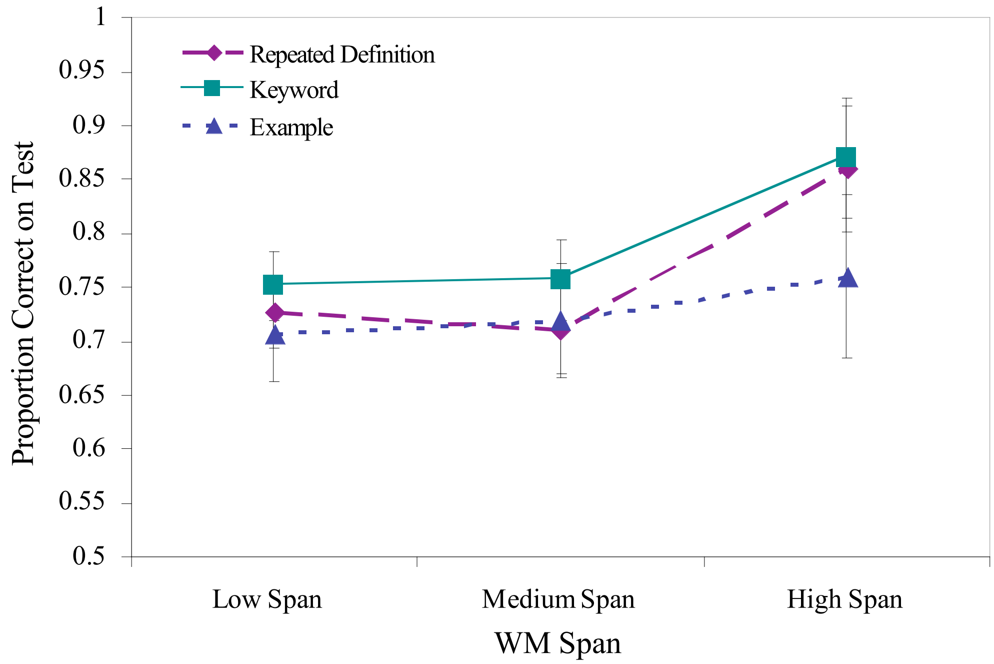

Phonological Loop
Central
Executive
Visuospatial Sketchpad



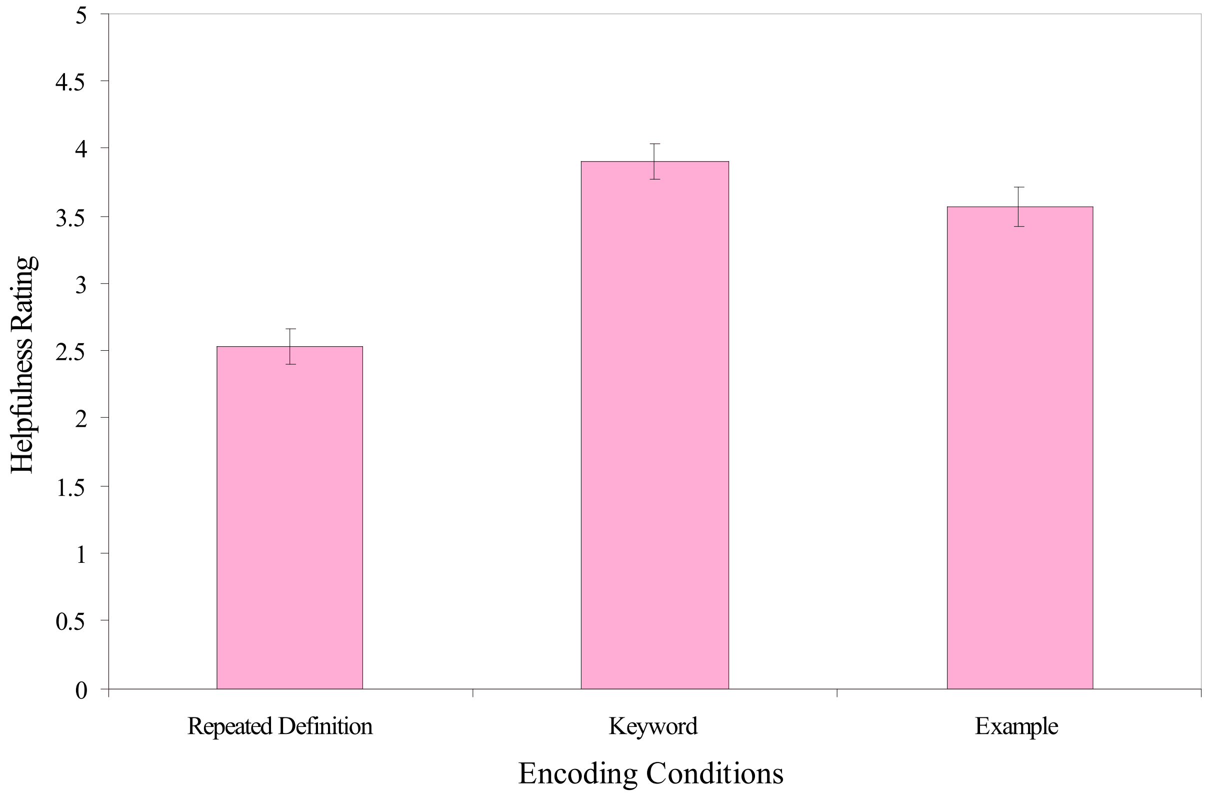
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
Proportion Correct on Test
Low Span
Medium Span
High Span
WM Span


1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
Proportion Correct on Test
Repeated Definition
Keyword
Example
Encoding Condition


1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
Proportion Correct on Test
Definition
Application
Question Type



Repeated Definition
Keyword
Example
Proportion Correct on Test
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
Low Span
Medium Span
High Span
WM Span


5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Helpfulness Rating
Repeated Definition
Keyword
Example
Encoding Conditions