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Problem solving ability in elementary school age children with hearing impairment

Donna Fisher Smiley

University of Tennessee

To the Graduate Council:

I am submitting herewith a dissertation written by Donna Fisher Smiley entitled "Problem solving ability in elementary school age children with hearing impairment." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Speech and Hearing Science.

James W. Thelin, Major Professor

We have read this dissertation and recommend its acceptance:

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Graduate Studies

PROBLEM SOLVING ABILITY IN
ELEMENTARY SCHOOL AGE CHILDREN WITH HEARING IMPAIRMENT

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Donna Fisher Smiley
May 2002

DEDICATION

"We cannot live for ourselves alone. Our lives are connected by a thousand invisible threads, and along these sympathetic fibers, our actions run as causes and return to us as results" -- Herman Melville

This dissertation is dedicated to my family and friends who have supported me in this endeavor.

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There is an old African proverb that says that it takes a whole village to raise a child. I believe that it takes a whole village to get a Ph.D. The support of my family, friends, teachers and students has helped me to be successful in this endeavor. Without them, this process might have been impossible for me.

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ABSTRACT

The present study was conducted to evaluate the problem solving ability of children with hearing impairment. This was done using mathematical problems that are a part of the typical school curriculum. The performance of a group of children with hearing impairment (HI Group) was compared to the performance of a group of children with normal hearing (NH Group).

The participants were two groups of school-aged children with 13 in each group. The two groups were equated on performance intelligence, language ability, grade level and sex. The participants were asked to solve two types of mathematical problems: those that required computation alone and word problems that required the use of both language and mathematical computation.

The results of this study revealed that there were no significant differences between the HI Group and NH Group in the ability to solve mathematical problems that involve the use of language and mathematical problems that involve only computation. In addition, it was found that problem solving ability was related to language ability and not to hearing ability in the children with hearing impairment. The results were quantitatively similar for the two groups in regard to problem solving ability. However, there was evidence to indicate that the two groups used different problem solving strategies.

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CHAPTER I

Introduction

In the United States educational system, a majority of children with hearing impairment who use an aural/oral mode of communication are mainstreamed into conventional schools rather than receiving their education in special schools for the deaf or hearing impaired. As a part of the assessment of educational abilities and needs in the mainstream, these children are evaluated using standardized measures of intelligence, language ability and academic achievement. Special intervention is provided when achievement or abilities are found to be below expectations on these standardized measures. Existing standardized measures provide a description of specific abilities and disabilities of children with hearing impairment. However, in most cases, these measurements provide minimal information about how the impairment may affect the child's ability to learn, to apply knowledge and to function in the school environment.

The ability to function successfully depends on the ability to solve a wide variety of problems to assist the individual in reaching diverse goals. New problem solving skills are acquired at each stage of the developmental and educational process. In the present study, the interest was on the ability of children with hearing impairment to apply knowledge by solving problems that were relevant to the child and that required the use of different processes than the problems used on standardized intelligence and language tests. The primary issue was to determine if the cognitive function of children with hearing impairment differs from that of children with normal hearing on higher-level tasks that require and do not require the use of language.

Function and Disability

Over the past several decades, research has been conducted by individuals and the World Health Organization (WHO) on the description of function and dysfunction and on the methods for assessing functional outcomes for person with disabilities (Granger, 1984; Nagi, 1965,1991; Pope & Tarlov, 1991; WHO, 1980, 1997, 1999, 2000 and 2001). To determine functional outcomes for a person with hearing impairment, the description of the disability begins with the specification of the disability in terms of hearing, but it extends to the effects of hearing impairment on all other aspects of functioning. For example, hearing impairment may affect the ability to measure intelligence, but it may also affect the acquisition of knowledge. It may affect the ability to acquire language, which in turn may affect any activity that requires the use of language. Thus, improvement of functional outcomes for children with hearing impairment depends on an understanding of the consequences of hearing impairment for a wide range of activities that are essential for functional adequacy.

The WHO (2001) has developed the *International Classification of Functioning and Disability* (ICF), which is a general system for classifying and listing the consequences of all types of impairments. An individual's ability to function can be viewed from the individual perspective and from the societal perspective. The individual perspective involves the execution of a task or action by a person. The societal perspective is the involvement of a person in a life situation (WHO, 2001). The application of this system to hearing impairment reveals that the consequences of hearing impairment have the potential for pervasive effects on the functioning of an individual (Fisher & Thelin, 1999). The WHO model has many uses, but, in the present study, it was used to identify the aspects of function and dysfunction that were considered to be most important to children with hearing impairment.

In the WHO model (2001), the term "functioning" is used to describe the activity of and participation in fundamental life processes such as learning, applying knowledge, communication, mobility, self-care, relationships, employment and social/community life. Each process is composed of components. For example, the process of applying knowledge includes focusing attention, thinking, reading, writing, calculating, and problem solving.

Issues in Problem Solving and Hearing Impairment

Problem solving is the means by which previously acquired knowledge, skills and understanding are used to satisfy the demands of an unfamiliar situation (Krulick & Rudnick, 1988). Thornton (1995) proposed that the psychological processes necessary for problem solving are a part of a "baby's basic endowment" (p. 32). She also states that the processes used in problem solving depend on the information or knowledge base of the child. In other words, the richer the child's knowledge base, the easier it is for the child to figure out how to solve a problem. The acquisition and use of a knowledge base are dependent on language and thinking skills. Children with hearing impairment may experience a diminished knowledge base and language impairment due to decreased auditory input. In addition, the thinking skills of children with hearing impairment may be affected by the presence of a language impairment.

Knowledge base

Due to the sensory deprivation and language impairment caused by a hearing impairment, children with hearing impairment may develop a smaller knowledge base. Children with hearing impairment are less likely to "overhear" information. This reduction in incidental learning may result in negative consequences of knowledge acquisition (Carney & Moeller, 1998). To further compound the problem, a limited knowledge base affects the acquisition of additional knowledge (Paul, 2001).

Language

The most debilitating aspect of hearing impairment is not the loss of hearing, but the subsequent language impairment that is a result of insufficient auditory input (deVillers & deVillers, 1978; Erber, 1982; Ling, 1984; McAnally, Rose, & Quigley, 1994). The central focus of educating children with hearing impairment has been and continues to be language acquisition (Easterbrooks & Baker, 2002). However, children with hearing impairment continue to demonstrate reading and writing skills that are significantly below that of individuals with normal hearing (Moores, 2000; Schirmer, 2000).

The degree to which language abilities are affected in children with hearing impairment depends on several factors which include the age of onset, the degree and the type of hearing impairment, the age of identification and amplification and the amount and type of habilitation (Lenneberg, 1967; McKay, Sinisterra, McKay, Gomez, & Lloreda, 1978; Quigley & Kretschmer, 1982; Yoshinaga-Itano, Sedey, Coulter & Mehl, 1998). The language impairment that is a consequence of hearing impairment may affect the development of all components of language -- phonology, syntax, semantics, pragmatics, reading and writing (Paul, 2001).

Intelligence

Standardized measures of intelligence quotient (IQ) contain a verbal section and a performance section. The combination of the scores from these two sections yields a full scale IQ. For individuals who are hearing impaired, the verbal score is almost always poorer than the performance score and it is also usually lower than the normal limit (Ross, Brackett, & Maxon, 1991). The verbal section of the intelligence test is affected by the language impairment that is a consequence of the hearing impairment. Therefore, the performance section of an IQ test provides a measure of intelligence that minimizes the effect of the language deficit. When the performance section of the IQ test is used in isolation, there is evidence to suggest that no major quantitative differences exist in the range of cognitive abilities between individuals who are deaf and individuals who have normal hearing (Braden, 1984; Braden, 1994; Levine, 1976; Zwiebel, 1991).

The relationship between problem solving and thinking

Problem solving can be considered in the context of thinking as a whole. Several hierarchies and frameworks of thinking have been proposed (Anderson, 1983; Gardner, 1983; Johnson-Laird, 1983; Perkins, 1981; Sternberg, 1980). Marzano et al. (1988) proposed a framework in which thinking has four dimensions: metacognition, critical/creative thinking, thinking processes and thinking skills. This framework, which has been diagrammed in Figure 1, illustrates that each successive dimension is embedded in the preceding dimension. In this framework metacognition is the awareness and control over one's own thinking, including commitment, attitudes, and attention. Critical thinking is reflective thinking that is focused on deciding what to believe or do. Creative thinking is the ability to form new combinations of ideas to fulfill a need. Thinking processes are macro-level operations that involve the combination of thinking skills in predictable sequences. Examples of thinking processes are problem solving, concept formation and composing. Thinking skills are specific or micro-level operations such as focusing, analyzing, integrating and evaluating. Thinking skills require the use of language and involve the application of knowledge. An individual cannot define a problem if she does not have

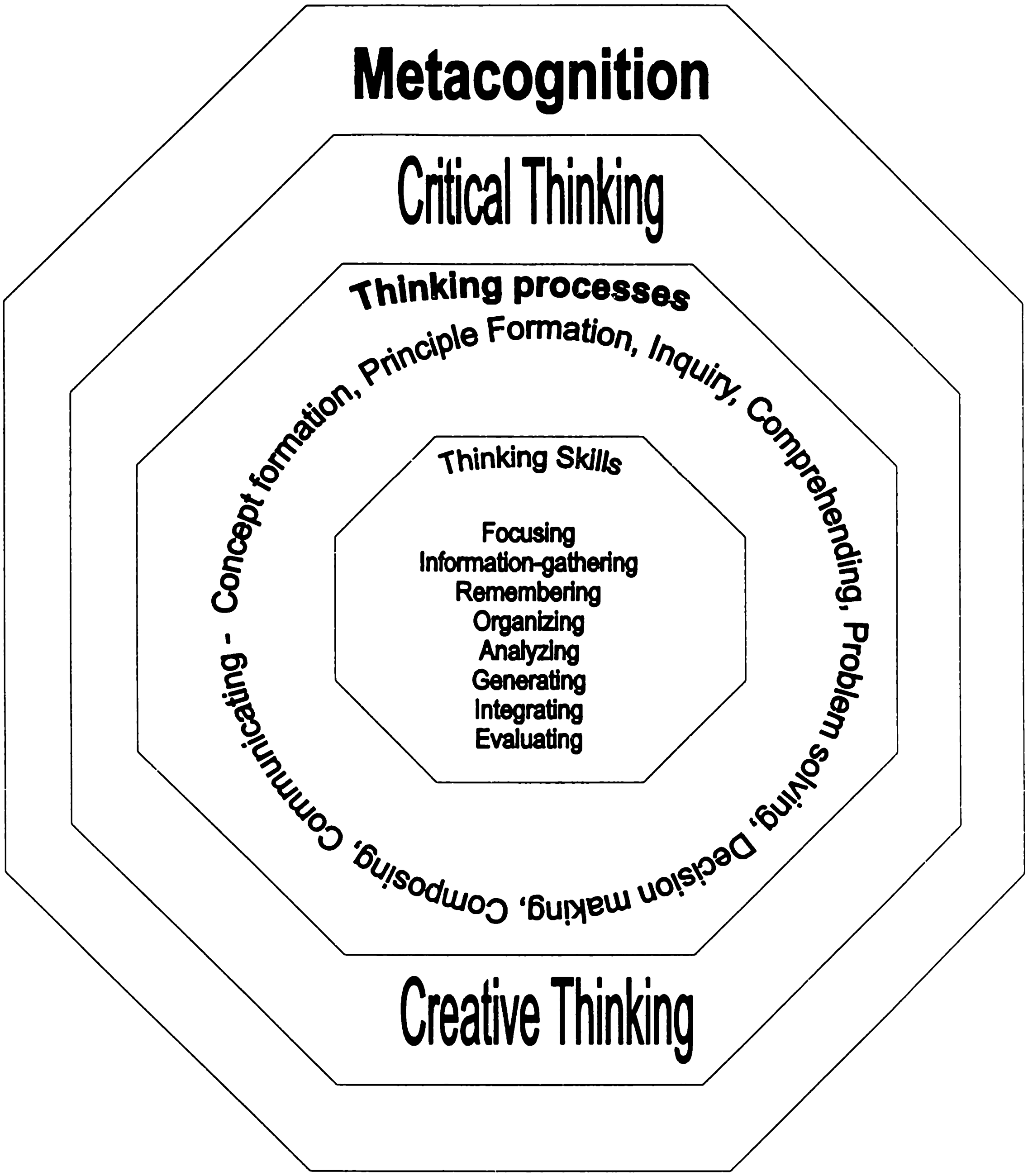

Figure 1. Framework for Developing Thinking
(adapted from Schirmer, 2001; based on Marzano, et al. 1988)

knowledge about the problem area or the language to label or describe the problem.

As there are frameworks for thinking, there have been several theories or models of problem solving proposed (Anderson, 1983; Newell & Simon, 1972; Van Dijk and Kintsch, 1983; Wickelgren, 1974). Polya (1957) advanced a model for understanding problem solving that is widely accepted by educators. The elements of this model are the abilities to (1) understand the problem, (2) devise a plan, (3) carry out the plan and, (4) evaluate the solution. When proceeding through this problem solving process, an individual must have a knowledge base to apply to the problem situation.

Problem solving skills in children with hearing impairment

Data from numerous investigators indicates that, on the average, children with hearing impairment are behind their hearing peers in academic achievements (Brackett & Maxon, 1986; Hine, 1970; Kodman, 1963; Paul & Young, 1975; Peckham, Sheridan, & Butler, 1972; Quigley & Thomure, 1968; Steer et al., 1961; Trybus & Karchmer, 1977). However, the body of literature about problem solving skills in children with hearing impairment is small. Several investigators have recognized that children with hearing impairment have difficulty functioning outside of the educational environment (Greenburg & Kusche, 1989; McGehee & Prendergrass, 1979; Martin, 1984; Rohr-Redding, 1985). It is their interpretation that these children have poor problem solving skills although this interpretation was made without the benefit of formal assessment. As a result, they undertook intervention strategies that demonstrated that children with hearing impairment proceed through the same stages of cognitive development. However, it is not known whether children with hearing impairment ever achieve the same level of problem solving ability as their hearing peers.

Luckner and McNeill (1994) compared the problem solving ability of children with hearing impairment to those of children with normal hearing on a formal test of logic. The task had considerable complexity. Because the task performed only required minimal use of language -- as is the case for the performance portion of an IQ test -- it was expected that the children with hearing impairment would perform similarly to their peers without hearing impairment. However, the results of this study revealed that the children with hearing impairment were delayed in their ability to solve problems when compared to their hearing peers. This finding suggests that problem solving abilities may be poorer for children with hearing impairment than for children with normal hearing when the complexity of the problem solving task is greater.

A different approach to studying problem solving was a single subject study by Fisher (2000), who was interested in the ability of the parent and the teacher to estimate the problem solving ability of a child with hearing impairment. Fisher found that on a language based problem solving test, the participant of the study did very poorly which was in marked contrast to the report of the teacher and the parent who said that the child's problem solving skills were good. This finding suggests that informal impressions of problem solving ability may not be accurate. The participant in this study did exhibit a moderate language delay. However, her scores were poorer on the language-based problem solving test than other children with comparable language impairments.

Vaden (2001) examined the language, vocabulary and problem solving test scores for 11 children with hearing impairment. She found that children with hearing impairment exhibited a wide range of abilities on a language-based test of problem solving. However, language and vocabulary test scores were found to be strong predictors of the differences in problem solving ability for these children.

Rationale and Research Questions

The ability to apply knowledge is a component of functioning and problem solving is one form of the application of knowledge. Luckner and McNeill (1994) found that children with hearing impairment performed significantly poorer than their hearing peers when performing a nonverbal problem solving task. The two groups were not equated on language since the task was non-linguistic; however, if language has a relationship to problem solving ability, a difference in language ability could explain the results of the study.

Vaden (2001) studied the problem solving ability of children with hearing impairment on a language based test of problem solving. On average, the children scored one standard deviation below normal; however, the children exhibited a wide range of performance from above normal to below normal on the test. The performance of these children on the language based test of problem solving could be predicted with great accuracy by their language and vocabulary scores. These results suggest that children with hearing impairment may have good problem solving skills if their language and vocabulary skills are also good.

The present study was conducted to evaluate the problem solving ability of children with hearing impairment. This was done using mathematical problems that are a part of the typical school curriculum. The performance of a group of children with hearing impairment was compared to the performance of a group of children with normal hearing. To address the issues raised in previous studies regarding the effect of language and intelligence on problem solving ability, the two groups were equated on performance intelligence and language ability. The two groups were asked to solve two types of mathematical problems: those that required computation alone and word problems that required the use of both language and mathematical computation. The primary research questions were: Does the ability of children with hearing impairment differ from the ability of children with normal hearing to solve mathematical problems that require computation alone? Does the ability of children with hearing impairment differ from the ability of children with normal hearing to solve mathematical word problems that require the use of both language and mathematical computation?

CHAPTER II

Review of the Literature

Consequences of Disability

Over the past three decades, investigators have recognized that descriptions of impairments alone have been inadequate for describing the effects of the impairment on the individual's overall ability to function (Granger, 1984; Nagi, 1965,1991; Pope & Tarlov, 1991). In 1980, the World Health Organization (WHO) published the first system for classifying and listing function and dysfunction associated with all types of impairments. Because the understanding of functioning has been evolving rapidly, the WHO has revised its initial model of the system three times in the last five years (ICIDH-2, 1997; ICIDH-2 Beta 1, 1999; ICIDH-2 Beta 2, 2000; ICF, 2001). Using the 1999 version of the WHO model, Fisher and Thelin (1999) described the numerous consequences of hearing impairment on functioning. This model has a classification hierarchy composed of dimensions, domains, facets and items. The consequences of hearing impairment have the possibility of affecting functioning in 5 of the 5 dimensions, 25 of the 39 domains, 232 of the 399 facets, and 793 of 1055 items. The model has been used as a conceptual framework for understanding the complexity of problems associated with hearing impairment. However, at present, it is too unwieldy to be used as a practical system for management of individuals with hearing impairment. The total consequences of hearing impairment will not be understood for many years. The process of understanding will begin with the study of topics selected because of their generality and significance.

Thinking and Problem Solving

A number of investigators have developed highly sophisticated theories and models of thinking (Anderson, 1983; Gardner, 1983; Johnson-Laird, 1983; Perkins, 1981; Sternberg, 1980). Marzano et al. (1988) have described problem solving in the context of a model of thinking. They have specified four dimensions of thinking: metacognition, critical/creative thinking, thinking processes and thinking skills. The relation of the dimensions to each other is illustrated in Figure 1. Problem solving is shown in the central core of this figure as a thinking process which depends on thinking skills (Schirmer, 2001). According to Krulick and Rudnick (1988), the problem solving process depends on a knowledge base, as well as what Marzano et al. (1988) have called thinking skills. Thus, problem solving is the use of knowledge and thinking.

Several authors have defined problem solving utilizing common features. Van Dijk and Kintsch (1983) state that problem solving occurs when a particular goal requires specific mental operations and steps. Wickelgren (1974) describes problem solving as the process used in attempting to reach a specific goal state. Anderson (1983) classifies any goal directed behavior, whether conscious or unconscious, as problem solving. Polya (1957) devised a model for describing the processes of problem solving. This model includes four steps:

1. **Understand the problem**. Restate the problem, identify the information that is needed to solve the problem, and determine what question is being asked.
2. **Devise a plan**. Choose a strategy by which a solution can be reached and predict what answer might be obtained.
3. **Carry out the plan**. Apply the strategy that has been chosen.
4. **Look back**. Reflect on choice of strategy and determine whether or not the solution is reasonable in light of the information given in the problem and whether or not the solution answers the question stated in the problem.

In utilizing this model for problem solving, the individual must see the problem, plan what to do, solve the problem and check the answer. Polya's model is used as a conceptual framework to understand problem solving and as an educational tool to teach problem solving skills.

Children with hearing impairment do not detect or understand the incidental language that goes on around them at home or at school (Ross et al., 1991). Because of sensory deprivation, children with hearing impairment have a smaller knowledge base. In addition, the language impairment that is a consequence of hearing impairment may be partially responsible for this diminished knowledge base. Although there is anecdotal information available regarding the diminished knowledge base of children with hearing impairments, there have been few formal studies of this topic. However, there is reason to believe that a diminished knowledge base places a child with hearing impairment at a disadvantage in problem solving situations.

Characteristics of Children with Hearing Impairment

Problem solving

Assessment of problem solving ability. Problem solving skills in children with hearing impairment have been primarily studied by educators and psychologists. One task that has been used in studying problem solving skills is the Tower of Hanoi. The Tower of Hanoi belongs to a class of tasks referred to as transformation problems that involve the attainment of a goal stated through the execution of a series of moves. It has well-defined initial and final states. It also has a set of legal operations which, when applied in the appropriate sequence, can transform the initial state into the final state. Newell and Simon (1972) state that these criteria conform to the definition of a well-defined problem.

Luckner and McNeill (1994) used the Tower of Hanoi to compare the problem solving skills of deaf and hard of hearing students to those of hearing students. The students who participated in this study ranged in age from 6 to 19 years and the students with hearing impairment had a mean unaided hearing loss of 89 dB HL. Performance on the Tower of Hanoi was judged based on the number of moves that it took the student to solve the problem. Both groups made incremental gains in their problem solving ability as they got older and the gap between the two groups narrowed. However, the deaf and hard of hearing students did significantly poorer than the hearing students at every age.

Luckner and McNeill (1994) suggest that the language delay that often exists for students who are deaf or hard of hearing may have been the cause for the discrepancy in the problem solving ability between the normal hearing students and the deaf/hard of hearing students. However, because the Tower of Hanoi is a non-linguistic task, the results of this study may indicate that there is a deficit or at the least a delay in the problem solving abilities of the deaf and hard of hearing students that may be unrelated to their language impairment.

Wansart (1990) also used the Tower of Hanoi to describe the problem solving behaviors in children. He compared the problem solving abilities of children with learning disabilities to those of normally developing children. The normally developing children reached more sophisticated levels of strategy use in solving the puzzle. However, the analysis of how learning proceeded while solving the puzzle indicates that the children with learning disabilities appear to be similar to the normally developing children. This may suggest a difference in the rate of learning for the two groups, but not a difference in the sequence of learning for the two groups.

The Test of Problem Solving - Elementary, Revised (TOPS-R)(Zachman, Huisingh, Barrett, Orman, & LoGiudice, 1994) is a standardized test used in the field of speech and language assessment. The TOPS-R is described as a diagnostic test of problem solving and critical thinking. It was designed to assess a student's language based critical thinking skills. The questions focus on a broad range of critical thinking skills that include analyzing, clarifying, generating solutions, evaluating and affective thinking. The TOPS-R relies heavily on the ability to understand and use language. Vaden (2001) utilized the TOPS-R to examine the relationship between problem solving ability and language ability in eleven children with hearing impairment. She found that problem solving ability that involved the use of language (as measured by the TOPS-R) was significantly related to expressive language, receptive language and receptive vocabulary in children with hearing impairment. Although the children in the Vaden study exhibited a wide range of individual differences in abilities, on the average the children in this study performed more poorly than typically developing children on the language, vocabulary and problem solving tests.

Poor problem solving skills have been identified as a barrier in school-to-community transition for both deaf and hard of hearing youth (Freeburg, Sendelbaugh, & Bullis 1991). Hearing impaired adults, parents of hearing impaired youth, educators of hearing impaired secondary-level students and rehabilitation specialists were asked to identify major problems associated with the successful transition from school to employment and independent living for youth who were deaf and hard of hearing. These individuals were considered to be expert informants who were familiar with the transition process. The informants in this study identified poor problem solving skills as limiting a deaf or hard of hearing youth from making appropriate decisions.

Fisher (2000) described the problem solving ability of one child with hearing impairment through the use of observation, interviewing, artifact collection and standardized testing. Each of these data collection techniques contributed unique information to the description of problems solving for this child. The teacher and the parent defined problem solving in different ways depending on the context. The child did exhibit difficulty with problem solving in her day to day classroom activities and she utilized several different strategies for coping with or approaching problem solving (e.g., giving up, impulsive answering, needing teacher assistance in breaking the problem into parts). However, her abilities varied from one context to another. A comprehensive language test revealed that she had a moderate language delay. In contrast, a language based, standardized measure of problem solving, indicated that her problem solving skills were much poorer in comparison to other children with comparable amounts of language delay. Fisher suggested that no one single measure may be adequate in describing the problem solving ability in a child with hearing impairment.

Intervention for the improvement of problem solving skills. In the studies discussed previously, investigators have focused on the assessment of problem solving skills in children with hearing impairment. However, improvements in the problem solving skills of children with hearing impairment have been documented as a result of a variety of intervention programs (McGehee & Prendergrass, 1979; Martin, 1984; Rohr-Redding, 1985). Social problem solving strategies were implemented with a group of 12 and 13-year-old children who were hearing impaired (McGehee & Prendergrass, 1979). These students were all enrolled in a total communication program. A strategy of utilizing classroom meetings in which the teacher assumed the role of facilitator as opposed to leader was implemented. The students were presented with an actual problem situation from their classroom and were led through the process of identifying the problem, formulating a plan of action, and determining the results. It was determined that the use of classroom meetings as a part of the curriculum for these students with hearing impairment had high potential for teaching social problem solving skills.

Martin (1984) and Rohr-Redding (1985) utilized a program of cognitive education called Instrumental Enrichment (IE) developed by Feuerstein (1978, 1980) with a group of adolescents with hearing impairment. Feuerstein's IE program is a series of mediated learning experiences that incorporate a metacognition approach in which the students are given repeated opportunities to reflect on their own thinking processes. At the end of a two year period, students with hearing impairment who had participated in the systematic cognitive education program were compared to a control group of students with hearing impairment. The following improvements specifically related to problem solving were noted for the experimental group: (a) consistent improvement in a problem solving interview in regard to practicality, completeness, organization, and systematic planning of the problem solutions (Martin, 1984); (b) significant improvement in nonverbal logical thinking skills (Martin, 1984); (c) more frequently expected themselves to be precise, were able to describe several strategies to solve a problem, and defended their opinions on the basis of logical evidence, according to a teacher observation checklist (Martin, 1984); (d) approached problem solving situations in the curriculum more systematically by analyzing component parts of a problem and with less impulsivity (Rohr-Redding, 1985); (e) improved their understanding of the reasons behind required assignments which increased their motivation to solve problems in English and mathematics (Rohr-Redding, 1985); (f) more frequently able to describe several strategies to solve a problem and could defend their opinions on the basis of logical evidence (Rohr-Redding, 1985).

There is evidence that suggests that deaf children and hearing children utilize similar strategies and proceed through the same stages of cognitive development even in difficult problem solving tasks (Greenburg & Kusche, 1989). However, the development of hearing children is more rapid, and it is not clear whether or not deaf children ever achieve the same level of understanding (Greenburg & Kusche, 1989; Luckner & McNeill, 1994). Furthermore, the performance by deaf children on problem solving tasks has been found to be related to exposure to language and correct verbal reasoning tends to accompany accurate performance (Meadow, 1980).

Cognition

Recent research has demonstrated that language mediates cognitive development in children with hearing impairment just as it does in children with normal hearing (Paul, 2001). Therefore, if the language development of a child is seriously delayed by hearing impairment then it is expected that cognition will be affected as a result (Quigley & Paul, 1984). However, research with individuals who are deaf indicates that there are no major qualitative differences between the range of their cognitive abilities and that of their hearing peers (Braden, 1984; Levine, 1976; Zwiebel, 1991).

A meta-analysis of the research literature on the effect of deafness on intelligence revealed that the IQ distribution of deaf individuals was nearly identical to that of hearing individuals (Braden, 1994). In the studies reviewed in this analysis, deaf individuals scored lower on verbal intelligence tests; however, on tests of nonverbal intelligence, no significant differences were evident between deaf individuals and hearing individuals. This pattern on IQ tests has also been reported for children with a range of hearing impairments (Ross et al., 1991).

There is general agreement that for children who are hearing impaired and who exhibit a discrepancy between the verbal and performance portions of an IQ test, that the use of the performance score only is a better representation of potential. However, an examination of the pattern of verbal and performance subtest scores may be useful in determining additional learning problems in children with hearing impairment (Ross et al., 1991). Figure 2 illustrates the patterns of verbal and performance IQ test scores for different diagnostic categories. The pattern for children with hearing impairment is identical to that of children with language learning impairment but different from that of children with learning disabilities.

Effects of hearing impairment on communication development

A variety of factors influence the development of communication in children with hearing impairment. These factors include the age of onset, the degree and the type of hearing impairment, the age of identification and

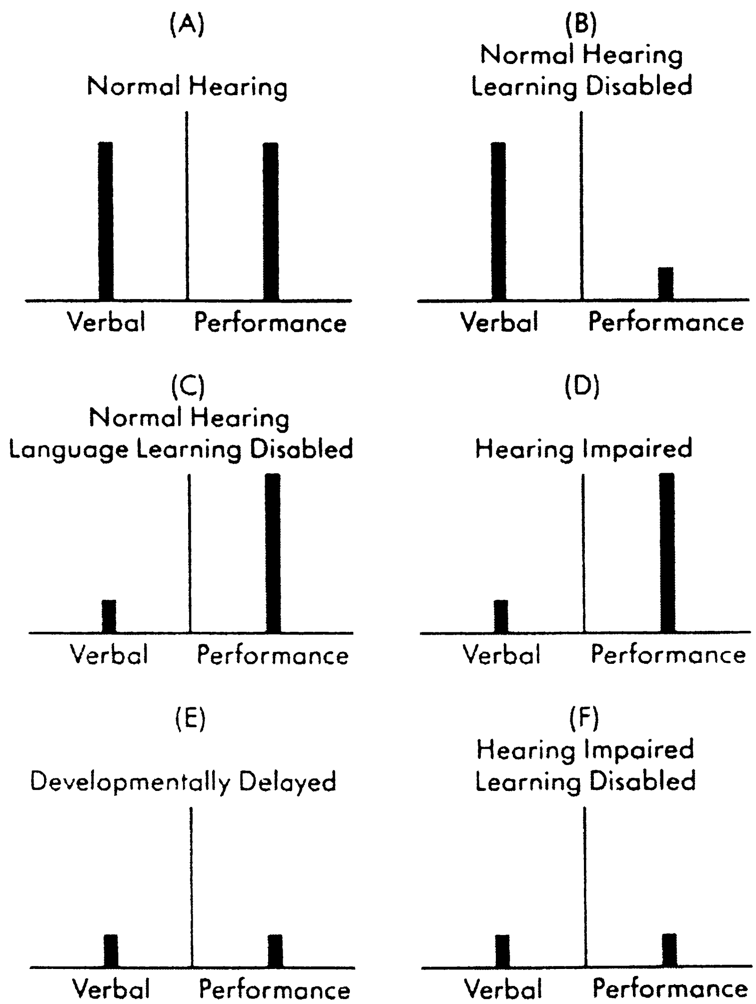

Figure 2. Patterns of verbal and performance test scores in differential diagnosis (Ross, et al., 1991)(Included by permission of the publisher)

amplification and the amount and type of habilitation (Quigley & Kretschmer, 1982). Also, the existence of other handicapping conditions can contribute to the overall effects of the hearing impairment (Diefendorf, 1996). The age at which the hearing impairment occurs is important because of the critical window of time that a child has to learn language (Lenneberg, 1967; McKay et al., 1978; Yoshinaga-Itano et al., 1998). If a child is born with a hearing impairment, it is expected that speech and language development will be more affected than if a child acquires a hearing impairment after speech and language development has begun. Hearing impairments can range in degree from mild to profound. Children with more severe degrees of hearing impairment are considered to be at risk for greater speech and language delays. Early identification and amplification are known to have strong, positive effects on language learning (Quigley & Kretschmer, 1982; Yoshinaga-Itano et al., 1998). The coexistence of other handicapping conditions such as physical disabilities, cognitive impairments and visual impairments can exaggerate the effects of the hearing impairment (Diefendorf, 1996).

Language

Paul (2001) provides a summary of the effects of hearing impairment on language development. She categorizes and summarizes these effects in the following subgroups: cognition and language, phonology, syntax, semantics, pragmatics and written language.

Phonology. Children with hearing impairment use at least partially rule-governed phonological systems (Dodd, 1976). Their phonological skills are like those of younger, normal hearing children. Initial and final consonant deletions are frequent.

One difference in the phonological development of children with hearing impairment is that vowel sounds are sometimes distorted or neutralized. Also, prosodic features of speech are affected including poor respiratory control, poor coordination of breathing with syntactic phrasing, inappropriate use of duration to create stress patterns, reduced speech rate, slow articulatory transitions with frequent pauses, and distorted resonance (Dunn & Newton, 1986). Decreased intelligibility of speech is also seen as utterances become more linguistically complex (Radziewicz & Antonellis, 1993).

Syntax. Although grammatical acquisition can be very delayed in children with hearing impairment, it does follow the same general order as in normal development. Delays may be seen in receptive, expressive, oral and written language (Quigley, Power, & Steinkamp, 1977). Especially difficult syntactical structures for children with hearing impairment are inflectional morphemes, adverbs, prepositions, quantifiers, and indefinite pronouns (Paul, 2001).

Some children with hearing impairment appear to generate syntactic structures that are not seen in normal development (Quigley, Smith, & Wilbur, 1974). These syntactic rules appear to be combinations of those in English and the approximations of English grammar that the children with hearing impairment were making.

Semantics. Children with hearing impairment who are learning oral language exhibit a range of semantic relations from an early age just as normal children do. However, their acquisition of these semantic relations occurs at a slower rate (Curtiss, Prutting, & Lowell, 1979). Delays in verbal semantic ability generally exist throughout the developmental period for children with hearing impairment who are learning oral language (Radziewicz & Antonellis, 1993). These children show difficulty in using concept words, figurative language and multiple meanings (Nelson, 1993).

Pragmatics. In general, the rate and pattern of pragmatic development in children with hearing impairment is similar to children with normal hearing. However, some gaps have been identified. These gaps exist in the areas of conversational initiation and ability to respond to partners' initiations (McKirdy & Blank, 1982), using rules for entering and continuing conversations (Weiss, 1986), and in narrative skills (Yoshinaga-Itano & Snyder, 1985). It has been concluded that the use of language for communication (pragmatics) is not the major problem for children with hearing impairment but rather difficulty in acquiring the conventional verbal forms of communication (Lahey, 1988).

Written Language. The acquisition of literacy skills is heavily dependent upon language (Paul, 2001). Therefore, reading and writing pose particular problems for children with hearing impairment. The average reading comprehension level for adolescents with hearing impairment has been reported at the 3rd to 4th grade level (King & Quigley, 1985; Trybus & Karchmer, 1977).

Language and problem solving

The difference in the performance between deaf and hearing subjects on various problem solving tasks has been attributed to the influence of language on thought (Luckner & McNeill, 1994; Oleron, 1977; Pettifor, 1968). However, this conclusion has been drawn without language actually being used in the experimental setting (Tellevik, 1981).

Tellevik (1981) suggested that sign language may be accepted as equally effective for logical and reasoning functions as spoken language at least when problem solving is the task. He paired students who were deaf (hearing impairment of 90 dB or more in the better ear at 500-2000 Hz) with students who had normal hearing on a problem solving task. Each participant was given a set of forms of different shapes and colors and placed face to face to their partner with a screen on the table to prevent them from seeing the material of the other. The goal of the task was for the deaf student and the hearing student to form an identical visual pattern with the materials that they were given. The instructions were given to the deaf students in sign language and to the hearing students in spoken language. The experiment consisted of four tasks. On all but one of the tasks, no significant difference was found between the two groups in the time that it took to solve the problem. Therefore, the hypothesis that a difference exists between deaf and hearing peers in performance on problem solving tasks was not confirmed by this study.

Language Impairment

Paul (2001) considers a child to have a language impairment (LI) if they have "a significant deficit in learning to talk, understand, or use any aspect of language appropriately, relative to both environmental and norm-referenced expectations for children of similar developmental level" (p. 3). A child with a language deficit is considered to have a specific language impairment when language test scores of 1.25 standard deviations below the mean are obtained in the presence of a performance IQ (PIQ) of 85 or higher (Leonard, 1998). This combination of language test scores and PIQ indicates that a child's language performance is significantly lower than intellectual performance on nonverbal tasks (Owens, 1999). In addition to the language deficit in the presence of normal nonverbal IQ, the diagnosis of SLI requires that a child have normal hearing, normal oral structures, developmentally appropriate motor function, no neurological dysfunction (e.g., seizure disorders, cerebral palsy, brain lesions), and no symptoms of impaired reciprocal social interactions or restriction of physical activity (Leonard, 1998).

The language characteristics of children with LI may manifest themselves in any combination of the language domains (e. g., form, content, or use). Furthermore, language problems may be classified as expressive and/or receptive in nature (Owens, 1999). Although, language difficulties may be noted in many different aspects of language, language form (i.e., syntax, phonology, morphology) seems to be affected more than either content or use (Aram, 1991; Johnston & Kamhi, 1984; Nelson, 1993). Additionally, Leonard (1998) noted that expressive language deficits are more common in children than are receptive or combination language deficits.

CHAPTER III

Methods

Participants

The participants in the present study were two groups of school-aged children with 13 in each group. The experimental group was composed of children with hearing impairment (HI Group). The control group was composed of children with normal hearing (NH Group). The two groups were matched on sex, grade level, intelligence and language ability. The descriptive statistics for each qualification parameter for both groups are presented in Table 1.

All participants were from monolingual homes in which English was the only language spoken. Participants were selected who had no known physical or mental disabilities other than those considered in the present experiment. The participants were enrolled in the 4th, 5th or 6th grade in a regular school.

Intelligence

All participants in this study were required to have normal nonverbal or performance intelligence as measured by the Wechsler Intelligence Scale for Children – III (WISC-III)(Wechsler, 1991). The WISC-III is commonly used in school standardized testing as an evaluation instrument for intelligence. Normal performance intelligence was defined as an intelligence quotient (IQ) score within the low average to above average range. Performance IQ (PIQ) scores were obtained either from a participant's academic record or from the administration of

Table 1: Summary statistics for participant qualification tests.

	HI Group	NH Group	HI – NH Difference
Sex	7 males; 6 females	7 males; 6 females	
Grade			
4th	5	7	
5th	4	4	
6th	4	2	
Mean Age ± SD (Range)	10.38 ± 1.12 (9-12)	10.15 ± .80 (9-11)	0.23 t(24) = 0.60, p = 0.55
Mean LQ ± SD (Range)	84.69 ± 18.9 (50-112)	88.46 ± 17.98 (55-115)	-3.77 t(24) = -0.52, p = 0.60
Mean PIQ ± SD (Range)	102.77 ± 11.90 (84-130)	98.54 ± 6.57 (83-107)	4.23 t(24) = 1.12, p = 0.27

the WISC-III by a licensed psychological examiner as a part of this study. The mean PIQ scores were not significantly different for the two groups ($t = 1.12$; $p = 0.27$).

Language

All participants were evaluated for language ability using the Clinical Evaluation of Language Fundamentals (CELF-3) (Semel, Wiig, & Secord, 1995) which is a test of receptive and expressive language. The CELF-3 is one of the most commonly used tests by speech language pathologists in school settings. Language was considered to be impaired if the standard score was more than 1.25 standard deviations below the mean (standard score ≤ 81). Language quotient (LQ) scores were obtained either from a participant's academic record or from the administration of the CELF-3. If the student had not been given the CELF-3 within 9 months prior to participation in the study, a speech-language pathologist, a graduate student in speech-language pathology or the investigator administered the test. Five of the 13 participants in each group were considered to have a language impairment based on the LQ score while the other eight participants in each group had normal language ability. The mean LQ scores were not significantly different for the two groups ($t = -0.52$; $p = 0.61$).

Hearing

In the HI Group, the degree of hearing impairment was determined by using the average of the pure tone air conduction thresholds at 500, 1000, and

2000 Hz. Participants in the HI Group had hearing impairments that ranged in degree from moderate to severe in the better ear. In addition, the following descriptions applied to each participant in the HI Group:

1. Hearing impairment was either known or assumed to be a congenital impairment;
2. Amplification was worn on a regular basis as reported by the participant and/or the parent;
3. Oral communication was the primary mode of communication; and
4. Education was provided in a regular school rather than a special school for the deaf.

The participants in the NH Group were given a pure tone hearing screening (500, 1000, 2000 and 4000 at 20 dB HL). Each participant passed the hearing screening at all frequencies in both ears.

Problem Solving Materials and Procedures

The problem solving test used for the present study was constructed of problems that were taken from a math series, Math Advantage (Burton et al., 1999) published by Harcourt Brace. Math Advantage is based on Polya's (1957) approach to problem solving. The key words -- understand, plan, solve and look back -- are used in every lesson as a method to teach the thinking process to students. Each textbook in this series for kindergarten through 8th grade is accompanied by a separate problem solving workbook.

In the construction of the test for this study, word problems were selected from each of the problem solving workbooks for $2^{nd} - 8^{th}$ grade. Problems were selected from the 2^{nd} - 8^{th} grade workbooks to develop a problem solving test with a level of difficulty below and above the grade level of each of the participants in this study ($4^{th} - 6^{th}$ grade). For each workbook, problems were chosen from the beginning, the middle and the end to represent the information covered throughout each grade level.

The problem solving test contained two types of math problems that are shown in Table 2. Word problems are shown in the middle column. Computation problems are shown in the right hand column. Each computation problem was constructed to match a word problem in the mathematical computations to be performed and in the computational difficulty. Each part of the test contained 21 problems (3 from each grade level) for a total of 42 problems. Within each of the two parts, problems were arranged in grade level order. That is, for both the computation and the word problem tests, the 2^{nd} grade problems were at the beginning of the test with each successive grade level following up to the 8^{th} grade problems.

The word problems contained in the test were analyzed for readability using the Flesch-Kincaid Grade Level Formula (Flesch, 1948). Reading levels for the word problems from each grade level are listed in Table 3. The readability for all sets of problems was either at or below grade level.

The experimental procedures and instructions that were adopted for the administration of the mathematical test items were based on the observation of

Table 2. Problem solving tests

Grade Level	Word Problem	Computation Problem
2nd	Sue saw 8 birds. Then 2 birds flew away. How many birds are left?	7 – 1
	How many books did Sue and Ed read the 1st week? **Graph needed**	14 + 15
	There are 827 adults at the fair. There are 441 children. How many more adults than children are there?	646 – 372
3rd	There are 5 bird's eggs in one nest. In another nest, there are 4 eggs. How many are in both nests?	4 + 3
	Darius had the money below. He spent 60 cents on juice. How much money did he have left? **Graph needed**	25 + 25 + 10 + 10 + 10 + 5 + 5 + 5 - 60
	Six students in Mr. Han's class each got 12 stars for good scores. How many stars did they get in all?	5 x 12
4th	A classroom has 6 rows of students with 5 students in each row. What is the total number of students in the classroom?	5 x 7
	Nora has 373 books to put in boxes. Each box will hold 8 books. How many boxes does she need?	365 / 8

Table 2 continued.

Grade Level	Word Problem	Computation Problem
5^{th}	Jayne has $34 when she gets home from the store. She spent $18 at the store. How much money did she have when she went to the store?	48 + 23
	Rhonda calls her brother in New York. She pays $0.25 per minute. If she stays on the phone for 14 minutes, how much is she charged?	25 x 0.14
	The average height between floors in the Penn Building is 10 ½ feet. If the total height is 147 feet, how many floors are there in the building?	184 / 11.5
6^{th}	In the auditorium, there are 32 rows of seats. Each row has 24 chairs. How many students can the auditorium seat?	31 x 25
	Paul has 1,716 eggs to put into cartons. Each carton holds 12 eggs. How many cartons does Paul need to store all of the eggs?	1815 / 11
	Donald bought 63 pens. He paid $2 each for the pens, not including tax. What is the total price Donald paid for the pens, not including tax?	52 x 4

Table 2 continued.

Grade Level	Word Problem	Computation Problem
7th	Michael went shopping with $32.50. He bought a book for $15.95, including tax. How much money did he have after buying the book?	44.51 – 26.86
	Gayle earned $8.25 per hour and worked 37 hours. How much did she earn?	9.26 x 36
	The local movie theater recorded how many tickets were sold each week for 4 weeks. The totals for the weeks were 987, 1457, 2081, and 1032. How many people attended the movies during the last 4 weeks?	876 + 1568 + 2172 + 2141
8th	Roger made $86.70 for working 15 hours. What is his hourly rate?	74.88 / 16
	Lois went shopping for a computer. The one she wanted was marked $1899. The salesperson offered it to her for only $1099. What percent of the original price was the sale price?	2189 / 3799
	Juan purchased 23 CDs on sale for $7.25 each, not including tax. How much did Larry pay the cashier for all 23 CDs, not including tax?	8.25 x 24

Word problems from *MATH ADVANTAGE, Problem Solving with Reading Strategies*, Teacher's Edition (2nd, 3rd, 4th, 5th, 6th, 7th and 8th grades).

Table 3. Flesch-Kincaid Grade Levels for Word Problems in Experimental Problem Solving Test

Grade Level of Word Problems	Flesch-Kincaid Grade Level
2^{nd}	1.8
3^{rd}	1.4
4^{th}	3.6
5^{th}	3.2
6^{th}	4.2
7^{th}	6.8
8^{th}	6.1

participant performance and on data obtained in a pilot study (Appendix A). Participants were allowed to have as much time as they needed for each part of the test. Participants were not allowed to use calculators while completing the test. The investigator had the participants read the first two word problems aloud. After this point, the participants were allowed to read the problems without assistance but were instructed to ask for help if there was a word that was unknown. Each participant was encouraged to show his/her work for each problem. All questions had a single answer and were scored as either correct or incorrect.

Vocabulary Assessment

After it was determined that a child would qualify for participation in this study, the Peabody Picture Vocabulary Test – Third Edition (PPVT-III)(Dunn & Dunn, 1997) was also administered. The PPVT-III is a test of receptive vocabulary and is used to assess receptive semantic ability. Children with hearing impairment typically receive PIQ testing and language testing in a school setting, however, vocabulary testing is not routinely performed. Vaden (2001) found that language based problem solving ability could be predicted by using receptive vocabulary, receptive language and expressive language scores. For this reason, the PPVT-III was administered, not as a means of qualifying participants, but as an additional test that might be related to the problem solving ability of the children with hearing impairment in the present study. The PPVT-

III was administered by the investigator or a graduate student in speech language pathology.

Experimental Test Protocol

Participant selection

Parents of potential participants were contacted by professional acquaintances (speech-language pathologists, teachers and audiologists) of the investigator. If the parent agreed to be contacted, the investigator was given the name of the parent. Prior to being selected to participate in this study, each parent/guardian completed a questionnaire (Appendix B) to ensure that the potential participant met the qualifications for the study. The parent/guardian also completed an informed consent form giving permission for their child to participate in the study (Appendix C). Each child gave assent to participate in the study (Appendix D).

Testing sessions

Each child in this study participated in a single test session that ranged in time from 60 to 180 minutes. In all testing sessions, snacks and frequent breaks were given to minimize participant fatigue. The testing sessions were divided into three sections: problem solving tests and vocabulary test, LQ test and PIQ test. The order of presentation of the sections was counterbalanced among participants. In addition, the order of the presentation of the computational test and the word problem test was counterbalanced among participants. The PPVT-

III and the problem solving tests were administered to all of the participants as a part of the study. The PPVT-III took approximately 15 minutes to administer. The problem solving tests took approximately 45 minutes for the participants to complete. For the participants who needed to complete an LQ test and/or a PIQ test, it took approximately 60 minutes for each of these tests to be administered.

Data Analysis

An independent samples t-test was used to determine if there were differences among the groups on the qualification criteria of PIQ and LQ. One sample t-tests were used to determine if the group means for PIQ and LQ were significantly different from the test means of 100. A multivariate analysis of variance (MANOVA) was used to determine differences between the performance of the HI Group and the NH Group on the computational problems and the word problems. Planned post hoc comparisons were made using Pearson product moment correlation coefficients and multiple linear regression.

CHAPTER IV

Results

Descriptive Measures of the HI and NH Groups

Qualification tests (PIQ and LQ) were used to equate the HI and NH Groups in the present study. These tests also provide a description of the level of functioning of the two groups. The mean PIQ was 103 for the HI Group and 99 for the NH Group. Neither of the mean scores for PIQ was significantly different from the mean standard score of 100 [$t(12) = .839$, $p = .418$ for the HI Group and $t(12) = -.803$, $p = .438$ for the NH Group]. The criterion level for significance for this test and subsequent tests was $p = .05$. For language, the mean LQ was 85 for the HI Group and 88 for the NH Group. Although these scores are within normal limits using accepted clinical criteria, they are significantly lower than the mean standard score of 100 for the HI Group [$t(12) = -2.920$, $p = .013$] and for the NH Group [$t(12) = -2.314$, $p = .039$].

The mean vocabulary test score was 86 for the HI Group and 94 for the NH Group. These scores are not outside the normal range using accepted clinical criteria, however they are significantly lower than the mean standard score of 100 for the HI Group [$t(12) = -2.198$, $p = .048$] and for the NH Group [$t(12) = -2.174$, $p = .050$]. Thus, PIQ for the HI Group and NH Groups is not different from normal; however, their scores are significantly lower than the mean standard score for LQ and vocabulary.

Problem Solving Abilities

A summary of the data for the problem solving tasks for the HI and NH Groups is shown in Table 4. Individual data for each participant is in Appendix E. The number of correct answers ranged from 2/21 to 19/21, which indicates that there were no end effects due to either total failure to perform the task or perfect performance.

The difference in performance for the HI and NH Groups was analyzed using a MANOVA that had one factor (group) with two levels (HI or NH) and two dependent variables (computation and word problems). The computation and word scores for the HI and NH Groups were not significantly different [F (2, 23) = 0.497, $p = .615$]. These results indicate that problem solving ability is not different for these groups.

Correlations Among Problem Solving Test Scores and Descriptive Measures

Relation of degree of hearing impairment to other measures of participant performance

The attempt was made to determine if there was a relationship between degree of hearing impairment and any of the other measures of participant performance in the present study. Pearson product-moment correlation coefficients were calculated between measures of participant performance and degree of hearing impairment. Hearing loss was not significantly related to any of these measures

Table 4: Summary data for the HI Group and the NH Group on the computational and word problems tests.

	COMP	WORD
HI Mean ± SD (Range)	9.92 ± 4.42 (5-18)	8.54 ± 5.29 (2-19)
NH Mean ± SD (Range)	8.54 ± 2.93 (4-14)	7.46 ± 4.03 (3-17)

Note: The scores are reported as number of items correct with a possible maximum score of 21.

hearing impairment vs. computation problems (r = .302)

hearing impairment vs. word problems (r = .102)

hearing impairment vs. PIQ (r = -.137)

hearing impairment vs. LQ (r=-.170)

hearing impairment vs. vocabulary (r = -.072)

It is possible, however, that these correlations were affected by range restriction. The full range of audibility is approximately 120 dB, whereas, the hearing impairments in this study spanned only about one-third of that range.

Relations between computation and word problem test scores

The computation problem test and the word problem test were designed to be equivalent in respect to mathematical operations to be performed and in computational difficulty. However, the word problem test had the added factor of language. The correlations between the computation problem test score and the word problem test score were significant and strong for both the HI Group (r = .889) and the NH Group (r = .759). These correlations indicate that performance on the computation problem test and the word problem test were related despite the added component of language in the word problems.

The scores on the computation problem test were higher than the scores on the word problem test for both groups. In the HI Group, the score on the computation problem test was 16% higher, and in the NH Group, it was 14% higher. When the difference between the computation problem test and the word problem test was considered independently for each group, the difference was not significant. However, when the results for the two groups were pooled, the computation problem test scores were significantly better than the word problem test scores [t(25) = 2.524, p = .018].

Correlation of Problem Solving Ability and Other Descriptive Measures

Pair-wise comparisons were made to identify relationships between the problem solving task scores and the descriptive measures of participant function (PIQ, LQ and vocabulary). The correlations are shown in Table 5. For the HI Group, all three descriptive measures were significantly related to the scores on the word problem test. However, for the NH Group only vocabulary and LQ were significantly related to the scores on the word problem test. For the computation problem test, only vocabulary was significantly related to performance in the HI Group. In the NH Group, only language was significantly related to performance on the computation problem test.

A multiple regression analysis was performed to determine the ability to predict problem solving ability using PIQ, LQ and vocabulary. The advantage of the multiple regression over pair-wise comparisons is that the contribution of all of the factors are considered simultaneously. The PIQ, the LQ and the vocabulary scores were grouped and labeled as the predictive tests. It was found that the PIQ score did not contribute significantly to the predictions and, therefore, it was dropped as one of the predictive tests. When the LQ and vocabulary scores were used as the predictors in the regression analysis for both parts of the problem solving test, the analysis yielded the following equations:

Table 5: Correlations between problem solving task scores and descriptive measures of the participants in the HI and NH groups.

GROUP	Problem Solving Task	Vocabulary	LQ	PIQ
HI	COMP	.677*	.373	.438
	WORD	.882*	.651*	.655*
NH	COMP	.340	.734*	.144
	WORD	.628*	.674*	.295

* = significant correlations after application of sequential Bonferroni corrections.

HI Group

predicted computation problem score = 2.653 + .214 (vocab) - .131 (LQ)

[r = .749]

predicted word problem score = -6.726 + .240 (vocab) - .062 (LQ)

[r = .892]

NH Group

predicted computation problem score = 3.606 -.095 (vocab) + .157 (LQ)

[r = .771]

predicted word problem score = -13.296 + .124 (vocab) + .103 (LQ)

[r = .710]

The relationship between the performance on the computation test and LQ and vocabulary are similar in both groups. In the HI Group, LQ and vocabulary account for 47% of the variability in the performance on the computation test. In the NH Group, language and vocabulary account for 51% of the variability in the performance on the computation test.

Based on adjusted r^2 scores, the performance on the word problem test is related more strongly to language and vocabulary in the HI Group than in the NH Group. For the HI Group, language and vocabulary account for 75% of the variability in the performance on the word problem test. In the NH Group, language and vocabulary account for only 40% of the variability in the performance on the word problem test.

CHAPTER V

Discussion and Conclusions

Problem Solving Ability in Children with Hearing Impairment

When the investigator in the present study served as an educational consultant to the Arkansas public schools, there was a concern that PIQ and LQ scores were being used to determine whether or not children with hearing impairment needed support services in order to function in the regular classroom. Children with hearing impairment were achieving scores within the normal limits on comprehensive language assessments as well as on the performance section of an IQ test. However, when these children with "normal" language and PIQ were asked to function in the regular classroom without the support of the speech language pathologist or other support staff, they were not able to do so successfully. As a result, there was the concern that PIQ and LQ may not adequately represent the level of functioning of children with hearing impairment.

In an effort to understand the relationship between formal test scores (intelligence and language) and the aspects of functioning that might be expected in an educational setting, the investigator in the present study used the WHO (2001) model of functioning and disability (the ICF). In the ICF, PIQ and LQ scores would be descriptions of an individual at the impairment level. In addition, the ICF provides a model for describing functioning beyond the impairment level by providing a way to describe the consequences of impairments on the daily activities and functioning of an individual. The information that can be obtained by using the ICF for the description of the consequences of hearing impairment and language impairment is extensive and complex. In examining the WHO model, it is evident that there are a large number of potential consequences of a hearing impairment (Fisher & Thelin, 1999). Based on the enormity of possible consequences of hearing impairment and clinical experience, the investigator in this study concluded that the measure of LQ and PIQ (impairment level) may not be enough to understand how a child functions in the classroom (activity and participation levels).

Problem solving ability is a necessary skill for educational achievement that is specifically listed in the WHO model as an activity that has the potential of being impacted by a disability. It is also a topic that classroom teachers and speech language pathologists have discussed with the investigator as an area of functional inadequacy for a significant percentage of children with hearing impairment. In previous studies on problem solving, children with hearing impairment have not performed as well as children with normal hearing. One explanation offered by the investigators of those studies is that problem solving ability may be affected by language ability for tasks that require the explicit use of language (Vaden 2001) and a task that is considered to be nonverbal (Luckner & McNeill, 1994). However, these investigators did not speculate about whether the performance on problem solving tasks would be expected to be worse, better or equal to language ability for children with hearing impairment.

When children with hearing impairment and with normal hearing were matched on PIQ, LQ, sex and grade level, it was found that there were no significant differences in their ability to solve mathematical problems that involve the use of language or mathematical problems that involve only computation. It was also determined that among children with a moderate to severe degree of hearing impairment, there is no relationship between degree of hearing loss and problem solving ability. The implication of these findings is that the deficits noted in problem solving ability by the present investigator, previous investigators, classroom teachers and speech-language pathologists are closely related to language ability and not degree of hearing loss.

The tasks in the present study were constructed to evaluate problem solving. They were modeled on a widely used mathematics curriculum for elementary school children, which is based on Polya's (1957) model of problem solving. The results of this study indicate that children with hearing impairment can perform this type of activity commensurate with their language abilities. This finding has two important implications. First, the knowledge of ability may serve as a useful predictor of function. One problem with the use of the ICF is that, although it provides a comprehensive model of functioning and disability, it would be difficult to measure all aspects of function in order to adequately describe functioning for an individual. The results of the present study provide preliminary evidence to support the idea that if language is age appropriate, then there is the likelihood that problem solving ability will be age appropriate as well. The second implication is that children with hearing impairment can solve problems that require the use of the principles in Polya's model. Therefore, the cognitive processes used by children with hearing impairment do not appear to be different from those of children with normal hearing – at least based on the tasks performed in the present study. These were not the findings that were expected at the outset of the present study. It was the opinion of the investigator that the problem solving ability of children with hearing impairment might be fundamentally different than children with normal hearing even when the two groups of children were matched on language ability.

Language Impairment in Children with Hearing Impairment

Since a majority of children with hearing impairment also have some degree of language impairment, it was necessary to compare children with hearing impairment and language impairment to children who have normal hearing and specific language impairment (SLI). In the participant selection process, it was found that a number of the children with hearing impairment had greater language impairments than any child with SLI. To match the groups on language ability, children with poorer language skills had to be excluded from the HI Group and children with better language skills had to be excluded from the NH Group. As a result, the children in the HI Group had better language abilities than the typical child with hearing impairment and the children in the NH Group had poorer language abilities than the typical child with normal hearing. This was necessary in order to make the comparison among participants with similar language abilities, but it reveals important differences between the groups. It indicates that, for children with normal hearing in the 4^{th}, 5^{th} or 6^{th} grade, when PIQ is relatively normal, there is probably some limit to the degree of language impairment. It also indicates that language deficits can be much greater for children with hearing impairment than with SLI. The conclusions about the problem solving abilities or functioning of children with hearing impairment in the present study may not apply to children with greater language deficits.

Formal Measures of Problem Solving

Based on anecdotal studies of the problem solving skills of children with hearing impairment and on the single-subject study conducted by the investigator in the present study, it appears that it may take special expertise to assess problem solving abilities without the assistance of formal tests. Professionals who work with children with hearing impairment on a regular basis may have a better understanding of the capabilities of the children than those who have not had experience with a number of children. A classroom teacher who has had limited experience with children who are hearing impaired and the parents of a child with hearing impairment might not have the necessary experience to informally evaluate a child's problem solving abilities (Fisher, 2000). In these cases, formal evaluation of problem solving skills may reveal capabilities or deficiencies that were not readily obvious to untrained observers.

Early Identification of Hearing Impairment and Language Development

Normal language development has been documented in children with hearing impairments who were identified, amplified and provided with intervention prior to six months of age (Yoshinaga-Itano et al., 1998). Children who were identified early showed significantly higher LQs than children who were identified after six months of age. The average LQ for children identified by six months of age was 91.3; whereas, children identified after six months had a mean LQ of 70.2. Yoshinaga-Itano and her colleagues have concluded that without early intervention, language development is delayed. However, if early intervention is provided before six months of age, the expectation is that language development will be normal. The results of the present study extend the findings of the Yoshinaga-Itano et al. study and indicate that problem solving, which is a higher level cognitive function, should be commensurate with language ability in children with hearing impairment. Therefore, if a child with hearing impairment develops normal language skills, the results of the present study would suggest that there is reason to expect that cognitive abilities, such as problem solving skills, may develop normally as well. If this is borne out by subsequent research, then it greatly increases the justification for Early Detection of Hearing Impairment programs.

Considerations for Future Research

The task called the Tower of Hanoi has been used to study problem solving abilities in children who are developing typically, children with learning disabilities (Wansart, 1990), and children with hearing impairment (Luckner & McNeill, 1994). Wansart developed an analysis procedure to compare the processes used in problem solving by children who were typically developing and children with learning disabilities. The use of an analysis strategy such as

Wansart's may be useful in studying the problem solving processes used by children with hearing impairment as well. In the present study, there was some evidence of differences between the processes used in problem solving for the two experimental groups. For the children with hearing impairment, there was a much stronger relationship between language and vocabulary and problem solving ability – both in computational and word problems. This is somewhat surprising because both groups would have been expected to have received significant amounts of language therapy. If this difference were understood it might shed some light on the processes used by children in both groups.

The relationship demonstrated in the present study between problem solving and language in children with hearing impairment may exist at other levels of thinking (Figure 1). It would be of interest to apply the design of the present study to the thinking processes (other than problem solving) such as concept formation and composing. In addition, the investigation of the effect of language and vocabulary skills on the foundational thinking skills might provide information relative to the influence of language and vocabulary on problem solving. Further study is warranted of the influence of language and vocabulary in children with hearing impairment on creative and critical thinking skills as well as metacognition.

There is an increasing amount of evidence that supports that early identification of hearing impairment in children is critical in the acquisition of normal language skills. It will be important to document not only the effects of early identification on language development, but also the effects on higher-level cognitive functions such as problem solving.

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APPENDICES

APPENDIX A

PILOT STUDY

The experimental problem solving task for the present study was devised by the investigator. A pilot study was conducted for the following purposes: to establish the experimental procedures and instructions for the administration of the mathematical test items, to identify issues/questions from the participants about the test items, to establish the time needed for administration of the test, and to determine test difficulty.

Participants

Three children were recruited to participate in the pilot study, one from each of the grade levels that would be represented in the study (4^{th}, 5^{th}, and 6^{th}). The participants were children whose parents are friends of the investigator. All participants were normally developing children who were enrolled in the public school system and received all of their education in the regular classroom. The parents of the participants gave informed consent and each child gave assent prior to participation in the study (included at the end of this appendix).

Experimental Conditions

Each participant completed the computation problem test first and then the word problem test. The problem solving test contained 28 problems in each section for a total of 56 problems. The participants were told that they could take as long as they needed to complete the tests. They were also told that they would not be receiving a grade for their participation, however, they needed to do the best that they could on the problems. Finally, the participants were instructed to ask questions if they did not understand a problem or if they needed help.

Some of the questions asked or comments made by at least one of the participants during the administration of the test were:

1. I don't know how to work this one, can I just skip it?
2. I don't know how to do number 14, 15, and 16 because I don't know how to subtract, multiple or divide decimals.
3. We do a lot of word problems at school.
4. I don't know how to do #12, can I skip it?
5. Problems are usually written sideways and then I write them up and down to work them (Note: the problems were written vertically and each participant was asked about this format).

Based on comment #5, the test questions were re-written to be in horizontal form.

The participants were able to complete both parts of the problem solving test in 28 to 47 minutes. The 4th grader completed the computation problems in 8 minutes and the word problems in 20 minutes for a total time of 28 minutes. The 5th grader completed the computation problems in 14 minutes and the word problems in 31 minutes for a total of 45 minutes. The 6th grader completed the computation problems in 22 minutes and the word problems in 25 minutes for a total of 47 minutes. It took the 6th grader longer than a 4th grader to complete the test. This was due to the fact that the 6th grader was able to work more of the math problems. The minimum score on the test was 12/28 (4^{th} grader) and the maximum score was 15/28 (5^{th} and 6^{th} grader).

Modifications to Test Protocol

After the three participants completed the pilot study, it was decided that the test might be too long especially for the children with language impairments. Due to the time that it would take to administer this test along with other qualification and descriptive tests, it was decided that some problems would be dropped from each part of the test. One problem from each of the grade levels (2^{nd} - 8^{th}) was dropped from both the computation problem test and the word problem test. The test that was used for the present study contained 21 problems in each of the parts for a total of 42 problems.

A list of instructions was formulated for use during the administration of the computation problem test and word problem test. The following instructions were given to each child:

1. I want you to work some math problems for me. Some of them are written with just numbers and others have words.
2. I want you to do your very best. But you will not be getting a grade on this.
3. Some of the problems may seem easy and some may seem hard. Just do your best.
4. Look at every problem and see if you can work it. If you don't know how to do it, skip it and go to the next problem. Some of the problems will be too hard but look at every one.

5. You can write anything you want to on the paper. Just be sure that I can see your answer. If you need to write the problem differently on the paper, you can.

6. If you have a question about a problem, ask me.

7. You cannot use a calculator.

8. Do you have any questions?

Informed Consent
Pilot Study

Date
Dear Parent(s),

I am a doctoral student in speech and hearing science at the University of Tennessee Knoxville and an instructor at the University of Central Arkansas. Currently I am working on designing a study that will focus on the problem solving skills of children who are hard of hearing. Specifically, I am interested in looking at problem solving skills through math assessment. In order to refine my math assessment tool I am asking for the participation of your child in a pilot study. Your child will be asked to complete a 2-part math assessment.

1. The first portion of the math assessment will be 28 math problems that require computation (e.g. 48 + 24 = x).
2. The second portion of the math assessment will be 28 math word problems that require problem solving (e.g. There are 365 days in a year. How many days are there in 2 years?).

The assessment has been designed to include math problems that are appropriate for 2^{nd} to 8^{th} graders. Therefore, some of the problems will be below grade level, at grade level and above grade level for your child. He/she will be given as much time as needed to complete the assessment. It is estimated that this task should take no more than 1 ½ hours to complete. Each of the two sections of the math assessment will be scored for percent correct. Also, any work that your child shows in completing the assessment will be examined. A data file with the following information will be kept for your child: his/her date of birth, current grade level, completed math assessment, time it took for the completion of math assessment, any questions that your child asked during the administration and completion of the assessment and percent correct scores for the two portions of the math assessment.

There are no known risks to you or your child for this study. The information in the study records will be kept confidential. In addition to myself and the faculty advisor, only you and your child will know that you are participants in my study. Data will be stored securely. My faculty advisor and myself will be the only ones who have access to all of the data. Your name will not be used in oral or written reports that could link you or your child to the study. While there is no direct benefit to you or your child in this study, you will have access to the information collected about your child.

If you have questions at any time about the study or the procedures, you may contact me, Donna Fisher, at the University of Central Arkansas at (501) 450-5484 or via email at <dfisher@mail.uca.edu> or my advisor, Dr. James Thelin at (865) 974-1796. If you have questions about your rights or your child's rights as a participant, you can contact the Compliance Section of the Office of Research at (865) 974-3466.

Your child's participation in this study is voluntary and you or he/she may decline to participate without penalty. If you decide to allow your child to participate you may withdraw your child from the study at anytime without penalty. If you withdraw from the study before data collection is completed, your data will be returned to you or destroyed.

I have read and understand the above information. I have received a copy of this form. I agree to allow my child to participate in this study.

Parent's signature: ______________________________ Date: __________

Child Assent Script
Pilot Study

The following script will be used to secure the child's assent, prior to conducting the study.

Jane/John, my name is Donna Fisher. I am a teacher at the University of Central Arkansas. I want to learn about how students, like yourself, solve math problems. In order to understand this, I would like to ask you to complete some math problems for me. What I would need for you to do is to solve the math problems that I give you and to show your work whenever you can. This is not a test and you will not receive a grade for it. You can take as much time as you need to solve these problems. I do not think that it will take you more than 1 ½ hours to complete this task.

Would you be willing to solve some math problems for me?

____ Yes ____ No

If you decide that you do not want to do the math problems you can stop at any time. You will not be in trouble if you decide that you do not want to the problems.

Do you have any questions? (pause and respond to any questions)

Remember that you do not have to do this if you do not want to.

____
Child's Name

____
Date

APPENDIX B

PARENT QUESTIONNAIRE FOR PARTICIPANT QUALIFICATION

Questions for parent of participant in the HI group:

1. Child's name:
2. Date of Birth:
3. Current grade level of your child:
4. Gender of child:
5. Do you speak any other languages in your home besides English?
6. Does your child have any other known physical or mental disabilities in addition to his/her hearing and language impairments?
7. How old was your child when his/her hearing loss was diagnosed?
8. Was the hearing loss considered to be present at birth?
9. How old was your child when he/she was fit with hearing aids?
10. Does your child wear hearing aids in both ears of only one ear?
11. Does your child wear his/her hearing aids on a consistent basis?
12. How many hours a day does he/she wear the hearing aids?

Specific questions for parent of participant in the NH group:

1. Child's name:
2. Date of Birth:
3. Current grade level of your child:
4. Gender of child:
5. Do you speak any other languages in your home besides English?
6. Does your child have any known physical or mental disabilities (note: other than language impairment in appropriate children)?

APPENDIX C

INFORMED CONSENT

This form will be copied front-to-back.

Informed Consent
Problem Solving Ability in Elementary School-Age Children with Hearing Impairment

_________________ (date)

Dear Parent(s),

I am a doctoral student in speech and hearing science at the University of Tennessee Knoxville and an instructor at the University of Central Arkansas. Currently I am conducting a study about the problem solving skills of children who are hearing impaired. Specifically, I am interested in looking at problem solving skills through math assessment. I am giving a 2-part math assessment to children in the 4^{th}, 5^{th} and 6^{th} grade. Some of the children in my study have hearing impairment and some do not..

In order to qualify for participation in this study the following information will be needed about your child:

1. Non-verbal intelligence -- If your child has had an intelligence test (specifically the WISC-R or the WISC-III) at school, the scores from his./her educational record will be used. If such a test has not been administered, a qualified examiner will administer a portion of this test (specifically the performance portion) to your child as a part of participation in this study. This test should take approximately 1½ hours.
2. Language age -- If your child has had a language test (specifically the Clinical Evaluation of Language Fundamentals - III) at school, the scores from his/her educational record will be used. If this test has not been administered, a qualified examiner will administer this test to your child as a part of participation in this study. This test should take approximately 1 ½ hours.
3. Vocabulary test – A qualified examiner will administer the Peabody Picture Vocabulary Test – 3^{rd} Edition to your child. This test assesses the vocabulary that your child understands. This test should take approximately 15 minutes.
4. Hearing evaluation -- If your child is hearing impaired, his/her latest hearing test results will need to be obtained from his/her audiologist. If your child does not have hearing impairment, he/she will receive a hearing screening as a part of participation in this study. The hearing screening will take approximately 10 minutes.
5. Parent questionnaire -- You will be asked to complete a questionnaire (see attached) regarding your child. This should take approximately 10 minutes.

After your child meets the qualification guidelines for inclusion in this study, he/she will be asked to complete the 2 - part math assessment. The first portion of the math assessment will be 21 math problems that require computation (e.g. 48 + 24 = x). The second portion of the math assessment will be 21 math word problems that require problem solving (e.g. There are 365 days in a year. How many days are there in 2 years?). The assessment has been designed to include math problems that are appropriate for 2^{nd} to 8^{th} graders. Therefore, some of the problems will be below grade level, at grade level and above grade level for your child. He/she will be given as much time as needed to complete the assessment. It is estimated that this task should take no more than 1 ½ hours to complete. Each of the two sections of the math assessment will be scored for number correct. Also, any work that your child shows in completing the assessment will be examined. A record of the time that it takes for your child to complete the assessment will also be made.

A data file with the following information will be kept about your child: his/her date of birth, current grade level, non-verbal intelligence score, language test score, vocabulary test score, hearing screening results or hearing evaluation results, parent questionnaire, completed math assessment, time it took for the completion of the math assessment, and number correct for the two portions of the math assessment.

There are no known risks to you or your child for this study. The information in the study records will be kept confidential. In addition to myself and my faculty advisor, only you and your child will know that you are participants in my study. Data will be stored securely in my office at the University of Central Arkansas for at least 3 years after the completion of my study. My faculty advisor and myself will be the only ones who have access to all of the data. Your name will not be used in oral or written reports that could link you or your child to the study. There is no direct benefit to you or your child in this study.

If you have questions at any time about the study or the procedures, you may contact me, Donna Fisher, at the University of Central Arkansas at (501) 450-5484 or via email at <dfisher@mail.uca.edu> or my advisor, Dr. James Thelin at (865) 974-1796. If you have questions about your rights or your child's rights as a participant, you can contact the Compliance Section of the Office of Research at (865) 974-3466 at the University of Tennessee or the Research Compliance Coordinator at the University of Central Arkansas at (501) 450-3451. This project has been reviewed and approved by the Institutional Review Board for the Protection of Human Subjects at both of the above universities.

Your child's participation in this study is voluntary and you or he/she may decline to participate without penalty. There is no cost for participating in this study. If you decide to allow your child to participate you may withdraw your child from the study at anytime without penalty. If you withdraw from the study before data collection is completed, your data will be returned to you or destroyed.

I have read and understand the above information. I have received a copy of this form. I agree to allow my child to participate in this study.

Parent's signature: ______________________________Date: __________

Parent's signature: ______________________________Date: __________

If available, I agree to the release of the information regarding intelligence testing and language testing from my child's educational records.

Parent's signature: ______________________________Date: __________

Parent's signature: ______________________________Date: __________

APPENDIX D

CHILD ASSENT SCRIPT

Child Assent Script
Problem Solving Ability in Elementary School-Age Children with Hearing Impairment

The following script will be used to secure the child's assent, prior to conducting the study.

(The first portion of the script would only be used if the child needs to complete the non-verbal intelligence test, and/or the language test and/or the vocabulary test)

Jane/John, my name is Donna Fisher. I am a teacher at the University of Central Arkansas. I want to learn about how students, like yourself, solve math problems. In order to understand this, I would like to ask you to complete some tests for me. On these test you just have to answer the questions that are asked. You do not have to study for these tests nor will you be given a grade for these tests. You can take a break whenever you need to during the time that we are working on these tests.

Would you be willing to take these tests for me?

____ Yes ____ No

If you decide that you do not want to take these tests, you can stop at any time. You will not be in trouble if you decide that you do not want to do the tests.

Do you have any questions? (pause and respond to any questions)

Remember that you do not have to do this if you do not want to.

(This part of the script will be used for all of the children)

Jane/John, my name is Donna Fisher. I am a teacher at the University of Central Arkansas. I want to learn about how students, like yourself, solve math problems. In order to understand this, I would like to ask you to complete some math problems for me. What I would need for you to do is to solve the math problems that I give you and to show your work whenever you can. This is not a test and you will not receive a grade for it. You can take as much time as you need to solve these problems. If you can't do a problem, you may go on to the next one. I do not think that it will take you more than 1 ½ hours to complete this task.

Would you be willing to solve some math problems for me?

____ Yes ____ No

If you decide that you do not want to do the math problems you can stop at any time. You will not be in trouble if you decide that you do not want to the problems.

Do you have any questions? (pause and respond to any questions)
Remember that you do not have to do this if you do not want to.

______________________________ ____________________
Child's Name Date

APPENDIX E

INDIVIDUAL PARTICIPANT DATA

Participant 1

DEMOGRAPHIC DATA		
Group	HI	
Sex	male	
Chronological Age in Years	11:10	
Grade Level	6	
PTA in Better Ear in dB HL	72	
QUALIFYING DATA		
	Raw Score	**Standard Score**
CELF-3 Total Language		100
CELF-3 Receptive		102
CELF-3 Expressive		98
Performance IQ		112
DESCRIPTIVE DATA		
PPVT-3 (vocabulary)		94
EXPERIMENTAL DATA		
Computational problems	12/21	
Word problems	13/21	

Participant 1
Correct responses on computational and word problems

	Computational	Word
1	✔	✔
2	✔	✔
3	✔	✔
4	✔	✔
5	✔	✔
6	✔	✔
7	✔	✔
8	✔	✔
9		✔
10	✔	
11		✔
12		
13	✔	✔
14		✔
15	✔	
16		
17		
18	✔	✔
19		
20		
21		

✔ denotes problems answered correctly

Participant 2

DEMOGRAPHIC DATA		
Group	HI	
Sex	female	
Chronological Age in Years	10:7	
Grade Level	5	
PTA in Better Ear in dB HL	60	
QUALIFYING DATA		
	Raw Score	**Standard Score**
CELF-3 Total Language		112
CELF-3 Receptive		114
CELF-3 Expressive		110
Performance IQ		108
DESCRIPTIVE DATA		
PPVT-3 (vocabulary)		120
EXPERIMENTAL DATA		
Computational problems	18/21	
Word problems	17/21	

Participant 2
Correct responses on computational and word problems

	Computational	Word
1	✔	✔
2	✔	✔
3	✔	✔
4	✔	✔
5	✔	✔
6	✔	✔
7	✔	✔
8	✔	✔
9	✔	✔
10	✔	✔
11	✔	✔
12		
13	✔	✔
14	✔	✔
15	✔	✔
16	✔	✔
17		
18	✔	
19	✔	✔
20		
21	✔	✔

✔ denotes problems answered correctly

Participant 3

DEMOGRAPHIC DATA		
Group	HI	
Sex	female	
Chronological Age in Years	11:10	
Grade Level	5	
PTA in Better Ear in dB HL	68	
QUALIFYING DATA		
	Raw Score	**Standard Score**
CELF-3 Total Language		75
CELF-3 Receptive		84
CELF-3 Expressive		69
Performance IQ		
DESCRIPTIVE DATA		
PPVT-3 (vocabulary)		63
EXPERIMENTAL DATA		
Computational problems	10/21	
Word problems	6/21	

Participant 3
Correct responses on computational and word problems

	Computational	Word
1	✔	✔
2	✔	✔
3	✔	
4	✔	
5		✔
6	✔	
7	✔	✔
8		
9	✔	
10	✔	✔
11		
12		
13		
14		
15	✔	✔
16		
17		
18	✔	
19		
20		
21		

✔ denotes problems answered correctly

Participant 4

DEMOGRAPHIC DATA		
Group	HI	
Sex	male	
Chronological Age in Years	12:3	
Grade Level	6	
PTA in Better Ear in dB HL	48	
QUALIFYING DATA		
	Raw Score	**Standard Score**
CELF-3 Total Language		96
CELF-3 Receptive		98
CELF-3 Expressive		96
Performance IQ		95
DESCRIPTIVE DATA		
PPVT-3 (vocabulary)		97
EXPERIMENTAL DATA		
Computational problems	9/21	
Word problems	11/21	

Participant 4
Correct responses on computational and word problems

	Computational	Word
1	✔	✔
2	✔	✔
3	✔	✔
4	✔	✔
5		✔
6	✔	✔
7	✔	✔
8		
9	✔	✔
10	✔	✔
11		
12		
13		
14		
15		✔
16		✔
17		
18	✔	
19		
20		
21		

✔ denotes problems answered correctly

Participant 5

DEMOGRAPHIC DATA		
Group	HI	
Sex	female	
Chronological Age in Years	10:8	
Grade Level	4	
PTA in Better Ear in dB HL	45	
QUALIFYING DATA		
	Raw Score	**Standard Score**
CELF-3 Total Language		107
CELF-3 Receptive		92
CELF-3 Expressive		122
Performance IQ		113
DESCRIPTIVE DATA		
PPVT-3 (vocabulary)		92
EXPERIMENTAL DATA		
Computational problems	6/21	
Word problems	6/21	

Participant 5
Correct responses on computational and word problems

	Computational	Word
1	✓	✓
2	✓	
3		
4	✓	
5	✓	✓
6		
7	✓	✓
8		
9		✓
10	✓	✓
11		
12		
13		
14		
15		✓
16		
17		
18		
19		
20		
21		

✓ denotes problems answered correctly

Participant 6

DEMOGRAPHIC DATA		
Group	HI	
Sex	male	
Chronological Age in Years	12:2	
Grade Level	7	
PTA in Better Ear in dB HL	60	
QUALIFYING DATA		
	Raw Score	**Standard Score**
CELF-3 Total Language		100
CELF-3 Receptive		98
CELF-3 Expressive		102
Performance IQ		130
DESCRIPTIVE DATA		
PPVT-3 (vocabulary)		132
EXPERIMENTAL DATA		
Computational problems	17/21	
Word problems	19/21	

Participant 6
Correct responses on computational and word problems

	Computational	Word
1	✔	✔
2	✔	✔
3	✔	✔
4	✔	✔
5	✔	✔
6	✔	✔
7	✔	✔
8	✔	✔
9	✔	✔
10	✔	✔
11	✔	✔
12		✔
13	✔	✔
14	✔	✔
15	✔	✔
16	✔	✔
17	✔	
18	✔	✔
19		✔
20		
21		✔

✔ denotes problems answered correctly

Participant 7

DEMOGRAPHIC DATA		
Group	HI	
Sex	female	
Chronological Age in Years	10:0	
Grade Level	5	
PTA in Better Ear in dB HL	67	
QUALIFYING DATA		
	Raw Score	**Standard Score**
CELF-3 Total Language		69
CELF-3 Receptive		72
CELF-3 Expressive		69
Performance IQ		90
DESCRIPTIVE DATA		
PPVT-3 (vocabulary)		69
EXPERIMENTAL DATA		
Computational problems	10/21	
Word problems	4/21	

Participant 7
Correct responses on computational and word problems

	Computational	Word
1	✔	✔
2	✔	
3	✔	
4	✔	✔
5	✔	✔
6	✔	
7	✔	
8		
9		
10	✔	✔
11		
12		
13		
14		
15		
16	✔	
17		
18	✔	
19		
20		
21		

✔ denotes problems answered correctly

Participant 8

DEMOGRAPHIC DATA		
Group	HI	
Sex	female	
Chronological Age in Years	9:3	
Grade Level	4	
PTA in Better Ear in dB HL	60	
QUALIFYING DATA		
	Raw Score	**Standard Score**
CELF-3 Total Language		95
CELF-3 Receptive		102
CELF-3 Expressive		90
Performance IQ		106
DESCRIPTIVE DATA		
PPVT-3 (vocabulary)		77
EXPERIMENTAL DATA		
Computational problems	5/21	
Word problems	5/21	

Participant 8
Correct responses on computational and word problems

	Computational	Word
1	✔	✔
2	✔	
3		
4	✔	✔
5		✔
6	✔	
7	✔	✔
8		
9		
10		
11		✔
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		

✔ denotes problems answered correctly

Participant 9

DEMOGRAPHIC DATA		
Group	HI	
Sex	female	
Chronological Age in Years	10:4	
Grade Level	5	
PTA in Better Ear in dB HL	88	
QUALIFYING DATA		
	Raw Score	**Standard Score**
CELF-3 Total Language		84
CELF-3 Receptive		82
CELF-3 Expressive		88
Performance IQ		95
DESCRIPTIVE DATA		
PPVT-3 (vocabulary)		95
EXPERIMENTAL DATA		
Computational problems	11/21	
Word problems	9/21	

Participant 9
Correct responses on computational and word problems

	Computational	Word
1	✔	✔
2	✔	
3	✔	✔
4	✔	✔
5	✔	✔
6	✔	✔
7	✔	✔
8		
9		
10	✔	
11		
12		
13		✔
14	✔	
15	✔	
16		
17		
18	✔	✔
19		
20		
21		✔

✔ denotes problems answered correctly

Participant 10

DEMOGRAPHIC DATA		
Group	HI	
Sex	male	
Chronological Age in Years	9:1	
Grade Level	4	
PTA in Better Ear in dB HL	46	
QUALIFYING DATA		
	Raw Score	**Standard Score**
CELF-3 Total Language		83
CELF-3 Receptive		86
CELF-3 Expressive		82
Performance IQ		104
DESCRIPTIVE DATA		
PPVT-3 (vocabulary)		93
EXPERIMENTAL DATA		
Computational problems	7/21	
Word problems	6/21	

Participant 10
Correct responses on computational and word problems

	Computational	Word
1	✔	✔
2	✔	
3		
4	✔	✔
5		
6	✔	✔
7	✔	✔
8		
9		✔
10	✔	✔
11		
12		
13		
14		
15		
16		
17		
18	✔	
19		
20		
21		

✔ denotes problems answered correctly

Participant 11

DEMOGRAPHIC DATA		
Group	HI	
Sex	male	
Chronological Age in Years	12:9	
Grade Level	6	
PTA in Better Ear in dB HL	62	
QUALIFYING DATA		
	Raw Score	**Standard Score**
CELF-3 Total Language		62
CELF-3 Receptive		53
CELF-3 Expressive		75
Performance IQ		95
DESCRIPTIVE DATA		
PPVT-3 (vocabulary)		70
EXPERIMENTAL DATA		
Computational problems	14/21	
Word problems	10/21	

Participant 11
Correct responses on computational and word problems

	Computational	Word
1	✔	✔
2	✔	
3	✔	✔
4	✔	✔
5	✔	✔
6	✔	✔
7	✔	✔
8	✔	
9		✔
10	✔	
11		
12		
13	✔	✔
14	✔	
15	✔	✔
16	✔	✔
17		
18	✔	
19		
20		
21		

✔ denotes problems answered correctly

Participant 12

DEMOGRAPHIC DATA		
Group	HI	
Sex	male	
Chronological Age in Years	9:5	
Grade Level	4	
PTA in Better Ear in dB HL	60	
QUALIFYING DATA		
	Raw Score	**Standard Score**
CELF-3 Total Language		68
CELF-3 Receptive		75
CELF-3 Expressive		65
Performance IQ		98
DESCRIPTIVE DATA		
PPVT-3 (vocabulary)		60
EXPERIMENTAL DATA		
Computational problems	5/21	
Word problems	3/21	

Participant 12
Correct responses on computational and word problems

	Computational	Word
1	✔	✔
2		
3		
4	✔	✔
5		
6	✔	
7	✔	
8		
9		
10		✔
11		
12		
13		
14		
15	✔	
16		
17		
18		
19		
20		
21		

✔ denotes problems answered correctly

Participant 13

DEMOGRAPHIC DATA		
Group	HI	
Sex	male	
Chronological Age in Years	10:4	
Grade Level	4	
PTA in Better Ear in dB HL	58	
QUALIFYING DATA		
	Raw Score	**Standard Score**
CELF-3 Total Language		50
CELF-3 Receptive		50
CELF-3 Expressive		50
Performance IQ		84
DESCRIPTIVE DATA		
PPVT-3 (vocabulary)		52
EXPERIMENTAL DATA		
Computational problems	5/21	
Word problems	2/21	

Participant 13
Correct responses on computational and word problems

	Computational	Word
1	✔	✔
2	✔	
3		
4	✔	✔
5		
6	✔	
7	✔	
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		

✔ denotes problems answered correctly

Participant 14

DEMOGRAPHIC DATA		
Group	NH	
Sex	female	
Chronological Age in Years	9:6	
Grade Level	4	
PTA in Better Ear in dB HL	<20	
QUALIFYING DATA		
	Raw Score	**Standard Score**
CELF-3 Total Language		115
CELF-3 Receptive		125
CELF-3 Expressive		104
Performance IQ		100
DESCRIPTIVE DATA		
PPVT-3 (vocabulary)		114
EXPERIMENTAL DATA		
Computational problems	9/21	
Word problems	11/21	

Participant 14
Correct responses on computational and word problems

	Computational	Word
1	✓	✓
2	✓	
3	✓	✓
4	✓	✓
5	✓	✓
6		✓
7	✓	✓
8		
9		✓
10	✓	✓
11		
12		
13		
14		
15	✓	✓
16		✓
17		
18	✓	✓
19		
20		
21		

✓ denotes problems answered correctly

Participant 15

DEMOGRAPHIC DATA		
Group	NH	
Sex	female	
Chronological Age in Years	11:6	
Grade Level	6	
PTA in Better Ear in dB HL	<20	
QUALIFYING DATA		
	Raw Score	**Standard Score**
CELF-3 Total Language		103
CELF-3 Receptive		110
CELF-3 Expressive		96
Performance IQ		99
DESCRIPTIVE DATA		
PPVT-3 (vocabulary)		99
EXPERIMENTAL DATA		
Computational problems	14/21	
Word problems	17/21	

Participant 15
Correct responses on computational and word problems

	Computational	Word
1	✔	✔
2	✔	
3	✔	✔
4	✔	✔
5		✔
6	✔	✔
7	✔	✔
8	✔	✔
9		
10	✔	✔
11		✔
12		
13		✔
14	✔	✔
15	✔	✔
16	✔	✔
17		✔
18	✔	✔
19	✔	✔
20		
21	✔	✔

✔ denotes problems answered correctly

Participant 16

DEMOGRAPHIC DATA		
Group	NH	
Sex	female	
Chronological Age in Years	10:11	
Grade Level	5	
PTA in Better Ear in dB HL	<20	
QUALIFYING DATA		
	Raw Score	**Standard Score**
CELF-3 Total Language		105
CELF-3 Receptive		104
CELF-3 Expressive		106
Performance IQ		103
DESCRIPTIVE DATA		
PPVT-3 (vocabulary)		103
EXPERIMENTAL DATA		
Computational problems	11/21	
Word problems	8/21	

Participant 16
Correct responses on computational and word problems

	Computational	Word
1	✔	✔
2	✔	✔
3	✔	✔
4	✔	
5	✔	✔
6	✔	✔
7	✔	✔
8		
9		
10	✔	✔
11		
12		
13		
14		
15	✔	
16	✔	✔
17		
18	✔	
19		
20		
21		

✔ denotes problems answered correctly

Participant 17

DEMOGRAPHIC DATA		
Group	NH	
Sex	male	
Chronological Age in Years	11:9	
Grade Level	6	
PTA in Better Ear in dB HL	<20	
QUALIFYING DATA		
	Raw Score	**Standard Score**
CELF-3 Total Language		93
CELF-3 Receptive		102
CELF-3 Expressive		86
Performance IQ		98
DESCRIPTIVE DATA		
PPVT-3 (vocabulary)		89
EXPERIMENTAL DATA		
Computational problems	12/21	
Word problems	9/21	

Participant 17
Correct responses on computational and word problems

	Computational	Word
1	✔	✔
2	✔	
3	✔	
4	✔	✔
5		✔
6	✔	✔
7	✔	✔
8	✔	
9		✔
10	✔	
11	✔	✔
12		
13		
14	✔	
15	✔	✔
16	✔	
17		
18		
19		
20		
21		✔

✔ denotes problems answered correctly

Participant 18

DEMOGRAPHIC DATA		
Group	NH	
Sex	male	
Chronological Age in Years	9:9	
Grade Level	4	
PTA in Better Ear in dB HL	<20	
QUALIFYING DATA		
	Raw Score	**Standard Score**
CELF-3 Total Language		109
CELF-3 Receptive		112
CELF-3 Expressive		106
Performance IQ		100
DESCRIPTIVE DATA		
PPVT-3 (vocabulary)		102
EXPERIMENTAL DATA		
Computational problems	9/21	
Word problems	11/21	

Participant 18
Correct responses on computational and word problems

	Computational	Word
1		✓
2	✓	✓
3		✓
4	✓	✓
5	✓	✓
6	✓	✓
7	✓	✓
8		
9		
10	✓	✓
11		
12		
13		
14		
15	✓	✓
16	✓	✓
17		
18	✓	✓
19		
20		
21		

✓ denotes problems answered correctly

Participant 19

DEMOGRAPHIC DATA		
Group	NH	
Sex	male	
Chronological Age in Years	10:11	
Grade Level	5	
PTA in Better Ear in dB HL	<20	
QUALIFYING DATA		
	Raw Score	**Standard Score**
CELF-3 Total Language		93
CELF-3 Receptive		94
CELF-3 Expressive		94
Performance IQ		107
DESCRIPTIVE DATA		
PPVT-3 (vocabulary)		99
EXPERIMENTAL DATA		
Computational problems	10/21	
Word problems	10/21	

Participant 19
Correct responses on computational and word problems

	Computational	Word
1	✔	
2	✔	✔
3	✔	✔
4	✔	✔
5	✔	✔
6	✔	
7	✔	✔
8		
9		✔
10	✔	✔
11		✔
12		
13		
14		
15	✔	✔
16	✔	✔
17		
18		
19		
20		
21		

✔ denotes problems answered correctly

Participant 20

DEMOGRAPHIC DATA		
Group	NH	
Sex	female	
Chronological Age in Years	11:8	
Grade Level	5	
PTA in Better Ear in dB HL	<20	
QUALIFYING DATA		
	Raw Score	**Standard Score**
CELF-3 Total Language		76
CELF-3 Receptive		90
CELF-3 Expressive		65
Performance IQ		83
DESCRIPTIVE DATA		
PPVT-3 (vocabulary)		85
EXPERIMENTAL DATA		
Computational problems	9/21	
Word problems	5/21	

Participant 20
Correct responses on computational and word problems

	Computational	Word
1	✔	✔
2	✔	
3	✔	
4	✔	✔
5	✔	✔
6	✔	
7	✔	
8		
9		
10	✔	
11		
12		
13		
14		
15	✔	✔
16		
17		
18		✔
19		
20		
21		

✔ denotes problems answered correctly

Participant 21

DEMOGRAPHIC DATA		
Group	NH	
Sex	male	
Chronological Age in Years	10:3	
Grade Level	4	
PTA in Better Ear in dB HL	<20	
QUALIFYING DATA		
	Raw Score	**Standard Score**
CELF-3 Total Language		70
CELF-3 Receptive		78
CELF-3 Expressive		65
Performance IQ		99
DESCRIPTIVE DATA		
PPVT-3 (vocabulary)		94
EXPERIMENTAL DATA		
Computational problems	5/21	
Word problems	6/21	

Participant 21
Correct responses on computational and word problems

	Computational	Word
1	✔	✔
2	✔	✔
3		✔
4	✔	✔
5		
6		
7	✔	✔
8		
9		
10	✔	✔
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		

✔ denotes problems answered correctly

Participant 22

DEMOGRAPHIC DATA		
Group	NH	
Sex	male	
Chronological Age in Years	9:5	
Grade Level	4	
PTA in Better Ear in dB HL	<20	
QUALIFYING DATA		
	Raw Score	**Standard Score**
CELF-3 Total Language		94
CELF-3 Receptive		96
CELF-3 Expressive		94
Performance IQ		106
DESCRIPTIVE DATA		
PPVT-3 (vocabulary)		90
EXPERIMENTAL DATA		
Computational problems	9/21	
Word problems	5/21	

Participant 22
Correct responses on computational and word problems

	Computational	Word
1	✔	✔
2	✔	
3	✔	
4	✔	✔
5		
6	✔	
7	✔	✔
8		
9		
10	✔	✔
11		
12		
13		
14		
15		
16	✔	
17		
18	✔	✔
19		
20		
21		

✔ denotes problems answered correctly

Participant 23

DEMOGRAPHIC DATA		
Group	NH	
Sex	female	
Chronological Age in Years	10:0	
Grade Level	4	
PTA in Better Ear in dB HL	<20	
QUALIFYING DATA		
	Raw Score	**Standard Score**
CELF-3 Total Language		69
CELF-3 Receptive		72
CELF-3 Expressive		69
Performance IQ		94
DESCRIPTIVE DATA		
PPVT-3 (vocabulary)		89
EXPERIMENTAL DATA		
Computational problems	4/21	
Word problems	4/21	

Participant 23
Correct responses on computational and word problems

	Computational	Word
1	✔	✔
2	✔	✔
3		
4		✔
5		✔
6		
7	✔	
8		
9		
10	✔	
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		

✔ denotes problems answered correctly

Participant 24

DEMOGRAPHIC DATA		
Group	NH	
Sex	male	
Chronological Age in Years	11:6	
Grade Level	4	
PTA in Better Ear in dB HL	<20	
QUALIFYING DATA		
	Raw Score	**Standard Score**
CELF-3 Total Language		55
CELF-3 Receptive		65
CELF-3 Expressive		50
Performance IQ		98
DESCRIPTIVE DATA		
PPVT-3 (vocabulary)		78
EXPERIMENTAL DATA		
Computational problems	5/21	
Word problems	4/21	

Participant 24
Correct responses on computational and word problems

	Computational	Word
1	✔	✔
2	✔	
3		
4	✔	✔
5		
6		
7	✔	✔
8		
9		
10	✔	
11		✔
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		

✔ denotes problems answered correctly

Participant 25

DEMOGRAPHIC DATA		
Group	NH	
Sex	male	
Chronological Age in Years	10:2	
Grade Level	4	
PTA in Better Ear in dB HL	<20	
QUALIFYING DATA		
	Raw Score	**Standard Score**
CELF-3 Total Language		75
CELF-3 Receptive		88
CELF-3 Expressive		65
Performance IQ		104
DESCRIPTIVE DATA		
PPVT-3 (vocabulary)		99
EXPERIMENTAL DATA		
Computational problems	6/21	
Word problems	4/21	

Participant 25
Correct responses on computational and word problems

	Computational	Word
1		✔
2	✔	✔
3	✔	
4	✔	✔
5		
6		
7	✔	
8		
9		
10	✔	✔
11		
12		
13		
14		
15	✔	
16		
17		
18		
19		
20		
21		

✔ denotes problems answered correctly

Participant 26

DEMOGRAPHIC DATA		
Group	NH	
Sex	female	
Chronological Age in Years	11:0	
Grade Level	5	
PTA in Better Ear in dB HL	<20	
QUALIFYING DATA		
	Raw Score	**Standard Score**
CELF-3 Total Language		93
CELF-3 Receptive		96
CELF-3 Expressive		92
Performance IQ		90
DESCRIPTIVE DATA		
PPVT-3 (vocabulary)		80
EXPERIMENTAL DATA		
Computational problems	8/21	
Word problems	3/21	

Participant 26
Correct responses on computational and word problems

	Computational	Word
1	✔	✔
2	✔	✔
3	✔	
4	✔	✔
5		
6	✔	
7	✔	
8		
9		
10	✔	
11		
12		
13		
14		
15	✔	
16		
17		
18		
19		
20		
21		

✔ denotes problems answered correctly

VITA

Vita

Donna Fisher Smiley was born in Little Rock, Arkansas on March 7, 1966. She was raised in Little Rock and graduated from Little Rock Central High School in May, 1984. Donna graduated from Henderson State University in Arkadelphia, Arkansas with a Bachelor of Science degree (1988) and from the University of Arkansas for Medical Sciences in Little Rock with a Master of Science degree (1990).

Donna worked as an audiologist at Arkansas Children's Hospital and then as an educational audiologist at Educational Services for the Hearing Impaired before teaching for two years at the University of Central Arkansas in Conway. In 1998 she entered the Ph.D. program in speech and hearing science at the University of Tennessee Knoxville and completed her degree in 2002. Donna has returned to the University of Central Arkansas to be a faculty member in the Department of Speech-Language Pathology.