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A review of research on working memory and its importance in education of the deaf

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A REVIEW OF RESEARCH ON WORKING MEMORY AND ITS IMPORTANCE IN EDUCATION OF THE DEAF

by

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Abstract: *This independent study provides an overview of working memory as it pertains to deaf and hard of hearing students.*

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Introduction

Recent research is bringing to light the importance of working memory in everyone's daily life in academic, professional, and social settings (cogmed.com). Simple examples of working memory include: remembering a phone number, short driving directions, names, one's hotel room number, and the last sentence someone just said. Working memory is especially important to communication skills. The purpose of this review is to review studies of working memory, especially those focusing on children who are deaf or hard of hearing with cochlear implants. A number of research studies have indicated that this aspect of cognition in deaf and hard of hearing children may be particularly important in spoken communication outcomes for this population. Therefore, this paper reviews the findings of several research studies that address working memory ability.

What is Working Memory?

Working memory is a tool used by everyone to help us perform efficiently and effectively in all aspects of our lives. This essential tool is defined as the ability to maintain and manipulate information in the mind for a brief period of time, often termed, “short-term memory” (Beer, Pisoni, Kronenberger, & Geers, 2010). Baddeley (1992) defines working memory as, “…the brain system that provides temporary storage and manipulation of the information necessary for such complex cognitive tasks as language, comprehension, learning, and reasoning” (p. 556). Working memory is necessary for staying focused on a task, blocking out distractions, and keeping one updated and aware of things that are going on in the environment (cogmed.com). Working memory is a vital ability for storing short-term information, words and meanings (Pisoni & Cleary, 2003). Research into working memory measures a student's capacity to acquire knowledge rather than measuring what the student has already learned (Alloway, 2011). This is important because it can predict outcomes independently from the student's IQ (Alloway, 2011).

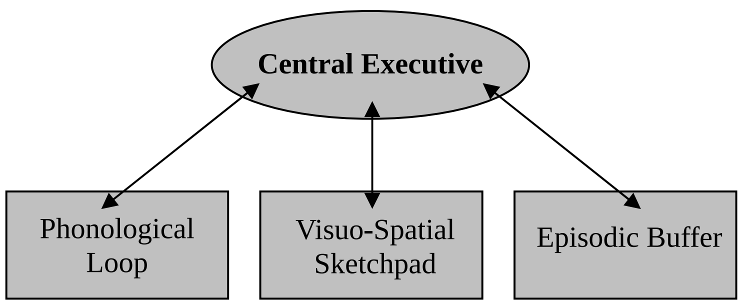
For many years working memory has been a popular area of research in regard to children who are deaf or hard of hearing. The term “working memory” was first coined by Miller, Galanter, and Pribram in the 1960s to compare the working of the mind to computer processes (wikipedia.com). Atkinson and Shiffrin also used the term to refer to short-term memory, which they called “short-term store.” Short-term memory is the essential link between accessing information and storing it. “Without rehearsal, elaboration and contact with long-term memory, information is quickly lost from short-term working memory” (Pisoni & Geers, 1998, p. 337).

Baddeley and Hitch, in their research, developed a model of working memory in which they proposed there are two slave systems, the phonological loop and the visuospatial sketchpad, along with the central executive system, which were responsible for the short-term maintenance of information (Baddeley & Hitch, 1974). They proposed that the central executive system was responsible for coordinating the slave systems, as well as for integrating information. In his research, Baddeley (2000) proposed that an additional slave system called the episodic buffer. The three slave systems are defined as:

- Phonological Loop-- This system is responsible for storing phonological (verbal) information. It continuously rehearses phonological information to prevent decay. Information is repeated over and over again through the act of sub-vocal rehearsal, such as when one tries to remember a telephone number and repeats it again and again. The phonological loop is used in reading, especially in reading unfamiliar words or novel non-word patterns (Pisoni & Geers, 1998). These new words or patterns are held and rehearsed, thus when the reader comes across them again they don't have to spend time decoding.

• Visuospatial Sketchpad-- This system is responsible for the storage of visual and spatial (non-verbal) information through the manipulation of visual images and the creation of mental maps.

• Episodic Buffer-- This is a limited-capacity temporary storage system that is capable of integrating information from a variety of sources. It is important in the role of feeding and retrieving information to and from the episodic long-term memory (Baddeley, 2000).



(Baddeley, 2000)

Researchers have attempted to measure working memory capabilities through both verbal (phonological) and nonverbal tasks (visuospatial). Verbal tasks used in research include:

• Digit Span-- Digit span is measured through a task in which a subject is given a span of numbers auditorily. In 2003, Geers explained an individual's digit span as “the number of spoken digits he or she is able to repeat back in the correct order (forward span) or in the reverse of the order (backward span)” (p. 62S). The string of numbers presented increases with every trial. The subject's digit span score is determined based on the length of the longest string of numbers he or she can recall correctly. Digit span is considered a measure of working memory capacity which has been found to be related to a variety of post implant outcome measures (Geers, 2003). Pisoni and Cleary (2003) explain that digit span is the most widely used measure of an individual's verbal working memory capacity.

- Serial Recall of Non-Words-- In this task the subject repeats lists of non-words, with the words increasing in length as the task proceeds. Burkholder and Pisoni (2003) used digit recall to assess the processing of verbal information to short-term memory. They found several differences between normal hearing children and children with cochlear implants. One difference is that normal hearing children were able to retrieve information three times faster than children with cochlear implants. Hearing children also had shorter pause times between retrieved segments than children with cochlear implants. From these results, the researchers believe that children with cochlear implants showed slower serial recall.

- Non-Word Repetition-- For this task the subject is required to repeat individual non-words of increasing length from one to five-syllable non-words.

- Sentence Completion and Recall-- This task requires the subject to listen to a series of sentences, fill in the missing last word in each sentence, and repeat the words of each of the sentences presented (Lyxell, Shalen, Wall, Ibertsson, Larsby, Hullgren, Maki-Torkko, 2008).

Visuospatial (nonverbal) tasks do not contain a verbal component. A nonverbal task may contain non -nameable objects or tones. Non-verbal tasks can include spatial tasks, some of which are typically done on a touch-screen computer. Several examples of nonverbal tasks include:

- Computer-based activities-- In this type of activity multiples of one kind of shape, such as a square, are displayed on the screen. Squares lights up one at a time to present a sequence. The number of squares in the sequence varies depending on performance. The subject is always being challenged. In other words, if the subject correctly identifies a sequence of four squares then the next sequence will contain five squares. However, if the subject incorrectly identifies the sequence than it will go back down to three squares. The object is for the subject to recall the sequence in which the squares were presented by touching them in that order.

- Visual matrix patterns test-- This is a task in which patterns of filled cells in a five by five matrix are displayed for two seconds. The subject must then replicate the pattern of filled cells in an empty matrix. The number of filled cells increases as the task progresses and the subject answers correctly.

- Corsi blocks-- This task is done using either a matrix of blocks, or a computer screen. The examiner will point to a sequence of blocks, or blocks will light up on the screen of the computer. The subject must then touch the blocks in the exact same order. The sequence increases in length as the task becomes more difficult.

Links between Working Memory and Skill Development in Language and Reading

Learning and memory are very closely related. Without memory, learning would not be sustainable (Alloway, 2011). Memory maintains information for immediate or later use (Alloway, 2011). "Working memory capacity, phonological processing skills, and lexical abilities are cognitive components that are central for processing of information in most language-related activities" (Lyxell et al., 2008, p. S47). Research on working memory in children with cochlear implant shows that their phonological storage capacity varies widely (Lyxell et al., 2008).

Working memory is unaffected by external environmental issues such as parents' educational level or socio-economic circumstances (Alloway, 2011). A study conducted by Alloway (2011) revealed that when children had low working memory skills, they had a pattern of poor performances in a range of core subjects as well as in areas like art and music. This pattern of poor performance remained even when the student's IQ was statistically accounted for. This study corresponds to evidence suggesting that working memory is even more important than other cognitive measurements such as IQ. For example, in typically developing students, Alloway found that their working memory skills at five years old, rather than IQ, were the best predictor of achievement in reading, spelling, and math outcomes six years later (Alloway, 2011).

One of the conclusions made by Geers in 2003 after comparing word reading and comprehension levels of children with early implantation was that children who experience deafness early in their development have a better prognosis for normal literacy development than ever before. "To the extent that use of a cochlear implant is associated with greater use of phonological coding strategies for decoding print, longer working memory spans for short-term storage of phonemes, words and sentences...and reading comprehension, early implantation affects acquisition of literacy" (Geers, 2003, p. 59S).

Much of the research presented in this review has shown a link between working memory and language acquisition as well as reading abilities. In typical hearing children, it is widely accepted that phonological awareness – the ability to distinguish between and manipulate the constituent sounds of words – is one of the strongest predictors of literacy achievement (Kyle & Harris, 2006). Therefore, we must conclude that auditory working memory is especially important for language skills and development. To integrate auditory information in a meaningful way, one must rely on domain-general processes such as attention, working memory, executive functions and processing speed (Beer et al., 2010). An example of auditory working memory in action is when the subject remembers individual sounds in a given word and then blends those sounds to recognize the word. From that point auditory working memory is used to remember the words of a sentence and their order so that the words can be put together to comprehend the meaning of the sentence. Those sentences are then remembered and put together to comprehend the meaning of a paragraph. Thus, working memory is critical for basic language skills that are required for recognizing words and understanding sentences and paragraphs. (Kronenberger, Pisoni, Colson & Henning, 2010). Also, because language learning and development require the individual to follow, retain, and integrate a stream of auditory information, working memory is likely to be a core component of language development following cochlear implants (Kronenberger & Pisoni, 2009).

Reading comprehension is closely linked to working memory. Research in Sweden by Kjeldsen and Muter and others showed that measures of reading comprehension and word decoding correlate with phonological skills in hearing children. This research implies that children with CI also use phonological (coding) skills in reading (Kjeldsen, Niemi, & Olofsson 2003; Muter, Hulme, Snowling, & Stevenson 2004). The central executive component of working memory allows one to store current information while the previous information is accessed. The two sets of information are then integrated so that one may understand what is being read. Basically, in order to comprehend while one is reading, it is necessary to “hold onto” what was just read while simultaneously “reaching back” to what was read previously. If one has a poor working memory, he or she has trouble holding onto the information or reaching back to connect the information. This places a heavy load on the reader, leaving less room to process and understand what is being read. One idea, suggested by researchers (Garrison, Long, Dowaliby, 1997) is that the overall capacity of working memory is not different between good and poor readers. Rather they suggested that good readers are simply more efficient at processing information. Another suggestion is that poor readers may have a smaller working memory capacity compared to good readers (Garrison, et al., 1997). The cognitive processes individuals use while reading involve a dynamic interplay between working memory and long-term memory (Garrison et al., 1997). Thus, it is important for teachers to recognize and address the difficulties that may arise due to poor working memory.

What does this mean for the academic progress of children who are deaf and hard of hearing? Since reading is crucial to learning and is the foundation of almost every other subject in education, it is clear that if deaf and hard of hearing students have a deficiency in reading, it has the potential to affect all other areas of academic progress. The deficiency can prevent these students from reaching the performance level of their typical hearing peers.

Auditory Deprivation

Typical hearing children and those who are deaf and hard of hearing acquire language in different ways. Those children with typical hearing are able to learn language through overhearing in their daily environment from birth. Deaf and hard of hearing children do not have the same advantage. They have a period of deprivation where the auditory signal is highly impoverished. This is called "auditory deprivation." Even with early identification and fittings with devices, many deaf children need direct instruction to learn to listen and acquire language.

Auditory deprivation is the absence of acoustic stimulation as a consequence of the development of a profound bilateral hearing loss. Auditory deprivation before implantation can lead to auditory processing deficiencies, in particular, a deficiency in auditory sequential, short-term memory

(SSTM) (Dawson, Busby, McKay, Clark, 2002). Auditory SSTM is the ability to remember auditory stimuli in the exact order it occurred. The brain is an integrated system in which no parts act alone; it is shaped by experience. Because of this, a period of poor or no access to sound may affect the neural organization and plasticity of brain systems, such as working memory, processing, executive control, attention, and learning. All of the above processes are required to learn, perceive and use language efficiently (Beer et al., 2010).

Deaf or hard of hearing children overall have fewer listening experiences compared to typical hearing peers. This could be a likely explanation of why typical hearing children perform better on cognitive tasks that are phonological in nature. The phonological component of working memory in children with cochlear implants may be affected by the quantity and quality of oral language they are exposed to (Pisoni & Burkholder, 2003).

Improving Working Memory: Responsibility of the Educators

Evidence suggests that low working memory skills create a high risk factor for educational underachievement and that working memory impacts all areas of learning and thinking. It is a key component in the learning of language. Thus, it is important to investigate whether working memory can be improved. It is important to address working memory at an early age because deficiencies in working memory will continue to compromise a child's chance of academic success. “The finding that general working memory capacity correlates with communicative behavior is an important... finding and may also have implications for design of rehabilitation programs, particularly those... that focus on communication styles” (Lyxell, et al., 2008, p. S51). Pisoni and Cleary (2003) emphasize the importance of overcoming the fragility and limited capacity of working memory through rehearsal techniques, that is, “methods of maintaining information by 'refreshing' or re-encoding the material to be remembered” (p. 108S). This can be vocal or sub-vocal (internal/silent) repetition of the material, such as hearing adults frequently do. There are commercially created as well as teacher made activities, games, and programs that can exercise working memory. Not only do these activities benefit children who are deaf or hard of hearing, but they also benefit typical hearing children.

Some programs have been created to improve working memory. Cogmed is a program designed to improve attention by effectively increasing working memory capacity through intensive systematic training (cogmed.com). Cogmed has developed three programs for different age levels to improve attention/working memory: Cogmed JM (preschoolers), Cogmed RM (school-age), and Cogmed QM (adults). The programs are evidence-based and inspired by the idea that when working memory is improved, the student can learn further skills more easily. The programs are performed on a computer in several sessions. The participant is required to complete five sessions a week over the course of five weeks. The sessions include different target components of working memory. The program challenges the participants' working memory capacity and automatically adjusts to challenge each individual (cogmed.com).

Lumosity is another company that has also developed a program that claims to improve working memory as well as creativity and attention. The program is online and can be fully accessed with a full membership. Members choose the areas in which they feel they need to improve, and a program is generated to improve those areas. The program consists of games and assessments that address specific cognitive functions. The games enhance the brain's ability to remember details, solve problems, pay attention and multitask. Members are expected to train for 10-15 minutes every day to improve speed, memory, attention, flexibility, and problem-solving (Lumosity.com). The exercises are novel and engaging, while constantly adapting in difficulty based on the individual's development. In both training programs, the games are adaptations of working memory skill tasks explained previously. Based upon research done with typical hearing children showing improvement after using programs or training tasks, investigation is deserved to see whether these programs will also benefit children who are deaf and hard of hearing.

Funds for the above programs and their memberships may not always be available to classroom teachers. However, there are activities and games that can easily be integrated into a teacher's weekly lesson plans. Children will have fun while simultaneously exercising their working memory skills. Games are engaging and motivating to any child. When striving to exercise working memory, games should include: planning/strategy aspects, a memory component, and should be challenging; requiring the participants to focus. Some games focus on <u>visual working memory</u> (Kronenberger, 2010).

- In an object memory game, children are presented with a tray of objects for an allotted amount of time. The items are then covered or removed. Once the objects are out of sight, the children must then repeat back or write as many objects as they can. This kind of game requires students to create some way of organizing the objects in their short-term memory.
- The eyewitness game is another memory game. In this game, a teacher or staff member enters a classroom and does a sequence of random tasks. Examples of the tasks include: sharpen a pencil, erase something from the board, move a book from one side of the room to the other, etc. Once the person leaves, children try to recall what the person looked like, what he or she was wearing, and the order in which the random tasks were performed. This game requires the children retain a lot of information and a sequence of events.
- Chess, Checkers, card games (Hearts, Spades), and educational video-games (“Math Blaster”)

will require the student to develop a strategy, or exercise working memory. These types of games challenge one to keep track of the other players as well as the changing conditions of the game. One must also thinking ahead to how they are going to react to an opponent's move. Educational video-games require one to not only solve a problem (such as a math equation) but typically they are required to be performing an additional task simultaneously. Thus both types of games require one to hold on to and process multiple pieces of information all at once.

Some activities can be done without props. These activities are done simply with auditory information.

- A group of students can "pack" a mental suitcase. In this activity each child must think of an item to "pack" in the suitcase. The adult or teacher can make up a story to explain why the suitcase is being packed (i.e., going on vacation). Children are seated in a circle. The first student should say, "We're going on vacation and we're bringing a..." The student will then insert the item he or she wishes to bring on vacation. The next student will say the same phrase and include the previous student's item and add his or her own item. As the children take a turn they must recite the list thus far and add their item to the end of the list. This activity requires the students to listen closely, and depend on their auditory skills to hear and then recite the sequence of items.

Conclusion

"One of the most important and influential proposals that has emerged from the information processing framework is the construct of working memory" (Pisoni & Cleary, 2003, p. 108S). Continued use of working memory is essential for maintaining concentration, purposeful thinking, and mental effort during learning (Kronenberger & Pisoni, 2009). Working memory research has shown that it is correlated to reading and language. Because these two areas are so important to all other learning, more research needs to be conducted to determine if working memory can be improved, and then to develop activities and methods to improve it. An important outcome of this research must be to train educators to realize the potential of focused activities and to encourage them to plan strategies to incorporate such activities in their daily work with deaf and hard of hearing children.

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