To the Graduate Council

I am submitting herewith a thesis written by Katie A Vaden entitled "Language in relation to problem solving abilities in children with hearing impairment" I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Audiology

James W. Thelin, Ph D
Major Professor

We have read this thesis
And recommend its acceptance

Accepted for the Council

Interim Vice Provost and
Dean of the Graduate School

Language in Relation to Problem Solving Abilities in Children with Hearing Impairment

A Thesis
Presented for the
Master of Arts
Degree
The University of Tennessee, Knoxville

Katie A. Vaden
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DEDICATION

This thesis is dedicated to my parents,

Paul and Nelia Vaden,

who have loved me, supported me, encouraged me,

and have taught me to be the person

that I have become

I love you both very much!

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Writing this thesis has been a significant accomplishment that would not have progressed as smoothly without the support of many people To these people, who supported, encouraged, and taught me about research, I give my gratitude for all that they have done

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The course of my life has been guided by a very loving, heavenly Father who has allowed me the privilege of knowing each one of these people It is His gift that I have such a fine education God is good

ABSTRACT

The relation between language-based problém solving ability and language skills was studied in 11 school-age children with hearing impairment significant enough to require amplification. The Test of Problem Solving-Revised (TOPS-R) was used to assess problem solving that required the use of language. The Clinical Evaluation of Language Fundamental-Revised (CELF-R) was used to measure receptive and expressive language ability. In addition, the Peabody Picture Vocabulary Test-Revised (PPVT-R) was used to measure receptive vocabulary

The mean results for each test represented with standard scores were 1 5-2.0 standard deviations below the mean for typically developing children With multiple regression analysis, it was determined that problem solving scores could be predicted accurately using receptive language, expressive language, and vocabulary scores The results suggest that problem solving that involves the use of language in children with hearing impairment is significantly related to their language skills and vocabulary.

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CHAPTER I

INTRODUCTION

Children with hearing impairment have a more difficult time learning language than do children with normal hearing (De Villiers & De Villiers, 1978; Erber, 1982; Ling, 1984, McAnally, Rose, & Quigley, 1994) Language is used for communication purposes, and it is also used in many cognitive processes – including problem solving. Although there are some forms of problem solving that may not require language, there are many forms that require an implicit or explicit use of language. The purpose of the present study was to examine the ability of children with hearing impairment to solve problems that require the use of language and relate it to their overall language ability

Problem Solving

Problem solving is a cognitive process that involves the ability to apply any existing knowledge to form a solution to a situation or problem at hand (Furth, 1966; Rice & Kemper, 1984, Small, 1983, Thornton, 1995) Thornton has proposed that children are born with the psychological processes necessary for interpreting the world and making inferences. She further states that each experience that a child undergoes contributes to his/her knowledge base which, in turn, serves as a foundation for problem solving. Success in problem solving results from using knowledge in conjunction with intellectual abilities and skills to reach a goal or desired state The acquisition of many forms of knowledge is dependent on the language that a child hears and consequently learns from each day.

Deficiencies in inferential/interpretive abilities, in language, and in abilities to acquire and store knowledge may all affect problem solving ability. Leonard (1998) studied children with specific language impairment and observed that they have difficulties in many areas of functioning – including problem solving The Elementary Test of Problem Solving, Revised (TOPS-R) (Zachman, Huisingh, Barrett, Orman, & LoGiudice, 1994) was developed to assess the ability to solve problems that are presented using spoken language In the standardization of the TOPS-R, problem solving ability was found to be poorer for children with language impairment than for children without language impairment. This finding is in agreement with Leonard's observation of the relation between language impairment and difficulty with problem solving.

Wansart (1990) studied problem solving in children with learning disabilities using a task that required visual-spatial skills and logical sequencing, but very little use of language The task, the Tower of Hanoi, requires the subject to transfer stacked, graduated disks among three pegs In performing this task, a hierarchy of problem solving strategies are required The Tower of Hanoi task requires students to use both visuo-spatial and logic skills. The addition of a logic task component made the Tower of Hanoi difficult because it involved student's use of a sequential steps strategy The results indicate that children with learning disabilities begin the task using lower level strategies and complete the task at lower strategy levels than do children who are normally achieving. Both groups use similar logic strategies to solve the problems, but the normally achieving children begin and end at higher levels of sophistication The results of Wansart's study indicate that non-linguistic deficiencies may also affect problem solving on tasks that require the use of fairly complex strategies

Problem Solving in Persons with Hearing Impairment

There is clear evidence that a congenital hearing impairment which is not treated early will result in language impairment (Yoshinaga-Itano, 1988). Since early identification and treatment of hearing loss has not been typical, the majority of children with congenital hearing impairment also have a language impairment. The development of problem solving skills in persons with hearing-impairment has been studied by a number of investigators (Conrad, 1979; Craig & Gordon, 1988, Edelheit, 1972, Luckner & McNeil, 1997, Streff, Barefoot, Walter, & Crandall, 1978, Tellevik, 1981) These studies evaluated persons with deafness who used sign language as the primary mode of communication Both verbal and non-verbal measures have been used with problem solving tasks to compare the performance of persons with deafness to persons with normal hearing Tasks such as linguistically formulated math word problems and cognitive function evaluations that assess verbo-spatial skills have been used to measure the problem solving abilities that are below age appropriate level Non-verbal intelligence tests (assessing visual identification, processing, and matching of objects) and assessment of visuo-spatial skills through cognitive function evaluations have been used to measure performance on problem solving tasks that require no use of language In the studies cited above, the results indicated that persons with deafness demonstrate normal ability on visual problem solving tasks

Luckner and McNeill (1997), however, studied the problem solving abilities of children with hearing impairment and deafness using a non-linguistic task that requires logical processes that are more complex than those examined by the above authors The

Tower of Hanoi was used in their study to demonstrate the problem solving skills of children with hearing impairment and deafness Young children (ages 5-10 years) with hearing impairment performed approximately 50% poorer than young children with normal hearing on this complex non-linguistic problem solving task However, the older students (age 13 and older) completed the task at a level similar to their hearing peers. The results strongly suggests that on a complex problem solving task which does not require language, young children with hearing impairment do not perform as well as their hearing peers, but the differences decrease with increasing age. This suggests that, for children with hearing impairment, problem solving ability may depend on both linguistic and non-linguistic factors.

Implications for Present Study

The present study was undertaken to examine the relationship between language ability and problem solving abilities of children with hearing impairment (who were likely to have a language impairment as a direct consequence of that hearing impairment) Language ability was measured using the Clinical Evaluation of Language Fundamentals, Revised (CELF-R) (Semel, Wiig, Secord, & Sabers, 1987), a widely-used test of language in school-age children Knowledge of vocabulary was assessed using the Peabody Picture Vocabulary Test, Revised (PPVT-R) (Dunn & Dunn, 1981) Problem solving ability was assessed using the TOPS-R, which relies heavily on the ability to understand and use language. The purpose of this evaluation was to determine the relationship between language age and problem solving age in children with hearing

impairment The following questions were addressed for children with hearing impairment.

1. Is the ability to solve problems that require the use of language related to receptive language ability, expressive language ability, and/or receptive vocabulary?
2 Is the ability to solve problems that require the use of language related to age of identification or treatment of hearing loss, degree of hearing loss, or aided hearing level?

CHAPTER II

REVIEW OF LITERATURE

Problem Solving

Problem solving is a dynamic activity that requires the use of cognitive processes and life experiences Thornton (1995) has proposed that problem solving includes the ability to make inferences using one's existing knowledge in order to obtain new information and ideas Although children are born with the processes necessary for interpreting the world and making inferences, the experiences that children have can add to their knowledge base Success in problem solving results from using knowledge in conjunction with intellectual abilities and skills to reach a goal or desired state (Furth, 1966; Rice & Kemper, 1984, Thornton)

Language and Learning in Relation to Problem Solving

Adequate cognitive development is at least a co-requisite for language development to occur In addition, language skills are expanded through unique experiences that add to one's knowledge The expansion of knowledge and concurrent learning of language is a natural process for most normally developing children, however, a significant deficit in language abilities may create weaknesses in other areas of functioning (Leonard, 1998) Children with specific language impairment have been shown to have greater difficulty in problem solving than their normal peers (Craig & Gordon, 1988, Leonard, 1998, Zachman, Huisingh, Barrett, Orman, & LoGiudice, 1994)

The authors of the Test of Problem Solving-Revised (TOPS-R) (Zachman, et al, 1994) compared a group of typically developing children and a group of language-impaired children The sole criterion for the inclusion of children in the group with language impairment was that they were receiving language therapy The results show that children with language impairments perform significantly poorer ($p < .01$) on problem solving tasks than their normally developing peers. They routinely achieved total test mean raw scores that were 11 to 19 points lower than their matched peers

Assessment of problem solving skills in children with learning impairments has been considered as well In 1990, Wansart used the Tower of Hanoi to compare the use of visuo-spatial skills and logical sequencing in children with learning disabilities and normally developing children. The test requires the transfer of stacked, graduated disks among three pegs A hierarchy of problem solving strategies involving both visuo-spatial skills and logic skills appear to be necessary in performing this task. The sequential steps strategy involved makes the Tower of Hanoi task more difficult for students The findings from this study indicated that although both groups use similar processing strategies, children with learning disabilities began and ended the task using lower level strategies than children who were normally achieving This suggests that non-linguistic deficiencies may also affect problem solving abilities on a task that requires the use of complex strategies

Hearing Impairment and Language

The most common finding among children with a congenital hearing loss is a language impairment (Yoshinaga-Itano, Sedey, Coulter, & Mehl, 1998). For a hearing

impaired child, the lack or reduction of auditory input creates a major problem for learning a spoken language. Without the advantage of auditory stimulation, these children often develop a significant language delay secondary to the hearing loss. The following factors appear to influence the language acquisition of a child: age when the hearing loss occurs, age when the hearing loss is identified, and the intervention provided to the individual (including amplification and habilitation efforts). Yoshinaga-Itano, et al. illustrated importance of these factors for language acquisition.

The age of hearing loss onset can greatly affect the development of language skills. An impairment that occurs after the acquisition of language skills, a post-lingual hearing impairment, generally will result in fewer communication and other secondary problems for the child since he/she has already formed a communication base. Conversely, children with a congenital hearing loss have never had the experience of normal hearing. Because of this, it is widely acknowledged that it is important that the hearing loss for these children be diagnosed early (before six months of age) and appropriate treatment to be implemented in order for the process of language acquisition to begin as early as possible (Yoshinaga-Itano, et al., 1998). Many children with hearing impairment, however, have not had the advantage of early identification and treatment. For these children, there was limited functional reception of auditory communication during the early period of language acquisition. As a result, language acquisition for these children is often delayed.

Problem Solving in Persons with Hearing Impairment

Several studies have reported deficits in the problem solving abilities in children with hearing impairment (De Villers & De Villers, 1978, Erber, 1982, Ling, 1984, McAnally, Rose & Quigley, 1994) Several specific studies have been completed to examine this question Edelheit (1972) examined the views of various investigators on the relationship of language development to problem solving abilities He concluded that although language ability is an independent process, which does not need to correspond to intelligence, problem solving ability is augmented by language More recent studies in this area show similar conclusions Tellevik (1981) compared the problem solving abilities of adolescents with hearing impairments and normal hearing adolescents. A visual problem solving task consisting of different forms and shapes were presented to paired subjects Through communication (manual or oral), each subject was required to explain the visual model to his/her partner The partner then had to produce a visually identical pattern or replica of the original model This task was purely language-based and was similar to barrier tasks that are commonly used in language therapy The results of the study indicated that manual communication methods were equally as effective for logical and reasoning functions as spoken communication.

Craig and Gordon (1988) studied cognitive function and reading achievement in adolescents with hearing impairment They noted that the reading problems observed in children with hearing impairment have been attributed to their lack of a substantial language base Craig and Gordon used a cognitive function evaluation to compare the subject's performance on visuo-spatial task and verbo-spatial tasks The results of this study indicated that performance on tests of specialized cognitive function by adolescents

with hearing impairment was below average for verbal and sequential skills but average and above for visuo-spatial skills

Another study comparing normal hearing young adults to young adults with hearing impairments in verbal and non-verbal abilities was completed by Streff, et al , (1978) Both verbal and nonverbal intelligence tests were used to assess critical thinking, processing, and problem solving abilities in the young adults Knowledge of spatial relationships and visual sequencing of non-meaningful figures (non-verbal measures) were compared to the subjects' performance on verbal tasks such as memory for verbal and written symbols and knowledge of basic linguistic morphology. General conclusions of the tests indicated that although the hearing subjects scored higher on tasks for verbal memory, both hearing young adults and young adults with hearing impairment performed at a similar level on tasks involving non-verbal assessment

Luckner and McNeill (1997) studied the problem solving abilities of children with hearing impairment and deafness using the Tower of Hanoi. This is a non-linguistic task that requires logical processes that are more complex that those examined in earlier studies The Tower of Hanoi task requires students to use both visuo-spatial and logic skills The additional component of a logic task made the Tower of Hanoi difficult because it involved student's use of a sequential steps strategy Instructions for the test were given both verbally and through manual communication Younger students with hearing impairment and deafness, age 5 to 10 years, demonstrated skills that were 50% lower than their hearing peers on the series of logic tasks using the Tower of Hanoi problem In older children, the differences in performance between the two groups decreased Children with hearing impairment and children with normal hearing (age 13

and older) perform very similarly (less than 10% difference between the performance scores of the two groups) These findings indicate that on a complex, non-linguistic problem solving task, children with hearing impairment may be delayed in their ability to solve problems; the delay appears to resolve with maturation so that problem solving skills eventually become similar to their normal hearing peers

Assessment Measures

Many different standardized tests are available to quantify the language abilities in children. The Clinical Evaluation of Language Fundamentals, Revised (CELF-R) (Semel, Wiig, Secord, & Sabers, 1987) was selected for use in this study to quantify the language abilities of children with hearing impairment. This test was designed to assess the receptive and expressive oral language skills associated with classroom success in students who range in age from 6 to 21 years. Sub-tests for receptive language include assessments of sentence structure, word classes, and concepts and directions Expressive language sub-tests assess formulated sentences, recalling sentences, and knowledge of word structure Composite scores for receptive and expressive language ability, as well as overall language age, may be generated. This particular version of the test was selected rather than the newer CELF-III (Semel, Wiig, & Secord, 1995) because of recent concerns regarding the diagnostic sensitivity of the new test (Perry & Milosky, 1999)

The Peabody Picture Vocabulary Test, Revised (PPVT-R) (Dunn & Dunn, 1981) was administered to assess the knowledge of receptive (hearing) vocabulary of the children in this study This test requires a listener to identify the picture that best represents the meaning of a stimulus word presented orally by the examiner. This

particular version of the test was chosen over the more recent PPVT-III because there is a known correlation of 52 with the CELF-R (Semel, Wiig, & Secord, 1987) The relationship between the scores on the PPVT-III (Dunn & Dunn, 1997) and the CELF-R is not known This modest correlation value suggested some overlap in the domains sampled between the PPVT-R and the CELF-R, but also suggested some independence between the two tests.

Although specific areas of weaknesses may be detected through language tests, the findings may not adequately reflect the child's day-to-day functioning abilities (Leonard, 1998) The TOPS-R (Zachman, et al , 1994) was designed to assess an individual's ability to use critical thinking skills to solve a given problem Using Bloom's Taxonomy of Education Objectives, the test represents six levels of critical thinking. knowledge, comprehension, application, analysis, synthesis, and evaluation Each of the critical thinking levels requires an individual to use his/her life experiences to relate known information to a new task. By following these steps, the TOPS-R is able to assess an individual's ability to think critically, problem solve, and to make decisions. The test also requires an extensive language base since the directions and test questions are heavily dependent on the student's ability to use and apply spoken English language Children are given a picture to examine Spoken questions such as "This man doesn't think he needs to protect his hearing What could you say to make him change his mind?" and "Why do these kids respect their coach?" are asked Subjects must answer the question based upon the information presented through the problem in the picture. Scores for the TOPS-R are based upon the number of problems that an individual can solve correctly Standardizations of the test were based on performance of 1578 normal

subjects (ages 6 0-11.11) for the tasks Age equivalents, percentile ranks, and standard scores are provided for each available raw score This test requires the subject to use language in a more complex form than is assessed by the CELF-R. For success on the TOPS-R, children must demonstrate the ability to use language and apply it to various presented situations This test will be used in the present study in order to assess the problem solving abilities in hearing-impaired children who use spoken English language as their primary mode for communication It was selected because it was the only commercially available norm referenced test of problem solving that requires the use of spoken language

Rationale for the Present Study

It is known that children with hearing impairment exhibit greater difficulties in language learning than do their normally developing peers. It is also known that children with language delays achieve poorer performance on tasks of problem solving that require both a knowledge and use of verbal language However, the problem solving ability of children with hearing impairment who use verbal language as their primary mode of communication does not appear to have been examined to date The present study was designed to examine the ability of children with hearing impairment to solve problems that require the use of spoken language and examine the relationship between spoken language ability and language-based problem solving ability with this population

CHAPTER III

METHODS

Participants

The participants were 11 children with hearing impairment who were enrolled in the University of Tennessee Child Hearing Service oral habilitation program. There were 2 males and 9 females who ranged in age from 6-11 years. Each participant met the following criteria bilateral hearing loss with appropriate amplification, no other known handicapping condition, and spoken language used as the primary mode of communication The following information was obtained from each participant's clinic records: (1) chronological age, (2) age at which hearing loss was identified, (3) age at which participant was first aided, (4) pure tone average in the better ear (threshold at 500, 1000, and 2000 Hz), and (5) aided pure tone average This information is shown in APPENDIX A

Experimental Tests

For each of the experimental tests, raw scores and standard scores were obtained When raw scores were low enough that they were below the minimum standard score provided with the test, linear interpolation was used to compute the standard score. This process was used to interpolate a total of five standard scores: 4 TOPS-R scores and 1 PPVT-R score A separate interpolation was required for each score based on the raw scores and standard scores provided with each test The interpolated values were different for each age group

Language Test

The Clinical Evaluation of Language Fundamentals, Revised (CELF-R) is a language test that is standardized for children from 6-21 years of age The test was administered orally The test measures receptive and expressive language abilities separately The receptive (CELF-R-Rec) and expressive (CELF-R-Exp) tests each contain three subtests. The particular subtests that are used to determine the receptive and expressive language scores depend on the participant's age In the present study, the results of the subtests were combined to obtain CELF-R-Rec and CELF-R-Exp raw scores and standard scores. Because of the broad range of the participants in the current study and the fact that different subtests are used at different ages, analysis at the level of individual subtests was not possible.

Vocabulary Test

The Peabody Picture Vocabulary Test, Revised (PPVT-R) was administered to assess the knowledge of receptive (hearing) vocabulary of the children in this study. This test required the listener to identify the picture that best represents the meaning of a stimulus word presented orally by the examiner. For one participant, the raw score fell below the lowest standard score provided, and as a result, the standard score was computed by linear interpolation

Problem Solving Test

The Test of Problem Solving, Revised (TOPS-R) was used to determine the problem solving abilities of children with hearing impairment This test is standardized

for children ages 6 0-11·11. The test was administered orally Standard scores were interpolated for four participants

Experimental Protocol

Participants were identified with the assistance of audiologists from Child Hearing Services The audiologist contacted the parents of children with hearing impairment who were potential participants. Once informed consent had been obtained from the parents of children with hearing impairment and informed assent had been obtained from their children (APPENDIX C), the three experimental tests were performed in two sessions: Session 1 CELF-R (45-50 minutes) and Session 2. PPVT (15 minutes) and TOPS-R (45 minutes). During each session, the participant was given as many breaks as he or she wanted – typically two breaks per hour The participants were given a small reward after participation in the study, they were not informed beforehand that they would receive a reward.

Analysis

Statistical analyses were performed using standard scores obtained with the four experimental procedures so that comparisons could be made across participants of different ages The data were analyzed using analysis of variance (ANOVA), correlations, and regression analyses

CHAPTER IV

RESULTS

Comparisons Among the Four Experimental Tests

Mean results for the 11 participants are shown in Figure 1 The four experimental tests are shown on the abscissa Standard scores are shown on the ordinate with a horizontal line at each standard deviation (SD) The range for the ordinate was determined on the basis of the high and low standard scores obtained for individual participants· +1 to –6 SD Group means are represented by filled squares with a dashed connecting line. Error bars indicate ± 1 SD The mean standard scores ranged from 77.7 for the CELF-R receptive language test (CELF-R-Rec) to 66 8 for the TOPS-R Thus, for these participants with hearing impairment, the mean standard scores were all located between 1.5 – 2.0 SDs below the mean (standard score = 100) It can be seen that the variability was smallest for the test with the highest score (CELF-R-Rec) and was largest for the test with the lowest score (TOPS-R)

An ANOVA was performed to examine the differences among results for the four experimental tests The results of this analysis indicate that there were no significant differences between the tests and that there were no significant interactions between tests

Because the purpose of this study was to determine the relationship between language ability/vocabulary and problem solving ability, the CELF-R-Rec, CELF-R-Exp, and PPVT-R were grouped and labeled as "the predictive tests," and a regression

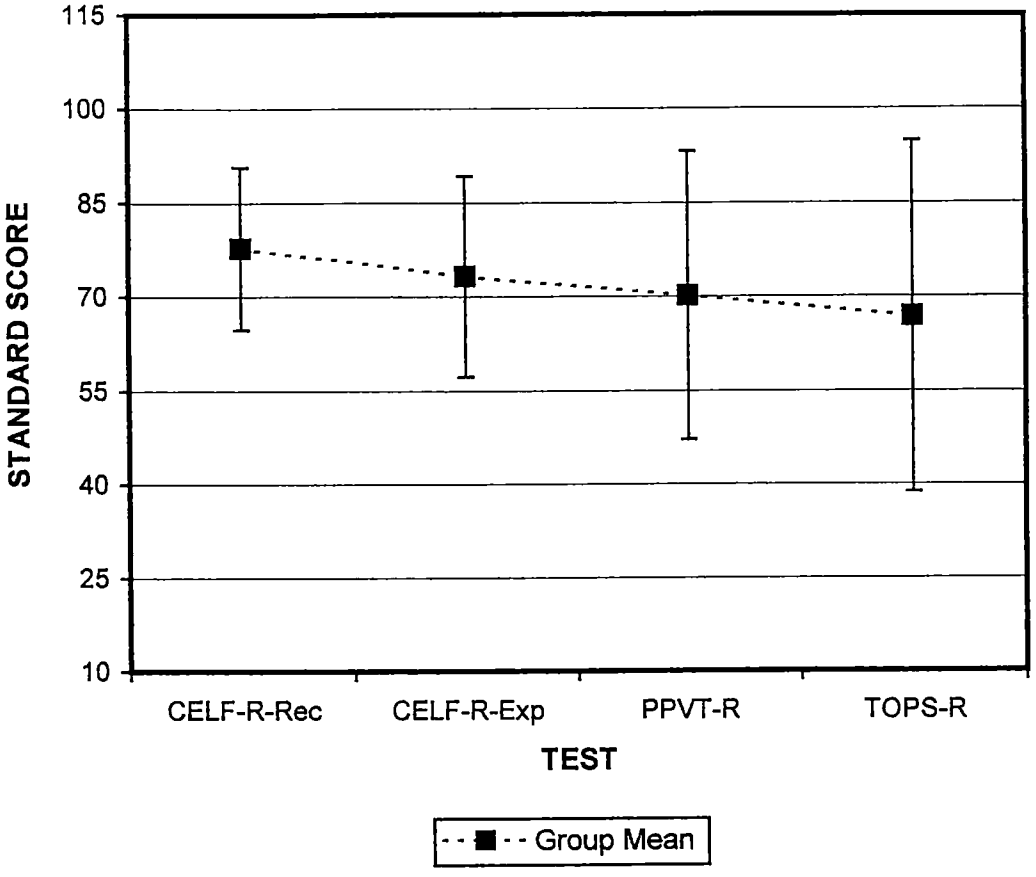

Figure 1. Group results: mean standard scores and SDs for 11 participants.

analysis was performed to determine if the results for the TOPS-R could be predicted using the combined results for the three predictive tests It was found that all three predictive tests considered together were useful in predicting the results for the TOPS-R [$F(3, 10) = 13.78$, $p = .003$] To determine why there was such a strong predictive relationship, the correlations between pairs of individual tests were obtained. The results of these analyses are shown in Table 1 Four of the six possible individual correlations were significant ($p < .05$) indicating that the results for the four tests, in general, were well correlated. Typically, when two measures are highly correlated, combining the measures – as was done in the regression analysis – does not increase the strength of the correlation However, in the present study, the regression analysis using the three predictive tests significantly improved the ability to predict the TOPS-R results From the regression analysis, partial correlation coefficients were computed to determine the contribution of each of the three predictive measures above and beyond all others. The multiple regression improved the ability to predict the TOPS-R scores because each of the predictive tests contributed significantly above and beyond all others CELF-R-Rec [$t = -2.520$, $p = .040$]; CELF-R-Exp [$t = 2.784$, $p = .027$]; PPVT-R [$t = 2.629$, $p = .034$]

The correlation coefficient for the multiple regression, R, was .925 and R^2 was .855 However, due to the reduced number of participants relative to the number of predictors, an adjusted R^2 was computed to be .793. The partial correlation coefficients were used to determine the coefficients of a linear regression equation for the

Table 1. Correlations between pairs of individual tests.

	CELF-R-Exp	PPVT-R	TOPS-R
CELF-R-Rec			
r =	891	556	425
p =	000	076	192
CELF-R-Exp			
r =		703	71
p =		016	014
PPVT-R			
r =			832
p =			001

computation of the predicted TOPS-R scores

$$\text{Predicted TOPS-R} =$$

$$21.864 + (-1.823 \text{ CELF-R-Rec}) + (1.906 \text{ CELF-R-Exp}) + (.67 \text{ PPVT-R})$$

In Figure 2, the relationships between measured and predicted TOPS-R scores are shown The diagonal line indicates where the data points would be located if the measured and predicted scores were identical The largest errors in prediction were ± 1.0 SD (two scores) and ± 0 8 SD (two scores)

Relation Between Experimental and Hearing-Related Measures

An attempt was made to determine if there were a relationships between each of the four experimental measures and each of the four hearing-related measures (1) age at which hearing loss was first identified, (2) age at which participant was first aided, (3) pure tone average in the better ear, and (4) aided pure tone average None of the 16 correlations was significant The highest correlation was between unaided pure tone averages in the better ear and the CELF-R-Exp scores [$r = .51$, $t(9) = 1.76$, $p > .05$]

Results for Individual Participants

The raw data for the 11 participants are shown in APPENDICES A and B The mean results shown in Figure 1 do not reflect the variety of patterns of results obtained for individual participants. As a result, the data for individual participants were broken into three groups based on pattern (1) those with TOPS-R scores that were better than

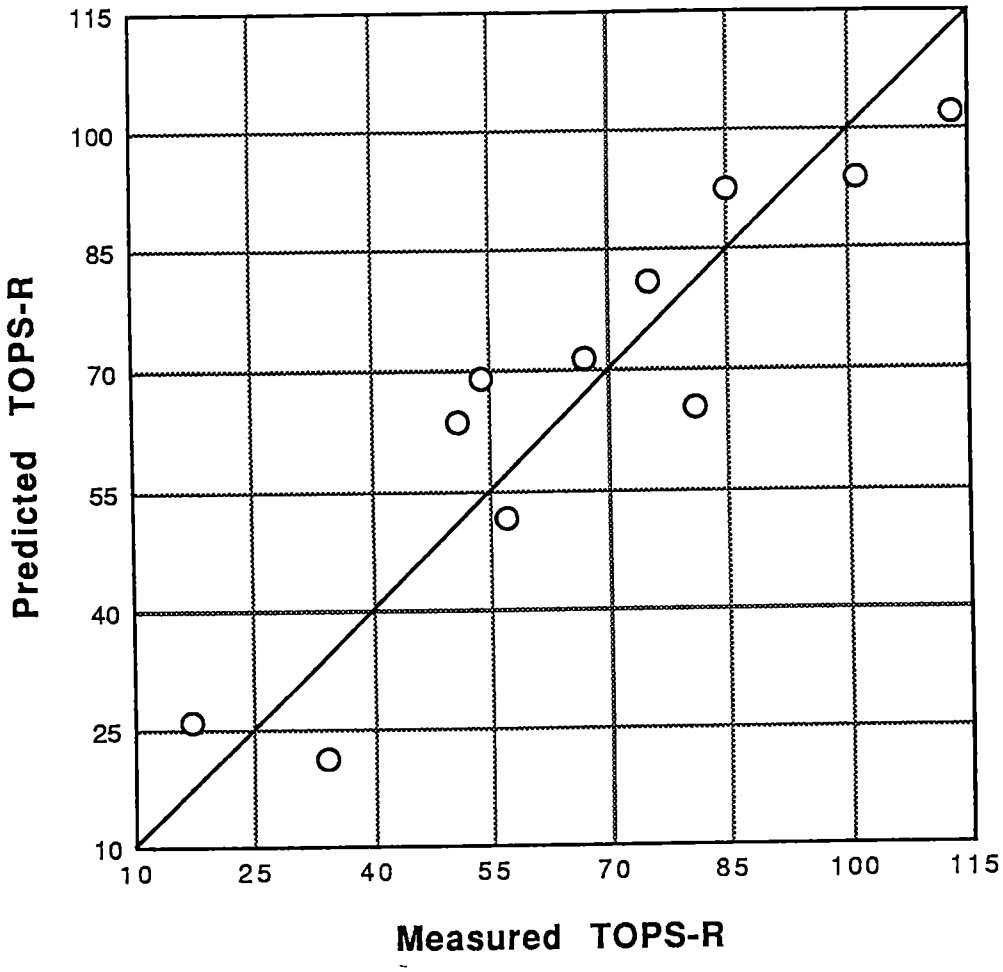

Figure 2. Measured TOPS-R and predicited TOPS-R (using CELF-R-Rec, CELF-R-Exp, & PPVT-R).

their CELF-R scores (Figure 3), (2) those whose TOPS-R and CELF-R scores were similar (Figure 4), and (3) those with TOPS-R scores poorer than their CELF-R scores (Figure 5)

The data in Figures 3, 4, and 5 were plotted using the same format as in Figure 1 The mean results are shown in Figures 3, 4, and 5 as they were in Figure 1 using filled squares and dashed connecting lines while the individual participant scores are shown using unfilled symbols and solid connecting lines

TOPS-R Scores > CELF-R Scores

For Participants 3, 4, and 9 (Figure 3), the problem solving scores were better than the language scores and vocabulary scores. For Participants 3 and 4, the language scores were above the group mean while for Participant 9, they were below the group mean For all three participants, the vocabulary scores were better than average and the problem solving scores were both better than average and better than the vocabulary scores

TOPS-R Scores = CELF-R Scores

For Participant 5, 8, 10, and 11 (Figure 4), the problem solving scores were similar to the language scores. Both the problem solving scores and the language scores were distributed around the group mean The vocabulary scores, in general, were slightly better than the problem solving scores and language scores

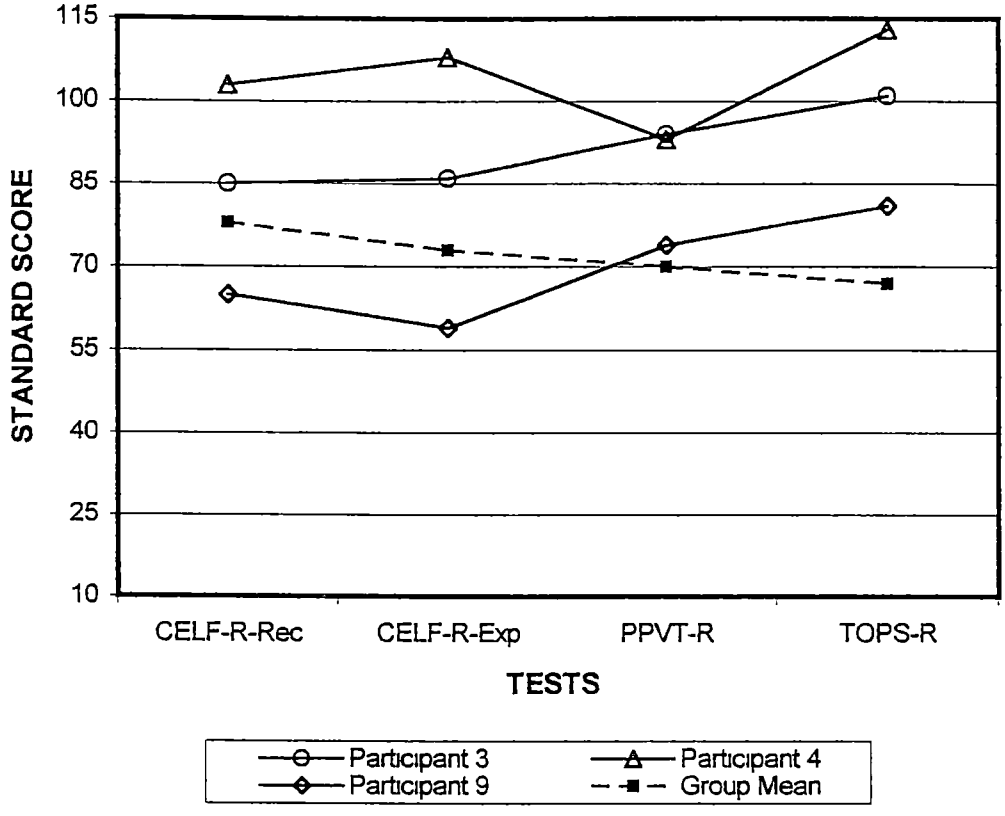

Figure 3. Problem solving abilities better than language skills for three participants.

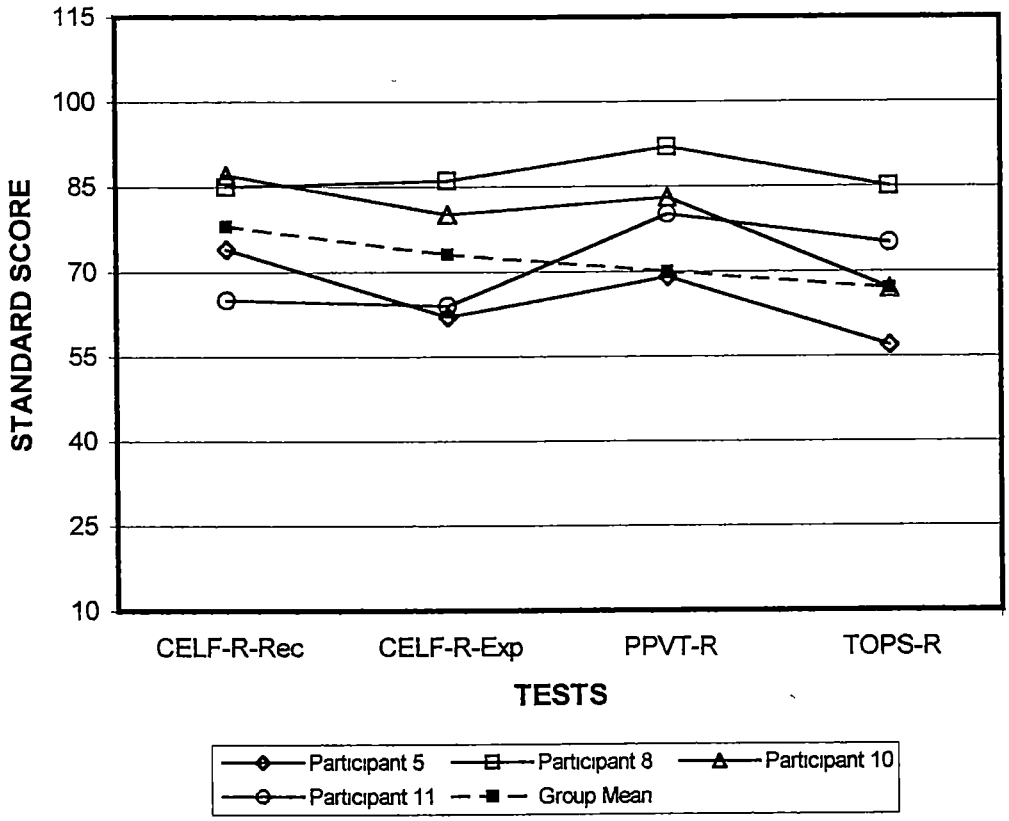

Figure 4. Problem solving abilities similar to language skills for four participants.

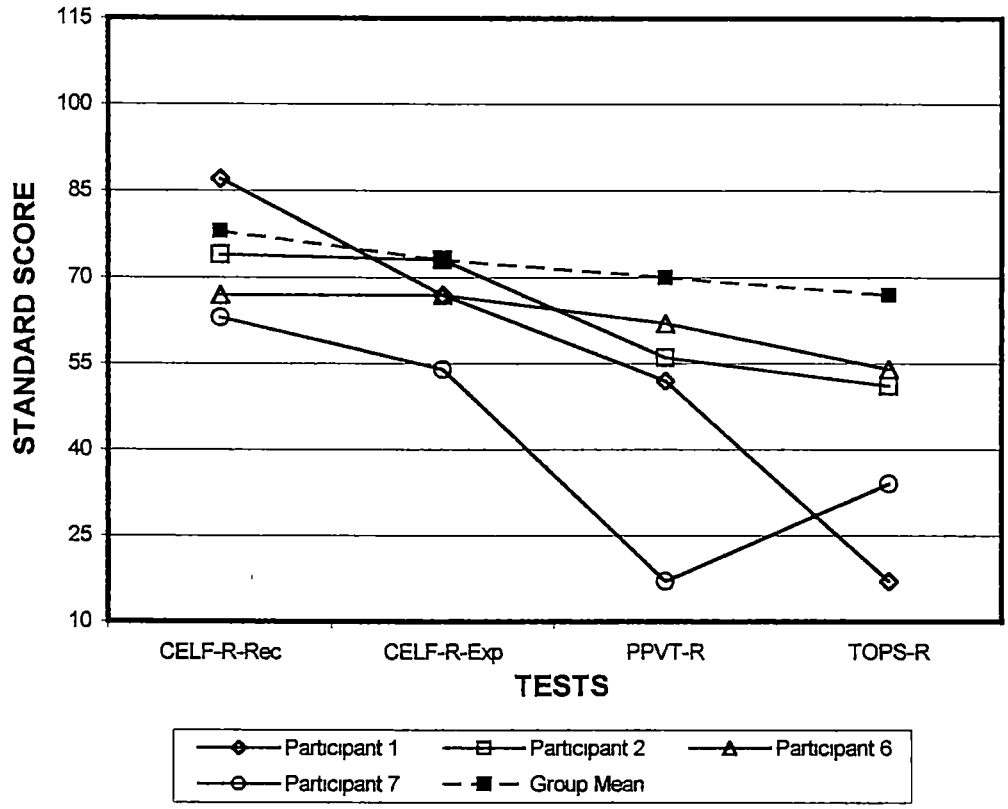

Figure 5. Problem solving abilities poorer than language skills for four participants.

TOPS-R Scores < CELF-R Scores

For Participants 1, 2, 6, and 7 (Figure 5), the problem solving scores were significantly poorer than the language scores In Figure 3, the individual participant functions turned upward indicating that problem solving ability was better than language ability In Figure 4, the functions are relatively flat indicating that problem solving and language abilities were similar But in Figure 5, the receptive language scores are distributed around the group mean, the expressive language scores are poorer, the vocabulary scores are poorer still, and the problem solving scores are the poorest All of the problem solving scores shown in Figure 5 were interpolated because they fell below the minimum standard scores provided with the TOPS-R test In this group, the very poor problem solving ability (3-5 SDs below normal) was associated with expressive language ability that was slightly below the group mean and vocabulary that was further below the group mean

CHAPTER V

DISCUSSION

Average Tests Results for Participants with Hearing Loss

In a single-subject study with a school-aged child with hearing impairment, Fisher (2000) found that problem solving ability measured with the TOPS-R was much poorer than would have been predicted from the child's language scores One reason for the present study was to determine if this was a typical finding in all children with hearing impairment. The mean results (Figure 1) indicate that problem solving ability is slightly, but not significantly, poorer than language abilities. Though some participant's problem solving abilities were much poorer than their language abilities – as Fisher had found – on average for the group, there were no dramatic differences between language scores and problem solving scores However, mean results for all measures (receptive language ability, expressive language ability, vocabulary, and problem solving ability) were all 1 5-2 0 SDs below the mean for typically developing children

Comparison of Problem Solving Ability with Normal Development, Language Impairment, and Hearing Impairment

In the documentation for the TOPS-R (Zachman, et al., p 114), a comparison is made between results for typically developing children and children with language impairment of unspecified degree For every age group from 6.0-11 11, the problem solving skills of children with language impairment were significantly poorer than for the normally developing children The data from Zachman, et al have been plotted in Figure 6 along with the scores for the 11 participants in the present study Raw scores are shown

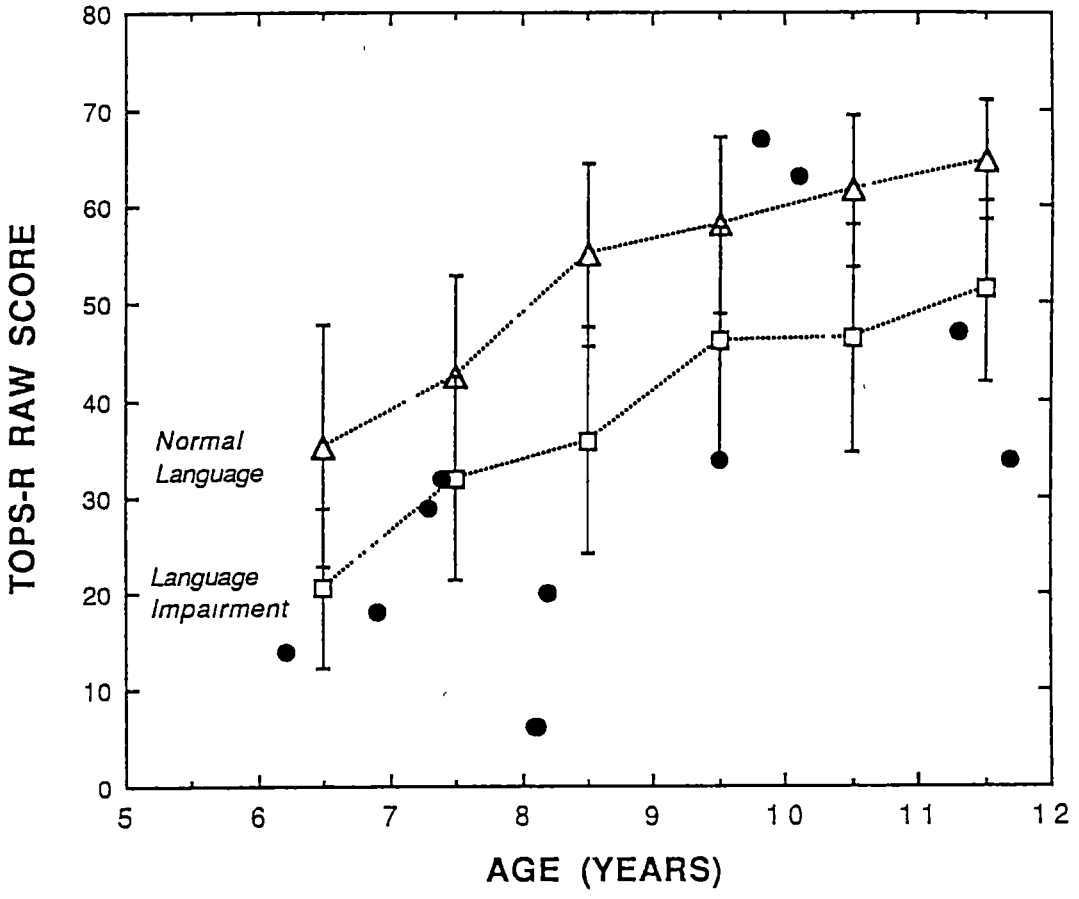

Figure 6. TOPS-R raw scores for children with hearing impairment compared to average raw scores for children with normal language and children with language impairment. The normal language group is represented by unfilled triangles and the language impairment group is represented by unfilled squares. The error bars indicate standard deviations. The results for the participants with hearing impairment in the present study are shown with filled circles.

on the ordinate; age in years is shown on the abscissa Means and SDs are shown for typically developing children (open triangles) and for children with language impairment (open squares); individual data points (solid circles) are the results for the 11 participants in the present study

Nine of the 11 participants had TOPS-R scores within the range or poorer than the mean scores for the children with language impairment who were in the same age group Three of the children with hearing impairment had poorer TOPS-R scores than the children with language impairment. In general, the participants with better language also had better problem solving skills. The participants could be placed into one of three groups:

(1) Normal language (CELF-R total language standard score = 106) and normal problem solving ability Participant 4

(2) Borderline normal language (CELF-R total language standard score = 82-84) and varying problem solving ability
- Normal problem solving ability Participant 3,
- Borderline normal problem solving ability· Participant 8,
- Poor problem solving ability Participant 10

(3) Poor language (CELF-R total language standard score < 76) and problem solving abilities Participants 1, 2, 5, 6, 7, 9, and 11

In summary, the participants in this group could be described as being language impaired Only one individual had normal language ability also had normal problem solving ability The three participants with borderline normal language ability had problem solving abilities that ranged from normal to poor However, the eight participants who were in the majority, had poor language abilities as well as poor problem solving ability.

Factors Related to Problem Solving Ability

The results of the regression analysis with partial correlations demonstrated that receptive language, expressive language, and vocabulary scores each contributed significantly to the prediction of the language-based problem solving scores Though the correlation between vocabulary and language-based problem solving was greatest, the language-based problem solving score was predicted most accurately when all three tests were considered together with the predictive equation The relationship specified by the equation accounts for 79 3% of the variance associated with the language-based problem solving scores This was the most important finding of the present study

At the outset of the present study, an attempt was made to identify the relevant factors in problem solving that involved the use of language Thornton (1995) proposed that problem solving was the use of language processes and knowledge base in conjunction with inborn abilities to make inferences The results of the present study provide evidence to support this view Language abilities were found to be significant factors in predicting problem solving abilities A second important finding of the present study was that receptive and expressive language abilities are related independently and differently to problem solving

A third important finding was that vocabulary was most strongly correlated with problem solving ability. This finding was not expected because of the description given by Zachman et al. (1994) of the thinking skills required to perform the TOPS-R knowledge, comprehension, application, analysis, synthesis, and evaluation Because of the wide range of skills that were required, it was anticipated that this form of problem solving ability would be more dependent on language skills than on the knowledge base

or lexicon. However, the results provide clear evidence that vocabulary (knowledge base) was a more important factor than either receptive or expressive language ability

Factors Related to Hearing Loss

A major concern in the design of the present study was consideration of factors related to hearing loss· age at which hearing loss was identified, age at which amplification was first fitted, degree of hearing loss, and aided hearing level. None of these factors were significantly related to problem solving ability, vocabulary, receptive language ability, or expressive language ability. However, in the present study, the range of ages and hearing losses was sufficiently narrow that these conclusions need to be confirmed in participants who are both older and younger and on participants with a wider range of hearing impairment

Conclusions

In the present study, it was found that problem solving ability that involved the use of language was very significantly related to receptive language, expressive language, and receptive vocabulary in children with hearing impairment Though there was a wide range of individual differences, on average, theses children performed below the mean for typically developing children in every measurement category This is consistent with the findings of previous studies. In children with hearing impairment, the cause for language impairment and reduced vocabulary are due to reduced auditory input.

The present results indicate that a more comprehensive evaluation of children with hearing impairment may be of value in determining their functional skills With the

four tests used in the present study, a great range of individual differences was revealed Knowledge of these differences may be of use in developing a plan to meet the needs of an individual

If language skills and vocabulary are important for solving certain types of problems, then it may be possible to improve problem solving abilities by teaching language and vocabulary Future work might include the study of other factors such as the contribution of non-verbal intelligence and the contribution of maturation and development.

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APPENDICES

APPENDIX A

RAW DATA SUMARY:

DEMOGRAPHIC AND EXPERIMENTAL

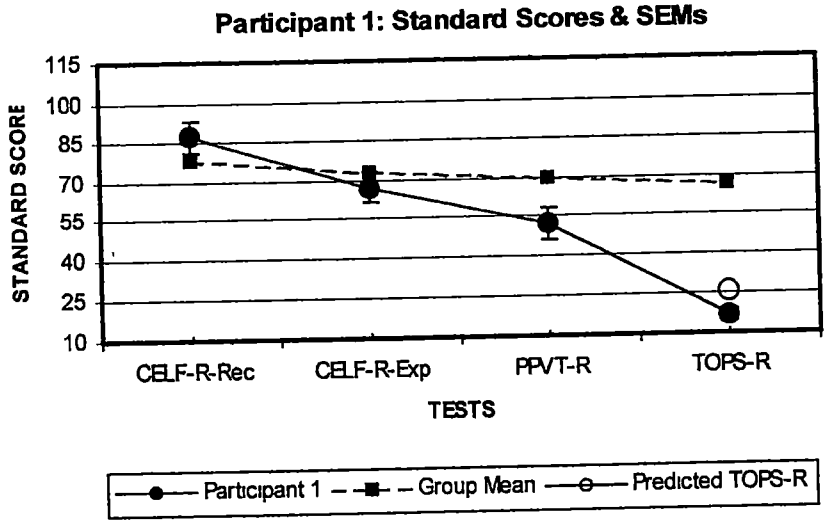
RAW DATA FOR INDIVIDUAL PARTICIPANTS

Participant 1

PARTICIPANT DEMOGRAPHIC DATA	
Sex	Male
Chronological Age in Years	11 7
Age HL Identified in Years	3.3
Age First Aided in Years	3 4
PTA in Better Ear in dB HL	62
Aided PTA in dB HL	35

EXPERIMENTAL DATA		
	Raw Score	**Standard Score (SEM)**
CELF-R Receptive	**24**	**87 (6)**
- Oral Directions	20	11 (2)
- Word Classes	18	6 (1)
- Semantic Relationships	16	7 (1)
CELF-R Expressive	**15**	**67 (6)**
- Formulated Sentences	31	3 (2)
- Recalling Sentences	54	5 (1)
- Sentence Assembly	13	7 (1)
CELF-R Total Language	39	75 (4)
PPVT-R	**73**	**52 (6)**
TOPS-R	**34**	**17 (2) ***
Predicted TOPS-R		**25.805**

*Interpolated

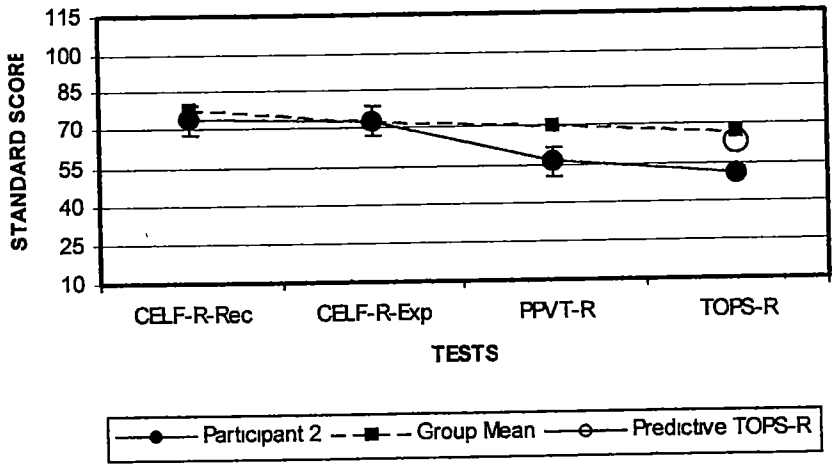


Participant 2

PARTICIPANT DEMOGRAPHIC DATA		
Sex	Female	
Chronological Age in Years	11 3	
Age HL Identified in Years	2 6	
Age First Aided in Years	3	
PTA in Better Ear in dB HL	56	
Aided PTA in dB HL	22	
EXPERIMENTAL DATA		
	Raw Score	**Standard Score (SEM)**
CELF-R Receptive	**18**	**74 (6)**
- Oral Directions	19	9 (2)
- Word Classes	17	5 (1)
- Semantic Relationships	9	4 (1)
CELF-R Expressive	**18**	**73 (6)**
- Formulated Sentences	45	6 (2)
- Recalling Sentences	40	6 (1)
- Sentence Assembly	9	6 (1)
CELF-R Total Language	36	72 (4)
PPVT-R	**76**	**56 (6)**
TOPS-R	**47**	**51 (2) ***
Predicted TOPS-R		**63.6**

* Interpolated

Participant 2: Standard Scores & SEMs

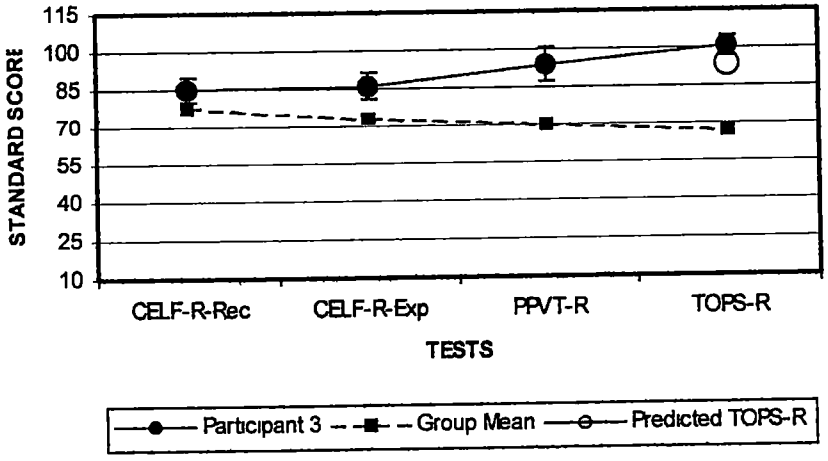


Participant 3

PARTICIPANT DEMOGRAPHIC DATA	
Sex	Female
Chronological Age in Years	10 1
Age HL Identified in Years	1
Age First Aided in Years	1 6
PTA in Better Ear in dB HL	57
Aided PTA in dB HL	27

EXPERIMENTAL DATA		
	Raw Score	**Standard Score (SEM)**
CELF-R Receptive	**23**	**85 (5)**
- Oral Directions	20	11 (2)
- Word Classes	15	5 (2)
- Semantic Relationships	16	7 (1)
CELF-R Expressive	**24**	**86 (5)**
- Formulated Sentences	47	7 (1)
- Recalling Sentences	63	9 (1)
- Sentence Assembly	12	8 (1)
CELF-R Total Language	47	84 (4)
PPVT-R	**101**	**94 (7)**
TOPS-R	**63**	**101 (4)**
Predicted TOPS-R		**93.8**

Participant 3: Standard Score & SEMs

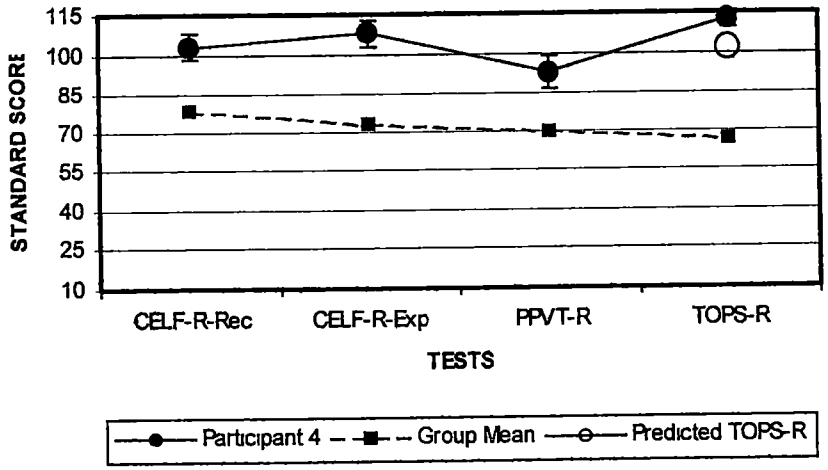


Participant 4

PARTICIPANT DEMOGRAPHIC DATA	
Sex	Male
Chronological Age in Years	9.8
Age HL Identified in Years	1
Age First Aided in Years	1 2
PTA in Better Ear in dB HL	82
Aided PTA in dB HL	33

EXPERIMENTAL DATA		
	Raw Score	**Standard Score (SEM)**
CELF-R Receptive	**32**	**103 (5)**
- Oral Directions	20	12 (2)
- Word Classes	20	9 (1)
- Semantic Relationships	20	11 (1)
CELF-R Expressive	**34**	**108 (5)**
- Formulated Sentences	57	13 (1)
- Recalling Sentences	65	10 (1)
- Sentence Assembly	17	11 (1)
CELF-R Total Language	39	106 (4)
PPVT-R	**91**	**93 (6)**
TOPS-R	**67**	**113 (3)**
Predicted TOPS-R		**102.3**

Participant 4: Standard Scores & SEMs

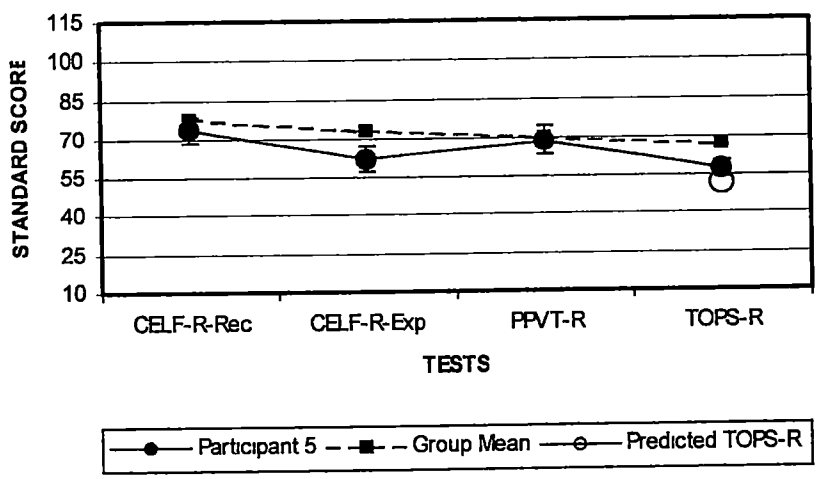


Participant 5

PARTICIPANT DEMOGRAPHIC DATA	
Sex	Female
Chronological Age in Years	9 5
Age HL Identified in Years	3
Age First Aided in Years	6
PTA in Better Ear in dB HL	53
Aided PTA in dB HL	25

EXPERIMENTAL DATA		
	Raw Score	**Standard Score (SEM)**
CELF-R Receptive	**18**	**74 (5)**
- Oral Directions	12	5 (2)
- Word Classes	17	7(1)
- Semantic Relationships	10	6 (1)
CELF-R Expressive	**13**	**62 (5)**
- Formulated Sentences	27	3 (1)
- Recalling Sentences	38	3 (1)
- Sentence Assembly	7	7 (1)
CELF-R Total Language	31	66 (4)
PPVT-R	**77**	**69 (6)**
TOPS-R	**34**	**57 (3)**
Predicted TOPS-R		**51.4**

Participant 5: Standard Scores & SEMs

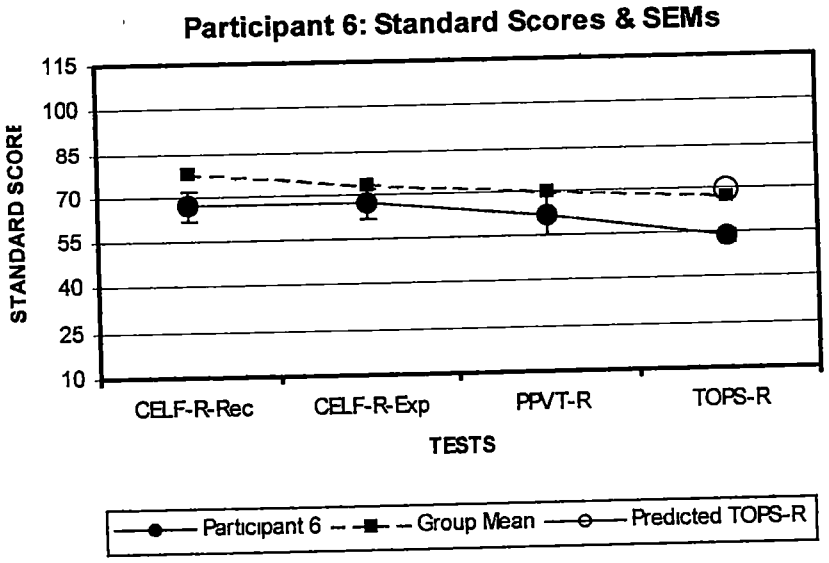


Participant 6

PARTICIPANT DEMOGRAPHIC DATA	
Sex	Female
Chronological Age in Years	8 2
Age HL Identified in Years	1 5
Age First Aided in Years	2
PTA in Better Ear in dB HL	72
Aided PTA in dB HL	32

EXPERIMENTAL DATA	Raw Score	Standard Score (SEM)
CELF-R Receptive	**15**	**67 (5)**
- Oral Directions	5	4 (1)
- Word Classes	6	5 (1)
- Semantic Relationships	7	6 (1)
CELF-R Expressive	**15**	**67 (5)**
- Formulated Sentences	31	4 (1)
- Recalling Sentences	36	3 (1)
- Sentence Assembly	9	8 (1)
CELF-R Total Language	30	65 (4)
PPVT-R	**61**	**62 (7)**
TOPS-R	**20**	**54 (2) ***
Predicted TOPS-R		**69.0**

* Interpolated



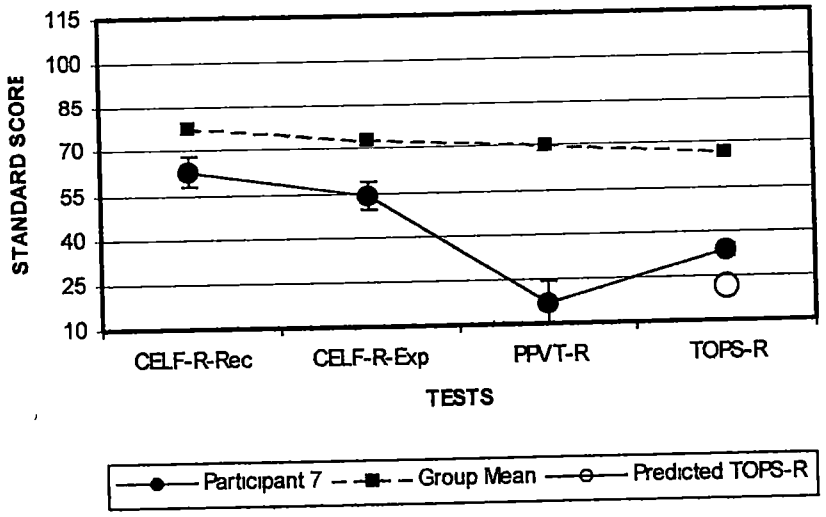
Participant 7

PARTICIPANT DEMOGRAPHIC DATA	
Sex	Female
Chronological Age in Years	8 1
Age HL Identified in Years	0
Age First Aided in Years	2 3
PTA in Better Ear in dB HL	62
Aided PTA in dB HL	27

EXPERIMENTAL DATA		
	Raw Score	**Standard Score (SEM)**
CELF-R Receptive	**13**	**63 (5)**
- Oral Directions	4	4 (1)
- Word Classes	7	5 (1)
- Semantic Relationships	3	4 (1)
CELF-R Expressive	**11**	**54 (5)**
- Formulated Sentences	18	3 (1)
- Recalling Sentences	24	3 (1)
- Sentence Assembly	1	5 (1)
CELF-R Total Language	24	55 (4)
PPVT-R	**24**	**17 (7) ***
TOPS-R	**6**	**34 (2) ***
Predicted TOPS-R		**21.3**

* Interpolated

Participant 7: Standard Scores & SEMs

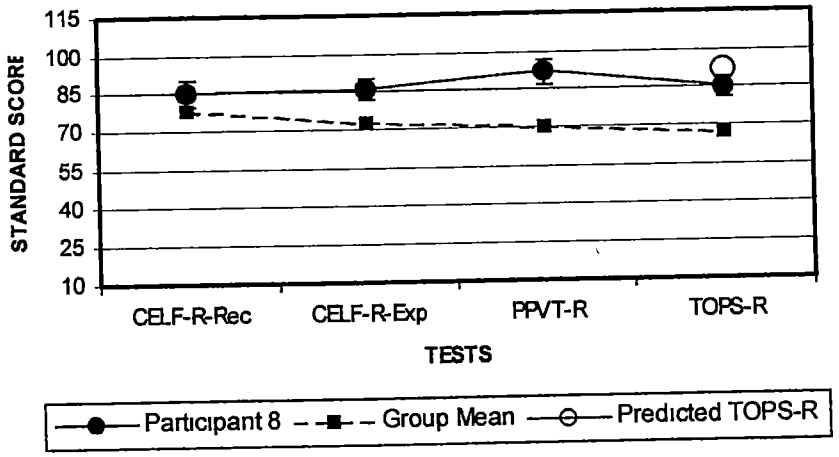


Participant 8

PARTICIPANT DEMOGRAPHIC DATA	
Sex	Female
Chronological Age in Years	7 4
Age HL Identified in Years	3
Age First Aided in Years	3 4
PTA in Better Ear in dB HL	80
Aided PTA in dB HL	40

EXPERIMENTAL DATA		
	Raw Score	**Standard Score (SEM)**
CELF-R Receptive	**23**	**85 (5)**
- Linguistic Concepts	18	10 (1)
- Sentence Structure	22	7 (1)
- Oral Directions	7	6 (1)
CELF-R Expressive	**24**	**86 (4)**
- Word Structure	29	8 (1)
- Formulated Sentences	47	10 (1)
- Recalling Sentences	40	6 (1)
CELF-R Total Language	47	84 (3)
PPVT-R	**78**	**92 (5)**
TOPS-R	**32**	**85 (4)**
Predicted TOPS-R		**92.5**

Participant 8: Standard Scores & SEMs

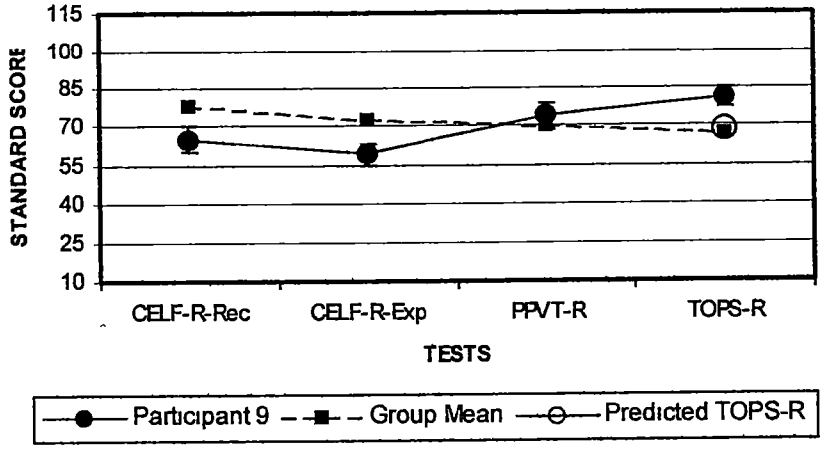


Participant 9

PARTICIPANT DEMOGRAPHIC DATA	
Sex	Female
Chronological Age in Years	7.3
Age HL Identified in Years	2.8
Age First Aided in Years	2.9
PTA in Better Ear in dB HL	65
Aided PTA in dB HL	28

EXPERIMENTAL DATA		
	Raw Score	**Standard Score (SEM)**
CELF-R Receptive	**14**	**65 (5)**
- Linguistic Concepts	9	5 (1)
- Sentence Structure	12	5 (1)
- Oral Directions	1	4 (1)
CELF-R Expressive	**12**	**59 (4)**
- Word Structure	18	5 (1)
- Formulated Sentences	23	4 (1)
- Recalling Sentences	26	3 (1)
CELF-R Total Language	26	59 (3)
PPVT-R	**62**	**74 (5)**
TOPS-R	**29**	**81 (4)**
Predicted TOPS-R		**65.4**

Participant 9: Standard Scores & SEMs

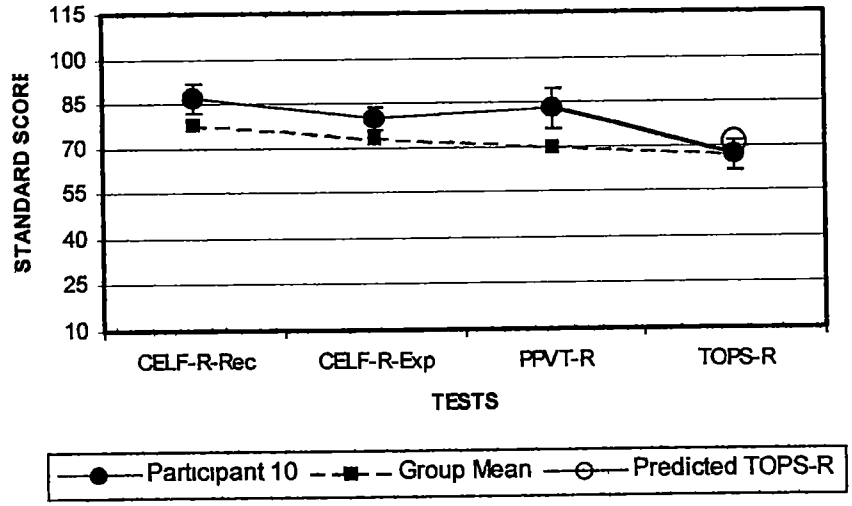


Participant 10

PARTICIPANT DEMOGRAPHIC DATA	
Sex	Female
Chronological Age in Years	6.9
Age HL Identified in Years	3
Age First Aided in Years	3
PTA in Better Ear in dB HL	72
Aided PTA in dB HL	28

EXPERIMENTAL DATA		
	Raw Score	**Standard Score (SEM)**
CELF-R Receptive	**24**	**87 (5)**
- Linguistic Concepts	13	7 (1)
- Sentence Structure	23	10 (1)
- Oral Directions	6	7 (1)
CELF-R Expressive	**21**	**80 (4)**
- Word Structure	21	6 (1)
- Formulated Sentences	26	7 (1)
- Recalling Sentences	43	8 (1)
CELF-R Total Language	45	82 (3)
PPVT-R	**65**	**83 (7)**
TOPS-R	**18**	**67 (5)**
Predicted TOPS-R		**71.4**

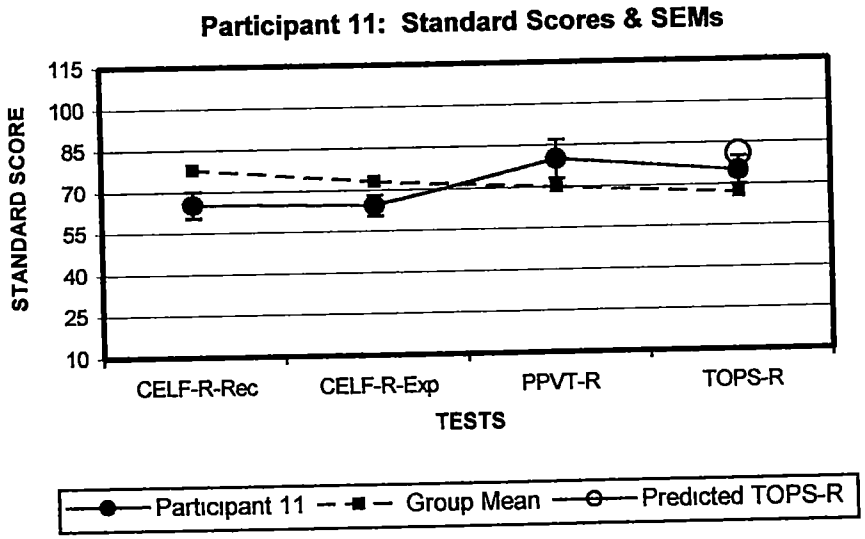
Participant 10: Standard Scores & SEMs



Participant 11

PARTICIPANT DEMOGRAPHIC DATA	
Sex	Female
Chronological Age in Years	6 2
Age HL Identified in Years	2.6
Age First Aided in Years	2 9
PTA in Better Ear in dB HL	77
Aided PTA in dB HL	33

EXPERIMENTAL DATA	Raw Score	Standard Score (SEM)
CELF-R Receptive	**14**	**65 (5)**
- Linguistic Concepts	3	3 (1)
- Sentence Structure	16	6 (1)
- Oral Directions	2	5 (1)
CELF-R Expressive	**14**	**65 (4)**
- Word Structure	12	4 (1)
- Formulated Sentences	19	6 (1)
- Recalling Sentences	23	4 (1)
CELF-R Total Language	28	63 (3)
PPVT-R	**53**	**80 (7)**
TOPS-R	**14**	**75 (5)**
Predicted TOPS-R		**80.9**



APPENDIX B

RAW DATA SUMMARY:

DEMOGRAPHIC AND EXPERIMENTAL

RAW DATA FOR ALL PARTICIPANTS

Participant	Sex	Chronological Age in Years	Age HL Identified in Years	Age First Aided in Years	PTA in Better Ear in dB HL	Aided PTA in dB HL	CELF-R Receptive	CELF-R Expressive	PPVT-R	TOPS-R
1	M	11.7	3 3	3 4	62	35	87	67	52	17
2	F	11 3	2.6	3	56	22	74	73	56	51
3	F	10.1	1	1 6	57	27	85	86	94	101
4	M	9 8	1	1 2	82	33	103	108	93	113
5	F	9 5	3	6	53	25	74	62	69	57
6	F	8 2	1 5	2	72	32	67	67	62	54
7	F	8 1	0	2.3	62	27	63	54	17	34
8	F	7 4	3	3 4	80	40	85	86	92	85
9	F	7 3	3	3	65	28	65	59	74	81
10	F	6 9	2.8	2 9	72	28	87	80	83	67
11	F	6 2	2 6	2.9	77	33	65	64	80	75
Mean		8 8	2 2	2 9	67.1	30 0	77 7	73 3	70 2	66 8
SD							12 7	15 6	23.0	28 2

APPENCIX C

PARENT INFORMED CONSENT FORM

AND

CHILD ASSENT FORM

RESEARCH STUDY ON "LANGUAGE-BASED PROBLEM SOLVING AND LANGUAGE ABILITY IN CHILDREN WITH HEARING IMPAIRMENT"

PARENT INFORMED CONSENT

I am a graduate student in audiology at the University of Tennessee, Knoxville. I am interested in the problem solving skills of children who are hearing impaired. I would like to ask for your child to participate in a study that will allow me to look at this issue. Your consent for your child's participation will allow me to assess his/her language ability and problem solving skills.

I will be asking your child to participate in two 60-minute test sessions – a total of no more than two hours. The two sessions may be scheduled for the same day or on two different days. In one test sessions, I will be administering a test of language ability (CELF-R), and in the other test session, I will be administering a vocabulary test (PPVT-R), and a test of problem solving (TOPS-R). The results of these tests will be compared to determine how language ability and vocabulary relate to problem solving ability. I also request your permission to obtain the following test results from your child's records: your child's hearing test results. I am also requesting to know the age at which your child first began wearing hearing aids. Will you provide this information?

_____

There are no known risks to your child for this study. The information in the study records will be kept confidential. Data will be stored securely and will be made available only to myself, my advisor, and to you. Your child's name will not be used in oral or written reports that could link your child to the study.

If you have questions at any time about the study or the procedures, you may contact me, Katie Vaden, or my advisor, Dr. James Thelin at 544A South Stadium Hall on the University of Tennessee, Knoxville campus or by phone at (865) 974-1796. If you have questions about 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 your child may decline to participate without penalty. If your child withdraws from the study before data collection is completed, the 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 participate and to allow my child to participate in this study.

Parent's signature: _____ Date: _____

RESEARCH STUDY ON "LANGUAGE-BASED PROBLEM SOLVING AND LANGUAGE ABILITY IN CHILDREN WITH HEARING IMPAIRMENT"

CHILD ASSENT SCRIPT

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

Jane/John, my name is Katie Vaden. I am a student and I work with people who have a hearing loss and wear hearing aids just like you do. I want to learn about how you solve problems and use language. I would like to have you complete a problem solving activity and answer some questions. There are no right or wrong answers to any of the questions, and you will not receive a grade for your answers. I would just like to show you some pictures and have you tell me what the pictures are and/or answer some questions about the pictures. I would like to meet with you two different days. Each meeting time will take about one hour, and you may stop at any time if you wish. Remember, if you decide that you do not want to do the activities with me, all you have to do is tell me, your parents, or your teacher.

- Do you think it would be ok to do the problem solving activities with you?
  Yes _____ No _____
- Would it be ok for me to ask you some questions?
  Yes _____ No _____
- Do you have any questions?
  Yes _____ No _____

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

_____
Child's Name

_____
Date

VITA

Katie Alice Vaden was born on February 15, 1977 She grew up on a farm in Franklin, Tennessee and was educated in the Williamson County School System Katie graduated from Fred J. Page High School in 1995 and began her college career at Auburn University. She enrolled in the speech pathology program with the intent of working on the speech and language development of children with hearing impairment.

During her second year of college, Katie enrolled in the University of Tennessee, Knoxville and pursued a major in Audiology. She graduated with her bachelor's degree in 1999. She continued her education at the University of Tennessee, receiving her master's degree in Audiology in May of 2001