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Memory skills of deaf learners: Implications and applications

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Abstract

This paper will review research on working memory and short-term memory abilities of deaf individuals delineating strengths and weaknesses. The areas of memory reviewed include weaknesses such as sequential recall, processing speed, attention, and memory load. Strengths include free recall, visuospatial recall, imagery and dual encoding. Phonological encoding, and rehearsal appear to be strengths when these strategies are employed. The implications of the strengths and weaknesses for language learning and educational achievement are discussed. Research questions are posed and remedial and compensatory classroom applications are suggested.

Introduction

Some psychologists consider working memory (WM) and short-term memory (STM) to be synonymous and representing a memory store that is constrained both by the number of items that can be maintained and the length of time these items can be active. Denh (2008) distinguishes WM and STM as follows. STM passively holds information. WM actively processes it.

Research over the past two decades has demonstrated that performance on WM and STM tasks is highly predictive of academic achievement in areas such as:

- reading (Cain, 2006; Cain & Oakhill, 2006)
- language comprehension (Engle, Carullo, & Collins, 1991)
- mathematics (Geary, Hoard, Nugent, & Byrd-Craven, 2007; Jarvis & Gathercole, 2003).
- science (Gathercole & Alloway, 2008; Gathercole & Pickering, 2000; Gathercole, Pickering, S.J., Knight, C. & Stegmann, 2004, Jarvis & Gathercole, 2003)

Long-term memory, the repository of knowledge, is able to acquire very little information without these gateways functioning properly (Denh, 2008). Deficits in WM and STM may potentially limit students' ability to learn and function in school (Alloway, Gathercole, Kirkwood, & Elliott, 2009). Although it is not yet well understood how these contribute to academic skills, it has been suggested that learning is hampered or fails when task demands exceed memory capacity (Ayres, 2009; Gathercole, Lamont & Alloway, 2006, Reber & Kotovsky, 1997).

For children with disabilities, deficits in memory processes have been found (Alloway & Gathercole, 2006; Pickering, 2006). For example, children with reading disabilities have specific difficulties in retrieving speech-based codes and monitoring attentional processes (Swanson, Zheng, & Jerman, 2009). WM deficits have also been described for groups of children who exhibit :

- mathematical learning disabilities (Geary, Hoard, Nugent, & Byrd-Craven, 2007)
- intellectual disabilities (Henry & Winfield, 2010)
- speech and language impairments (Archibald & Gathercole, 2006)
- autism (Bennetto, Pennington, & Rogers, 1996)
- attention deficit/hyperactivity disorder (Rapport, et al,, 2008).

A greater understanding of the memory limitations in children can ultimately inform the development of communication and classroom practices and may result in improved language learning and school outcomes. To date, however, relatively little research has been conducted to develop and evaluate innovative approaches to minimize memory demands in the classroom (Gathercole & Alloway, 2008) or directly improve memory for students who are most at risk for communicative or academic failure (Holmes, Gathercole, & Dunning, 2009; Klingberg et. al., 2005; Swanson, Kehler, & Jerman, 2010). The low levels of academic achievement common for deaf individuals (Gallaudet Research Institute, 1996; Marschark, 2006; Meadow-Orleans, 2001; Moores, 2001, 2003; Traxler, 2000) may also have a basis in memory processes (Blair, 1957; Marschark, et al., 2009).

This paper will review research on working memory and short-term memory abilities of deaf individuals. In this paper, “deaf” refers to those individuals with a hearing loss of 70 decibels or higher. This review focuses on deaf signing individuals. The areas of memory reviewed include those in which deaf individuals exhibit deficiencies and strengths. Deficiencies refer to areas in which deaf individuals perform less well than hearing individuals and strengths refer to areas in which deaf individuals perform equal to or better than hearing individuals. Deficiencies include sequential recall, processing speed, attention, and memory load. Areas of strength include free recall, visuospatial recall, imagery, and dual encoding. Areas which emerge as strengths when the particular strategy is employed include phonological encoding and rehearsal. The implications of the deficiencies and strengths for language learning and educational achievement are discussed. The results of the literature review then form the basis for suggested remedial and compensatory activities to enhance learning. Research questions are also delineated regarding the proposed educational applications.

Memory Skills of Deaf Learners

Memory Deficits and their Effects on Language Learning and Academic Achievement

Sequential memory.

Sequential memory is recall or processing of a list or other stimulus such as a sentence in the same order as it was presented. Bebko (1984) has noted that deaf individuals have greater difficulty with sequential memory processing tasks than hearing individuals. For deaf individuals, deficits have been found in comparison to hearing chronologically age-matched peers for immediate sequential recall of lists of:

- digits (Blair, 1957; Flaherty & Moran, 2004; Koo, Crain , LaSasso, Eden, 2008; Olsson & Furth, 1966; Parasnis, Samar, Betger, & Sathe, 1996; Pintner & Patterson, 1917; Tomlinson-Keasey & Smith-Winberry, 1990)
- printed words (Flaherty & Moran, 2004; Hanson, 1982; Krakow & Hanson, 1985)

- pictures (Blair, 1957; Bebko, 1984; Bebko & McKinnon, 1990; Campbell & Wright, 1990)
- American Sign Language signs(for deaf subjects) versus English words (for hearing subjects) (Bavelier, Newport, Hall, Supalla, & Boutla, 2008; Bellugi & Siple, 1974; Bellugi, Klima, & Siple, 1975; Boutla, Supalla, Newport, & Bavelier,2004 ; Geraci, Gozzi, Papagno, & Cecchetto, 2008; Krakow & Hanson, 1985)
- Fingerspelled words (for deaf subjects) versus English words (for hearing subjects) (Krakow & Hanson, 1985)

Various researchers have discussed the reasons for this deficit. Their hypotheses include the longer articulation length of signs compared to speech (Wilson & Emmorey, 1997), the shorter decay rate of visual/sign memory compared to echoic/speech-based memory (Boutla, Supalla, Newport & Bavelier, 2004), and the formational complexity of signs versus speech (Geraci, Gozzi, Papagno, & Cecchetto, 2008). Regardless of the theoretical viewpoint, deaf individuals sequential based WM appears to be somewhat limited when compared to hearing individuals. A recent review (Marschark & Wauters, 2008) has suggested that deaf children are less likely than hearing children to utilize sequential processing strategies and this may account for at least some of their linguistic WM deficit and language comprehension difficulties.

Processing speed.

Processing speed refers to the speed with which an individual can perform a cognitive task such as recognizing a word or sign or comprehending a sentence. Speed of processing deficits have been found to inhibit the oral and written language as well as the math ability of hearing children (Fletcher, Lyon, Fuchs & Barnes, 2007; Mather, & Jaffe, 2002; Prifitera, Saklofske, &Weiss, 2005). Slow word recognition while reading has also been related to deficits in reading fluency and comprehension (Kelly, 1993; Johns, 2009; Nagy, Anderson, Schommer, Scott, & Stallman, 1989). Deaf students have been shown to have processing speed deficits based on the results of the Processing Speed index subtests of the WISC-4 (Leutzinger, 2002; Maller & Ferron 1997). Processing Speed subtests are also positively correlated with academic achievement of deaf students (Braden, 1990; Kelly & Braden, 1990; Stewart, 1981).

According to Felser and Clahsen (2009) children and late-second language learners usually exhibit slower language processing speed than mature native speakers. For children, this slower processing speed is most likely due to their reduced attention and WM spans as compared to adults. For non-native late second language learners, language processing is thought to be cognitively more demanding than for native adults. While children seem to be able to use monolingual adult-like processing routines from fairly early on in development, late-learners' processing of some aspects of grammar appear to remain non-native-like even at higher proficiency levels.

As learners experience a language, spoken or signed, one of the primary tasks is to separate out the discrete symbols of the language from the flow of sound or sign for comprehension or acquisition purposes (Felser & Clahsen, 2009; Hirsh-Pasek & Gollinkoff, 1996). Mayberry and Fischer (1989) have found that non-native signers are still struggling with this task even in adulthood as compared to native signers who exhibit language processing skills more indicative of automatic sign recognition. For non-native signers this "bottleneck" in processing has been related to deficits in the recall and comprehension of signing.

Attention.

Attention is the cognitive process of focusing on one aspect of the immediate environment and is of great importance in the function of WM (Engle, 2002). Attention as measured subjectively by the Attention Deficit Disorder with Hyperactivity Comprehensive Teacher Rating Scale, the Attention-Activity section of the ANSER, and the Conners' Parent Rating Scale indicated that 14.1% of deaf children of deaf parents would be considered to have attention deficits compared to 38.7% of deaf children of hearing parents (Kelly, et al, 1993). Approximately 8-10 % of hearing children in the United States have been diagnosed with attention deficits (Centers for Disease Control and Prevention, 2010). Other subjective rating scales have suggested no difference between deaf and hearing children in attention skills (Meadow, 1976).

On empirical measures of attention, deaf children have been compared to hearing children. These comparisons have revealed:

- deficits (Altshuler, Deming, Vollenweider, Ranier, & Tendler,1976; Mitchell & Quittner, 1996; Mykelbust & Brutten , 1953; Proksch & Bavalier, 2002; Parasnis, Samar & Berent, 2003; Werner & Strauss, 1941)
- superior ability (Larr, 1956; McKay, 1952).

Deaf individuals are better at attending to and processing information in peripheral vision than hearing individuals (Chen, Zhang & Zhou, 2006; Loke & Song, 1991). The lack of hearing to alert the deaf to the location of motion or animate objects in the environment may have fostered this compensation. However, in a classroom where attention should be centered on the teacher or interpreter attending to peripheral movement may be problematic (Dye, Hauser, & Bavelier, 2008). Sustaining and appropriately directing attention in the classroom does appear to be troublesome for deaf students. Matthews and Reich (1993) found that deaf high school students attended to a classmate's signing about 30% of the time when that classmate was communicating with the teacher about class material. When the teacher was signing to the whole class the students attended to the teacher 44% of the time. If the teacher addressed a particular student, that student's attention to the teacher increased to 50%. Marschark, et al., (2005) found similar inattentiveness in college classrooms of deaf students.

Memory load.

Memory load is the cognitive complexity a task presents to an individual. For example, the memory load inherent in comprehending a twelve word sentence is higher than that for comprehending a three word sentence. As memory load increases performance often decreases (Denh, 2008). One factor that increases memory load is the redundancy and juxtaposition of similar words in a sentence. For hearing individuals such sentences are termed tongue-twisters ("She sells seashells by the seashore"). Tongue-twisters increase task memory load. Subsequently, comprehension is significantly less accurate for these sentence types as compared to simple control sentences ("She buys her clothes at Old Navy.") (Kennison, Sieck, & Briesch, 2003; McCutchen & Perfetti, 1982; Perfetti & McCutchen, 1982). Thus, formational similar items employed in the dame utterance can increase memory load.

When processing sign language deaf adults have been shown to code items based on the cherological (Stokoe, 1960) or sign-based formational features of the items (Bellugi, Klima & Siple, 1975; Hamilton & Holzman; 1989; Hanson, 1982; Shand, 1982; Wilson & Emmorey, 1997, 1998). Deaf children have also shown evidence of cherological coding for signs (Hamilton, 1984, 1985; Hirsh-Pasek & Treiman, 1982; Treiman & Hirsh-Pasek, 1983). Print, it appears, can be coded phonologically (Hanson, 1990; Hanson & Lichtenstein, 1990) or cherologically (Krakow & Hanson, 1985; Shand & Klima, 1981; Wilson & Emmorey, 1997, 1998). For deaf individuals, Treiman and Hirsh-Pasek (1983) examined the comprehension of "finger-fumbler" sentences (Kilma & Bellugi, 1979) in which signs for the printed words were formationally similar. Results indicated that as task difficulty increased, reading comprehension of single sentences decreased for less-proficient deaf readers. Comprehension was significantly lower for sentences which contained words whose signs were formationally similar such as "I ate apples at home yesterday." than for control sentences such as "I ate the bananas at work last week.". According to Treiman and Hirsh-Pasek, the underlined words have signs which are considered visually similar. These words were culled from the data collected by Bellugi and Siple (1974), Bellugi, Klima, and Siple (1975), and Klima and Bellugi (1979). Their similarity lies in the fact that they are all produced in locations around the mouth and lower front side of the face. EAT and HOME also share handshape while HOME and YESTERDAY share a similar movement and location.

In the area of sequential recall, Rudner and Ronnberg (2008) have provided evidence that deaf adults are similar to hearing adults in sequential recall of pictures when memory load requirements are low. However as memory load increases sequential recall becomes more difficult for deaf individuals sooner than for hearing individuals.

Memory Strengths and Research Questions for Language Learning and Education

Free recall.

For free recall or recalling a list in any order, memory span is equivalent in adult deaf ASL signers and hearing English speakers for printed words (Hanson,1982, 1990) and ASL signs and spoken words, respectively (Boutla, Supalla, Newport and Bavelier (2004). For children

Liben (1979) has found free recall for line drawings to be similar for deaf and hearing subjects. Similarly, there is no significant difference between the free recall of sequentially presented shapes by deaf and hearing children (Todman & Seedhouse, 1994). Can this strength be useful in academic learning where free recall ability is beneficial such as remembering the names of the states or the bones in the body?

Visuospatial recall.

Visuospatial recall refers to the recall of items presented in some form of visual array such as blocks on a table or objects in a grid. For sequential recall of nonlinguistic visuospatial items, such as in the Corsi block test, deaf adults and children prove superior to hearing individuals (Alamargot, Lambert, Thebault,& Dansac, 2007; Geraci, Gozzi, Papagno, & Cecchetto, 2008; Logan, Mayberry, & Fletcher, 1996; Wilson, Bettger, Niculae, & Klima, 1997). In the Corsi block test, the experimenter touches a static series of blocks randomly arranged on a board and the subject must touch the blocks in the same sequential order. In a similar task, the Knox Cube test which employs a static straight line of blocks, deaf children are also superior to hearing children in sequential recall of this visuospatial array (Blair, 1957). Deaf children have also shown equal sequential visuospatial recall ability to hearing children in the Simon game in which a sequence of flashing colored lights arranged in a circle is recalled by touching them in order of presentation (Tomlinson-Keasey & Smith-Winberry, 1990).

Also in the nonlinguistic visuospatial domain, Parasnis, Samar, Betger, and Sathe (1996) utilizing the Revised Visual Retention Test (Benton,1974) found no significant difference between hearing and deaf children in their ability to recall (by drawing) a series of geometric figures presented via a static sequential pattern (a line of figures presented all at once). Utilizing adult native deaf signers and the Rey–Osterrieth Complex Figure Test, Hauser, Dye, Cohen, and

Bavelier (2007) found no significant difference between hearing and deaf subjects on recall by drawing of simple and complex geometric figures. The Rey–Osterrieth Complex Figure Test addresses spatial perception and visual memory. Similar results on this test have been found for deaf children (Eldredge, 1984; Eldredge & Zhang, 1988; Parasnis & Kirk, 2004).

Deaf adolescent and adult subjects also have performed equal to hearing subjects on recall of static sequential presentation of shapes (a line of shapes shown all at once) but less well than the hearing subjects on temporal sequentially presented shapes (the shapes were presented one at a time and disappeared before the next shape appeared) which required serial recall. Similar results were found when digits (linguistic stimuli) were utilized as the recall items (Olsson & Furth, 1966).

Also investigating linguistic items, Flaherty and Moran (2004) studied the sequential recall of deaf and hearing college students who read phonologically-based English and Japanese deaf and hearing college students familiar with reading kanji symbols (logographs) which are not phonologically based. This study found deaf participants showed shorter sequential memory spans than hearing participants for English words. However, sequential memory spans were similar for deaf and hearing participants for words in kanji. Japanese deaf students reported using a visual gestalt memory strategy, seeing the sequence as a whole rather than the sequential strategy often reported by the English-reading deaf students. Similar results were revealed in a study utilizing only hearing and deaf Japanese students (Flaherty & Moran, 2001).

Investigating free recall of visuospatially arranged linguistic items, Blair (1957) found deaf children superior to hearing children in the free recall of everyday objects placed on a grid. The children were shown fifteen items on a grid for twenty seconds. The items were then removed and the children's task was to place them back in their original location.

It appears that deaf individuals' strength appears to lie in the recall of information presented in static visuospatial format. This appears to hold for both nonlinguistic and linguistic items. Can educators devise presentation strategies which allow deaf students to take advantage of this memory strength for the processing of sequential linguistic information, particularly English print?

Imagery.

Imagery is the ability to create, maintain, and manipulate a visual image in WM. Enhanced visuospatial abilities of deaf individuals compared to hearing individuals have been reported for imagery (Blair, 1957; Emmorey & Kosslyn, 1995; Emmorey, Kosslyn, & Bellugi,1993; McKee, 1988) and mental rotation of visuospatial stimuli (Emmorey, Klima, &Hickcok, 1998; McKee, 1988). Can use of the deaf individuals enhanced imagery ability be utilized for increased learning and academic achievement to either enhance WM or reduce the WM load presented by a learning task?

Dual-encoding.

Dual-encoding refers to the individual's use of both sign and speech codes when signs and speech are presented simultaneously. This simultaneous presentation is called simultaneous communication. Though often maligned in research literature, simultaneous communication of lists of words was recalled better than sign-only and speech-only presentations by both hearing and deaf signers. This effect was particularly strong for deaf signers (Hamilton & Holzman, 1989). Problematically, however, research has shown that skill in the use of simultaneous communication is often erratic with elements of the syntax, grammar, and meaning of a message being inconsistent. In the classroom, most teachers use a form of PSE that is neither a strict coding of English nor ASL but contains features of both languages, along with speech, and consistently follows English word order (Akamatsu, Stewart & Mayer, 2004). Hearing teachers using PSE often drop signs from signed sentences (Kluwin 1981; Luetke-Stahlman, 1988; Marmor & Petitto 1979; Woodward and Allen, 1988). I n classroom signing Luetke-Stahlman (1991) found that hearing teachers trying to represent English when signing were able to encode the meaning of the target sentence about 71 percent of the time and omitted a sign or sign marker over 50 percent of the time and also used wrong or invented signs. These same signers believed they were accurately communicating via signs. Other researchers, however, found that if teachers were given appropriate training and were committed to signing English, they could effectively sign at a speech-to-sign ratio of greater than 90 percent. This was not the majority of hearing signers, however (Mayer and Lowenbraun, 1990).

Research is needed in this area. Is recall and comprehension of simultaneous communication superior to sign-only communication in the classroom during presentation of information more complex than simple word lists? If so, can the utilization of simultaneous communication be improved in general or should its use be targeted for controlled simple communication settings?

Memory Strengths when Strategy Employed

Phonological encoding.

Phonological encoding refers to speech-based/articulatory encoding (Dodd & Hermelin, 1977; Hanson, 1991). This forms the basis for the "functional equivalence hypothesis" as stated by McQuarrie and Parrila (2009)

> "The central claim of the functional equivalence hypothesis posits that visible speech information (seen articulatory gesture) extracted from the speech signal by the deaf learner is interpreted as a phonologically plausible signal by the brain (Campbell, 1987; Dodd, 1976; Dodd & Hermelin, 1977). …On this basis, it has been further suggested that

with the help of the visual information acquired through speechreading (Campbell, 1987; Dodd, 1976; Dodd & Hermelin, 1977) and the articulatory feel of words that comes through intensive speech training (Marschark & Harris, 1996), deaf children can develop phonological representations of words. "

The use of a speech-based phonological code has been positively correlated with reading comprehension in hearing children (Cain, 2006, de Jonge & de Jonge , 1996; Engle, Carullo, & Collins, 1991; Engle, Kane, & Tuholski, 1999; Goswami & Bryant, 1990). Thus, phonological encoding is currently a "hot" topic in deaf education, particularly in the area of reading (Allen, et al., 2009; Paul, Wang, Trezek, & Luckner 2009; Mayberry, del Giudice, & Lieberman, 2011; Wang, Trezek, Luckner & Paul, 2008).

It appears, though, that when reading, some deaf individuals employ phonological encoding while others do not. Research indicates that deaf children are less likely than hearing children to employ phonological coding in WM, reading, and spelling across a range of tasks (Beech & Harris, 1997; Harris & Beech, 1998; Leybaert & Alegria, 1995; Merrills, Underwood, & Wood, 1994; Nielsen & Luetke-Stahlman, 2002; Transler & Reitsma, 2005). When employed, phonological or articulatory-based coding has been shown to facilitate sequential recall by deaf adults (Kyle, 1981; Lichtenstein, 1998) and children (MacSweeney, 1998) and also been positively correlated with reading comprehension ability of deaf individuals (Campbell & Wright, 1988; Dyer, MacSweeney, Szczerbinski, Green, & Campbell 2003; Harris and Beech,1998; Kyle & Harris, 2006, 2010; Lichtenstein, 1985, 1998; Perfetti & Sandak,2000; Wang, Trezek, Luckner, & Paul, 2008). No positive relation has been found between phonemic awareness (the ability to hear, identify, and manipulate phonemes) and reading ability of deaf students (Harris & Beech, 1998; Kyle & Harris, 2006; Narr, 2008).

Mayberry, del Giudice, & Lieberman (2011) in a meta-analysis of studies investigating phonological encoding and reading in deaf students found that phonological encoding accounted for only about 11% of the variance in reading ability while language ability accounted for 35% of the variance. Not surprisingly, language does account for more variance in reading ability than phonological encoding. The development of language is crucial for all aspects of a child's life and sign language is often the most effective tool for facilitating language acquisition for deaf children. That does not negate the fact that phonological encoding does account for some variance in reading ability and is an important area to consider.

Thus, the ability to code information phonologically is a WM strength which should be considered when designing instruction. Phonological encoding does not rely on higher level phonemic awareness for which hearing ability seems important. Rather phonological encoding for deaf individuals appears to rely on whole word phonological/articulatory encoding that may be enhanced via the development of speechreading which has been positively correlated with reading ability of deaf children (Harris & Moreno, 2006; Kyle & Harris, 2006, 2010).

Can speechreading training which specifically targets the development of phonological/articulatory coding enhance the sequential recall, and language and reading comprehension of deaf students? Can speech articulation training enhance the quality and use of phonological/articulatory encoding?

Rehearsal.

Rehearsal refers to the overt or covert repetition of items to be recalled or learned. For deaf learners overt sign rehearsal has been shown to increase immediate sequential recall of :

- printed words (Bonvillian, Rea, Orlansky, & Slade , 1987)
- images (Bebko, 1984; Bebko & McKinnon, 1990)

- signed phrases (Weaver, Hamilton, Bruckman,& Starner, 2010).

It is important to note that deaf students do not spontaneously utilize rehearsal as early in life as hearing students. Rehearsal appears in hearing students around age 7-8 as compared to deaf signing students at age 10 or later (Bebko, 1979; Flavell, Chinsky, & Beach, 1966, Gill, Klecan-Aker, Roberts, & Fredenburg, 2003). However, after instruction in overt rehearsal and employment of this strategy deaf students have performed as well as hearing students in recall tasks (Bebko, 1984; Belmont, Karchmer, and Pilkonis, 1976).

One study has reported evidence of 6- and 8-year old deaf children spontaneously using both sign- and speech-based rehearsal during recall tasks for pictures, shapes, fingerspelling, and print. Rehearsal, however, did not appear to enhance recall for these children (Liben & Drury, 1977). The emergence of rehearsal in deaf students appears to be directly related to language experience, (Bebko & McKinnon, 1990) and more specifically, language proficiency and automatized or automatic language processing. (Bebko & Metcalf-Haggart, 1997; Bebko, Bell, Metcalfe-Haggert,& McKinnon, 1998).

Implications for Learning

Memory Deficits

Perhaps the most striking implication regarding the deaf individual's deficiencies in WM lies is the fact that they are all processes that are utilized during the comprehension and learning of language. Attention is absolutely necessary as a first step in acquiring language data in the environment. Processing speed must then be adequate to encode and manipulate this data. Automatized recognition of signs is imperative so that the "bottleneck" described by Mayberry and Fischer (1989) does not stress memory load causing processing difficulties. Finally, the ability to maintain sequential linguistic information in WM is a key component of cognition, particularly during language parsing (McElree, Foraker,& Dyer, 2003; Sperber, Premack, & Premack,1995). Willis and Gathercole (2001) have suggested that limited, less accurate sequential WM ability may be responsible for slow acquisition of language in hearing children and thus sequential memory skills are considered a crucial part of the language learning mechanism for young children. The lack of sequential processing skills or failure to use a sequential strategy during processing of linguistic information in WM may limit the deaf individual's ability to grasp syntactic order. Such a deficit can negatively affect language development and subsequently comprehension of signed or printed material which negatively impacts academic achievement.

With deficient WM abilities deaf children of hearing parents, in particular, are put in double jeopardy for communicative and academic failure. Not only are they deprived of language interaction (Goldin-Meadow & Mylander, 1990; Goldin-Meadow,1999; Gallaudet Research Institute, 2008; Lederberg, 2006) that fosters communicative and academic growth (and most likely WM capacity for language), they are attempting to process the relatively few accessible linguistic interactions they are privy to with WM abilities that are sub-par compared to hearing children who receive a wealth of linguistic input and interaction. The quantity and quality of language interaction has also been related to language learning and educational achievement of hearing children (Risley & Hart, 2002). Research has found strong predictive relationships between language skills and reading ability which is a major component of academic achievement for hearing children (Bowey & Patel, 1988; Dickinson, McCabe, Anastasopoulos, Peisner-Feinberg, & Poe, 2003; Juel, Griffith, & Gough, 1986; Snow, Tabors, & Dickinson, 2001) and deaf children (Harris & Moreno, 2004; Kyle & Harris, 2006; Mayberry, del Giudice, & Lieberman, 2011; Padden & Hanson, 2000; Strong and Prinz, 1997). The synergistic relationship between language, WM, and reading is currently realized in deaf high school students, as 50% read at the 4th grade level or below upon graduation(Gallaudet Research Institute, 1996; Traxler, 2000) and 30% leave high school functionally illiterate (Marschark, 1997; Marschark, Lang, & Albertini, 2002). The academic achievement of deaf students has remained at these levels for approximately thirty years (Qi & Mitchell, 2007) regardless of the educational or language policy of the day. Language delay and educational underachievement of deaf individuals may then be attributed to at least two factors; lack of accessible linguistic interaction with skilled signers and subsequently deficient WM skills to assist during language and academic learning.

Memory Strengths

The WM strengths of deaf individuals in the areas of free recall, imagery, visuospatial recall, dual encoding, phonological encoding, and rehearsal all have implications for improving the design and delivery of instruction. The deaf individual's strengths can be utilized and deficiencies remediated or compensated for so that communication and academic achievement can be enhanced. The WM strengths, just listed, are applied in the instructional design of the WM interventions described below in order to enhance processing skills and subsequent learning. Other strategies may also be useful and empirical validation is necessary in all cases.

Applications for learning

WM Interventions

Gerneral definitions.

Now that the WM deficiencies and strengths of deaf learners and the subsequent implications have been described how can these deficiencies be remediated or strengths utilized to enhance learning? One way is through WM interventions. Feifer and DeFina (2000) have suggested that memory intervention is most successful during early childhood and early elementary years due to brain maturation. Change is more difficult once neural structures are established and myelination is complete. However several studies have shown that children age 7-15 can benefit from WM intervention (Comblain, 1994; McNamara & Scott, 2001; Minear & Shah, 2006).

Denh (2008) describes interventions for WM as either compensatory or remedial. Compensatory methods typically involve training in memory strategies and may also include various external aids and methods for bypassing the deficient processes and reducing task demands. Remedial methods generally address the individual's memory deficits to enhance them. The research literature is mixed in its findings regarding the effectiveness of remedial interventions. Lee and Riccio (2005) found remedial intervention ineffective but others (Comblain, 1994; Holmes, Gathercole & Dunning, 2009; Klingberg, Forssberg, & Westerberg 2002; Klingberg et al., 2005; Mezcappa & Buckner, 2010) have described successful remedial interventions. A combined intervention approach utilizing both compensatory and remedial techniques has been shown to be most successful (Denh, 2008).

Interventions can also be either domain specific or domain general. Domain specific skills are those involving specific areas of knowledge such as language skills or math facts. Domain general skills focus on higher order more abstract cognitive skills such as WM capacity (Roberts, 2007). Remedial and compensatory interventions addressing these two domains will now be described. This list is not exhaustive as other activities can also serve to address WM and enhance language learning and academic achievement.

Specific interventions.

Preschool years- birth to kindergarten.

As has been stated in many research articles in the area of deafness early exposure to accessible language is imperative. This often means sign language. Interaction with fluent signers allows the child to develop the language and processing skills needed to achieve academically. As a general rule of thumb for interacting with young children and beginning signers, adults should sign slowly, clearly, and utilize short sentences so as not to overload the child's memory during processing. This is a strategy used by parents of young hearing children (Snow, 1977), teachers of children learning English as a second language (Kottler, Kottler, & Street, 2007) and is suggested for teachers of children with WM deficits (Gathercole & Alloway, 2008).

An environment in which the child is surrounded by fluent signers is often not available to most deaf children, however (Goldin-Meadow & Mylander; 1990, Goldin-Meadow,1999; Gallaudet Research Institute, 2008; Lederberg, 2006). As a substitute, signed video and games may be tools that can help enhance the child's facility with vocabulary, automatic sign recognition, and hence WM. It should be stated, however, that signed video and games can not be seen as an equal substitute for interaction with fluent signers.

During the sign presentation in the video or game it is probably best to have a still image behind the signer as deaf individuals have been shown to attend to peripheral distractors (Chen, Zhang & Zhou, 2006; Loke & Song, 1991) rather than the central information which in this case is the signer. If the content of the media contains action that the signer is describing it may be best to utilize a sequential presentation in which the signer is followed by the action, again for attention reasons. The efficacy of signed videos and games and the particular presentation formats that facilitate language processing and development are open research questions which merit investigation. Many signed videos and games are available on commercial DVDs and for free at the "Electric Language Factory" (ELF, www.cats.gatech.edu/cats/ELF/index.htm).

Rehearsal can be utilized with young deaf children to improve sequential WM skills and subsequently language processing skills by reciting nursery rhymes, singing songs, and performing action chants. This is a common practice in many homes and preschools for hearing children and may serve an unintended purpose of developing sequential WM for language. "Jack be nimble" and "The wheels on the bus" are examples of English rhymes and songs, respectively. Action chants are simple rhymes that are accompanied by physical actions as opposed to simply saying the rhyme. "Ring around the rosie" is an English action chant in which children hold hands and walk in a circle reciting the chant and then "all fall down". An ASL action chant which follows the format of an ASL number story could be "ONE, TWO SQUIRRELS HOP-AROUND" after which the persons reciting the chant hop around the room. Other examples of sign language nursery rhymes, songs, and chants are available on YouTube, sign2me.com and in Hamilton (1987, 1988). As was noted earlier deaf children are similar to hearing children in recall of sequential information when trained to rehearse. The rote recitation inherent in producing signs of rhymes, songs, and action chants may aid in the development of sign language and WM skills, particularly rehearsal. It is suggested that pictures, animations, or physical responses such as hopping, as in the action chant above, accompany production of these verses to allow for better understanding of the signing.

Completing daily household tasks can further assist the child in sequential WM development. The adult can start by asking the child to do a single task such as "Get your shirt." And then progress to two tasks such as "Get your dirty clothes and put them in the wash" and then to three or more tasks which should be done sequentially. The use of the ASL mechanism for referencing items of a list on the non-dominant hand (Baker-Shenk & Cokely, 1991) may facilitate recall for the child as this provides a visuospatial reference for each item. Adults could help the child rehearse the tasks to be done as both use the non-dominant hand placeholders. Empirical validation of this ASL mechanism as a memory support tool is needed.

For free recall, the parent can tell the child what items are needed in the store during a shopping trip and then have the child lead the search to find them. For young children who cannot find items in a store yet the parent can simply tell the child an item or two they need as they go through the store and when they find the item repeat the name of the item. Parents can increase the number of items as the child becomes more adept with language. For other activities that address WM with young children see Gibson, (2003).

School years- grade 1-12.

Regardless of students' language background and WM ability schools are mandated to teach academic content. For that reason, this paper will discuss techniques to address WM skills within the domain specific areas of language arts, mathematics, and content area subjects as well as techniques for managing WM load through instructional design.

Language art- Language comprehension.

The drag-and-drop feature available in PowerPoint provides an easy-to-use tool for teachers to develop activities that focus on sequential memory during sentence comprehension. Figure 1 shows a slide that can be used for such an activity. Many of the images are animated to represent the action of the verb as clearly as possible. These and similar images are available at www.animfactory.com

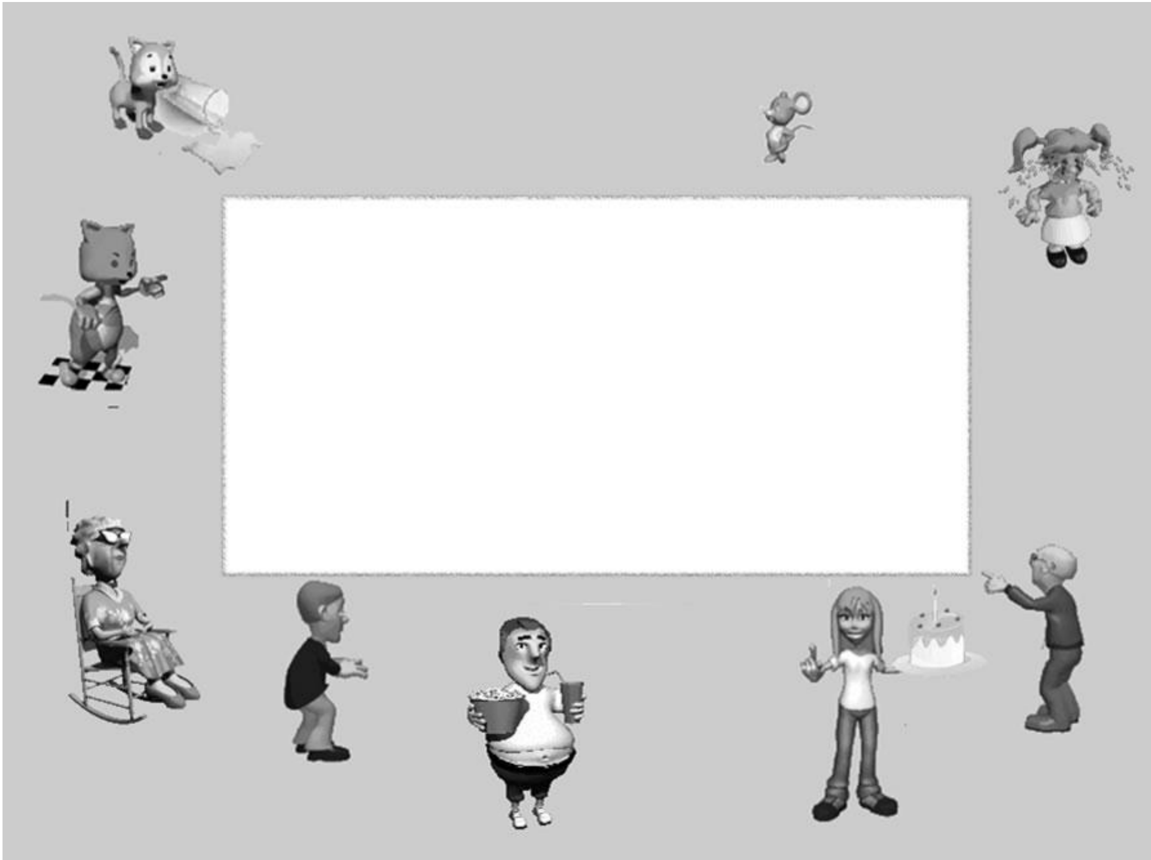

Figure 1. Drag-and-drop slide

Using the slide in figure 1, the teacher can present a sentence in sign and a student can drag images on to the white area to create a picture that represents the meaning of the sentence. The student must maintain the sequential order of the sentence in WM long enough to comprehend it and then manipulate the images to create the picture. It is important to use sentences in which the subject and object are interchangeable. This forces the students to use sequential information to correctly comprehend the sentence. Short sentences such as “The girl is scolding the man.” and “The man is scolding the girl” are just two examples. Longer sentences such as “The mouse is looking at the fat man” and “The man with the popcorn and drink is watching the girl who is crying.” can also be used with this same slide.

It is also important to use absurd or silly sentences that require sequential processing in order to be understood correctly. The students must follow the word order of the sentence to correctly comprehend the sentence even when the result produces an image with a low probability of actually occurring in real life. A sentence such as “The cat is scolding the girl” can be made using the images in figure 1. Until about age 4 years 6 months, hearing children will often comprehend such sentences by using an “event probability” strategy (i.e., make sense of the sentence regardless of word order), in this case producing a picture showing the girl with the cake scolding the cat near the spilt milk. Evidence for this behavior has been found not only for English speaking children (Stroehner & Nelson, 1974) but also for speakers of Italian (Bates, 1976; Bates, MacWhinney, Caselli, Devescovi, Natale, & Venza, 1984; Duranti & Ochs, 1979), French (Sinclair & Bronckart, 1972), Spanish (Reyes, 2003), and German (Lindner, 2003). Data collected by the author for ASL indicates non-native signers, hearing and deaf, tend to use “event probability” during language processing, often to a greater extent than hearing children.

Also of interest in this area is the work of Treiman and Hirsh-Pasek (1983). Their research indicated that sentences which contained signs which were visually similar were more difficult to comprehend than sentences with visually dissimilar signs due to the WM load involved in each (see discussion above). When constructing sentences for a comprehension task teachers should be aware of this phenomenen so they can either avoid such sentences or include such sentences depending on the students and goal of the lesson.

Language arts- Reading.

Reading English print is primarily a sequential WM processing task as English utilizes a rather strict adherence to word order to communicate meaning. For instructional purposes, print can actually serve to reduce WM load inherent in the sequential presentation of signs which appear and then are gone. Print provides a static visuaospatial sequential stimuli and allows the teacher to visually reference key words or phrases by simply pointing to them. Thus, the compensatory elements afforded by print and employed by the teacher may help reduce the WM load inherent in processing sequential language for non-native signers. All words used in such an activity must be automatized or the added memory load of encountering unknown words will negate the advantage gained from the static sequential presentation.

The drag-and-drop task described above can also be utilized for reading instruction and will allow for imagery to be used by the teacher and students to aid in comprehension. Rather than single sentences, a story could be used as the content for the activity. For illustration purposes, a reading activity addressing pronominal reference will be described. Using figure 1, the short story presented could be “The man scolded the cat. He was angry. She spilled the milk”. After creating a picture to show the meaning of the first sentence the images created can be used to support further comprehension of the pronominal reference in the other two sentences. The teacher can refer to the image created on the screen to show pronoun reference. A similar sentence sequence could then be presented substituting different nouns and asking the students to imagine what the scene would look like and then draw it, drag-and-drop images, or answer questions about the new sentence sequence to indicate comprehension. Pictures and text from storybooks, guided readers, or chapter books could also be used. A commercially available program, the Lindamood-Bell Learning Process program, has been shown to improve reading scores of hearing students by teaching the students to use visualization and imagery (Sadoski & Willson, 2006). This may be a useful program for deaf students.

Processing speed is very important during reading (Legols & Perfetti, 1978; Perfetti & Lesgold, 1978) and is best represented by the term automaticity, the instantaneous recognition of words. Grushkin (1998) has suggested that automatic word recognition can alleviate memory load during the act of reading comprehension. Conversely, struggling to recognize words when reading causes fewer WM resources to be available during reading comprehension (Denh, 2008). Simple repetition activities to foster overlearning of printed words can help the learner attain automaticity.

Reading words or sentences presented for a short period of time can assist in developing speed of processing. This can be done in the classroom via PowerPoint presentation with the word, sentence, or short paragraph presented on a slide which is set to transition to a blank slide via the timer feature in PowerPoint. The use of tachistiscope programs may also be useful. There are several free programs available on the internet such as RAM4 (http://www.slu.edu/colleges/AS/languages/classical/ram/ram.html). A low tech solution is to simply present the target word(s) on a white board and then cover or erase them after a short time.

Captioned video is also useful for building processing speed and sequential WM as the caption presentation is time-limited and sequential. The teacher can pause the video immediately after the presentation of the caption and ask the students what the caption said and questions about the caption. The caption presentation also can build focused attention as the student must ignore the activity on the screen and focus attention on the captions. Without automatic word recognition, proficient processing speed, sufficient sequential WM, and the ability to focus attention on the caption and not the peripheral action it would seem that captioned video is non-beneficial to the viewer.

The lack of knowledge of English printed words also affects reading greatly. When readers know less than 90% of the words in a passage comprehension drops to 50% or less

(Johns, 2009). This is particularly true for deaf readers (Albertini & Mayer, 2011; Davey & King, 1990; LaSasso & Davey, 1987; Paul, 1996; Paul & Gustafson, 1991; Paul & O'Rourke, 1988). During the reading of any print material, online or off, the English-ASL dictionary SMARTSign-Dictionary (www.cats.gatech.edu) provides a tool for quickly finding a sign or signs for a word and also reduces the memory load inherent in mentally searching for signs for unknown or non-automatized words. Students can simply type the English word into the SMARTSign-Dictionary and then see the sign(s) for that word. Often picture support is provided to enhance the learning of the word-sign pair by providing imagery for the concept represented. This is especially important for young readers who are new to signs and may be encountering the sign for the first time via exposure to the English word in a book. “Google images” also provides a powerful tool which allows users to enter words and search for images. “Google images” essentially functions as a picture dictionary.

Online electronic dictionary use is common among adult second language learners. Lan (2005) reports that over 70% of the interviewed students at Hong Kong Polytechnic University who were learning English as a second language were online dictionary users. Use of an electronic dictionary such as the SMARTSign-Dictionary may assist deaf readers during the reading process. It can be used on desktop computers or laptop computers, tablet computers, and cell phones for mobility.

As discussed earlier language ability accounts for a large part of reading ability. Viewing the reading process as a whole, language skills, vocabulary knowledge, reading fluency as evidenced by the automatized recognition of words, and general world knowledge also make major contributions to reading comprehension (Denh, 2008). Phonological encoding is also important. To develop phonological encoding, activities focusing on speechreading (Kyle &

Harris, 2006, 2010) and articulation (McQuarrie & Parrila, 2009) can be done. It seems important to relate speechread and spoken articulated words directly to known printed words in order to have an effect on reading (Marschark & Harris, 1996).

In the classroom, speaking information during highly contextualized routine situations can address phonological encoding via speechreading. If it is time for lunch and the teacher has daily signed “Time for lunch” this information can be presented via signs then speech and finally through speech alone as the students become familiar with the situation. It will be important to ask the students what was said and then also quickly present the print for the spoken words to make the speechreading-print connection. Asking the students to say the phrase will also build the phonological/articulatory representation for the target phrase. It is likely that the representation the student produces does not need to match a “perfect English” representation of the words. The representation should however be different than the representation of other words or phrases. This will allow the student to utilize an internally consistent phonological/articulatory code which is of benefit in WM. If the students codes all words with the same articulatory code (e.g., buh) it seems less likely that such a code will be beneficial. Speech therapists may make a significant contribution to literacy development by including speachreading and articulation activities related to print in their work with students. Research is needed to determine the empirical validity of this hypothesis.

Language arts: Writing.

Building English schema via visuospatial scaffolding has proven successful in helping deaf students develop basic English writing skills (Hamilton & Jones, 1989). According to Chi, Glaser, and Rees (1982) a schema categorizes elements of information according to the manner in which they will be used. Schemas are examples of sophisticated rules and are stored in long term memory. It is important for schemas to become automatized so they can be used quickly and effortlessly. Practice with the schema help them become automatized (Paas, 1992). Learners who have automated schema have more WM capacity available to use the schema to solve more sophisticated problems (Sweller, 1988).

Denh (2008) describes scaffolding as a strategy that can enhance WM. Scaffolding provides the learner with initial support for the learning task and gradually removes the support while maintaining a low-error environment for the student. As students show success, the support is removed until the student is performing the task correctly without the scaffolding. A tool that provides scaffolding for building schema for writing basic English sentences, "Simple Sentence Lab" (SSL), contains activities that are both compensatory and remedial in nature. Teachers can utilize any subject matter in SSL simply by typing sentences into the program. The sentences could be about a field trip, storybook, news event, or academic content from science or social studies. As few as five and as many as fifteen sentences can be entered. These limits are established to manage WM load by not overloading it. Long stories can be broken into chapters and content information can be broken into multiple units if necessary. Over a dozen activities which address sequential memory, sentence production, spelling, chunking of English phrases, rehearsal, and schema building for written English are available and provided in a suggested sequence that initially provides supportive scaffolding and then progressively removes it. Both computer-based and paper-and-pencil tasks are utilized.

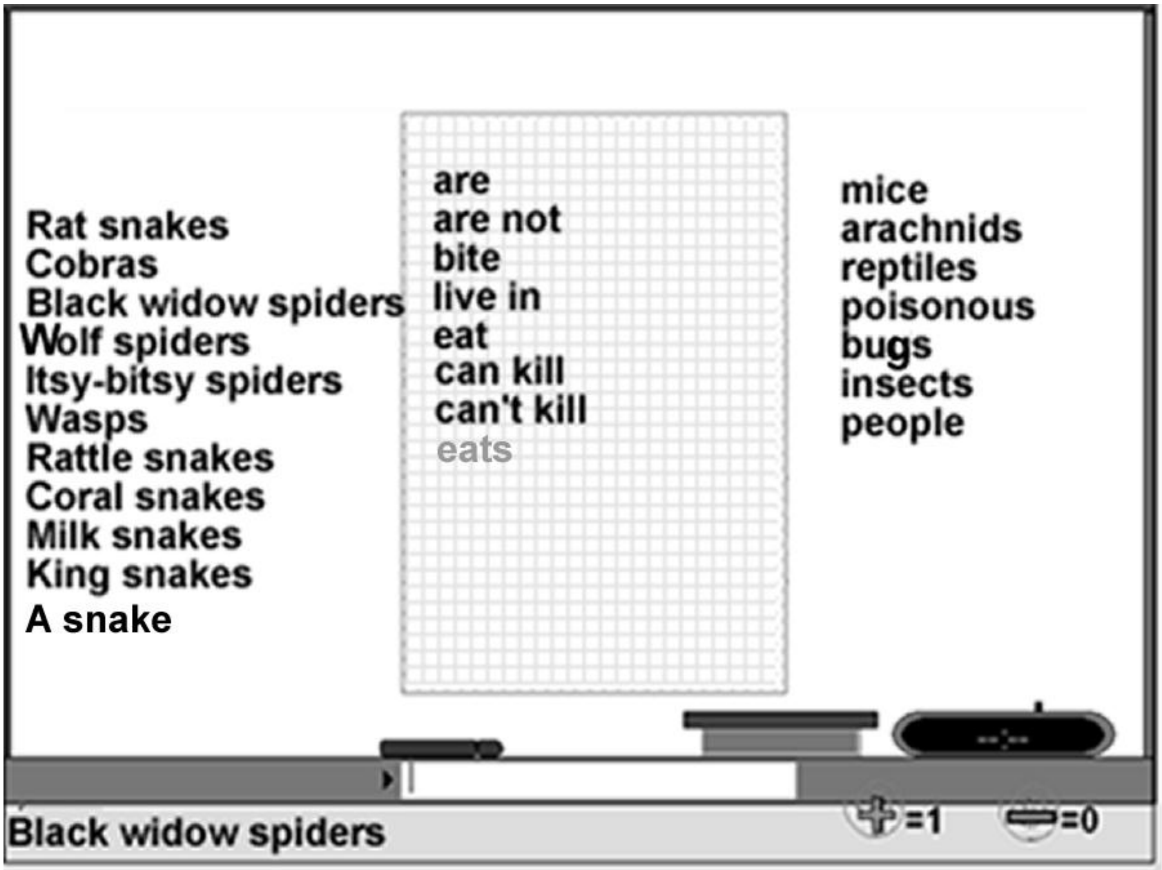

Figure 2. Simple Sentence Lab screen

Figure 2 illustrates the schema and visual scaffolding provided for sentences entered into the SSL program. Students can create a story, summarize content, or answer teacher questions using this schema. As shown in figure 2, the student has already typed in the subject noun phrase of a sentence and is ready to type the verb phrase. When that is done correctly the grid and text entry box move to the third column and the student enters the final phrase. The scaffolding support provided by the columns and sliding grid is faded away as students are successful. The English sentences produced will be syntactically and grammatically correct due to the responses allowed in each column. The visual schema and procedure of SSL allows only correct syntactic sentences and a built-in grammar only allows grammatically correct responses. For example, the student can type “Rattle snakes eat mice.” but not “Rattle snakes eats mice”. As shown in Figure

2 “eats” is grayed-out and SSL’s artificial intelligence will not allow it as an acceptable verb due to the subject-verb agreement necessary with “Rattle snakes”. The semantic accuracy of the students’ responses must be evaluated by the teacher. SSL would allow the grammatically correct sentence “King snakes can’t kill mice.” when actually the opposite is true. This allows teachers to see what students understand about the target content while providing scaffold-supported practice for writing English.

SSL provides a grammatically “errorless” environment for learning English which is important for students with WM deficits (Gathercole, Lamont, & Alloway, 2006). Compensatory support via a static visuospatial organization of English utilizes the deaf individual’s strength in sequential recall of static visuospatial items (the SSL grid) and also lessens sequential WM load as well as organizing English words via grammatically-based chunking. Chunking is the grouping of to-be-remembered items into meaningful rule-governed units. Verbal sequential WM capacity expands as chunks are formed by the items to be managed in WM (Denh, 2008). This is particularly useful in language processing as chunking allows an increase of nearly threefold in memory span of native speakers when sentences rather than unrelated words are to be recalled (Baddely, 2003, Case, 1977). Language chunks appear to be based on the rule governed constituents of the particular language known by the individual such as noun-phrases and verb-phrases (Case, 1977). Thus, chunking is a very important aspect of maintaining and manipulating linguistic items in WM. Providing external visual aids that show the students English chunks as in figure 2 may help them to create chunks corresponding to phrases or clauses, thereby creating more manageable units of information (Montgomery, 2003). SSL is free and available at www.cats.gatech.edu/cats/CatSoft/SSL.htm .

Language arts: Vocabulary and spelling.

In this paper, learning vocabulary will refer to learning the meaning of unknown words or signs. Once a word or sign is part of the students known vocabulary the spelling of the printed English word can be learned. The student may be simultaneously learning vocabulary and the spelling of that vocabulary in school.

Learning vocabulary in a classroom can be enhanced by utilizing visual imagery. Studies indicate that the imageability of a word is a key factor in determining its ease of acquisition (Gillett, Gleitman, Gleitman, & Lederer, 1999; Ma, Golinkoff, Hirsh-Pasek, McDonough, & Tardif, 2009). Visual imagery has been shown to be particularly useful for students with deficits in verbal WM when they possess a strong visuospatial WM. Mnemonic strategies in which a verbal utterance, in this case the meaning of a word or sign, is related to a visual image have been successfully used for many years to assist in recall and learning (Eslinger, 2002; Levin, 1993; Mastropieri & Scruggs, 1998; Pavio & Caspo, 1969). It is most effective when the image created is unique, funny, or bizarre (Ritchie & Karge, 1996). As mentioned earlier, the Lindamood-Bell Learning Process program focuses specifically on the use of imagery to enhance reading and its tenets and procedures could be employed during vocabulary learning. For deaf students providing an image along with a sign(s) for vocabulary would appear to be helpful. Combining visualization of the meaning of the verbal string with rehearsal has been found to be more effective than rehearsal alone (Clark & Klecan-Aker, 1992).

Learning the spelling of words (that is the sequence of letters in a word) generally involves the use of rehearsal. For increasing sequential WM skills, rehearsal has been found to be a useful strategy (Comblain, 1994; Minear & Shah, 2006) and facilitates information storage in long-term memory (Denh, 2008). Training deaf students in the use of rehearsal at an early age can pay benefits immediately and in the future.

Chunking can be also used to reduce memory load for deaf students as they learn vocabulary which will be used during reading or writing by taking advantage of the single sign ASL representation of English phrases such as “look up”, “jump over”, and “get on”. When these printed phrases are recognized as a chunk, sequential memory span has fewer items to maintain thus reducing memory load. Teaching the student these English phrases as is done in the Fairview method (Schimmel & Edwards, 2003; Schimmel, Edwards, & Prickett, 1999) may prove beneficial.

For classroom vocabulary or spelling instruction the use of simultaneous communication may be beneficial. Deaf individuals have been shown to recall simultaneous communicated lists significantly better than lists that were presented only in sign (Hamilton & Holzman, 1989). By utilizing simultaneous communication for controlled, structured classroom presentation of vocabulary and spelling the memory enhancement of this dual code may be realized while eliminating the detrimental aspects of simultaneous communication such as dropped signs and faulty syntax. Drasgow and Paul (1995) suggest that the processing requirements for producing simultaneous sign and speech causes signers to delete or incorrectly code signs due to WM overload. By limiting simultaneous communication to short bits of information during vocabulary and spelling instruction WM overload may be eliminated for the teachers while the simultaneous signal enhances recall for the students. This suggestion requires empirical validation.

Math.

Visual imagery has been shown to be particularly valuable in learning mathematics for hearing students (McLean & Hitch, 1999) and deaf students (Blatto-Vallee, 2007; Lang & Pagliaro, 2010). Nunes, (2006) has described visual displays that may enhance mathematics learning by deaf students. These provide scaffolding to support number recognition for early math facts and for more advanced math processes such as word problems.

Static sequential visuospatial presentation of math facts (e.g., 2+4=6) provides students with an information format that allows for use of their WM strength in this area and may foster more efficient learning. Providing math fact tables for study may also assist students by providing a visuospatial schema of the to-be-learned facts. This scaffolding can be faded away as it is internalized and students automatize the math facts.

To increase processing speed and automaticity as well as attention the teacher can use a timed PowerPoint presentation to flash a math fact or simply write the math fact on the whiteboard and then erase it. After the math fact is removed from view students can write it on paper in a race type of format which will also encourage an increase in processing speed.

Dictating math problems to students may also aid the development of WM and math skills. This is a remedial intervention designed to “exercise” and increase WM as opposed to the compensatory strategy described earlier utilizing static sequential visuaspatial presentation. The students can write the dictated problem on paper and then solve it. If needed, the words used in the dictation can be randomly displayed to eliminate the WM load caused by unknown spellings. Alternatively, the words could be arranged in a visual schema similar to the one shown earlier in Figure 2. This schema adds scaffolding for recalling the dictation using English syntax.

By writing the problem on paper WM load is reduced during problem solution and the teacher also can see how much of the problem the students actually recalled. To exercise and enhance WM load capabilities the teacher can require the students to solve the problem without writing it on paper after they are successful in the writing task. This is an example of scaffolding being removed.

Using the ASL grammatical feature in which objects are located in space and then referred to may also be an effective means of reducing working memory load. This type of presentation would also allow deaf students to employ imagery to “see” the math problem and allow the teacher to manually manipulate the invisible items to explain the necessary mathematical process. For example, the word problem “Jack has 3 dogs. Jill has two dogs. How many dogs do they have all together?” could be signed by placing Jack’s 3 dogs in a location in the left of the signing space, Jill’s 2 dogs in a location to the right and holding the signs for 3 and 2 in the respective locations. The signs can then be brought together in a middle location showing that 3 and 2 combine.

Memory load can also be reduced during math activities by providing calculators for students who have not automatized math facts. This would be useful in learning the process of balancing a checkbook or planning a budget. For higher order math processes such as those in geometry, trigonometry, or calculus automatized math facts are imperative so that WM can focus on the math processes involved in these subject areas and not be overloaded by deficient computational knowledge.

Content areas: Science, Social Studies.

Deaf individuals have shown equal free recall abilities as compared to hearing individuals across several tasks. Two particular types of learning tasks, labeling tasks such as labeling the fifty states on a map, and categorizing tasks such as categorizing animals versus plants lend themselves to free recall. These types of activities accompanied by rehearsal practice can enhance the learning of content which is not sequentially bound.

Rehearsal can be valuable in the area of learning factual information in content areas. Using repetition for this important information can facilitate long term storage of these facts (Denh,

2008) and improve the automaticity of their access for higher level cognitive processes such as understanding chemical bonding between atoms or the principles of a democratic government.

By utilizing the consistent visuospatial schema for English as provided by SSL (see figure 2) with a variety of content, the content information may be learned more efficiently and English language skills may increase (Hamilton & Jones, 1989). Variability of practice materials results in beneficial effects on transfer of learning (Cormier and Hagman, 1987; Jelsma, van Merrienboer, and Bijlstra, 1990; Singley and Anderson,1989). Thus, variability (different subject area content) over the problem situation (learning the content and producing English sentences) is expected to encourage learners to develop efficient schemas for the target information because it increases the probability that similar features can be identified and that relevant features can be distinguished from irrelevant ones. Consistent use of a tool such as SSL is imperative if it is to be successful in building schema.

Rudner and Ronberg (2008) suggest that a presentation style that places less emphasis on the temporal order of information may facilitate recall performance for deaf subjects. The use of visuospatial tools such as flowcharts, boxes, or diagrams fit this presentation style. Such tools reduce memory load (Grushkin, 1998) and subsequently enhance recall and learning. O'Donnell and Adenwalla (1991) compared the use of visually diagrammed information maps and texts by deaf undergraduate biology students. These students scored higher on recall and multiple choice comprehension tasks when using the visually mapped information for learning purposes.

"Thinking maps" (Hyerle & Yeager, 2007, www.thinkingmaps.com) take advantage of the visuospatial abilities of deaf students for static presentations of information. These are graphic organizers with different visual structures that are designed to consistently represent the same type of relationships between information thus building a schema for the content. Such graphic organizers are especially powerful when the students create the organization of the visual schema themselves (Davies, 1980). “Inspiration”, “FreeMind”, and “XMind” are computer programs that allow for quick free-form construction of visual graphic organizers. The last two listed are free and available online. Luckner, Bowen, and Carter (2001) have also described visual displays for reducing WM load for deaf students.

***General concerns for all instruction*.**

Attention.

Attention is extremely important during WM processing (Engle, 2002). If a student is not attending, little information can be acquired or comprehended. An attention strength of deaf individuals may also serve to be a problem during language processing. Deaf individuals are highly attuned to information in peripheral vision. Thus, movement on either side of the student or teacher can be distracting. To develop attention to the signer and not peripheral movement a teacher could give directions while standing near a computer or television screen that displays some type of movement. Students then follow the directions. Start with short simple directions and progress to longer directions. It may be useful to explain to the students the purpose of the activity in order to enlist a metacognitive strategy that encourages the students to make a concerted effort to attend to the signer. Also, by adding a distractor such as a moving image to a slide of information being presented focused attention can also be addressed. However, be aware that adding such distractors may cause even greater loss of attention to the teacher than the 50% described by Matthews and Reich (1993). Research into the use of such attention building activities is needed.

Memory load.

The classroom is notorious for overloading the memory abilities of all students on a daily basis (Denh, 2008). Assessing the WM load of a task and adjusting it as necessary is important for facilitating student success. Some general principles for reducing WM load are:

- Language processing, particularly of long utterances, may overload WM. Comprehension of verbal material will be enhanced by using language that is simple, structured, and redundant.
- Multitasking by students places undo strain on attention and hence WM. Focus on one activity at a time.
- Students with WM deficits can learn if they have ample exposure to material while the demands on WM are minimal.
- Allow students time to process new information. More learning occurs when students are given time to rehearse the information and apply memory strategies.
- Repetition or practice of a task is very important.
- External support aids such as visual cues, checklists, and prompts will reduce WM load.
- Provide learners with graduated learning support (scaffolding) until the support is no longer needed. Gathercole, Lamont, and Alloway (2006) have suggested that “errorless learning”, where errors are prevented or minimized, is much more effective for individuals with WM deficits than “errorful learning”, essentially learning by trial and error. Several studies have shown this to be the case (Baddeley & Wilson, 1994; Clare, Wilson, Carter, Roth & Hodges, 2002; Hamilton & Jones 1989). If a child has a WM deficit it is extremely important to minimize task failure due to WM load.

American Sign Language may also help reduce WM load. Geraci, Gozzi, Papagno, and Cecchetto (2008) have suggested that ASL grammar has evolved overtime to utilize the enhanced visuospatial memory abilities of deaf individuals and downplay the deficits. Such a development seems only natural. Research should address how the use of ASL (for reducing WM load) and simultaneous communication (for providing an enhanced signal which is recalled better than sign alone) can be best utilized for communication and instruction.

WM activities in the classroom.

Denh (2008) suggests the following tenets for addressing WM in the classroom. WM activities should:

- be brief and focused on one strategy.
- be spaced, with two or three per week over a long period of time.
- provide plenty of practice that allows the child to utilize the target strategy and encourage the child to attribute his/her success to the strategy.
- provide multiple sessions so that ultimately the strategy is overlearned.
- provide positive reinforcement for successful use of the strategy.
- include teaching a child when and how to use a strategy so the child can apply this metacognitive knowledge as necessary.
- match the needs of the learner and be adaptive. As the child’s skills increase so should the task difficulty (Holmes, Gathercole & Dunning, 2009; Klingberg et al., 2005; Klingberg, Forssberg, & Westerberg 2002)

Utilizing these tenets and enhancing WM can facilitate language learning and academic achievement of deaf students

Conclusion

This paper has reviewed literature on the memory skills of deaf learners and described activities which take advantage of the deaf individual's memory strengths to facilitate learning and reduce memory load or to enhance deficit memory skills which are important to learning. The deaf learner's memory deficiencies include sequential memory, processing speed, attention, and memory load. Strengths include free recall, visuospatial recall, imagery and dual encoding. When utilized, phonological encoding and rehearsal emerge as strategies which enhance recall. These strategies are not spontaneously used by all deaf individuals, however, and may be prime candidates for instruction.

Instructional design and classroom practices can utilize deaf learners' memory strengths, compensate for weaknesses, and attempt to remediate basic information processing skills so that linguistic competence and academic achievement can be increased. Activities that can address these areas have been described above. Not all suggested activities have been empirically validated as the importance of WM in education is just now being realized. The specific questions below should be investigated.

- Can visuospatial organization facilitate recall and learning of sequential linguistic information such as English syntax?
- Can deaf individuals utilize imagery for increased learning and academic achievement?
- Can viewing signed video and playing sign-enhanced video games enhance language learning?

- Due to the visual constraint of being able to attend to one item at a time (Wolfe, 2000) what particular presentation formats for media can best facilitate language comprehension and learning?
- Can attention to the signer, rather than to peripheral distractors in a classroom, be trained so it exceeds the current 50% benchmark?
- Can speechreading training which specifically targets development of phonological/articulatory coding enhance the sequential recall, and language and reading comprehension of deaf students?
- Can speech articulation training facilitate phonololgical/articulatory coding to enhance recall regardless of vocal intelligibility?
- Is recall and comprehension of simultaneous communication superior to sign-only communication in the classroom during presentation of information more complex than simple word lists? If so, can the utilization of simultaneous communication be improved? Is simultaneous communication best utilized only in limited presentation/communication instances as opposed to open-ended communication?
- Can use of ASL spatially established referents and manipulation of these referents facilitate math problem solving?
- How can the use of ASL (for reducing WM load) and simultaneous communication (for providing an enhanced signal which is recalled better than sign alone) be best utilized for communication and instruction?

Finally, instructional practice can adopt the suggestions of Denh (2008) and others for limiting working memory load and creating error-free learning environments to enhance learning. For example, the use of visual schemas and scaffolding hold great promise for deaf education due to their ability to reduce memory load and call into play the visuosapatial WM strengths of deaf students. This paper has provided a starting point for raising the awareness of educators of deaf students on the important issue of WM. It has also detailed suggestions for areas of future research investigating the utility of specific WM activities. The field of WM and its application to education provide new and exciting possibilities for enhancing language learning and academic achievement of deaf students

References

Akamatsu, C. T., Stewart, D., & Mayer, C. (2004). Is it time to look beyond teachers' signing? In G. Leigh (Ed.), *Educating deaf students* (pp. 40–54). Washington, DC: Gallaudet University Press.

Alamargot, D., Lambert, E., Thebault, C., & Dansac, C. (2007). Text composition by deaf and hearing middle-school students: The role of working memory. *Reading and Writing, 20*, 333-360.

Allen, T.E., Clark, M.D., del Giudice, A., Koo, D., Lieberman, A., Mayberry, R, & Miller, P. (2009). Phonology and Reading: A Response to Wang, Trezek, Luckner, and Paul *American Annals of the Deaf , 154*(4), 338-345.

Albertini, J. & Mayer, C. (2011). Using miscue analysis to assess comprehension in deaf college readers. *Journal of Deaf Studies and Deaf Education*, *16(*1), 35-46.

Alloway T.P. & Gathercole, S.E.(2006). Verbal and visuospatial short-term and working memory in children: are they separable? *Child Development*, 77(6), 1698 – 1716.

Alloway, T.P., Gathercole, S.E., Kirkwood, H., & Elliott, J. (2009). The cognitive and behavioral characteristics of children with low working memory. *Child Development*, 80(2), 606–621.

Altshuler, K.Z., Deming, W.E., Vollenweider, J., Rainer, J.D., & Tendler, R.(1976). Impulsivity and profound early deafness: A cross cultural inquiry. *American Annals of the Deaf*, *121*(3), 331-45.

Archibald, L. M., & Gathercole, S. E. (2006). Short-term memory and working memory in specific language impairment. In T. P. Alloway, & S. E. Gathercole (Eds.), *Working memory and neurodevelopmental disorders* (pp. 139-160). New York, NY: Taylor & Francis.

Ayres, P. (2009). State of the art research on cognitive load theory. *Computers in Human Behavior, 25(2),* 253-257.

Baddeley, A. (2003). Working Memory: Looking back and looking forward. *Journal of Communication Disorders*, *36*, 189–208.

Baddeley, A. D., & Wilson, B. A. (1994). When implicit learning fails: Amnesia and the problem of error elimination. *Neuropsychologia*, *32*, 53-68.

Baker-Shenk, C. & Cokely, D. (1991). *American Sign Language Green: A Teacher's Resource Text on Grammar and Culture.* Washington, DC: Gallaudet University Press.

Bates, E. (1976). *Language and context: Studies in the acquisition of pragmatics.* New York: Academic Press.

Bates, E., MacWhinney, B., Caselli, C., Devescovi, A., Natale, F., & Venza, V. (1984). A cross-linguistic study of the development of sentence interpretation strategies. *Child Development*, 55, 341-354.

Bavelier, D., Newport, E.L., Hall, M., Supalla, T., & Boutla, M. (2008). Ordered short-term memory differs in signers and speakers: Implications for models of short-term memory. *Cognition*, *107*(2): 433–459.

Bebko, J.M. (1979) Can recall differences among children be attributed to rehearsal effects? *Canadian Journal of Psychology*, *33*, 96-105.

Bebko, J. M. (1984). Memory and rehearsal characteristics of profoundly deaf children. *Journal of Experimental Child Psychology*, *38*, 415-428.

Bebko, J. M. & McKinnon, E. (1990). The language experience of deaf children: Its relation to spontaneous rehearsal in a memory task. *Child Development*, *61*(6) 1744-1752.

Bebko, J. M., Bell, M , Metcalfe-Haggert, A., & McKinnon, E. (1998). Language proficiency and the prediction of spontaneous rehearsal use in children who are deaf. *Journal of Experimental Child Psychology, 68*(1) 51-69.

Beech, J. R., & Harris, M. (1997). The prelingually deaf young reader: A case of reliance on direct lexical access? *Journal of Research in Reading*, 20(2), 105–121.

Bellugi, .U, Klima, E.S., & Siple, P. (1975). Remembering in signs, *Cognition*, 3, 93-125.

Bellugi, U. & Siple, P (1974). Remembering with and without words. In F. Bresson (Ed.) *Current problems in psycholiniguistics* (pp.215-235). Paris: Centre National de la Recherche Scientifque.

Belmont, J. M., Karchmer, M. A., & Pilkonis, P. A. (1976). Instructed rehearsal strategies' influence on deaf memory processing. *Journal of Speech and Hearing Research, 19,* 36-47**.**

Benton, A. L. (1974). *Revised Visual Retention Test. Clinical and experimental applications (4th ed.).* New York: The Psychological Corporation.

Blair, F. (1957). A study of the visual memory of deaf and hearing children. *American Annals of the Deaf, 102*, 254-263.

Blatto-Vallee, G. & Kelly, R.R. (2007). Visual–spatial representation in mathematical problem solving by deaf and hearing students. *Journal of Deaf Studies and Deaf Education, 12*(4), 432-448..

Bonvillian, J. D., Rea, C. A., Orlansky, M. D., & Slade, L. A. (1987). The effect of sign language rehearsal on deaf subjects' immediate and delayed recall of English word lists. *Applied Psycholinguistics*, *8*, 33-53.

Boutla, M., Supalla, T., Newport, E.L., & Bavelier, D. (2004). Short-term memory span: Insights from sign language. *Nature Neuroscience*, *7*, 997–1002.

Bowey, J. A., & Patel, R. K. (1988). Metalinguistic ability and early reading achievement. *Applied Psycholinguistics*, *9*, 367-383.

Braden, J.P. (1990). Do deaf persons have a characteristic psychometric profile on the Wechsler Performance Scales? *Journal of Psychoeducational Assessment, 8*(4), 518-526.

Cain, K. (2006). Individual differences in children's memory and reading comprehension: An investigation of semantic and inhibitory deficits. *Memory*, *14*(5), 553 – 569.

Cain, K. & Oakhill, J.(2006).Profiles of children with specific reading comprehension difficulties. *The British Journal Of Educational Psychology*, *76*(4), 683-96.

Campbell, R.(1987) The cerebral lateralization of lip-reading. In B. Dodd B & R. Campbell (Eds.), *Hearing by eye: The psychology of lip-reading* (pp215-226). Hillsdale, NJ: Lawrence Erlbaum Associates.

Campbell, R., & Wright, H. (1988). Deafness, spelling, and rhyme: How spelling supports written word and picture rhyming skills in deaf subjects. *Quarterly Journal of Experimental Psychology* , *40*, 771–788.

Campbell, R., & Wright, H. (1990). Deafness and immediate memory for pictures:

Dissociations between inner speech and the inner ear? *Journal of Experimental Child Psychology*, *50*, 259-286.

Case, R. (1977). *Intellectual and linguistic development in the preschool years* (final report) Spencer Foundation.

Centers for Disease Control and Prevention (2010). Increasing prevalence of parent-reported attention-deficit/hyperactivity disorder among children --- United States, 2003 and 2007. *Morbidity and Mortality Weekly Report, 59*(44);1439-1443.

Chen, Q., Zhang, M., & Zhou, X. (2006). Effects of spatial distribution of attention during inhibition of return (IOR) on flanker interference in hearing and congenitally deaf people. *Brain Research, 1109*, 117–127.

Chi, M., Glaser, R. & Rees, E. (1982). Expertise in problem solving. In: R. Sternberg (Ed.), *Advances in the Psychology of Human Intelligence* (pp. 7–75). Hillsdale, NJ: Lawrence J. Erlbaum.

Clare, L., Wilson, B. A., Carter, G., Roth, I., & Hodges, J. R. (2002). Relearning of face–name associations in early-stage Alzheimer's disease. *Neuropsychology*, *16*, 538–547.

Clark, C.B., & Klecan-Aker, J. (1992). Therapeutic strategies for language disordered children: The impact of visual imagery and verbal encoding in vocabulary instruction. *Journal of Childhood Communication Disorders*, *14*, 129-145.

Comblain, A. (1994). Working memory in Down's syndrome: Training the rehearsal strategy. *Down's Syndrome: Research and Practice, 2,* 123-126.

Cormier, S.M. & Hagman, J.D. (1987). *Transfer of learning: Contemporary research* *and applications*. San Diego: Academic Press.

Cornett, O. (1967). Cued speech. *American Annals of the Deaf*, *112*, 3-13.

Darwin, C.J., Turvey, M.T. & Browder, R.G. (1972). An auditory analogue of the Sperling partial report procedure: Evidence for brief auditory storage. *Cognitive. Psychology*. *3*, 255–267.

Davey, B., & King, S. (1990). Acquisition of word meanings from context by deaf readers. *American Annals of the Deaf, 135*, 227-234.

Davies, G.M. (1980). Can memory be educated? *Educational Studies*, *6*, 155-161.

Denh, M, (2008) *Working memory and academic learning: assessment and intervention*. Hoboken, NJ: John Wiley & Sons.

de Jonge P. & de Jong P.F. (1996). Working memory, intelligence and reading ability in children. *Personality and individual differences*, *21*(6), 1007-1020.

Dickinson, D. K., McCabe, A., Anastasopoulos, L., Peisner-Feinberg, E. S., Poe, M. D. (2003). The comprehensive language approach to early literacy: The interrelationships among vocabulary, phonological sensitivity, and print knowledge among preschool children. *Journal of Educational Psychology*, *95*(3), 465-481.

Dodd B. (1987). Lip-reading, phonological coding and deafness. In: Dodd B., Campbell, R. (Eds.) Hearing by eye: The psychology of lipreading(pp 177-189).. London: Lawrence Erlbaum Ass. Ltd.

Dodd B, & Hermelin B. (1977). Phonological coding by the prelinguistically deaf. *Perception and Psychophysics 21*, 413–417.

Drasgow, E., & Paul, P. (1995). A critical analysis of the use of MCE systems with deaf students: A review of the literature. *Association of Canadian Educators of the Hearing Impaired*, *21*, 80–93.

Duranti, A., & Ochs, E. (1979). Left-dislocation in Italian conversation. In T. Givon (Ed.) *Syntax and semantics. vol. 12: Discourse and Syntax* (pp 377-416) New York: Academic Press.

Dye, M.W., Hauser, P.C, & Bavelier, D. (2008). Visual attention in deaf children and adults. In M. Marschark & P.C, Hauser (Eds.) *Deaf Cognition: Foundations and outcomes* (pp. 250-263). Oxford: Oxford University Press.

Dyer, A., MacSweeney, M., Szczerbinski, M., Green, L., & Campbell, R. (2003). Predictors of reading delay in deaf adolescents: The relative contributions of rapid automatized naming speed and phonological awareness and decoding. *Journal of Deaf Studies and Deaf Education*, *8*, 215–229.

Eldredge, N. (1984). The impact of hearing loss on the development of visual perception: Development of trends in graphic strategies used to copy the Rey-Osterrieth Complex Figure. Unpublished doctoral dissertation, Oregon State University, Corvallis.

Eldredge, N., & Zhang, N. (1988). A cross cultural view of cognitive development: Visual perception, memory, and deafness in the United States, and the People's Republic of China. In D. Watson, G. Long, M. Taff-Watson, & M.Harvey (Eds.), *Two decades of excellence: A foundation for the future*, *Monograph No. 14* (pp. 163–181). Little Rock, AR: American Deaf and Rehabilitation Association.

Emmorey, K., Klima, E., & Hickok, G. (1998). Mental rotation within linguistic and nonlinguistic domains in users of American sign language. *Cognition*, *68*, 221-246.

Emmorey, K_, Kosslyn, S. M., & Bellugi, U. (1993). Visual imagery and visual spatial language:

Enhanced imagery abilities in deaf and hearing ASL signers. *Cognition, 46,* 139-181.

Emmorey, K., & Kosslyn, S. (1996). Enhanced image generation abilities in deaf signers: A right hemisphere effect. *Brain and Cognition*, *32*, 28–44.

Engle, R. W. (2002). Working memory capacity as executive attention. *Current Directions in Psychological Science, 11*, 19-23.

Engle, R. W., Kane, M. J., & Tuholski, S. W. (1999). Individual differences in working memory capacity and what they tell us about controlled attention, general fluid intelligence and functions of the prefrontal cortex. In Miyake, A. & Shah, P. (Eds.), *Models of working memory: mechanisms of active maintenance and executive control* (pp.102-134). London: Cambridge Press.

Engle, R. W., Carullo, J. J., & Collins, K. W. (1991). Individual differences in the role of working memory in comprehension and following directions. *Journal of Educational Research*, *84*, 253-262.

Eslinger, P. (2002). *Neuropsychological Interventions: Clinical research and practice*. New York: The Guilford Press.

Feifer, S. G. & DeFina, PA. (2000). *The neuropsychology of reading disorders: Diagnosis and intervention.* Middletown, MD: School Neuropsychology Press, LLC.

Felser, C. & Clahsen, H. (2009). Grammatical processing of spoken language in child and adult language learners. *Journal of Psycholinguistic Research*, *38*(3) 305-319.

Flaherty, M. & Moran, A. (2001). Memory span for Arabic numerals and digit words in Japanese kanji in deaf signers**.** *Japanese Psychological Research*, *43*(2), 63–71.

Flaherty, M., & Moran, A. (2004). Deaf signers who know Japanese remember words and numbers more effectively than deaf signers who know English. *American Annals of the*

Deaf, 149(1), 39–45.

Flavell, J. H., Beach, D. R., & Chinsky, J. M. (1966). Spontaneous verbal rehearsal in a memory task as a function of age. *Child Development, 37*,283-299.

Fletcher, J.M., Lyon, G.R., Fuchs, L.S., & Barnes, M.A. (2007) *Learning disabilities: From identification to intervention*. New York: Guilford.

Gallaudet Research Institute. (1996). *Stanford Achievement Test, 9th Edition, Form S, Norms Booklet for Deaf and Hard-of-Hearing Students*. Washington, DC: Gallaudet University.

Gallaudet Research Institute. (2008). *Regional and national summary report of data from the 2007–08 annual survey of deaf and hard of hearing children and youth*. Washington, DC: Gallaudet University.

Gathercole, S.E. & Alloway, T.P. (2008). *Working memory and learning: A practical guide*. London: Sage Publication

Gathercole, S.E., Lamont, E., & Alloway T.P. (2006). Working memory in the classroom. In Pickering, S. (Ed.) *Working memory and Education* (pp. 219-240). San Diego: Academic Press.

Gathercole, S.E. & Pickering, S.J. (2000). Working memory deficits in children with low achievements in the national curriculum at seven years of age. *British Journal of Educational Psychology*, *70*, 177–194.

Gathercole, S.E., Pickering, S.J., Knight, C. & Stegmann, Z. (2004). Working memory skills and educational attainment: Evidence from National Curriculum assessments at 7 and 14 years of age. *Applied Cognitive Psychology*, *40*, 1–16.

Geary, D.C., Hoard, M.K., Nugent, L. & Byrd-Craven, J. (2007). Development of number line representations in children with mathematical learning disability. *Developmental Neuropsychology*, *33*(3), 277–299.

Geraci, C., Gozzi, M., Papagno, C., Cecchetto,C. (2008). How grammar can cope with limited short-term memory: simultaneity and seriality in sign languages. *Cognition*. *106*(2), 780-804. doi:10.1016/j.cognition.2007.04.014.

Gibson, I. (2003).*Teaching strategies used to develop short-term memory in deaf children*. British Association of Teachers of the Deaf. Retrieved from http://www.batod.org.uk/content/articles/mgwts/teachingstrategiesmgwts.pdf .

Gill, C.B., Klecan-Aker, J. Roberts, T., Fredenburg, K.A. (2003). Following directions: Rehearsal and visualizatin strategies for children with specific language impairment. *Child Language Teaching and Therapy*, *19*(1), 85-103.

Gillette, J., Gleitman, H., Gleitman, L., & Lederer, A.(1999). Human simulations of vocabulary learning. *Cognition 73*, 135-176.

Goldin-Meadow, S. (1999). What children contribute to language-learning. *Science Progress*. *82* (1), 89-102.

Goldin-Meadow,S. & Mylander, C. (1990). The role of parental input in the development of a morphological system. *Journal of Child Language*. *17*(3):527-63.

Goswami, U., & Bryant, P. E. (1990). *Phonological skills and learning to read.* Hillsdale, NJ: Erlbaum.

Grushkin, D. (1998). Why shouldn't Sam read: Towards a new paradigm for literacy and the deaf. *Journal of Deaf Studies and Deaf Education*, *3*, 179–204.

Hamilton, H. (1984). Cheremic perception by deaf children. *Sign Language Studies, 42*. 23-30.

Hamilton, H. (1985). Linguistic encoding and adult-child interaction. In D. S.Martin (Ed.), *Cognition, Education and Deafness: Directions for Research and Instruction* (pp. 91-93). Washington: Gallaudet College Press.

Hamilton, H. (1987). Grandfather Moose: Sign language nursery rhymes. *Perspectives. X*.

Hamilton, H. (1988). *Grandfather Moose: Rhymes, games, and chants in sign language*. Los Alamitos, CA: Modern Signs Press.

Hamilton, H. & Holzman, T. (1989). Linguistic encoding in short-term memory as a function of stimulus type. *Memory and Cognition*. *17*(5), 542-550.

Hamilton, H. & Jones , G. (1989). The box: A low-error method for teaching English skills. *Volta Review*, *91*(1), 19-26.

Hanson, V. L. (1982). Short-term recall by deaf signers of American Sign Language: Implications of encoding strategy for order recall. *Journal of Experimental Psychology: Learning, Memory and Cognition, 8*, 572-583.

Hanson, V. L. (1989). Phonology and reading: Evidence from profoundly deaf readers. In D. Shankweiler & I. Liberman (Eds.), *Phonology and reading disability: Solving the reading puzzle* (pp. 69–89). Ann Arbor, MI: University of Michigan Press.

Hanson V. (1990). Recall of order information by deaf signers: Phonetic coding in temporal order recall. *Haskins Laboratories Status Report on Speech Research*, SR-103/104, 165-172

Hanson, V. (1991). Phonological processing without sound. In S. Brady & D. Shankweiler (Eds.), *Phonological processes in literacy: A tribute to Isabel Y. Liberman* (pp.153-161). Hillsdale, NJ: Lawrence Erlbaum Associates.

Hanson, V. L., &: Lichtenstein, E. H. (1990). Short-term memory coding by deaf signers: The primary language coding hypothesis reconsidered. *Cognitive Psychology, 22*, 211-224.

Harris, M., & Beech, J. R. (1998). Implicit phonological awareness and early reading development in pre-lingually deaf children. *Journal of Deaf Studies and Deaf Education*, *3*(3), 205–216.

Harris, M., & Moreno, C. (2004). Deaf children's use of phonological coding: Evidence from reading, spelling and working memory. *Journal of Deaf Studies and Deaf Education*, *9*, 253–268.

Harris, M., & Moreno, C. (2006). Speech reading and learning to read: A comparison of 8-year-old profoundly deaf children with good and poor reading ability. *Journal of Deaf Studies and Deaf Education, 11*(2), 189–201.

Hauser, P., Dye, M.W.G., Cohen, J., & Bavelier, D. (2007). Visual constructive and visual-motor skills in deaf native signers. *Journal of Deaf Studies and Deaf Education, 12* (2), 148 –157.

Henry, L. & Winfield, J. (2010). Working memory and educational achievement in children with intellectual impairments. *Journal of Intellectual Disability Research, 54*, 354-365.

Hirsh-Pasek, K., & Treiman, R. (1982). Recoding in silent reading: Can the deaf child translate print into a more manageable form. *Volta Review*, 84, 72-82.

Hirsh-Pasek, K., & Golinkoff, R. M. (1996). *The origins of grammar: Evidence from early language comprehension*. Cambridge, MA: MIT Press.

Holmes, J., Gathercole, S.E., & Dunning, D.L. (2009). Adaptive training leads to sustained enhancement of poor working memory in children. *Developmental Science, 12* (4), 9–15.

Hyerle, D. & Yeager, C. (2007). *Thinking Maps: A Language for Learning*. Cary, NC: Thinking Maps, Inc.

Jarvis H.L & Gathercole S.E.(2003*).* Verbal and non-verbal working memory and achievements on National Curriculum tests at 11 and 14 years of age. *Educational and Child Psychology*, *20*(3) 123-140.

Jelsma, O., van Merrienboer, J. J. G., & Bijlstra, J. P. (1990). The ADAPT design model: Towards instructional control of transfer. *Instructional Science, 19,* 89-120*.*

Johns, J. (2009). *Basic Reading Inventory*. Dubuque, IA: Kendall/Hunt.

Juel C., Griffith P. L. & Gough P. B. (1986). Acquisition of literacy: A longitudinal study of children in first and second grade. *Journal of Educational Psychology*, *78*, 243-255.

Kelly, D , Kelly, B., Jones, M., Moulton, N., Verhulst, S., & Bell, S. (1993). Attention deficits in children and adolescents with hearing loss**.** *American Journal of Diseases of Children, 147*, 737-741.

Kelly, L. (1993). Recall of English function words and inflections by skilled and average deaf readers. *American Annals of the Deaf, 138*(3), 288-296.

Kelly, M., & Braden J.P. (1990). Criterion validity of the WISC-R performance scale with the Stanford achievement test -Hearing Impaired edition. *Journal of School Psychology*, *28*, 147-151.

Kennison, S. M., Sieck, J. P., & Briesch, K. A. (2003). Evidence for a late occurring effect of phoneme repetition in silent reading. *Journal of Psycholinguistic Research*, *32,* 297-312.

Klima, E.S., & Bellugi, U. (1979) *The signs of language.* Cambridge, MA: Harvard University Press.

Klingberg, T., Fernell, E., Olesen, P., Johnson, M., Gustafsson, P., Dahlstrom, K., et al. (2005). Computerized training of working memory in children with ADHD—A randomized, controlled trial. *Journal of the American Academy of Child and Adolescent Psychiatry*, *44,* 177–186.

Klingberg, T., Forssberg, H., & Westerberg, H. (2002). Training of working memory in children with ADHD. *Journal of Clinical and Experimental Neuropsychology*, *24,* 781–791.

Kluwin, T. N. (1981). The grammaticality of manual representations of English. *American Annals of the Deaf, 126,* 417-421.

Koo, D., Crain, K., LaSasso, C. and Eden G.F. (2008). Phonological Awareness and Short Term Memory in Hearing and Deaf Individuals of Different Communication Backgrounds. *Annals of the New York Academy of Sciences*, *1145,* 83-99.

Kottler, E., Kottler, J.A., Street, C. (2007). *Children with Limited English: Teaching Strategies for the Regular Classroom*. Thousand Oaks, CA: Corwin.

Krakow, R. A. & Hanson, V.L. (1985). Deaf signers and serial recall in the visual modality: memory of signs, fingerspelling and print. *Memory and Cognition*, *13*, 265-272.

Kyle, J.G. (1981). Signs and memory: The search for the code. In B. Woll, J. Kyle, & M. Deucaher (Eds.) *Perspectives on British Sign Language and Deafness* (pp.71-88). London: Croon Helm.

Kyle, F. E., & Harris, M. (2006). Concurrent correlates and predictors of reading and spelling achievement in deaf and hearing school children. *Journal of Deaf Studies and Deaf Education*, *11*(3), 273–288.

Kyle, J.G & Harris, M (2010). Predictors of reading development in deaf children: A 3-year longitudinal study. *Journal of Experimental Child Psychology*, *107*, 229-243.

Lan, L. (2005). The growing prosperity of on-line dictionaries. *English Today*, *21*(3), 16-21.

Lang, H. & Pagliaro, C (2010). Factors predicting recall of mathematics terms by deaf students: Implications for teaching. *Journal of Deaf Studies Deaf Education. 12(*4), 449-460.

Larr, A. L. (1956). Perceptual and conceptual ability of residential school deaf children. *Exceptional Children, 23,* 63 – 66.

LaSasso, C , & Davey, B. (1987). The relationship between lexical knowledge and reading comprehension for prelingually, profoundly hearing-impaired students. *Volta Review, 89,* 211-220.

Lederberg, A. (2006). Language development of deaf children with hearing parents, In K. Brown, (Ed.) *Encyclopedia of Language & Linguistics* (pp 361-368). Oxford: Elsevier.

Lee, D., & Riccio, C. A. (2005). Understanding and implementing cognitive Neuropsychological retraining. In R. C. D'Amato, E. Fletcher-Janzen, & C. R. Reynolds (Eds.) *Handbook of school neuropsychology* (pp. 701–720). Hoboken, NJ: Wiley.

Leutzinger, M.R. (2002). Use of the WAIS – III performance scale with deaf adults. *Dissertation abstracts international: the sciences and engineering*, *63* (2 – B), 1036.

Leybaert, J., & Alegria, J. (1995). Spelling development in deaf and hearing children. Evidence for use of morpho-phonological regularities in French. *Reading and Writing*, *7,* 89–109.

Lesgold, A.M. & Perfetti, C.A. (1978). Interactive processes in reading comprehension. *Discourse Processes*, *1,* 323–336.

Liben, L. S. (1979). Free recall by deaf and hearing children: Semantic clustering and recall in trained and untrained groups. *Journal of Experimental Child Psychology*, *27*, 105–119.

Liben, L. & Drury, A. (1977). Short-term memory in deaf and hearing children in relation to stimulus characteristics. *Journal of Experimental Child Psychology*, *24*, 60-73.

Lichtenstein, E. H. (1985). Deaf working memory processes and English language skills. In D. S.Martin (Ed.), *Cognition, education, and deafness: Directions for research and instruction* (pp. 111-114). Washington, D.C.: Gallaudet College Press.

Lichtenstein, S. (1998). The relationship between reading processes and English skills of college deaf students. *Journal of Deaf Studies and Deaf Education*, *3*, 80-134.

Lindner, K.(2003). The development of sentence-interpretation strategies in monolingual German-learning children with and without specific language impairment. *Linguistics*, 41(2), 213- 242.

Logan, K., Mayberry, M., & Fletcher, J. (1996). The short-term memory of profoundly deaf people for words, signs, and abstract spatial stimuli. *Applied Cognitive Psychology*, *10*, 10-119.

Loke, W. H. & Song, S. (1991). Central and peripheral visual processing in hearing and non-hearing individuals. *Bulletin of the Psychonomic Society*, *29*(5), 437– 440.

Luckner, J., Bowen, S., & Carter, K. (2001). Visual teaching strategies for students who are deaf or hard of hearing. *Teaching Exceptional Children*, *33*, 38-44.

Luetke-Stahlman, B. (1988). Documenting syntactically and semantically incomplete bimodal input to hearing-impaired subjects. *American Annals of the Deaf*, *133*(3), 230-234.

Luetke-Stahlman, B. (1991) Following the rules: Consistency in sign. *Journal of Speech and Hearing Research*. *34*, 1293-1298.

Ma, W., Golinkoff, R.M., Hirsh-Pasek, K., McDonough, C., & Tardif, T. (2008). Imageability predicts the age of acquisition of verbs in Chinese children. *Journal of Child Language*, *36*, 405–423.

MacSweeney, M. (1998). Short-term memory processes and reading by deaf children. *Proceedings of the Second ACFOS International Colloquium, Paris 1998*: *Deafness and Access to Written Language*, *1*, 165-173.

Maller, S. J., & Ferron, J. (1997). WISC– III factor invariance across deaf and standardization samples. *Educational and Psychological Measurement*, *57*, 987 – 994.

Marmor, G. S., & Petitto, L. (1979). Simultaneous communication in the classroom:

How well is English grammar represented? *Sign Language Studies, 23,* 99-136.

Marschark, M. (1997). *Raising and educating a deaf child*. New York: Oxford University Press.

Marschark, M. (2006). Intellectual functioning of deaf adults and children: Answers and questions. *European Journal of Cognitive Psychology, 18*(1), 70–89. doi:10.1080/09541440500216028.

Marschark M, & Harris M. (1996). Success and failure in learning to read: The special case of deaf children, In C. Cornoldi & J. Oakhill (Eds.), Reading comprehension difficulties: Processes and intervention (pp 279–300). Mahwah, NJ: Lawrence Erlbaum Associates.

Marschark, M., Lang, H., & Albertini, J. (2002). *Educating deaf students: From research to practice*. New York: Oxford University Press.

Marschark, M., Pelz, J., Convertino, C., Sapere, P., Arndt, M. E., & Seewagen, R. (2005). Classroom interpreting and visual information processing in mainstream education for deaf students: Live or Memorex? *American Educational Research Journal*, *42*, 727–762. doi:10.3102/00028312042004727.

Marschark, M., Sapere, P., Convertino, C. M., Mayer, C., Wauters L., & Sarchet, T. (2009). Are deaf students' reading challenges really about reading? *American Annals of the Deaf*, *154*(4), 357-70.

Marschark, M. & Wauters, L. (2008). Language comprehension and learning by deaf students. In M. Marschark, M. & P.C. Hauser (Eds.), *Deaf cognition: Foundations and outcomes* (pp.309-350). New York: Oxford University Press.

Mastropieri, M.E., & Scruggs, T.E. (1998). Enhancing school success with mnemonic strategies. *Intervention in School and Clinic*, *33*, 201-208.

Mather, N., & Jaffe, L. E. (2002). *Woodcock-Johnson III: Reports, recommendations, and strategies.* New York: Wiley.

Matthews, T.J., & Reich, C.F. (1993). Constraints on communication in classrooms for the deaf. *American Annals of the Deaf*, *138*, 14-18.

Mayberry, R.I. & Fischer, S.D. (1989). Looking through phonological shape to lexical meaning: The bottleneck of non-native sign language processing. *Memory and Cognition*, 17 (6), 740-754.

Mayberry, R., del Giudice, A.A. & Lieberman, A.M. (2011). Reading achievement in relation to phonological coding and awareness in deaf readers: a meta-analysis. *Journal of Deaf Studies and Deaf Education*, *16(*2), 164-188

Mayer, P., & Lowenbraun, S. (1990). Total communication use among elementary teachers of hearing-impaired children. *American Annals of the Deaf, 135*, 257-263.

McCutchen, D., & Perfetti, C. A. (1982). The visual tongue-twister effect: Phonological activation in silent reading. *Journal of Verbal Learning and Verbal Behavior*, *21*, 672–687.

McElree, B., Foraker, S., & Dyer, L. (2003). Memory structures that subserve sentence comprehension. *Journal of Memory and Language*, *48*, 67-91.

McKay, B. E. (1952). *An exploratory study of the psychological effects of severe hearing impairment.* Syracuse, NY: Syracuse University.

McKee, D. (1988). *An analysis of specialized cognitive functions in deaf and hearing signers.* Unpublished doctoral dissertation, University of Pittsburgh.

McLean, J.F. & Hitch, G.J. (1999). Working memory impairments in children with specific arithmetic difficulties. *Journal of Experimental Child Psychology 74*, 240–260.

McNamara, D. S., & Scott, J. L. (2001). Working memory capacity and strategy use. *Memory & Cognition*, *29*, 10-17.

Meadow, K. P. (1976). Behavior problems of deaf children. In H. S. Schlesinger and K. P. Meadow (Eds.), *Studies of family interaction, language acquisition and deafness* (pp. 257–293). San Francisco: University of California.

Meadow-Orleans, K. P. (2001) Research and deaf education: Moving ahead while glancing back. *Journal of Deaf Studies and Deaf Education*, *6*(2), 143 -148.

Merrills, J. D., Underwood, G., & Wood, D. J. (1994). The word recognition skills of profoundly, prelingually deaf children. *British Journal of Developmental Psychology*, *12,* 365–384.

Mezzacappa, E. & Buckner, J.C, (2010).Working memory training for children with attention problems or hyperactivity: A school-based pilot study. *School Mental Health*, *Feb*., 1-7.

Minear, M., & Shah, P. (2006). Sources of working memory deficits in children and possibilities for remediation. In S. J. Pickering (Ed.), *Working memory and education.* (pp. 273-307). London: Elsevier.

Mitchell, T. V. & Quittner, A. L. (1996). Multimethod study of attention and behavior problems in hearing-impaired children. *Journal of Clinical*

Child Psychology, 25(1), 83 – 96.

Montgomery, J. (2003). Working memory and comprehension in children with specific language impairment: What we know so far. *Journal of Communication Disorders, 36*, 221-231.

Moores, D. F. (2001). *Educating the deaf: Psychology, principles, and practices* (5th ed.). Boston: Houghton-Mifflin Co.

Moores, D. F. (2003). Short term memory, morphology, and reading (editorial). *American Annals of the Deaf, 148*(1), 3–4.

Myklebust, H. R. & Brutten, M. A. (1953). A study of the visual perception of deaf children. *Acta Otolaryngologica*, Supplement 105.

Nagy, W., Anderson, R., Schommer, M., Scott, J., & Stallman, A. (1989). Morphological families in the internal lexicon. *Reading Research Quarterly, 24*, 262–282.

Narr, R. F. (2008). Phonological awareness and decoding in deaf/hard-of-hearing students who use Visual Phonics. *Journal of Deaf Studies and Deaf Education, 13*(3), 405–416.

Nielsen, D. C., & Luetke-Stahlman, B. (2002). Phonological awareness: One key to the reading proficiency of deaf children. *American Annals of the Deaf, 147*, 11–19.

Nunes, T. (2006). Promoting deaf children's mathematical reasoning by using the visual-spatial strengths. In R.J. Sternberg & R. F. Subotnik (Eds.) *Optimizing Student Success in School with the Other Three Rs: Reasoning, Resilience, and Responsibility* (pp. 75-94). Greenwich, CN: IAP-Information Age.

O'Donnell, A. M., & Adenwalla, D. (1991). Using cooperative learning and concept maps with deaf college students. In Martin, D. S. (ed.), *Advances in Cognition, Learning, and*

Deafness (pp. 348–355). Washington, DC: Gallaudet University Press.

Olsson, J. E., & Furth, H. G. (1966). Visual memory-span in the deaf. *American Journal of Psychology,* 79(3) , 480-484.

Paas, F. (1992). Training strategies for attaining transfer of problem-solving skill in statistics: A cognitive load approach. *Journal of Educational Psychology, 84*, 429-434.

Padden, C., & Hanson, V. (2000). Search for the missing link: The development of skilled reading in deaf children. In K. Emmorey & H. Lane (Eds), *The signs of language revisited: An anthology to honor Ursula Bellugi and Edward Klima* (pp. 435–447). Mahwah, NJ: Erlbaum.

Parasnis, I., & Kirk, U. (2004). The Rey-Osterrieth Complex Figure Test performance: Evidence for strategy differences in deaf signers. Unpublished manuscript, Rochester Institute of Technology

Parasnis, I., Samar, V., & Berent, G. (2003). Deaf adults without attention deficit hyperactivity disorder display reduced perceptual sensitivity and elevated impulsivity on the Test of Variables of Attention (T.O.V.A.). *Journal of Speech Language and Hearing Research, 46*, 1166-1183.

Parasnis, I., Samar, V. J., Bettger, J. G., & Sathe, K. (1996). Does deafness lead to enhancement of visual spatial cognition in children? Negative evidence from deaf nonsigners. *Journal of Deaf Studies and Deaf Education*, *1*(2), 145-152.

Paul, P.V. (1996). Reading vocabulary knowledge and deafness. *Journal of Deaf Studies and Deaf Education. 1*(1), 3-15.

Paul, P., & Gustafson, G. (1991). Comprehension of high frequency multi-meaning words by students with hearing impairment. *Remedial and Special Education (RASE), 12*

(4), 52-62.

Paul, P., & O'Rourke, J. (1988). Multimeaning words and reading comprehension: Implications for special education students. *Remedial and Special Education (RASE), 9* (3), 42-52.

Paul, P.V., Wang, Y, Trezek, B. J., & Luckner, J. L., (2009). Phonology is necessary, but not sufficient: a rejoinder. *American Annals of the Deaf, 4,* 346–56.

Perfetti, C.C., & Lesgold, A.A. (1978). Discourse comprehension and sources of individual differences. In M. Just and P. Carpenter (Eds.) *Cognitive processes in comprehension* (pp141-183). Hillsdale, NJ: Earlbaum.

Perfetti, C. A., & McCutchen, D. (1982). Speech processes in reading. In N. Lass (Ed.), *Speech and language: Advances in basic research and practice* (Vol. 7, pp. 237–269). New York, NY: Academic Press.

Perfetti, C. A., & Sandak, R. (2000). Reading optimally builds on spoken language: Implicationsfor deaf readers. *Journal of Deaf Studies & Deaf Education, 5*(1), 32-50.

Pickering, S.J. (2009). *Working memory and education*. London: Academic Press.

Pintner, R., & Patterson, D. G. (1917). Psychological tests for deaf children. *Volta Review, 19,* 661–667.

Prifitera, A., Saklofske, D. H., & Weiss, L. G. (Eds.). (2005). *WISC-IV clinical use and interpretation:Scientist-practitioner perspectives*. New York: Elsevier.

Proksch, J., & Bavelier, D. (2002). Changes in the spatial distribution of visual attention after early deafness. *Journal of Cognitive Neuroscience*, *14*, 687-701.

Qi, S., & Mitchell, R. E. (2007). Large-scale academic achievement testing of deaf and hard-of-hearing students: Past, present, and future. *Paper presented at the annual meeting of the American Educational Research Association*. Chicago, IL.

Rapport M. D, Alderson RM, Kofler MJ, Sarver DE, Bolden J, Sims V.(2008). Working memory deficits in boys with attention-deficit/hyperactivity disorder (ADHD): the contribution of central executive and subsystem processes. *Journal of Abnormal Child Psychology*, *36*(6), 825-837.

Reyes, I. (2003). A study of sentence interpretation in Spanish monolingual children. *First Language*. *23*(69) 285-309.

Risley, B. & Hart, T.R. (2002). *Meaningful Differences in the Everyday Experience of Young American Children.* Baltimore: Brookes. Press.

Ritchie, D. & Karge, B. D. (1996). Making information memorable: Enhanced knowledge retention and recall through the elaboration process. *Preventing School Failure*, *41*(1), 28-33.

Roberts, M.J. (2007). *Integrating the Mind: Domain General versus Domain Specific Processes in Higher Cognition*. New York: Psychology.

Rudner M, & Rönnberg J. (2008). Explicit processing demands reveal language modality-specific organization of working memory. *Journal of Deaf Studies and Deaf Education*. *13*(4), 466-484.

Sadoski, M. and Willson, V. (2006). Effects of a theoretically based large-scale reading intervention in a multicultural urban school district. *American Educational Research Journal*, 43(1), 137-154...

Schimmel, C., Edwards, S, & Prickett, H. (1999) Reading?...Pah! (I got it.) *American Annals of the Deaf*, 144 (4), 298-308.

Schimmel, C. & Edwards, S. (2003) Literacy strategies for the classroom: putting Bi-Bi theory into practice. *Odyssey, 5*(2), 58-63.

Shand, M.A. (1982). Sign-based short-term coding of American sign language signs and printed English words by congenitally deaf signers. *Cognitive* Psychology, *14*(1), 1-12.

Shand, M. A., & Klima, E. S. (1981). Nonauditory suffii effects in congenitally deaf signers of American Sign Language. *Journal of Experimental Psychology: Human Learning and Memory*, *7*, 464-474.

Singley, M. K. and Anderson, J. R. (1989). *The transfer of cognitive skill.* Cambridge, MA: Harvard University Press.

Snow, C. E. (1977). The development of conversation between mothers and babies. *Journal of Child Language*, *4*, l-22.

Snow, C.E., Tabors, P.O., & Dickinson. D.K. (2001). Language development in the preschool years. In D.K. Dickinson & P.O. Tabors (Eds.) *Beginning literacy with language* (pp. 1-26). Baltimore: Brookes.

Sperber, D., Premack, D., & Premack, A.J. (1995). *Causal cognition: A multidisciplinary debate* New York, NY: Oxford University Press.

Stewart, J.H. (1981). Wechsler Performance IQ scores and social behaviors of hearing-impaired students. *The Volta Review*, *83*(4), 215-222.

Stokoe, W. C. (1960). Sign Language Structure: An Outline of the Visual Communication Systems of the American Deaf, *Studies in linguistics: Occasional papers (No. 8)*. Buffalo: Dept. of Anthropology and Linguistics, University of Buffalo.

Stroenher, H & Nelson, H. (1974). The young child's development of sentence comprehension: Influence of event probability, nonverbal context, syntactic form, and strategies. *Child Language. 45*, 564-576.

Strong, M., & Prinz, P. (2000). Is American Sign Language skill related to English literacy? In C. Chamberlain, J. Morford, & R.I. Mayberry (Eds*.) Language acquisition by eye* (pp. 131-141). Mahwah, NJ: Earlbaum.

Swanson, H. L., Kehler, P., & Jerman, O. (2010). Working memory, strategy knowledge, and strategy instruction in children with reading disabilities. *Journal of Learning Disabilities, 43*(1), 24-48.

Swanson, H. L., Zheng, X., & Jerman, O. (2009). Working memory, short-term memory, and reading disabilities: A selective meta-analysis. *Journal of Learning Disabilities*, *42*(3), 260-287.

Sweller, J. (1988). Cognitive load during problem solving, *Cognitive Science* 12: 257–285.

Todman, J., & Seedhouse, E. (1994). Visual-action code processing by deaf and hearing children. *Language and Cognitive Processes, 9*, 129-141.

Tomlinson-Keasey, C., & Smith-Winberry, C. (1990). Cognitive consequences of congenital deafness. *The Journal of Genetic Psychology*, *151*(1), 103-115.

Treiman, R. & Hirsh-Pasek, K. (1983) Silent Reading: Insights from second generation congenitally deaf readers. *Cognitive Psychology*, *15*, 39-65.

Transler, C. & Reitsma, P. (2005). Phonological coding in reading of deaf children:

Pseudohomophone effects in lexical decision. *British Journal of Developmental Psychology*, *23*(4) , 525–542.

Traxler, C.B. (2000). The Stanford Achievement Test, 9th edition: National norming and performance standards for deaf and hard of hearing students. *Journal of Deaf Studies and Deaf Education*, *5*, 337–348.

Waddy-Smith, B., & Wilson, V. (2003). See that sound! Visual Phonics helps deaf and hard of hearing students develop reading skills. *Odyssey: New Directions in Deaf Education, 4*(3), 14–17.

Wang, Y., Trezek, B., Luckner, J., & Paul, P. (2008). The role of phonology and phonological-related skills in reading instruction for participants who are deaf or hard-of-hearing. *American Annals of the Deaf*, *153*(4), 396-407.

Weaver, K., Hamilton, H., Bruckman, A.S. & Starner, T. (2010). Improving the Language Ability of Deaf Signing Children through an Interactive American Sign Language-Based Video Game. *Paper presented at the International Conference on Learning Sciences,* June, 2010.

Werner, H. & Strauss, A. A. (1941). Pathology of figure-background relation in the child. *Journal of Abnormal and Social Psychology*, *36,* 236 – 248.

Willis, C. S., & Gathercole, S. E. (2001). Phonological short-term memory contributions to sentence processing in young children. *Memory, 9,* 349-364.

Wilson, M, Bettger, J.G., Niculae, I., & Klima, E.S. (1997). Modaility of language shapes working memory: Evidence from digit span and spatial span in ASL signers. *Journal of Deaf Studies and Deaf Education*, *2*, 152-162.

Wilson, M., & Emmorey, K. (1997). The visuo-spatial 'phonological loop' in working memory: Evidence from American Sign Language. *Memory and Cognition*, *25* (3), 313-320.

Wilson, M., & Emmorey, K. (1998). A 'word length effect' for sign language: Further evidence for the role of language in structuring working memory. *Memory and Cognition*, *26* (3), 584-590.

Wolfe J. (2000).Visual attention. In: K.K., De Valois, (Ed.). *Seeing*. 2nd ed. (pp. 335-386). San Diego, CA:Academic Press.

Woodward, J. and Allen, T. (1988). Classroom use of artificial sign systems by teachers. *Sign Language Studies*, *61*, 405-418.