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An analysis of the problem solving skills of children who are deaf or hard of hearing

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AN ANALYSIS OF THE PROBLEM SOLVING SKILLS OF CHILDREN WHO ARE DEAF OR HARD OF HEARING

By

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Abstract: **Literature Review**: Problem-solving skills are important to reasoning through everyday situations, and underlie social competence and academic achievement. Cognitive skills such as theory of mind and executive function contribute to problem-solving ability. Children who are deaf or hard of hearing often present with delays in these areas. **Data Analysis**: Data for 10 students who are deaf or hard of hearing who were administered the Test of Problem Solving – Elementary, Third Edition is analyzed. **Results**: Problem-solving abilities of students who are deaf or hard of hearing tend to fall on the lower end of the average range, where the average range is standardized by the typical population.

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TABLE OF CONTENTS

Acknowledgements ii

Table of Contents iii

List of Tables iv

Introduction 1

Problem Solving 4

Theory of Mind 8

Executive Function 16

Expanding on Executive Function Skills 21

Test of Problem Solving – Elementary, Third Edition (TOPS-3) 26

TOPS-3 Standard Score Analysis 29

Discussion and Implications for Instruction 31

References 37

Table 1 39

LIST OF TABLES

Table 1: TOPS-3 Standard Scores from 10 Children who are Deaf or Hard of Hearing

INTRODUCTION

Research supports that hearing loss has an effect on a child's language, social, and cognitive development (Marschark & Everhart, 1999). Delays in these developmental domains have a positive reciprocal relationship in that when one domain is affected so too is another. For example, it is generally believed that delays in key aspects of cognitive development are linked with language delay (Schick, de Villiers, de Villiers, & Hoffmeister, 2002), which many children who are deaf or hard of hearing present with.

Language has been described as "the tool of thought" (Luckner & McNeill, 1994) by some theorists. Individuals use this tool to communicate not only with others, but also with ourselves. This ability to think internally aids cognitive organization, planning, and the regulation of our actions and behaviors (Luckner & McNeill, 1994). When language is delayed, the ability to think about situations critically is affected. Critical thinking skills, such as analyzing, applying standards, discriminating, information seeking, logical reasoning, predicting, and transforming knowledge, are central to problem solving (Scheffer & Rubenfel, n.d.). Thus, language delay is linked with delays in problem solving.

Problem solving is the "means by which we use previously acquired knowledge, skills, and understanding to satisfy the demands of unfamiliar situations" (Luckner & McNeill, 1994). When faced with an unfamiliar situation, we employ our problem solving skills to analyze the information available and use reason to come to a possible solution to the situation ("What are," 2006).

Luckner & McNeill (1994) maintain that children who have underdeveloped linguistic ability are likely to have difficulty in mentally manipulating variables when trying to solve multi-element problems due to a diminished ability to communicate internally about those problems. Consistent with this, higher levels of inner speech have been found to have a positive effect on problem-solving skill development (Edwards, Figueras, Mellanby, & Langdon, 2010).

The internal speech used during problem solving is seen as a key role of executive function, an associated cognitive skill which enables problem solving (Remine, Care, & Brown, 2008). Executive Function in Education: Theory to Practice defines executive function as "an umbrella term for the complex cognitive processes that serve ongoing, goal directed behaviors" (Meltzer, 2007). Many components make up executive function and they will be discussed in further detail below.

Remine and colleagues (2008) propose that executive functions are mental processes which allow for flexible organization of information, planning, decision-making, and the incorporation and implementation of strategies towards obtaining a goal. In essence, these processes facilitate "intelligent thought, problem solving, and learning" (Remine et al., 2008).

Considering this, a delay in executive function – and thus problem-solving skills – may lead to academic and social difficulties. While children who are deaf or hard of hearing may not present with overall differences in intellectual abilities when compared to their peers who have typical hearing (Luckner & McNeill, 1994), an inability to reason and solve problems appropriately can have a profound effect on their social interactions and learning.

Theory of mind is another key cognitive skill which underlies problem-solving ability. Theory of mind is an individual's ability to view the desires, beliefs, and thoughts of others as possibly different from his/her own (Moeller & Schick, 2006). When a delay occurs in theory of mind, a child's problem-solving ability is adversely affected.

The ability to discriminate between different mental states makes it possible for an individual to reason about daily events and to predict the actions and behaviors of others

(Moeller & Schick, 2006). If the ability to distinguish another's desires, beliefs, and thoughts is diminished, then a child will have a difficult time reasoning appropriate solutions to problems. Thus, a theory of mind deficit leads to inadequate social functioning (Ketelaar, Rieffe, Wiefferink, & Frijns, 2012) and poor academic achievement (Schick et al., 2002).

Given the importance of problem-solving skills to social and academic success, it is important to better understand problem solving and the cognitive skills which underpin problem solving. Although there are many skills which contribute to problem-solving ability, the associated skills of theory of mind and executive function in particular are reviewed in further detail here.

PROBLEM SOLVING

In the study, “Performance of a Group of Deaf and Hard-of-Hearing Students and a Comparison Group of Hearing Students on a Series of Problem-Solving Tasks,” Luckner and McNeill (1994) examined the following: 1) whether or not a difference existed in problem-solving ability between individuals with and without hearing impairment, 2) whether this difference persisted across age levels, 3) whether overall problem-solving ability improved with age, and 4) whether the rate of improvement was similar for both groups.

For this study, the subjects included 43 students with severe to profound hearing loss who utilized manual communication as their primary communication method. The students were recruited from mainstream settings. After closely matching for age, gender, and race, 43 students with typical hearing were also selected for the study. Four age-groups were established: 5-8 year olds, 9-10 year olds, 11-12 year olds, and 13 year olds and older (Luckner & McNeill, 1994).

The Tower of Hanoi was utilized as the problem-solving task in this study. This task was chosen due to the minimal experience required by the children to produce good solution strategies to the problem, and due to its use in previous problem-solving research (Luckner & McNeill, 1994). The nature of the Tower of Hanoi problem requires an individual to solve the problem by executing a series of moves to obtain a goal (Luckner & McNeill, 1994).

The Tower of Hanoi problem at its most basic consists of three vertical pegs or towers and three circular disks of differing sizes. In the initial position, the three circular disks are placed on one of the towers from largest to smallest with the largest disk situated at the base. The goal is to move all of the disks from the initial tower to one of the other empty pegs in as few moves as possible. The subject in the study must do this task following two simple rules: 1) only one disk can be moved at a time, and 2) a larger disk can never be placed on top of a smaller disk (Luckner & McNeill, 1994).

Luckner and McNeill (1994) found that there were differences in problem-solving ability. They also found that as children with hearing impairment got older, they made gains in bridging the gap between their and their peers with typical hearing in problem-solving ability (Luckner & McNeill, 1994). It should be noted, however, that gains were made in narrowing the gap, but that a gap still remained even with increasing age.

The researchers suggested that due to their experiential and linguistic delays, individuals with hearing loss may not be as efficient in organizing information mentally or may have difficulty implementing appropriate problem-solving strategies (Luckner & McNeill, 1994). Furthermore, results from this study suggest that problem solving is a difficult skill for many children who are deaf or hard of hearing and that they may benefit from direct instruction in problem-solving skills in the classroom (Luckner & McNeill, 1994).

In the study, "Problem-Solving by Deaf and Hearing Students: Twenty Questions," Marschark and Everhart (1999) explored how problem-solving skills were affected by the presence of a pre-lingual severe to profound hearing loss in children. The researchers were interested in learning more about how their problem-solving performance might differ from their typical age-mates'. The strategies that these children may utilize in their problem solving were also of interest (Marschark & Everhart, 1999).

For the first experiment, the subjects included 36 children with hearing loss who had parents with typical hearing. The majority of these participants had severe to profound hearing loss. All participants were recruited from residential schools for the deaf and primarily used manual language to communicate. Thirty-six children with typical hearing from the public school system also were recruited for this experiment (Marschark & Everhart, 1999).

For the second experiment, Marschark and Everhart (1999) recruited 14 college-age students with hearing loss and 14 college-age students without hearing loss. Participants were recruited from the Rochester Institute for Technology (RIT) with the students with hearing loss coming from the National Technical Institute for the Deaf college housed at RIT. Subjects with hearing impairment had hearing loss ranging from moderately severe to profound (Marschark & Everhart, 1999).

A variation of the 'Twenty Questions' game was utilized as the problem-solving task in this study. Children were required to solve the task by asking yes/no questions in an effort to figure out which of 42 pictures had been chosen by the experimenter. This task allowed the examiners a view of the information-seeking strategies used by the subjects (Marschark & Everhart, 1999).

In the first experiment, participants were divided into three age groups: 7-8 year olds, 10-11 year olds, and 13-14 year olds. Analysis of the results revealed marked differences. When compared to their peers with typical hearing, children with hearing loss were less efficient and less effective at solving the task (Marschark & Everhart, 1999).

Children with hearing loss guessed more often and failed to adopt "a cognitively efficient strategy in the 'Twenty Questions' game" (Marschark & Everhart, 1999). Children with typical hearing more often utilized hierarchical, constraint seeking strategies than their peers who were deaf or hard of hearing (Marschark & Everhart, 1999). By using these strategies, they were more likely to succeed in solving the task than their age mates with hearing impairment.

When comparing between age groups, younger children guessed more than older students in both the hearing and hearing-loss groups; however, it should be noted that students with hearing impairment guessed more often than their age mates with typical hearing (Marschark & Everhart, 1999). This suggests that while problem-solving strategies may become more refined with age, children with hearing impairment still fall behind their peers with typical hearing in strategy use and efficiency.

In their second experiment, Marschark and Everhart (1999) evaluated college-age students. Data collected from Experiment 2 was compared with that from Experiment 1. This experiment revealed that both groups – typical hearing and hearing-impaired – were able to solve the tasks; however, an evident difference in regards to the efficiency of strategies used existed. Students with hearing loss still utilized less constraint seeking strategies than their peers. Also, students with hearing loss made ad hoc guesses as to the solution, while their age mates with typical hearing did not (Marschark & Everhart, 1999). These results suggest that differences in problem-solving ability between these two groups may alter, but do not disappear with age.

THEORY OF MIND

Developing appropriate theory of mind skills bolsters a child's ability to problem solve by giving the child the tools necessary to reason through situations and predict actions and behaviors. Children are able to better utilize their problem-solving skills by being able to consider the desires, thoughts, and beliefs – the differing mental states – of others (Moeller & Schick, 2006). Without these skills, children have difficulties developing appropriate social skills (Ketelaar et al., 2012; Moeller & Schick, 2006) and achieving academically (Schick et al., 2002).

Around 4 years of age, typically-developing children develop theory of mind understanding (Schick et al., 2002). Once theory of mind develops, children are able to more accurately predict another's behaviors and actions based on what the other person believes to be true, even when that person's belief is not reality (Schick et al., 2002). This understanding of False Belief is seen as a hallmark of theory of mind development, and as such is used often in testing theory of mind understanding in children as evidenced in the overview of the following studies.

"Language has long been considered an important underpinning to the reasoning process" (Edwards et al., 2010). As suggested by the previous studies outlined above, quantitative deficits in language exposure have an effect on a child with hearing loss's ability to efficiently and effectively problem solve (Luckner & McNeill, 1994; Marschark & Everhart, 1999), but what about the effects caused by the quality of language in the environment? How does the quality of linguistic input affect a child with hearing loss's ability to utilize his/her theory of mind skills, and in turn his/her ability to successfully problem solve?

Moeller and Schick (2006) sought to investigate the relationship between quality of maternal input and theory of mind skill development in children who are deaf. In their study, "Relations Between Maternal Input and Theory of Mind Understanding in Deaf Children," Moeller and Schick (2006) explored: 1) the frequency in which mothers engaged their signing children who are deaf in mental state talk, 2) the influence a mother's signing proficiency has on the quality of mental state talk language, and 3) the relationship between a mother's ability to talk about mental states and her child's theory of mind skills.

The participants in this study included 22 mother/child pairs in the hearing loss group and 26 mother/child pairs in the typical group. Children with hearing loss averaged about 7 years (range: 4 years, 3 months – ~10 years) in age and were reported to have severe to profound hearing loss (> 85 dB) which was pre-lingual in nature. The majority of these subjects were recruited from a total communication setting in public schools where both sign and spoken language were utilized. Only two children came from a school for the deaf. Of the 22 children with hearing loss, 10 utilized bilateral hearing aids, 10 utilized cochlear implants (average age at implantation – ~4 years, 4 months), and 2 were unaided. Despite having auditory aids, it was determined that all of the subjects with hearing loss relied on sign as their primary communication method. There were no differences found in language or theory of mind skills between cochlear implant or hearing aid users. All mothers had typical hearing (Moeller & Schick, 2006).

Subjects with typical hearing came from homes where spoken English was the primary communication method. Children without hearing loss averaged 5 years (range: 4 years, 3 months – ~6 years) in age. It should be noted that these children came from a significantly higher socioeconomic status than their peers with hearing loss. Both children and mothers in this group had typical hearing (Moeller & Schick, 2006).

Moeller and Schick (2006) recorded each mother/child pairing in a playroom setting for one hour while the pair engaged in three different play activities. Mothers were asked to interact with their children in as natural a manner as possible. The three activities included the mother and child playing with a toy (e.g. a construction toy), the two sharing family pictures, and the pair watching and discussing a movie clip. Language used during these sessions was transcribed and all instances of mental state talk were coded and compiled (Moeller & Schick, 2006).

The theory of mind task utilized by Moeller and Schick (2006) was the False Belief Task. In order for individuals to successfully solve a false belief task, they must be able to understand that another person "holds a belief about reality that contradicts his/her own belief" (Ketelaar et al., 2012). All child participants were presented with three different false belief scenarios. Two verbal tasks and one low verbal task composed the three false belief tasks (Moeller & Schick, 2006). Moeller and Schick (2006) included a low verbal task due to the possibility that the "level of language demand inherent in standard false belief tasks may mask deaf children's true social understanding."

Moeller and Schick (2006) found that mothers of children with typical hearing used mental state talk significantly more often than mothers of children with hearing impairment. Not only did they produce more mental state talk, but mothers of children with typical hearing also produced a greater diversity of mental state terms. Mothers of children who are deaf who had a high proficiency in sign ability produced more mental state talk terms than their peers with lower sign ability (Moeller & Schick, 2006).

Differences in theory of mind ability were revealed. Children with hearing loss who were exposed to greater and more diverse utterances of maternal mental state talk scored higher on their false belief understanding than their peers with hearing loss who did not receive the same kind of exposure. Children with hearing loss who were exposed to less maternal mental state talk also scored significantly lower in their false belief understanding when compared to their peers with typical hearing (Moeller & Schick, 2006).

The researchers suggest that these results indicate that a mother's signing skill affects the quality of the linguistic input a child who is deaf receives (Moeller & Schick, 2006). This relationship supports the idea that talking about mental states is important to the development of theory of mind understanding. Considering that a relationship between the overall length of language transcripts from each pair's interactions and false-belief understanding was not found, it is suggested that quality – more so than quantity – of input is the most influential on theory of mind development (Moeller & Schick, 2006).

Access to qualitative input improves theory of mind ability in children who are deaf or hard of hearing (Moeller & Schick, 2006). That the study revealed that mothers of children with typical hearing had quantity and quality of input in their conversations with their children is important. It should also be noted that mothers with higher signing ability of children with hearing impairment, and thus, a better ability to richly communicate with their children also had quantity and quality in their input during their conversations with their children (Moeller & Schick, 2006). As Marschark and Everhart (1999) maintain, "deaf children of hearing parents typically do not have effective modes of communication with their parents during the early years." There is a mismatch in communication (i.e. mother speaks, child signs) which leads to less quantity and quality of linguistic input until mothers can reach a signing ability to adequately communicate with their deaf children.

It should be noted that the Marschark and Everhart (1999) study was conducted at a time when cochlear implants were not nearly as advanced as they are now. It was not until 2000 that the Food and Drug Administration (FDA) approved cochlear implantation in children as young as 1 year (NIH Facts Sheet, 2010). With the advent of increasingly more advanced technology and earlier implantations, more and more children with hearing loss may not experience this mismatch in communication to the same extent as those in the past. In the Moeller and Schick (2006) study, nearly half of the subjects with hearing loss utilized a cochlear implant; however all of those participants had received their implants late by today's standards (mean age at implantation = ~4 years, 4 months, range = 3 years – 8 years) (Moeller & Schick, 2006).

Earlier implantation, in theory, would allow for more access to spoken linguistic input at an earlier age. According to Ketelaar and colleagues (2012), research has demonstrated that early implantation leads to improved language and communication skills, as well as social competence in children with hearing loss. Is improvement in social skills indicative of improvement in theory of mind? Does one's ability to better utilize language to communicate with others improve reasoning and social understanding? How does early implantation affect the development of these skills?

In the study, "Does Hearing Lead to Understanding? Theory of Mind in Toddlers and Preschoolers with Cochlear Implants," Ketelaar and colleagues (2012) examined differing aspects of theory of mind – intent, desires, and beliefs – in children who received their cochlear implants at an early age. They also investigated how their performance in theory of mind understanding compared with their typically developing peers. Furthermore, they explored how language relates to theory of mind development in children with cochlear implants (Ketelaar et al., 2012).

The study included 72 children with cochlear implants who were recruited from counseling services and hospitals. There were also 69 children with typical hearing recruited from day cares and public schools. All of the children ranged from 1 year to 6 years of age, had parents with typical hearing, no additional disabilities, and came from similar socioeconomic status backgrounds. Children with hearing impairment presented with profound hearing loss and pre-lingual deafness. With the exception of one child, all children with hearing loss received their first implant before the age of 3 years (Ketelaar et al., 2012).

In order to investigate the various aspects of theory of mind, Ketelaar and colleagues (2012) utilized three intention tasks, two desire tasks, and a standard false belief task in their study. Due to the belief that intention understanding is developed earlier than the understanding of desires or beliefs, all children were administered the intention tasks. Only children who were 30 months or older were deemed to have sufficient language to participate in the desire and false belief tasks (Ketelaar et al., 2012).

Ketelaar and colleagues (2012) found that there was no difference between the two groups when it came to their ability to comprehend the intentions of others; however, significant differences were found between the two groups for desire and false belief understanding. Overall, children with typical hearing did better on the desire and false belief tasks than their peers with hearing impairment. For all children, the scores on the false belief task were their lowest, with children without hearing loss still outperforming the children with cochlear implants (Ketelaar et al., 2012).

There was a notable difference in performance between the two groups on the two differing desire tasks. One desire task tested the children's understanding of common desires, while the other tested for uncommon desires. When compared with their peers with typical hearing, the children with cochlear implants did just as well on the common desires task, but fell behind their peers on the uncommon desires task. This difference in ability to understand common versus uncommon desires did not appear in the children with typical hearing (Ketelaar et al., 2012).

This study shows that despite earlier implantation, children who are deaf still present with delays in theory of mind. The findings in this study also point to a developing but delayed theory of mind in children who are deaf with cochlear implants, rather than a "qualitatively different developmental path" (Ketelaar et al., 2012). The differences found between the groups in their abilities to understand common and uncommon desires suggest that there is a hierarchical path for theory of mind development (Ketelaar et al., 2012). The results further indicate that children with hearing loss seem to follow a similar developmental path towards complete theory of mind understanding, but fall behind their peers with typical hearing, time-wise, in achieving theory of mind development.

Schick and colleagues (2002) support this idea by maintaining that a theory of mind delay is not caused by a cognitive difference between individuals who are deaf and individuals who are not, but rather the delay is an effect of their decreased access to language overall. In a review of the research on this topic, Schick and colleagues (2002) found that language skills in children with hearing impairment were directly related to their theory of mind skills. In other words, children who possessed more advanced language skills – particularly in the areas of vocabulary and comprehension of grammatical elements – had a higher likelihood of performing well on false belief tasks and theory of mind understanding. This also corroborates the findings in the Ketelaar et al. study (2012), as it lends credence to the notion that earlier cochlear implantation leads to more ready and early access to sound and speech, and thus helps to decrease the gap seen in theory of mind understanding between children with and without hearing loss.

Language is important not only for communication, but also for learning about the world around us. Language provides the building blocks for learning about how minds - our own and others' - work (Schick et al., 2002). In this regard, language development is key to increasing understanding of differences in mental states. As such, it directly affects the development of an individual's ability to reason and problem solve.

Schick and colleagues (2002) postulate that theory of mind is a prerequisite skill necessary for a child to fully comprehend stories and the written word. They believe that the delay in reading skills which many children with hearing loss experience is a result of deficits in theory of mind development and not just a result of their delays in vocabulary and syntax understanding (Schick et al., 2002). If theory of mind can affect a child's ability to read, it can also be connected to a child's difficulties in other academic domains such as math, science, etc. Reading skills are usually required, along with reasoning and problem solving skills to be able to achieve academically. As such, delays in language and theory of mind have an overall global effect on a child's ability to be successful.

EXECUTIVE FUNCTION

There are many definitions for executive function. Executive function constitutes a variety of skills, which has led to a variety of definitions. As such, no one definition fully represents a true definition of executive function. The National Center for Learning Disabilities defines executive function as “a set of mental processes that help us connect past experience with present action” (2013). Anderson, Anderson, Northam, Jacobs, and Catroppa (as cited in Remine et al., 2008) define executive function as “using the separate but integrated components of attentional control, cognitive flexibility, cognitive inhibition, and goal setting.” Perhaps the definition found in Executive Function in Education: Theory to Practice is best in regards to simplicity and clarity: executive function is “an umbrella term for the complex cognitive processes that serve ongoing, goal directed behaviors” (Meltzer, 2007).

The cognitive skills of executive function and attention are required when problem solving (“What are,” 2006). Executive function skills are needed to attend to, recognize, gather, and organize facts in an effort to solve a problem. When an individual has proper executive function skills, he/she are better problem solvers (“What are,” 2006).

The primary goal of problem solving is the obtainment of an end goal. Executive function skills give an individual the tools necessary to be able to utilize appropriate strategies in an effort to meet that goal (Remine et al., 2008). As such, when an individual has a deficit in executive function, his/her ability to problem solve is impaired. This can lead to negative ramifications in social interactions and academic achievements.

Skills which fall under the umbrella of executive function include: impulse control, emotional control, attention, planning/prioritizing, flexibility, working memory, self-monitoring, task initiation, and organization (NCLD Editorial Team, 2013). To see a listing of some primary executive function skills, their definitions, and how a delay in those specific areas affect an individual academically and/or socially, refer to the following section: Expanding on Executive Function Skills.

In the study, “Language Ability and Verbal and Nonverbal Executive Functioning in Deaf Students Communicating in Spoken English,” Remine and colleagues (2008) investigated the relationship between verbal and nonverbal executive functioning and language ability in students who are deaf from auditory-oral programs. Within the language domain, they investigated the effects of both receptive and expressive language on executive function performance. They hypothesized a subject’s language ability would have effects on verbal and nonverbal executive functioning performance (Remine et al., 2008).

The participants in this study included 37 students with hearing loss between 12 years and 16 years in age. All children presented with severe to profound bilateral hearing loss (>70 dB) and pre-lingual deafness. All subject participants were aided within 2 months of diagnosis and were enrolled in an auditory-oral early childhood intervention classroom. At time of testing, all students were being directly taught by a teacher of the deaf in the classroom or were being provided with itinerant teacher of the deaf services. Eleven students were in total communication placements, but did not utilize sign language and were taught through auditory-oral instruction. None of the participants in this study utilized sign language. They relied solely on listening and spoken language for communication (Remine et al., 2008).

Remine and colleagues (2008) utilized one verbal and one nonverbal task for this study. Each task is designed to assess different key executive functions. The verbal task was a variation of the ‘Twenty Questions’ game, much like the task used by Marschark and Everhart (1999) in their study. The variation of the ‘Twenty Questions’ game used by Remine and colleagues (2008) was a standardized assessment tool named the Delis-Kaplan Executive Function System (D-KEFS): 20 Questions Test. The objective of the task is to ask the fewest number of yes/no questions possible to figure out which picture in the array is the examiner's chosen stimulus. In contrast to Marschark and Everhart's (1999) problem-solving task which used 42 picture stimuli as possible solutions, the D-KEFS: 20 Questions Test only utilized 30 picture stimuli (Remine et al., 2008). Key executive functions assessed by the D-KEFS: 20 Questions Test include abstract thinking, categorical processing, and effective strategy use in problem solving through the utilization of feedback (Remine, et al., 2008).

The nonverbal task utilized by the researchers was a standardized assessment tool named the Delis-Kaplan Executive Function System (D-KEFS): Tower Test. This test resembled the Tower of Hanoi problem-solving task used by Luckner and McNeill (1999) in their study; however, it is important to note that the D-KEFS: Tower Test is a combination of three different tower tasks - the Tower of Hanoi, the Tower of London, and the Tower of Toronto. The objective of the task is similar to the Tower of Hanoi's in that the participant is presented with disks on pegs and expected to figure out how to reach the end goal position in the fewest moves possible while adhering to a set of rules (Remine et al., 2008). Key executive functions assessed by the D-KEFS: Tower Test include rule learning, spatial planning, stabilizing and maintaining cognitive set, and inhibition of impulse responding (Remine, et al., 2008).

Test performance results revealed that each student in the sample achieved standard scores that fell within the average range for both tasks. This suggests that when compared with their age mates with typical hearing, children with hearing impairment performed similarly. As such, the children in this sample demonstrated average verbal and nonverbal executive function in accordance with their ages (Remine et al., 2008).

In regards to the D-KEFS: 20 Questions Test (the verbal task), Remine and colleagues (2008) found that the students were able to use a high level of categorization, as well as a combination of both constraint-seeking and hypothesis-seeking questions as part of their strategy to solve the problem presented by the task (Remine et al., 2008). This is in direct contrast to the findings in the Marschark and Everhart (1999) study, where the children presented with low efficiency and effectiveness in their problem solving strategies (Remine et al., 2008).

When assessing the relationship between language and verbal executive function performance, Remine and colleagues (2008) found that expressive language ability was the only independent variable that had a significant effect on verbal executive function performance. Receptive language did not have a significant effect (Remine et al., 2008). This suggests that children with low expressive language ability may have more difficulties with problem solving.

Performance on the D-KEFS: Tower Test (the nonverbal task) revealed that contrary to findings in the Luckner and McNeill (1994) study, the children tested in the present study had average organization and spatial planning skills when compared with their peers with typical hearing (Remine et al., 2008). Children in the present study also demonstrated average rule learning, impulse control, and inhibition skills (Remine et al., 2008). As for the relationship between language and nonverbal executive function performance, the researchers found that neither expressive nor receptive language has a significant effect on nonverbal executive performance (Remine et al., 2008).

Differences in communication mode could account for the differences found between the present study and the Marschark and Everhart (1999) and Luckner and McNeill (1994) studies. The children with hearing loss in both the Marschark and Everhart (1999) and Luckner and McNeill (1994) studies, utilized manual communication as either their sole or primary mode of communication. Remine and colleagues (2008) tested children with hearing loss who utilized spoken language as their primary communication method. The dissimilarity in results could be related to language modality differences. It is also possible that due to differences in modality, children with hearing loss may present with fundamental differences in the strategies they utilize to solve problems (Remine et al., 2008).

EXPANDING ON EXECUTIVE FUNCTION SKILLS

This section lists some primary executive function skills, their definitions, and how a delay in each area may affect an individual academically and/or socially. Unless otherwise noted, the following information comes from the e-book, Executive Function 101, released by the National Center for Learning Disabilities (NCLD Editorial Team, 2013).

- **Emotional Control** – "The ability to manage feelings by thinking about goals" (NCLD Editorial Team, 2013).

  Emotional control allows a student to manage his/her emotions so that the emotions do not take control of the situation at hand. This executive function skill is necessary to avoiding problematic interpersonal situations.

  Deficits in emotional control can result in the student having tantrums, withdrawing from lessons and others, and being prone to arguing. Weakness in emotional control can result in unproductive and self-destructive reactions to upsetting or unexpected situations. The student may have trouble accepting criticism (constructive or otherwise), and may deviate from reaching a goal or working on assignments when distressed.

- **Impulse Control** – "The ability to stop and think before acting" (NCLD Editorial Team, 2013).

  Impulse control allows a student to hold back on initiating an action or from saying something until consequences for doing so can be considered.

  Deficits in impulse control can cause a student to have a diminished ability to regulate his/her speech and behavior. The student may find it difficult to stop and think before acting, and he/she may have relatively poor reflection skills. As such, he/she may experience social issues as he/she may say or act inappropriately at inappropriate times, or he/she may talk incessantly or have the tendency to interrupt his/her peers. The student may also experience academic problems as he/she may rush through their school work answering questions on impulse.

- **Attention** – The ability to attend to what you need to attend to (NCLD Editorial Team, 2013).

  Attention allows a student to pay attention to a task in order to work on and complete that task. He/she also needs to be able to attend to the important aspects of a problem or situation, while inhibiting the unimportant aspects.

  Deficits in attention cause a student to have issues in all areas of social interaction and academic work as he/she must be able to attend to a stimulus before any reaction can occur.

- **Planning/Prioritizing** – "The ability to create steps to reach a goal and to make decisions about what to focus on" (NCLD Editorial Team, 2013).

  Planning and prioritizing skills allow a student to prioritize tasks by the goals the student has in mind and on the level of importance he/she attributes to each goal.

  Deficits in planning and prioritizing can affect a student's ability to juggle long-term and short-term tasks, to manage the competing demands of deadlines, academic and extracurricular activities, and to select the important information from lectures, notes, and study materials.

- **Flexibility** – "The ability to change strategies or revise plans when conditions change" (NCLD Editorial Team, 2013).

  Flexibility skills allow a student to interpret information in multiple ways. Flexibility skills also allow for a student to be able to change his/her strategies and approaches to any given situation and/or problem as necessary.

  Deficits in flexibility may cause a student to have difficulties in reading comprehension, math competency, learning a foreign language, writing compositions, on determining the most relevant information in science and history, and in studying and taking tests effectively. He/she may also have difficulties with coping with changes to schedules and routines.

- **Working Memory**[1] – "The ability to hold information in mind and use it to complete a task" (NCLD Editorial Team, 2013).

  Working Memory is utilized by a student when he/she is working on math problems, or listening to or reading a story. They have to be able to retain the numbers long enough to work with them and they have to remember the sequence of events in a story while also thinking about what the overarching theme of the story is.

  Deficits in working memory may cause a student to have difficulties in reading comprehension, solving mathematical problems, following multi-step oral instructions,

[1] Working Memory is considered to not be an executive function in and of itself; however, it is considered to be a "foundation that supports the executive functions" (NCLD Editorial Team, 2013). Carpenter, Just, and Reichle (2000) describe the difference between the executive functions and working memory as, "Executive processes are implicated in complex cognition, such as novel problem solving, which entails identifying and coordinating the steps to a new goal, evaluating the intermediate outcome, and modifying the plan as needed…. Working memory has been operationalized primarily as the processes and structures that keep information available over a relatively short time, such as postulated verbal and spatial peripheral buffers…. In this standard perspective, executive processes *manipulate* the contents of the working memory buffers."

learning language, comprehending tasks, visualizing, remembering patterns, images, and sequences of events.

- **Self-Monitoring** – "The ability to monitor and evaluate your own performance" (NCLD Editorial Team, 2013).

  Self-monitoring allows a student to be aware and mindful of the task at hand, how he/she approaches the task, what strategy he/she utilizes, and of the outcome which results.

  Deficits in self-monitoring may cause a student to have difficulties in monitoring and decoding vocabulary, reading comprehension, understanding and planning a written composition appropriately, monitoring and using the correct operation in math problems, monitoring his/her awareness and understanding of science and history concepts, completing homework assignments correctly and on time, as well as in studying and test-taking.

- **Task Initiation** – "The ability to recognize when it is time to get started on something and begin without procrastinating" (NCLD Editorial Team, 2013).

  Task initiation skills allow a student to start a task when it is necessary to do so. This is important as beginning a task is the first step towards completing it. Being able to begin working on a task and not putting it off is important to completing assignments accurately and on time.

  Deficits in task initiation may cause a student to become overwhelmed with assignments, leading to incomplete assignments, rushed assignments, or inaccurate assignments. This may also result in the student not doing the assignment at all. In turn, this may lead to the student having feelings of inadequacy or lowered self-esteem, which can cause students to withdraw socially and academically.

A failure to begin a project or an assignment may be a sign that the student does not know *how* to begin the task at hand. This may also be an indication that the student may have difficulties in planning/prioritizing and organization skills.

- **Organization** – "The ability to create and maintain systems to keep track of information or materials" (NCLD Editorial Team, 2013).

Organization skills allow a student to accomplish tasks through the successful management of schedules and the ability to keep track of important information in an orderly fashion. With each successive grade level, stronger and stronger organizational strategies are required of every student.

Deficits in organization skills may affect a student's ability to complete his/her homework, manage long-term projects, study efficiently and effectively, and write coherent and cohesive compositions.

TEST OF PROBLEM SOLVING – ELEMENTARY, THIRD EDITION (TOPS-3)

Research indicates that children who are deaf or hard of hearing present with delays and/or differences in problem-solving abilities. As part of the regular test battery administered to their students, the staff at the Moog Center for Deaf Education in St. Louis, Missouri administered the Test of Problem Solving – Elementary, Third Edition (TOPS-3) (Bowers, L., Huisingh, R., & LoGiudice, C., 2005) to 10 children who are deaf or hard of hearing. They are currently enrolled or were enrolled at the auditory-oral school for the deaf at the time of testing. Children who were tested ranged in age from 7 years, 3 months to 10 years, 9 months.

The TOPS-3 is designed to evaluate the linguistic ability to problem solve and reason in children who are 6 years through 12 years, 11 months in age. The TOPS-3 uses questions designed to evaluate language-based reasoning skills, including problem solving, inferring, classifying, associating, predicting, analyzing, clarifying, determining causes, sequencing, generating solutions, evaluating, affective thinking, and understanding directions. In essence, the TOPS-3 measures the skills that form the foundation of an individual's overall ability to problem solve.

Eighteen full-color photographs depicting realistic situations are utilized to assess six critical thinking areas: Making Inferences, Sequencing, Negative Questions, Problem Solving, Predicting, and Determining Causes. The realistic situations portrayed in the eighteen photographs were chosen due to their relevance to most students and were deemed to be common across cultures and most home settings and school environments.

The test consists of six subtests with one subtest for each of the six critical thinking areas outlined above. All responses are elicited by questions from the examiner that refer to the eighteen photographs. Depending on the relevancy and quality of the response given by the student, a score of 0, 1, or 2 is assigned for each test item. Acceptable responses for each score for each test item are outlined on the test form to be readily utilized by the examiner at the time of testing. No basals or ceilings are utilized by this test.

The TOPS-3 provides reliable and valid standardized information for each of the subtests tested. The six subtests are described below. The same full-color photograph - a firefighter holding a small child in front of a two story building – is used to provide the examples of test questions given here.

Making Inferences:

The student is asked to give a logical explanation about the situation depicted in the photograph. To do this, the student must combine his/her knowledge about previous experiences and background information with what can be seen in the photograph. For example: The examiner would ask, "Why is the firefighter holding the boy" (Bowers et al., 2005)?

Sequencing:

The student is asked to determine and explain everyday sequences of events logically. To do this, the student must have an understanding of the situation in order to clearly express a logical sequence of events. For example: The examiner would ask, "What's the first thing you should do if there's a fire where you live" (Bowers et al., 2005)?

Negative Questions:

The student is asked to explain why a given situation would not occur or why an individual should not perform an action in context. To do this, the student must attend to, understand, and be able to express what would be appropriate in the given situation. For example: The examiner would ask, "The fire has just been put out and the building looks okay on the outside. Why isn't it safe for people to go back inside the building yet" (Bowers et al., 2005)?

Problem Solving:

The student is asked to recognize the problem, think of possible solutions, evaluate available options, and pick the most appropriate solution. The student's ability to avoid problems is also evaluated. For example: The examiner would ask, "This boy is deaf. How can the firefighter communicate with him" (Bowers et al., 2005)?

Predicting:

The student is asked to anticipate what will happen in the future. To do this, the student must reflect on past experiences to predict the future. For example: The examiner would ask, "Where might the firefighter take this boy" (Bowers et al., 2005)?

Determining Causes:

The student is asked to give a logical reason for a given aspect of the situation presented. To do this, the student must be able to see how the action and the outcome are related. For example: The examiner would ask, "How do you think the fire started" (Bowers et al., 2005)?

TOPS-3 STANDARD SCORE ANALYSIS

Standardized test scores were obtained for each of the 10 children evaluated in all subtests. A standardized Total Test score also was obtained. Standard scores (SS) are based on the average scores obtained by children in the normative sample. This standardization of scores allows for each child's individual performance to be compared to other children his/her age in the normative population. Each child's standard score allows the child's performance to be placed within a range (e.g. average, below average, above average, etc.).

On the TOPS-3 assessment test, scores for the average range fall between 85 and 115, with 100 representing the mean. The normative sample consists of children who represent the typical population as established by National Census data in regards to age, gender, race, and educational placement. As such, standard scores obtained by the children who are deaf or hard of hearing will reflect how their problem-solving skills compare to their age mates who are typically hearing.

Standard scores obtained for each subtest and a Total Test score for the TOPS-3 are listed for each of the 10 children in Table 1. Analysis of the data revealed no overall pattern; however, the data does show individual strengths and weaknesses in varying problem-solving skills for each of the children tested.

The students vary widely when their subtest scores are compared among students. For example, Student B is within the average range in ***Making Inferences*** (SS = 91), but on the borderline for above average in ***Sequencing*** (SS = 114). Student C is on the higher end of the average range in ***Making Inferences*** (SS = 112), but below average in ***Sequencing*** (SS = 79). Student E presents with virtually the same score within the average range for both ***Making Inferences*** (SS = 102) and ***Sequencing*** (SS = 103).

When looking at performance individually, some students varied greatly from one subtest to the next showcasing their individual strengths and weaknesses. For example, Student A is on the lower end of the average range in ***Making Inferences*** (SS = 86), but on the higher end of the average range in ***Problem Solving*** (SS = 111). Student F is below average in **Negative Questions** (SS = 77), but within the average range for ***Predicting*** (SS = 108). Student H is in the extremely low average range in ***Determining Causes*** (SS = 69), but on the higher end of the average range in ***Negative Questions*** (SS = 113).

In regards to Total Test scores, all students fell within the average range; however, it should be noted that with the exception of Student B (SS = 110), all of the students fell below the median of 100, placing them on the lower end of the average range. This suggests that while the students are within the average range, they are still falling behind the majority of their peers who have typical hearing.

It is also of note that four of the students' Total Test scores were on or near the borderline between the average and below average range (i.e. Student D: SS = 88, Student F: SS = 85, Student G: SS = 85, and Student I: SS = 86). These students are at the most risk and should receive intervention to prevent falling further behind.

Eight out of 10 students fell below the average range in at least one subtest despite all students achieving a Total Test score within the average range. This indicates that the majority of the students present with specific problem-solving skills which need to be addressed with intervention.

DISCUSSION AND IMPLICATIONS FOR INSTRUCTION

Results from testing indicated no obvious trend in problem-solving ability among the children; however individual weaknesses and strengths in differing problem-solving areas were revealed for each child. This information is highly valuable to teachers in the classroom.

As previously stated, the majority of the students tested here present with specific problem-solving skill needs which should be addressed with intervention. The data available from TOPS-3 testing can help a classroom teacher individualize problem-solving skill instruction based on each student's specific needs. Classroom teachers can keep these areas of need in mind when developing their curriculum. Suggestions for how classroom teachers can help a student who may have a weakness in one or more of the specific subtest areas are described below.

Making Inferences:

Students who have difficulty making inferences may have difficulties with understanding reading material, comprehending a story character's motivations and intentions, answering mathematical word problems, understanding another person's perspective, or reasoning about what they perceive in text and in social interactions.

These students may be having problems with determining the important facts and details about a given situation and as such cannot effectively utilize this information to formulate an appropriate response or they may not have the language necessary to communicate an appropriate response. They may also just not realize that they should be thinking about the implications of what they see, read, or experience.

Teachers can help students improve their inferencing skills by pointing out the important facts and details in a given situation. This not only provides a model of what the student should be looking for, but it helps the students to begin to understand which details are important and which details are superfluous. By doing this, teachers are also demonstrating that students should be thinking more critically about what they see, read, or experience. For those students who have a lower language level, the teacher can first work on building the appropriate, prerequisite linguistic structures necessary to communicate appropriate responses.

Sequencing:

Students who have difficulty with sequencing may have difficulties with following instructions, studying effectively, solving math and science problems, determining the main idea vs. details in text, and/or may have trouble completing assignments due to being unable to determine a logical sequence of steps towards that goal.

Teachers can help by teaching their students better planning/prioritizing and organization strategies. For example, teachers can model how to use outlines, graphic organizers, and planners for their students. Teachers can also help to improve sequencing skills by incorporating the use of ordinal numbers – "[numbers] designating the place (as first, second, or third) occupied by an item in an ordered sequence" (Ordinal Number, n.d.) – into their daily interactions as well as into their lessons. For example, a teacher might do this when describing the steps a student is supposed to take in their morning routine or when describing the directions to a problem or assignment.

Negative Questions:

Students who have difficulty answering negative questions may have difficulties with following instructions and answering questions appropriately due to an inability or lower ability to detect the negative markers in the questions. These students may also appear to be impulsive as they seem to not be listening or reading closely enough to notice negative markers.

This failure to detect negative markers could also be a result of lower language skills. Research supports that negative question understanding is more difficult than positive question understanding for most students in general (Bowers et al., 2005). As such, for a student with language delay, understanding the meaning or underlying function of negative markers in questions would be difficult for him/her.

Teachers can help by teaching their students to better attend to these negative markers. This is the first step towards developing a deeper understanding of their use and meaning in speech and text. For example, teachers can create activities in a variety of subject areas which utilize an assortment of negative question types. The teacher can walk the students through answering the negative questions using the think-aloud strategy.

The think-aloud strategy is a strategy utilized by many teachers in an effort to boost their students' ability to effectively approach difficult problems by improving their critical thinking processes in various subject areas (e.g. reading comprehension, mathematical problem solving, answering positive/negative questions, and other cognitively demanding tasks). Teachers verbalize their inner speech while solving the problem or answering a question in order to provide their students with an appropriate model (Teacher Vision, 2014).

Teachers can utilize this strategy to emphasize the importance of the negative markers in negative questions. Teachers can acoustically highlight the negative markers during their think-aloud to bring additional attention to these words. Teachers can also think out loud about what these negative markers mean and how that changes the criteria of what an appropriate answer to the question would be. For those students who have a lower language level, the teacher can first work on building the appropriate, prerequisite linguistic structures necessary to understanding and answering negative questions.

Problem Solving:

Students who have difficulties with problem solving may have difficulties with reading comprehension and mathematical word problems, as well as with avoiding problems. They may demonstrate difficulties in identifying and explaining causes for events or even recognizing that problems are present. Socially, students with weak Problem Solving skills may not recognize that their behavior is inappropriate and may repeat mistakes. They may also have trouble solving day-to-day problems and planning practical schedules.

Teachers can help by building their students' experiential background knowledge. Considering that an integral part of a student's ability to problem solve effectively is based on his/her reliance on his/her past experiences, a diminished experiential background knowledge can be negatively affecting. A weakness in problem-solving ability can also be due to a lack of appropriate role models.

For example, teachers can attempt to develop background knowledge by integrating a variety of activities in different subject areas based on a common theme into their curriculum. The teacher can also help to improve their students' social problem-solving abilities by modeling appropriate social interactions. Teachers can also step-in when inappropriate social interactions are taking place and help the students resolve the issue while explaining what some appropriate solutions to the problem may be.

Predicting:

Students who have difficulties making predictions may have difficulties with predicting the main idea of a story, guessing probable outcomes to science experiences, anticipating the actions of characters in a story, or predicting the actions of peers. They may also have trouble with predicting the consequences of their own actions, which can lead to them having behavior issues in and out of the classroom.

Considering that a student needs to be able to effectively reflect on past experiences in order to predict likely outcomes in the future, teachers can help by teaching their students to critically reflect on their past successes and failures. For example, teachers can implement a reflection journal in class where students spend a designated amount of time per day reflecting on a personal experience from earlier in the day or on a joint experience with their fellow students. Teachers can also incorporate reflection time into activities during the day. For example, after finishing an activity, the teacher can ask students questions which require them to reflect on the activity they just finished.

Determining Causes:

Students who have difficulties with determining causes may also have difficulties with predicting skills and sequencing skills as these abilities blend with one another in many instances. For example, a student who presents with difficulties in determining causes for events may have difficulty with predicting and comprehending the outcomes of science experiences and certain math problems, or the consequences of a story character's actions. They may also demonstrate difficulty with sequencing stories or steps to directions in the appropriate order.

Teachers can help by utilizing strategies similar to those suggested in the Sequencing and Predicting sections above. Teachers can also help by adding cognitive activities to their lesson planning, which utilize the 'If-Then' concept. If students can begin to readily understand this concept, then they will have an increased ability to understand cause and effect, which will only help to increase their ability to determine causes.

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TABLE 1

Student	Age	Making Inferences	Sequencing	Negative Questions	Problem Solving	Predicting	Determining Causes	Total Test
A	10-9	86	95	97	111	94	98	97
B	8-7	91	114	110	115	104	116	110
C	8-11	112	79	79	105	99	107	97
D	9-1	99	91	94	88	80	96	88
E	9-0	102	103	84	95	99	92	95
F	9-4	89	78	77	82	108	96	85
G	9-0	95	85	100	87	84	67	85
H	8-5	91	104	113	87	80	69	90
I	8-9	84	76	97	95	88	92	86
J	7-3	94	106	84	105	99	93	97

TOPS-3 Standard Scores from 10 Children who are Deaf or Hard of Hearing (Data presented in Table 1 is used with permission from The Moog Center for Deaf Education, 2014.)