PROFOUNDLY DEAF STUDENTS' PERFORMANCE ON ARITHMETICAL WORD PROBLEMS

by

MARGUERITE CHAUVET LAPAWA
B.Ed., University of Alberta, 1975

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF ARTS

in the Department
of
Special Education

We accept this thesis as conforming
to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

Department of SPECIAL EDUCATION

The University of British Columbia
2075 Wesbrook Place
Vancouver, Canada
V6T 1W5

Date 80-10-30

ABSTRACT

The investigation examined the performance of profoundly hearing impaired students on one-step word problems in arithmetic. Students were administered a computation task and those who met the pass requirements were given a word problem task. These ninety subjects were divided into four age groups as follows: 8-11 years; 12-13 years; 14-15 years; and 16+ years. Statistical treatment of the data showed no significant differences when age and gender were examined for any of the word problems which involved the four operations of addition, subtraction, multiplication or division. Significant differences however, were found for type of question for addition and subtraction word problems. There was a significant interaction between type of question, age, and gender for division problems. When age and gender were collapsed, a second analysis revealed that operation, type of question, and the interaction between operation and type of question were all significant. Error analysis revealed that profoundly hearing impaired students, when faced with a word problem requiring subtraction or division, were likely to either add or multiply. Educational implications are discussed and suggestions made for futher research.

TABLE OF CONTENTS

	Page
TITLE PAGE	i
ABSTRACT	ii
TABLE OF CONTENTS	iii
LIST OF TABLES	v
LIST OF FIGURES	vi
ACKNOWLEDGEMENT	vii
CHAPTER I. INTRODUCTION	1
DEFINITION OF TERMS	4
CHAPTER II. PROBLEM	6
STATEMENT OF THE PROBLEM	6
REVIEW OF THE LITERATURE	6
STATEMENT OF HYPOTHESES	20
CHAPTER III. METHOD	21
SAMPLE POPULATION	21
TEST INSTRUMENTS	22
SCORING	26
PROCEDURE	27
DATA ANALYSIS	28
CHAPTER IV. RESULTS AND DISCUSSION	29

	Page
CHAPTER V. CONCLUSIONS	51
SUMMARY	51
LIMITATIONS	54
IMPLICATIONS	54
FUTURE RESEARCH	56
BIBLIOGRAPHY	58
APPENDIX A	64

LIST OF TABLES

TABLE		Page
I	Number and Percentage Distribution of Gender Within Age	22
II	Three Way Analysis of Variance (univariate) Age by Gender by Type of Question (Addition)	30
III	Performance Means and Standard Deviations Type of Question by Age Group (Addition)	30
IV	Error Analysis for Addition	32
V	Three Way Analysis of Variance (univariate) Age by Gender by Type of Question (Subtraction)	34
VI	Performance Means and Standard Deviations Type of Question by Age Group (Subtraction)	34
VII	Error Analysis for Subtraction	36
VIII	Three Way Analysis of Variance (univariate) Age by Gender by Type of Question (Multiplication)	38
IX	Performance Means and Standard Deviations Type of Question by Age Group (Multiplication)	38
X	Error Analysis for Multiplication	40
XI	Three Way Analysis of Variance (univariate) Age by Gender by Type of Question (Division)	42
XII	Performance Means and Standard Deviations Type of Question by Age Group (Division)	42
XIII	Error Analysis for Division	44
XIV	Summary ANOVA (univariate) Mathematical Operation by Type of Question	46
XV	Performance Means and Standard Deviations Mathematical Operation by Type of Question	46
XVI	Total Error Analysis	50

LIST OF FIGURES

FIGURE Page

1 Interaction Graph, Type of Question by Age 35

2 Interaction Graphs, Gender by Age for Both Types of Question 43

3 Interaction Graph, Type of Question by Operation 48

ACKNOWLEDGEMENTS

The writer wishes to acknowledge the assistance which she received from the administration and staff of Jericho Hill School for the Deaf. It was through their cooperation that the work of data collection was facilitated.

To the members of my committee Dr. T. Rogers and Dr. P. Leslie, go my thanks for their advice and time on this study.

A special note of appreciation to Dr. B. R. Clarke my advisor, whose encouragement and positive thinking made this study a special educational experience.

CHAPTER I

INTRODUCTION

The word problem has long held an important place in instruction in elementary school arithmetic. Nevertheless, there is a general lack of agreement as to just which of the many variables studied significantly influence one's ability to solve verbal problems.

Researchers (Coffing 1941, Hansen 1944, Van der Linde 1964, Meyer 1978, and Webb 1979) studying one or more factors relating to problem solving have in general concluded the following: a) intelligence was significantly related to problem solving ability, b) problems in addition were the easiest to solve followed by subtraction, multiplication, and division in that order, c) sex differences do not appear to effect problem solving ability, d) no significant differences exist in achievement between problems in textbooks and problems written by children using familiar settings and people, e) computational difficulties appear to be a major deterrent to finding correct answers, f) reading ability is positively correlated with problem solving ability (see Suydam and Weaver 1977).

Coffing (1941) concluded that a positive relation existed between silent reading and the ability to solve reasoning problems. Van der Linde (1964) however, stated that vocabulary was one of the main factors in the same ability.

Other investigations (Monroe and Engelhart 1933, Faulk and Landry

1961) demonstrated the advantage of a given method of problem analysis as an aid to problem solving and showed that encouraging children to solve problems in a variety of ways appears to help children develop problem solving skills. Results showed instruction in systematic approaches, reading oriented approaches or specific skill instruction were associated with successful problem solving.

While some investigators examined skills associated with the ability of problem solving or methods of instruction, others tried to discover specific causes of failure in solving arithmetic problems (Roling, Blume and Morehart 1924, Stevenson 1925, and Lenore 1930). A composite of their findings regarding causes of difficulty includes: 1) physical and mental defects; 2) difficulties with word recognition; 3) lack of knowledge of vocabulary and technical terms; 4) carelessness in reading the problem; 5) focus upon numbers rather than meaning; 6) confusion caused by numbers larger than those commonly encountered; 7) direction by verbal cues rather than the mathematical relationships within the problems; 8) lack of ability to understand and compare quantitative relations; 9) lack of ability in fundamental operations; 10) lack of knowledge of basic arithmetic facts, rules, and formulae; 11) inability to think reflectively; 12) lack of ability to choose the main computational process including inability to recognize the main elements; 13) inaccurate copying of numerals; 14) lack of variety of good problems resulting in adaptation of the pupil to the problems rather than the problem to the pupil; 15) lack of interest and effort; 16) failure to regularly verify results; and 17) poor teaching, including failure to help pupils translate problems into their own experiences.

Teachers of the deaf are quick to acknowledge the problems their hearing impaired students face when attempting to solve word problems in arithmetic. Research indicates that the average deaf student's achievement in arithmetic word problems is generally low (Hargis 1969, Suppes 1974). In his review of the literature on cognition in handicapped children, Suppes reported no studies other than his own had been found regarding the mathematical abilities of deaf children beyond the level of computational arithmetic. These studies which he reported were primarily assessments of achievements on standardized tests. Suppes concluded that objective features of the curriculum, for example, whether a vertical addition problem required carrying or not, dominate the ease or difficulty of exercises in much the same way for both deaf and normal hearing children. The low language level of deaf children, however, is a factor in frustrating reading efforts including the ability to solve word problems.

Goetzinger and Rousey (1959) using the WAIS and Stanford Binet performance subtests tested 101 hearing impaired students ages fourteen to twenty-one years. The mean scores in arithmetic reasoning were found to be less than sixth grade and means in paragraph meaning approximately fourth grade. Hine (1970) tested 104 students 7.8 to 16.5 years of age with an average hearing loss of 60 dB. The Schonell's Essential Mechanical Problem Arithmetic Test was administered and the results showed that hearing impaired students aged ten performed as well as an average hearing student of eight and deaf students aged fifteen scored equal to that of a hearing ten year old. Messerley and Aram (1980) confirmed previous studies with their investigation on seventeen year old students. The Stanford Achievement Test scale scores of these students on mathematics applications were at the seventh grade - a level reached by hearing students by the age of twelve.

In a recent British Columbia study (Rogers et al. 1978) 148 hearing impaired students aged five to seventeen years and older were tested. The scaled scores on the Stanford Achievement Test, Special Edition for Hearing Impaired Students (SAT-HI) for mathematics applications ranged from 147.5 (fourth grade) for the five to eight year old group to 172.0 (seventh grade) for the seventeen plus age group. Performance increased with increasing age but no significant differences among hearing loss categories were found for mathematics applications. With the mean adjusted for age and severity of hearing loss the performance of students with at least one additional handicap was significantly lower than students with no additional handicap.

It would appear that language factors play an important role in success of arithmetic problem solving. Further it has been found that hearing impaired students are severely retarded in their language achievement (Cooper and Rosenstein 1966). It would therefore follow that the hearing-impaired student would have difficulty with word problems and the difficulty is caused mainly by his low level of language achievement (Hargis 1969).

Definition of Terms

Throughout the study various terms will be used as defined below:

1. Hearing Impairment - The term describes the hearing threshold level (HTL) which may range from mild moderate (<59 dB), marked severe (60-89 dB) to a profound (>90 dB) degree. It incorporates the conditions known as hard of hearing and deafness.
2. Degree of Hearing Loss - Hearing loss is discussed in terms of average hearing threshold in decibels (dB) using the American National Standards Institute (ANSI) criteria and is equal to the arithmetic

mean of the pure tone thresholds obtained at 500, 1000, and 2000 Hz in the better ear.

3. Profound Hearing Loss - An average hearing threshold level of 90 dB or greater (>90 dB) in the better ear.
4. Word Problems - Those problems typically found in elementary mathematics textbooks that are presented in words. To solve the word problem, the operations of addition, subtraction, multiplication, and/or division are used. The term "word problem" may also be stated as a verbal problem or story problem.
5. One-step Word Problem - A word problem that requires only one mathematical operation for its solution.

CHAPTER II

PROBLEM

I. Statement of the Problem

The specific purpose of this study was to investigate the following questions:

1) Is there an order of difficulty in one-step word problems requiring one of the four operations of addition, subtraction, multiplication, or division?

2) Is the ability to solve word problems related to age?

3) Is the ability to solve word problems associated with gender?

4) Does the frequency of a question type as found in elementary mathematics texts, affect the ability to solve word problems?

II. Review of the Literature

Researchers have been exploring the many difficulties associated with the solution of arithmetic word problems for many years. As problem solving is viewed as a vital part of doing mathematics, it therefore seems natural to analyze carefully what is involved in the process so that appropriate learning environments and instructional techniques can be developed. Research will be discussed under the classifications of general intelligence, computation, reading ability, mathematical vocabulary and syntax, and language influences on mathematical development with normally hearing subjects. In the final section pertinent research with hearing impaired students will then be examined.

General Intelligence - Pitts (1952), Erikson (1958) and Wrigley (1958) found that there is a close connection between mathematical and general ability and that high general intelligence is an important factor for success in mathematics and problem solving. Erikson examined factors of intelligence and reading ability and their effects on achievement in arithmetic concepts and problem solving for sixth graders. It was found that intelligence and reading ability each correlated positively with both concepts and solving of problems.

Wrigley (1958) in his study of students aged fourteen years and older concluded that high general intelligence can account for a large part of the variability shared by verbal and mathematical ability, but a significant degree of overlap between the last two variables remains unexplained. He stated that "there exists a clearly identifiable mathematical group factor. The different branches of mathematics are linked together more closely than they would be if a general ability is eliminated, verbal ability has little connection with mathematical ability (page 77)." Further research implied that reading (linguistic) ability is the "unexplained" variable since differences in reading ability may be used to explain the positive correlation between scores on mathematics tests and intelligence tests (Muscio 1962).

Computation - Stevens (1932) in his investigation examined four variables thought to be associated with problem solving ability: 1) ability in silent reading; 2) power in the fundamental operations of arithmetic; 3) power in solving reasonable problems in arithmetic; and 4) "general" intelligence test scores. The results indicated that power in the fundamental operations of arithmetic was most closely related to ability in problem solving when statistically the effect of general reading ability was held constant.

Engelhart (1932) also studied the effects of reading ability, intelligence and computational ability on problem solving ability. Examination of the findings showed that the largest amount (42.05%) of variance in problem solving ability was accounted for by computational ability.

Sixth graders were tested by Hansen (1944) on twenty-eight factors related to arithmetic reasoning, reading and general reasoning ability. The upper and lower twenty-seven per cent on a test of problem solving were compared and results indicated that those factors associated with numbers and reasoning appeared to be most closely related to successful problem solving.

Chase (1960) administered a series of standardized tests in intelligence, arithmetic computation, arithmetic problem solving and reading to sixth graders. He wanted to discover the skills and intellectual factors primarily related to the ability to solve word problems. Of the fifteen variables tested only three - computation, reading to note details, and fundamental knowledge in arithmetic - were identified as of major importance in the ability of problem solving.

Differences between matched pairs of high and low achievers in seventh grade problem solving were investigated by Alexander (1960). In favor of the high achievers differences included: 1) specific mental abilities, 2) quantitative skills, 3) general reading skills, 4) problem solving reading skills, and 5) ability to interpret quantitative facts and relationships.

Results of recent national assessments (Carpenter et al. 1975, 1976, 1980) showed that computation skills of thirteen year olds were almost as good as adults on the four operations involving whole numbers. Although the performance on one-step word problems was slightly lower than performance on computation exercises requiring the same operations, the difference was less than ten per cent. Carpenter et al. (1980) stated that it appeared that if children had not mastered a computational algorithm they could not generate solutions for even simple problems that might have been solved intuitively or by using physical representatives.

Reading Ability - Measures of general reading abilities were found to correlate positively with scores on arithmetic and mathematics tests (Balow 1964, Chase 1960, Coffing 1941, and Muscio 1962). Coffing (1941) administered standardized tests of paragraph meaning and arithmetic reasoning to students in grade four through eight. A positive correlation was found between silent reading and ability to solve reasoning problems.

Balow (1964) found that for any given level of computation ability, problem solving increased as reading ability increased and that for any given level of reading ability, problem solving increased as computation ability increased.

Muscio (1962) examined the relationship between sixth graders quantitative understanding and certain mental abilities, achievements, and attitudes. The results indicated that achievement on the measure of quantitative understanding was closely related to achievement on measures of general reading abilities, computation, reasoning and mathematical vocabulary.

Some researchers regard reading not as a generalized ability but as a composite of specific skills and therefore examined the influence of various specific reading abilities on success in problem solving. Newcomb (1922), Stevenson (1924) and Washburne and Osburne (1926) investigated the worth of systematic and logical procedures in solving problems as compared to students' own methods. The three studies had experimental groups receive instruction in specific skills of reading and analyzing problems, vocabulary, and guides to reasoning. Newcomb and Stevenson found that the specific instruction increased seventh and eighth grade students' ability to solve problems. Washburne and Osburne, however, concluded that students solving problems using their own techniques were more successful at problem solving than students using a special technique or finding similarities between difficult and easy problems.

Monroe and Engelhart (1933) studied the effectiveness of a program of systematic instruction in the reading of verbal problems. The experimental group received practice in reading of problems, restatement of problem, diagraming, accurate reading of figures, and emphasis on terms indicating the process to be used. The mean gains in reading, computation and problem solving were found not to be significant - a finding not in accord with the majority of the studies.

Faulk and Landry (1961) in a similar study tested twenty-two classes of sixth grade students. Again the experimental group had instruction in a systematic approach to problem solving. Students studied vocabulary, meanings of words, diagraming and estimating. The results showed the gains in achievement were significant for this group.

Call and Wiggen (1966) compared effects of a reading oriented approach to a conventional approach to teaching problem solving. The reading approach included vocabulary, use of context to get the meaning and seeing relationships. Findings indicated that the reading oriented approach was more successful in improving the ability of problem solving.

Treacy (1944) studied eighteen factors in the areas of arithmetic problem solving, mental ability, and reading ability in a study of seventh graders. When mental age was held constant, the results showed good achievers in problem solving superior to poor achievers in four reading skills all associated with vocabulary, quantitative relationships, vocabulary in context, vocabulary (i.e. isolated words), and arithmetic vocabulary.

Corle (1958) tested seventy-four pupils on eight word problems and concluded that the ability of problem solving was greater if students understood the meaning of the problem, used word and number clues, and understood the meaning of the words.

Henney (1971) wrote that to solve problems the students must be able to 1) read (recognize, comprehend) the words of the problem, 2) visualize the situation, 3) recognize the question asked, 4) note important facts given, 5) infer the relationship of the facts, and 6) interpret the solution obtained in terms of the question asked. Henney stated that although there is a lack of agreement on which factors have the greatest influence, there is consensus that children must be able to recognize words and comprehend thought units in the problem, logically interpret the problem situation, and organize the information in such a way as to lead to an answer to the question. It was found that the specific reading abilities were no more highly correlated than general reading ability with arithmetic problem solving.

Mathematical Vocabulary and Syntax - Research done by Hansen (1944) and Johnson (1949) indicated that knowledge of vocabulary was important in solving mathematical problems for students in grades six and eight. A study which examined seventh grade students, as previously stated, found that four reading skills that affected achievement in problem solving were all associated with vocabulary (Treacy 1944).

To elaborate on earlier studies of mathematical vocabulary, Olander and Ehmer (1971) and Linville (1976) also examined vocabulary in mathematics. Olander and Ehmer tested 1200 students in grades four, five and six on one hundred vocabulary items and compared them with students' performances in 1930. It was found that grades four and five with means of 49 and 57 performed better than the 1930 students of the same grades but the sixth graders in 1930 scored higher than those of this study.

Linville (1976) tested fourth grade students on four tests involving levels of difficulty in syntax and vocabulary. The study showed there were significant main effects in favor of easy syntax and easy vocabulary tests with vocabulary being more crucial. It was found that students scored higher on word problems with easy vocabulary than difficult vocabulary across levels of syntax and higher on problems with easy syntax than difficult syntax across levels of vocabulary.

Another approach to studying the relationship of knowledge of vocabulary to achievement in mathematics is to determine whether specific training in vocabulary has an effect on mathematical performances. Johnson (1944) found that for seventh graders specific instruction in vocabulary led to significant growth in 1) the knowledge of the specific terms and 2) the solution of numerical problems involving the use of the terms. Van der Linde (1964) tested fifth graders after instruction on 242 terms (8 terms studied each week). Results showed a significant gain for the experimental group on arithmetic concepts and problem solving.

In agreement with previous findings, Lyda and Duncan (1967) instructed students in grade two on 178 terms from five categories - arithmetic, time, measurement, quantity, and geometry. It was found that a direct study of quantitative vocabulary contributes significantly to growth in problem solving.

Research that concerns the relationship of vocabulary and syntax to ease of reading has involved the application of readability formulas to mathematical texts and problems. Heddens and Smith (1964) examined five textbooks used for elementary mathematics using the Spache formula for grades one to three and the Dale-Chall formula for grades four to six. It was found that 1) the readability level of the selected texts seemed to be generally above the assigned grade level, 2) there was considerable variation of readability levels among the textbooks considered and 3) the variation within each book indicated that some portions of the texts should be comprehended by most students, while other portions of the same text were written on a relatively more difficult level.

Smith (1971) also applied the Dale-Chall formula to the word problems in sixth grade texts and three mathematical achievement tests. It was found that the average readability of the problems fell within bounds for the grade level although the results indicated wide variation from problem to problem. Smith stated, "In problem solving situations that involve verbal materials, a person is ordinarily expected to read a statement, analyze the data, use computational skills, and arrive at the correct answer. If a child cannot read the statement, then his abilities to think, analyze and compute are hampered . . . It is also possible the achievement test scores in problem solving in mathematics sometimes reflect a child's limitation in reading rather than his mathematical performance. (p.559)"

Language Factors - Investigators have referred to various aspects of the interaction between language development and the growth of mathematical understanding. Kramer (1933) studied four factors: 1) sentence form (declarative versus complex interrogative); 2) style (language detail versus concise, compressed language); 3) vocabulary (familiar versus unfamiliar); and 4) problem situation (interesting versus uninteresting). She tested 237 sixth grade students. Regarding sentence form the differences were small but in favor of the complex interrogative form. Concise compressed language and familiar vocabulary resulted in greater success in problem solving. The differences in success with interesting and uninteresting material were negligible. Kramer stated that cue words, rather than facts and requirements of the problem were a factor in determining the selection of process. The numbers, in particular relationships and patterns, appeared to serve as cues to mathematical operations.

Expanding on the investigation of Kramer, with regards to sentence form and style are studies by Schell and Burns (1965), Steffe (1968) and Underhill (1977). Schell and Burns examined second graders on three types of subtraction problems: 1) "take away" - a quantity is removed (transformational) and what remains is to be identified; 2) "how many more are needed"; 3) "comparison or difference" - quantities matched and excess of one over the other is identified. Twelve questions of each type were administered. Results showed that the students performed best on the "take-away" problems, followed by "how many more are needed" and "comparison" in that order.

Steffe (1968) studied the factors of conservation on number capabilities and performances on transformational and non-transformational addition word problems. Results indicated that high conservers performed better than low conservers and that transformational problems were easier to solve than non-transformational problems.

Underhill (1977) elaborated on Steffe's results by examining kindergarten and first graders in addition and subtraction problems with the use of manipulatives. He found that addition (transformational and non-transformational) and transformational "take away" subtraction (how many left?) were easier to solve than the non-transformational comparison subtraction (how many more?) and transformational additive subtraction ($3 + \square = 5$).

Rose and Rose (1961) stated that childhood training in precise language is essential for performing well in mathematics. Piaget (1954) and Bruner (1966) also stressed the importance to mathematical ability of language ability. Growth in linguistic ability according to Piaget follows the development of concrete operational thought rather than preceding it, although language is important in the completion of such cognitive structures. In contrast Bruner et al. maintain that the development of adequate terminology is essential to cognitive growth.

Using Piaget's classifications of concrete and formal operations, Days, Wheatley and Kulm (1979) examined the processes used by fifty-eight students in grade eight. Two types of word problems were used: 1) simple structure and 2) complex structure. No differences were found between the concrete and formal operational students in the use of understanding, representational, and recall processes. Use of production and evaluation processes did differ between the two groups. Problem structure played a bigger role in determining process use by formal operational students than by students at the concrete level.

The research on arithmetic problem solving shows that a knowledge of arithmetic vocabulary is pertinent to achievement in solving word problems. Reading comprehension and arithmetic achievement tend to be positively related. Almost without exception instruction in vocabulary and/or reading skills in arithmetic paid off in terms of higher achievement.

Research with Hearing Impaired Students - Although performances on standardized achievement tests of deaf students indicate a relatively greater ability in mathematics than other academic areas, it is still below the norms established for hearing students. Goetzinger and Rousey (1959) tested 101 deaf students between the ages of fourteen and twenty-one on the performance subtests of the WAIS and Stanford Binet. Results showed a mean grade level score of 6.5 in computation and 6.0 for arithmetic reasoning. These scores are approximately equal to those of an average hearing ten year old.

Trybus and Karchmer (1977) collected national data on achievement scores and concluded that the mean growth line for hearing students in mathematics was equivalent to the ninetieth percentile for the hearing impaired. In other words only ten per cent of the hearing impaired students obtain scores equal to that of the average hearing student of the same age. Results showed that the average twenty year old hearing impaired person scored just below the eighth grade level (equal to that of an average hearing student at thirteen years). Trybus and Karchmer stated " . . . a group of hearing impaired children whose reading comprehension scores at a third grade level will typically obtain scores about one grade level lower than third on the vocabulary test, and one to two grades higher on the mathematics computation (p.68)."

Academic achievement test data were collected by Rogers et al. (1978) on 383 hearing impaired students aged five to seventeen years and older. The results showed that for computation, student performance increased significantly with increasing age. The scaled scores ranged from 131.1 to 178.1 which corresponds to raw scores obtained by normal hearing students of third to seventh grade (ages eight to twelve years).

Messerly and Aram (1980) examined Stanford Achievement Test scores of seventeen year old deaf students of hearing parents and deaf students of deaf parents. Although the sample was small (n = 16) and not representative of the national group, the results showed the mean scores of both mathematics computation and mathematics applications were below the eighth grade level. The findings again were in accord with previous studies.

Achievement scores on standardized tests indicate that the average deaf child achieves close to normal levels in arithmetic computation. Their arithmetic reasoning skills however are generally well below normal. This is believed to be a result primarily of low levels of reading and language (Hargis 1969, Suppes 1974). Cooper and Rosenstein (1966) undertook an extensive survey examining the language skills of reading and written expression in deaf children. The researchers reported that these students were significantly retarded in their achievement test scores in terms of both reading and written expression.

In a study of deaf students aged 10.5 and 16.5 years, Furth (1966a) found reading grade equivalents of 2.7 and 3.5 respectively. He concluded that the measurement of reading disability presupposes linguistic competence which is not present in the deaf. The low reading level of the deaf does not constitute a reading deficiency but rather a linguistic incompetence.

Many other studies using results from standardized achievement tests also obtained low reading levels for deaf students (Goetzinger and Rousey 1959, Vernon 1970, 1971, Conrad 1977, Karchmer, Milone and Wolk 1979, and Messerly and Aram 1980). Vernon tested deaf students aged fifteen years on the Stanford Achievement Test and found reading scores less than the fifth grade. Conrad administered tests to fifteen and sixteen year old students and discovered reading ages approximately equal to the average hearing nine year olds. His results also showed that reading ability depended significantly on degree of hearing loss.

In agreement with these findings was the investigation of Karchmer, Milone and Wolk (1979). Seven thousand students were tested on the Stanford Achievement Test, Special Edition for Hearing Impaired Students (SAT-HI). Reading comprehension scores differed significantly with degree of hearing loss. With the increase of severity of hearing loss, student performances declined.

In a recent national survey (Trybus and Karchmer 1977) data showed that in reading, the average hearing-impaired student aged twenty and over scored at the grade equivalent of 4.5 (below or barely at newspaper literacy). At best only ten per cent of the eighteen year olds were reading at or above the eighth grade level. An average hearing student reaches this level before age fourteen.

Rogers et al. (1978) reported reading comprehension scores for hearing impaired students on the SAT-HI test. Grade level mean performances ranged from 1.5 for five to eight year olds to 4.9 for students seventeen years and older. Student performance in reading comprehension increased with age but appeared to have a decline with increase of hearing loss. Demographic variables which significantly affected reading comprehension, adjusted for age and severity of hearing loss were found as follows: 1) girls did better than boys; 2) the students using personal hearing aids performed better than the group not using aids; 3) the group with additional educational handicapping conditions scored lower than the group without these handicaps; 4) the oral communication students outperformed the total communication group; 5) the students in special classes and schools performed below the students enrolled in regular school. In their examination of academic achievement of hearing impaired students Rogers and Clarke (1980) found three personal variables (age, severity of loss, and additional educational handicaps) and one manipulable variable (educational setting) were significant predictors of reading comprehension. For mathematics computation and applications only personal variables (age and additional educational handicaps) contributed significantly to the regression equation.

Hamp (1972) in a study of 367 deaf and partially hearing children ages nine to fifteen years stated that reading performances improved only 0.8 of a grade between ages eleven to sixteen years. It was concluded that the effects of age and intelligence were of greater significance than the degree of hearing impairment. In a survey of cognition of deaf children, Suppes (1974) wrote that the cognitive performances of deaf children is as good as that of normal hearing children when the cognitive task does not directly involve verbal skills.

In almost all surveys examining achievement scores, results showed the deaf to be severely retarded in their language achievement (Cooper and Rosenstein 1966). Furth (1966) has concluded that language and words behind the math concepts are not always clear and may run counter to conventional usage in the mind of a young child.

According to Hargis (1969) "It is apparent that the deaf child's deficiency in arithmetic reasoning is caused primarily by his low level of language achievement. He may master the mechanical aspect of arithmetic (computational skills); but when an arithmetic problem requires understanding of the language the deaf child often fails (p.766)." Suppes (1974) was in agreement when he wrote that the competence in a standard natural language is the outstanding defect and problem of deaf persons.

III. Statement of Hypotheses

1) One-step word problems requiring the operation of addition will be easiest for deaf students to solve followed by problems requiring the operations of subtraction, multiplication or division in that order.

2) The ability to solve arithmetic word problems will increase as age increases.

3) The ability to solve word problems will be significantly different between deaf males and females.

4) The frequency of a question type as found in elementary mathematics texts will affect the ability to solve word problems for hearing impaired students in that the more frequently occurring question type will be more easily solved.

CHAPTER III

METHOD

I. Sample Population

For the purpose of this study the subjects were selected from a population of students attending Jericho Hill School for the Deaf and who met the following criteria:

a) had reached their eighth but not twentieth birthday and were attending a class for the hearing impaired under the jurisdiction of Jericho Hill School on May 1st, 1980. This included fourteen classes on campus and eight self-contained classes situated in regular schools. Throughout the study the following age groups were used:

8-11 years
12 & 13 years
14 & 15 years
16+ years

b) had a profound hearing loss from birth or prior to the age of two years.

c) had been judged by school personnel as having no disability which would prevent task completion, and in the professional opinion of the teacher had no reason to be excluded from the study.

All the students who met the above criteria were administered the computation task (see Instruments). Of the 116 students who attempted the first test, fifteen were deleted from the study for not meeting the pass requirement (i.e. at least four of the six questions correct in each of addition, subtraction, multiplication, and division questions).

Another eleven students had to be dropped from the study because they did not complete the computation and/or word problem tasks. The final study sample was comprised of ninety subjects. Table 1 shows the cross-tabulation of the four age groups with gender.

TABLE 1

NUMBER AND PERCENTAGE DISTRIBUTION
OF GENDER WITHIN AGE

Age in Years	Gender: Male f	Male %	Female f	Female %	Total f	Total %
8-11	13	68.4	6	31.6	19	100.0
12&13	8	50.0	8	50.0	16	100.0
14&15	13	50.0	13	50.0	26	100.0
16+	19	65.5	10	34.5	29	100.0
Total	53	58.9	37	41.1	90	100.0

II. Instruments

Computational Task - In this study, the solution methods used by profoundly hearing impaired students due to language structure rather than computation were examined. To ensure that a computation variable would not affect the solving of the word problems a computational task was administered first. This task consisted of three pages - the first page required information from the students such as name, date of birth, and teacher's name. On the same page four examples, one for each type of operation, were given to introduce the students to the type of questions, the task format, and the method of response. (See Appendix A).

The following two pages comprised the actual computation tasks.

These consisted of twenty-four questions - six on each mathematical operation (addition, subtraction, multiplication, and division). Six pairs of numbers were used in the twenty-four questions: 6 and 2; 8 and 2; 10 and 2; 3 and 3; 6 and 3; and 9 and 3. These particular pairs were chosen as these were the only combination of digits between 1 and 10 which would result in a different answer for each of the four operations.

e.g. 6 and 2

$$6 + 2 = 8$$
$$6 - 2 = 4$$
$$6 \times 2 = 12$$
$$6 \div 2 = 3$$

Each pair of numbers was applied to each of the four operations, resulting in the twenty-four questions. These questions were randomly assigned a position from one to twenty-four. (See Appendix A).

The mathematical sentences on the computation task were written horizontally, the reason being that although addition, subtraction, and multiplication can be represented vertically, division is not written in this manner in the textbooks. The larger number of the number pair in all cases, was written first to ensure that the questions would give no indication as to which operation was to be used. For each question all possible answers were listed horizontally below the sentence from smallest to largest. The student was asked to circle the correct answer.

e.g. A) 6 + 2 =

3 4 8 12

The twenty-four items were lettered (A to X) to ensure that the students would not get confused as to whether a number was part of the question or not.

The operations were assigned as follows:

Page 2		Page 3	
a) addition	b) multiplication	m) addition	n) division
c) multiplication	d) division	o) addition	p) subtraction
e) addition	f) subtraction	q) addition	r) subtraction
g) division	h) multiplication	s) subtraction	t) addition
i) multiplication	j) multiplication	u) multiplication	v) division
k) division	l) division	w) subtraction	x) subtraction

Word Problem Task - The second instrument used in this study was the one-step word problem task (see Appendix A). The "Investigating School Mathematics" texts, grades two through six inclusive, were examined to determine the most popular forms of questions used for each of the four operations. The two most common forms of each operation were then selected for this study (Type A and Type B, see below). To ensure that a language variable would not affect the performance of the students, the vocabulary used was restricted to "John," "Bill," "Susan," "toys," "boxes," "had" (as main verb), "found," "lost," "saw," and "put" in the story part of the problems. To control the syntax of the problems, all statements prior to the actual question were written as simple, active, declarative statements in the form of "John had 6 boxes." The one exception to this pattern is the wording of the Type B multiplication problems. It was worded as follows:

> Bill had _____ boxes.
> Susan saw _____ times as many boxes.
> How many boxes did Susan see?

All the questions were written as they appeared in the textbooks with the controlled vocabulary inserted. Type A problems were the most common type of question (found in the texts) with Type B problems next in frequency. Examples for both types of problems for each operation are:

Addition

A	B
John had _____ toys. Bill had _____ toys. How many toys in all?	Susan had _____ boxes. Susan found _____ boxes. How many boxes were there?

Subtraction

A	B
Susan had _____ toys. John had _____ boxes. How many more toys than boxes?	John had _____ toys. John lost _____ toys. How many toys left?

Multiplication

A	B
John had _____ boxes. John had _____ toys in each box. How many toys in all?	Bill had _____ boxes. Susan saw _____ times as many boxes. How many boxes did Susan see?

Division

A	B
Bill had _____ toys. Bill had _____ boxes. How many toys in each box?	John had _____ toys. Bill had _____ toys in each box. How many boxes?

Like the computation task, this second task had twenty-four questions. These questions used exactly the same number pair and operation as the corresponding question on the computation task. For example, item A on both the computation task and word problem task was the addition of six and two. Because there were two types (A and B) of question for each operation, these were randomly assigned - resulting in three items for each type of question for each operation (e.g. three Type A addition problems, three Type B addition problems).

The type A and Type B questions were arranged as follows:

Page 1

A) Type A addition	B) Type A multiplication
C) Type A multiplication	D) Type B division
E) Type B addition	F) Type B subtraction
G) Type A division	H) Type B multiplication

Page 2

I) Type A multiplication	J) Type B multiplication
K) Type B division	L) Type B division
M) Type B addition	N) Type A division
O) Type B addition	P) Type A subtraction

Page 3

Q) Type A addition	R) Type B subtraction
S) Type A subtraction	T) Type A addition
U) Type B multiplication	V) Type A division
W) Type B subtraction	X) Type A subtraction

Again the larger digit of the number pair was given first to ensure that no indication as to type of operation could be derived from the order of the number. Following the pattern of the computation task, the answers were listed horizontally below the word problems and the student was asked to circle the correct answer:

e.g. m) Susan had 9 boxes.
Susan found 3 boxes.
How many boxes were there?

3 6 12 27

III. Scoring

Computation Task - There was a total of twenty-four questions with six items for each operation of addition, subtraction, multiplication, and division.

The students were required to correctly answer at least four of the six questions for each operation. Of the ninety students who met this requirement seventy-four had no errors on the entire task. Nine students had one error and seven students had two or more errors. The computational errors made, appeared to be random - that is no child made consistent errors.

Word Problem Task - Again there were twenty-four questions with six items for each operation. As well there were two types of question for each operation. If an item on the computation task was addition, the item on the word task was also addition (Type A or Type B).

As the type of question as well as the operations were being examined, the students received a score out of three for each type of question for each operation. For example, on Type A addition questions (A, Q and T) a student could obtain a score of 3, 2, 1, or 0 (indicating the number correct). Each student received eight such scores - two for each in addition (Type A and Type B), subtraction, multiplication, and division.

There was a total of 270 items (90 students x 3 questions) for each type of question for each operation. Each operation had 540 items with a total of 2,160 items on the word problem task for the entire sample population.

IV. Procedure

The procedure of this study can be divided into two parts - the computation task and the word problem task.

Teachers were approached by the investigator to indicate which of their students fitted the study criteria and could perform the four operations on number facts up to thirty. These students were then given the first task - the computation task which was administered by the teachers to their own pupils. The teachers were asked to help the students complete the first page to ensure the students understood what was required for the task. If in the estimation of the teacher, the students needed more examples, the teachers were asked to provide additional questions similar to the ones on the first page. The results were scored by the writer and verified by discussion with the class teacher.

The students who met the criteria of correctly answering four of the six questions for each operation were given the word problem task approximately two weeks later. To meet the school's convenience, this second task was administered on three separate days by the investigator, to three different groups. The students were grouped for this task according to the level of their class: primary, intermediate, or senior. The scoring for this task was also done by the writer.

V. Data Analysis

The data on the students along with the results of the word problem task were then keypunched onto computer cards. Hypotheses 1, 2, 3, and 4 were tested using a 4 x 2 x 2 (age-by-gender-by-type) fixed effects design, with repeated measures on the third factor. The problems (corresponding to the four operations were examined with respect to age, gender, and type of question (A or B). The computer program used was BMD P2V-Analysis of variance and covariance with repeated measures.

As type of questions was the only significant source of variance identified in the above analysis (see Chapter 4), age and gender were collapsed and an analysis of type of question by operation was completed by using a repeated measures analysis. As well, a qualitative error analysis was carried out for the operations separately and combined. That is, the errors were examined for each operation and then the total number of errors were studied.

CHAPTER IV

RESULTS AND DISCUSSION

The analysés were conducted in three phases as stated previously. First, the word problems corresponding to the four operations of addition, subtraction, multiplication, and division were examined separately with respect to age, gender and type of question (A or B). As will be shown, the only significant source of variance was type. Therefore it was decided to collapse age and gender, thereby allowing an analysis of type of question by operation (repeated measures ANOVA). Finally the distribution of error scores was examined.

The results of the analyses described in the last section of the previous chapter are presented in this chapter. First, data are present separately for each operation in three tables. The first table summarizes the significance test for the differences for type of question, age and gender. The second table contains the means and standard deviations of both types of question for each age group and for the total sample. Error analysis for the operation is shown in the third table.

Addition - There were no significant differences for age or gender on addition word problems (see Table II). However type of question was significant ($F = 10.54$, $df = 1, 82$; $p<.01$). The overall mean for Type A questions in addition was 2.63 (possible total of 3.00) (see Table III). For Type B questions in addition the overall mean was 2.27 (see Table III). The overall mean of Type A and B questions for the entire

TABLE II

Three Way Analysis of Variance (univariate)
Age by Gender by Type of Question

Addition

Source of Variance	df	Mean Square	F
Between persons			
age	3	1.33463	1.32
gender	1	2.97090	2.94
age x gender	3	1.13084	1.12
error	82	1.01222	
Within persons			
type	1	4.32867	10.54**
type x age	3	0.56130	1.37
type x gender	1	0.01484	0.04
type x age x gender	3	0.54960	1.34
error	82	0.41059	

** = $p < .01$

TABLE III

Performance Means and Standard Deviations
Type of Question by Age Group

Addition

Age in Years		A $\bar{X}$	A SD	B $\bar{X}$	B SD	Total $\bar{X}$	Total SD
	Males	2.00	0.82	1.69	1.03	1.85	0.98
8-11	Females	2.50	0.55	2.67	0.82	2.58	0.69
	Both	2.16	0.73	2.00	0.96	2.08	0.85
	Males	2.50	1.07	2.50	0.76	2.50	0.42
12 & 13	Females	3.00	0.00	2.63	0.52	2.81	0.26
	Both	2.75	0.54	2.57	0.64	2.66	0.59
	Males	2.92	0.28	2.31	1.18	2.62	0.73
14 & 15	Females	2.77	0.60	2.38	0.77	2.58	0.69
	Both	2.85	0.44	2.34	0.98	2.60	0.71
	Males	2.58	0.77	2.26	1.15	2.42	0.96
16+	Females	2.90	0.32	2.10	1.20	2.50	0.76
	Both	2.69	0.61	2.21	1.17	2.45	0.94
Overall		2.63	0.57	2.27	0.98	2.45	0.78

sample was 2.45. Although the means for Type B questions in addition were lower than the means for Type A questions for each age group, the difference was not significant.

The difference in performance on the two types of addition questions might be explained by the difference in wording of the two questions. The Type A addition question (How many toys in all?) may have suggested to the students that a total was required. The phrase "in all" suggests a bigger answer. On the other hand, the Type B addition question (How many boxes were there?) may have given little indication of the type of operation to be used since "how many" occurs in all problems involving all four processes.

The total number of items for addition Type A was 270 (3 questions by 90 subjects) (see Table IV). The total number of errors was 33 (12.2%). These errors were distributed as follows: on 20 occasions (60.6%) multiplication was used instead of addition; subtraction 10 times (30.3%) and division 3 times (9.1%). The large percentage of multiplication errors is probably due to the fact that the question form for Type A addition and Type A multiplication are identical (How many toys in all?). As stated previously, this question form probably indicated that a total was required.

Type B addition questions, as shown in Table IV, were answered incorrectly 66 times (24.4%). Of the total number of errors for this type of question 38 items (57.6%) were multiplied; 19 items (28.8%) were subtracted; and 9 items (13.6%) were divided. Although the percentage of errors made was doubled for Type B questions (24.4% compared with 12.2%) the distribution of errors was similar. In both cases the majority of students who made errors generally elected to multiply.

TABLE IV

Error Analysis for Addition

Age Group	A Total n	A Total (%)	A Composite* n	A Composite* (%)	B Total n	B Total (%)	B Composite* n	B Composite* (%)	Totals Total n	Totals Total (%)	Totals Composite* n	Totals Composite* (%)
			6	(37.5)-			9	(47.4)-			15	(42.9)-
8-11	16	(28.1)	9	(56.3)x	19	(33.3)	8	(42.1)x	35	(30.7)	17	(48.6)x
			1	(6.2)÷			2	(10.5)÷			3	(8.5)÷
			0	(0.0)-			1	(14.3)-			1	(9.1)-
12&13	4	(8.3)	3	(75.0)x	7	(14.6)	5	(71.4)x	11	(11.5)	8	(72.7)x
			1	(25.0)÷			1	(14.3)÷			2	(18.2)÷
			1	(25.0)-			5	(29.4)-			6	(28.6)-
14&15	4	(5.1)	3	(75.0)x	17	(21.8)	10	(58.9)x	21	(13.5)	13	(61.9)x
			0	(0.0)÷			2	(11.7)÷			2	(9.5)÷
			3	(33.3)-			4	(17.4)-			7	(21.9)-
16+	9	(10.3)	5	(55.6)x	23	(26.4)	15	(65.2)x	32	(18.4)	20	(62.5)x
			1	(11.1)÷			4	(17.4)÷			5	(15.6)÷
			10	(30.3)-			19	(28.8)-			29	(29.3)-
Total	33	(12.2)	20	(60.6)x	66	(24.4)	38	(57.6)x	99	(18.3)	58	(58.6)x
			3	(9.1)÷			9	(13.6)÷			12	(12.1)÷

* = The composite numbers and percentages add up to the total errors (100%) for each age group.

Subtraction - The differences for age and gender again were not significant (see Table V). The differences in type of question, however, again was significant ($F = 88.44$; $df = 1, 82$; $p < .01$). The overall mean performance for Type A subtraction questions was 0.74 and for Type B questions was 2.23 (see Table VI). The Type A means ranged from 0.53 to 1.44. The means for Type B ranged from 1.37 to 2.72.

For subtraction, the interaction between type of question and age was also significant ($F = 5.08$; $df = 3, 82$; $p < .01$). Figure 1 shows the interaction between the two types of question. The age group means for Type A problems were 0.53 (8-11 years); 1.44 (12 & 13 years); 0.73 (14 & 15 years); and 0.52 (16+ years); for Type B questions, the means were 1.37 (8-11 years); 2.19 (12 & 13 years); 2.35 (14 & 15 years); and 2.72 (16+ years). Type A subtraction questions were uniformly more difficult for all age groups. As would be expected, the mean performances for the Type B subtraction questions improved as age increased. With the Type A questions although, the means of the two younger groups (8-11 and 12 & 13 years) were much the same as in the Type B questions. The two older groups (14 & 15 and 16+ years) showed a decrease in performance on Type A questions. In fact, the means for these two older groups were similar to that of the 8 to 11 year old group.

The Type A subtraction questions (How many more toys than boxes?) proved to have the most difficult question form of the entire task with 202 (74.8%) of the questions answered incorrectly (see Table VII). The Type A subtraction question errors were distributed as follows: 81 (40.1%) of the total 270 items were added; 64 (31.7%) were multiplied; and 57 (28.2%) were divided. The two younger age groups added rather than multiplied or divided; the 14 and 15 year old group evenly added or

TABLE V

Three Way Analysis of Variance (univariate)
Age by Gender by Type of Question

Subtraction

Source of Variance	df	Mean Square	F
Between persons			
age	3	2.66885	1.85
gender	1	3.10919	2.16
age x gender	3	2.89893	2.01
error	82	1.43970	
Within persons			
type	1	81.38360	88.44**
type x age	3	4.67552	5.08**
type x gender	1	2.26199	2.46
type x age x gender	3	0.63295	0.69
error	82	0.92022	

** = p<.01

TABLE VI

Performance Means and Standard Deviations
Type of Question by Age Group

Subtraction

Age in Years		Type of Question A $\overline{X}$	A SD	B $\overline{X}$	B SD	Total $\overline{X}$	Total SD
	Males	0.38	0.65	0.84	0.98	0.61	0.82
8-11	Females	0.83	1.17	2.50	1.22	1.67	1.20
	Both	0.53	0.81	1.37	1.06	0.95	0.94
	Males	1.38	1.41	2.00	1.20	1.69	1.31
12 & 13	Females	1.50	1.60	2.38	1.06	1.94	1.33
	Both	1.44	1.51	2.19	1.13	1.82	1.32
	Males	0.85	1.28	2.46	1.13	1.65	1.21
14 & 15	Females	0.62	1.19	2.23	1.30	1.42	1.25
	Both	0.73	1.23	2.35	1.22	1.54	1.23
	Males	0.58	1.12	2.63	0.68	1.61	0.90
16+	Females	0.40	0.97	2.90	0.32	1.65	0.65
	Both	0.52	1.07	2.72	0.56	1.62	0.82
Overall		0.74	1.14	2.23	0.96	1.49	1.05

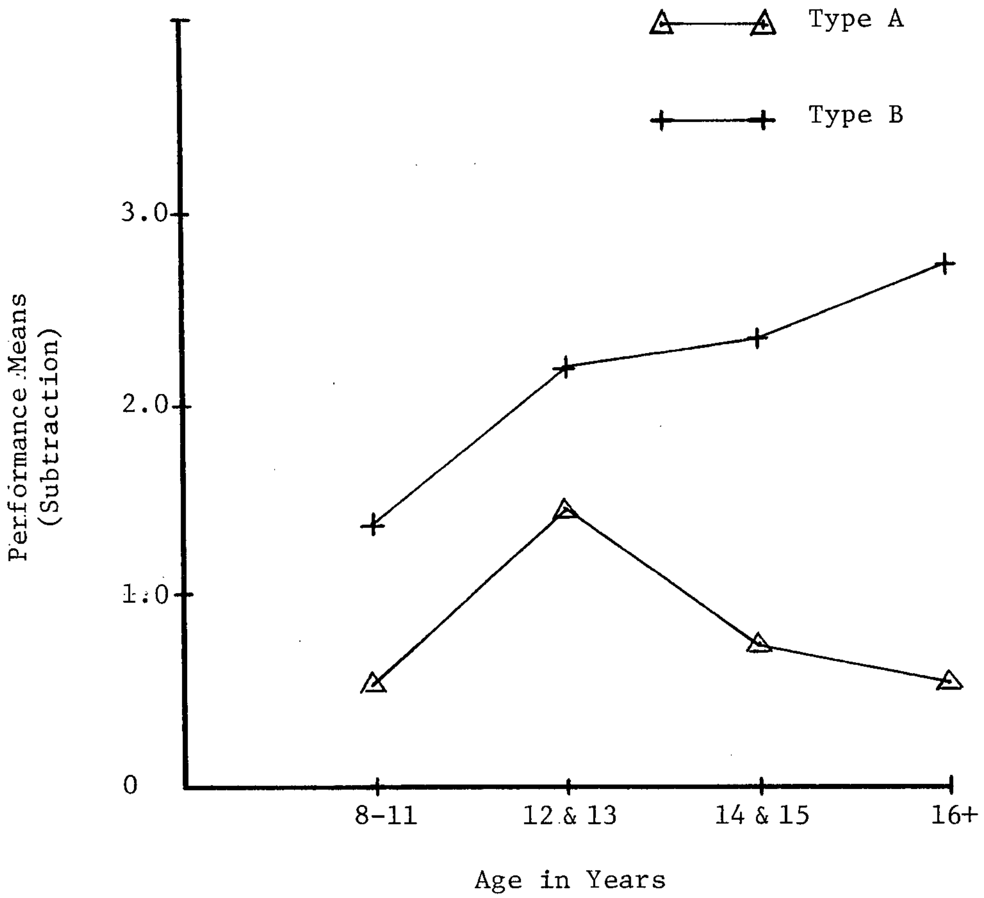

Figure 1: Interaction Graph, Type of Question by Age

TABLE VII

Error Analysis for Subtraction

Age Group	A Total n	A Total (%)	A Composite* n	A Composite* (%)	B Total n	B Total (%)	B Composite* n	B Composite* (%)	Totals Total n	Totals Total (%)	Totals Composite* n	Totals Composite* (%)
			27	(57.4)+			21	(67.7)+			48	(61.5)+
8-11	47	(82.5)	14	(29.8)×	31	(54.4)	4	(12.9)×	78	(68.4)	18	(23.1)×
			6	(12.8)÷			6	(19.4)÷			12	(15.4)÷
			15	(60.0)+			3	(23.1)+			18	(47.4)+
12&13	25	(52.1)	2	(8.0)×	13	(27.1)	0	(0.0)×	38	(39.6)	2	(5.2)×
			8	(32.0)÷			10	(76.9)÷			18	(47.4)÷
			22	(37.3)+			14	(82.4)+			36	(47.4)+
14&15	59	(75.6)	12	(20.3)×	17	(21.7)	2	(11.8)×	76	(48.7)	14	(18.4)×
			25	(42.2)÷			1	(5.8)÷			26	(34.2)÷
							2	(25.0)ϕ			2	(2.5)ϕ
16+	71	(81.6)	17	(23.9)+	8	(9.2)	3	(37.5)+	79	(45.4)	20	(25.3)+
			36	(50.8)×			1	(12.5)×			37	(46.9)×
			18	(25.3)÷			2	(25.0)÷			20	(25.3)÷
							2	(2.9)ϕ			2	(0.7)ϕ
Total	202	(74.8)	81	(40.1)+	69	(25.6)	41	(59.4)+	271	(50.2)	122	(45.0)+
			64	(31.7)×			7	(10.1)×			71	(26.2)×
			57	(28.2)÷			19	(27.6)÷			76	(28.1)÷

* = Composite numbers and percentages add up to the total errors (100%) for each age group.

multiplied; whereas the oldest group (16+ years) multiplied. It would appear that for the two youngest groups of students that the "more" in question Type A suggested addition. For the next older group (14 & 15 years) the same word might have indicated a total or larger number was required resulting in an even distribution of errors of addition or multiplication for these subtraction items. It might be that for the oldest group (16+ years) "more" indicated a larger number and the operation of multiplication.

The Type B subtraction questions (How many toys left?) were answered incorrectly 69 times (25.6%) (see Table VII). Of these errors 41 (59.4%) of the items were added; 19 items (27.6%) were divided; 7 items (10.1%) were multiplied and 2 items (2.9%) were no responses. All the age groups with the exception of the 12 and 13 year olds made a greater percentage of errors by adding rather than multiplying or dividing. This second group made more errors by dividing. Unlike Type A subtraction questions there was no indication in the Type B question of which operation was to be used. Also the overall error pattern shows that students tend to add when no indication of operation is contained in the question form. The 12 and 13 year olds showed deviant behavior in their error pattern by dividing. This type of error might be a result of work done on division problems. When the students are asked to find the remainder, often the question is "How much is left?" The word "left" may suggest division to these students.

<u>Multiplication</u> - Examination of Table VIII shows that age, gender, and type of question were not significant for multiplication word problems. The overall mean performance for Types A and B ranged from 0.76 (8-11 years) to 1.64 (16+ years) with a total mean performance of 1.35 (see Table IX). Although the performance on multiplication questions improved slightly with increasing age these differences were not statistically significant.

TABLE VIII

Three Way Analysis of Variance (univariate)
Age by Gender by Type of Question

Multiplication

Source of Variance	df	Mean Square	F
Between persons			
age	3	3.70168	1.84
gender	1	7.95995	3.96
age x gender	3	1.31622	0.65
error	82	2.01221	
Within persons			
type	1	0.45002	0.47
type x age	3	1.71605	1.78
type x gender	1	0.01903	0.02
type x age x gender	3	1.65317	1.71
error	82	0.96415	

TABLE IX

Performance Means and Standard Deviations
Type of Question by Age Group

Multiplication

Age in Years		A $\bar{X}$	A SD	B $\bar{X}$	B SD	Total $\bar{X}$	Total SD
	Males	0.46	0.52	0.54	0.78	0.50	0.65
8-11	Females	1.83	1.17	0.83	0.98	1.33	1.08
	Both	0.89	0.67	0.63	0.82	0.76	0.75
	Males	1.13	1.55	0.88	1.36	1.00	1.46
12 & 13	Females	1.25	1.39	2.00	1.20	1.63	1.30
	Both	1.19	1.47	1.44	1.28	1.32	1.38
	Males	1.00	1.15	1.62	1.45	1.31	1.30
14 & 15	Females	1.38	1.45	1.85	1.41	1.62	1.43
	Both	1.19	1.30	1.74	1.43	1.47	1.37
	Males	1.68	1.16	1.58	1.26	1.63	1.21
16+	Females	1.50	1.18	1.80	1.23	1.65	1.21
	Both	1.62	1.17	1.66	1.25	1.64	1.21
Overall		1.27	0.97	1.42	1.13	1.35	1.18

Of the Type A multiplication questions (How many toys in all?) 155 of the 270 items (57.4%) were answered incorrectly (see Table X). Of these errors 124 problems (80%) were added; 17 problems (10.9%) were multiplied; and 14 problems (9.1%) were divided. This question type is identical to the Type A addition question and the result is therefore not unexpected. As with addition, the "in all" phrase may have proved ambiguous because of the suggestion that a greater number was required for the solution. The fact that addition and multiplication responses were selected most frequently supports this thesis.

Table X also shows 142 (52.6%) of Type B multiplication questions incorrectly answered. This question type (How many boxes did Susan see?) produced the following errors: instead of multiplication being used, on 89 items (62.7%) addition was used; on 32 items (22.5%) subtraction was used; on 20 items (14.1%) division was used; and on 1 item (0.7%) there was no response. As the wording in these problems was different to the other questions on the task the entire word problem was examined to find a suggestion for the higher percentage of subtraction used in error compared with Type A questions (22.5% for B compared with 10.9% for A).

e.g. Bill had _____ boxes.
Susan saw _____ times as many boxes.
How many boxes did Susan see?

It appears the term "times" gave little indication of multiplication to those students who made the errors. There is no apparent reason for the increase of the subtraction operation instead of multiplication for Type B questions.

TABLE X

Error Analysis for Multiplication

Age Group	A Total n	A Total (%)	A Composite* n	A Composite* (%)	B Total n	B Total (%)	B Composite* n	B Composite* (%)	Total Total n	Total Total (%)	Total Composite* n	Total Composite* (%)
			30	(75.0)+			28	(62.2)+			58	(68.2)+
8-11	40	(70.1)	7	(17.5)-	45	(78.9)	12	(26.7)-	85	(74.6)	19	(22.4)-
			3	(7.5)÷			5	(11.1)÷			8	(9.4)÷
							1	(4.0)ϕ			1	(1.8)ϕ
12&13	29	(60.4)	24	(82.7)+	25	(52.1)	18	(72.0)+	54	(56.3)	42	(77.8)+
			4	(13.7)-			4	(16.0)-			8	(14.8)-
			1	(3.6)÷			2	(8.0)÷			3	(5.6)÷
			36	(78.3)+			18	(54.5)+			54	(68.4)+
14&15	46	(58.9)	2	(4.3)-	33	(42.3)	9	(27.3)-	79	(50.6)	11	(13.9)-
			8	(17.4)÷			6	(18.2)÷			14	(11.5)÷
			34	(85.0)+			25	(64.2)+			59	(74.6)+
16+	40	(45.9)	4	(10.0)-	39	(44.8)	7	(17.9)-	79	(45.4)	11	(13.9)-
			2	(5.0)÷			7	(17.9)÷			9	(11.5)÷
							1	(0.7)ϕ			1	(0.4)ϕ
Total	155	(57.4)	124	(80.0)+	142	(52.6)	89	(62.7)+	297	(55)	213	(71.7)+
			17	(10.9)-			32	(22.5)-			49	(16.5)-
			14	(9.1)÷			20	(14.1)÷			34	(11.4)÷

* = Composite numbers and percentages add up to the total errors (100%) for each age group.

Division - As with the multiplication problems, no significant differences among age group, gender or type of question were found for division questions. There was however, at the .05 level a significant interaction between type of question, age and gender ($F = 3.66$; $df = 3, 82$; $p<.05$) (see Table XI). The overall mean for Type A was 1.29; for Type B was 1.13 with a total mean performance for both of 1.21 (see Table XII).

Figure 2 shows that both females and males in the three youngest age groups (8-11, 12 & 13, 14 & 15) perform in much the same manner for both type of questions. For both question types the highest score for girls was the 12 and 13 year old group but the highest score for boys was the 14 and 15 year old group. The oldest group (16+ years) of students had the most disparate performance. On Type A division questions the females ($\overline{X} = 1.50$) scored higher than the males ($\overline{X} = 1.26$), but on Type B questions these 16+ year females scored lower ($\overline{X} = 0.80$) than the males ($\overline{X} = 1.53$). The girls performance was also erratic with respect to the third age group (14 and 15 years). Again on Type A questions the oldest females performed better than the younger ones ($\overline{X} = 1.50$ compared with 1.00). On Type B questions however the situation was reversed and the oldest group of girls did not perform as well as the younger group (0.80 compared with 1.08). This result seems to defy plausible interpretation and the probability of a Type I error cannot be overlooked.

Table XIII shows the error analysis for both types of division problems. The Type A questions (How many toys in each box?) had 154 out of 270 items (57%) answered incorrectly. Of these errors, 77 items (50%) were added instead of divided; 64 items (41.6%) were multiplied; 12 items (7.8%) were subtracted; and 1 item (0.6%) had no response. This percentage

TABLE XI

Three Way Analysis of Variance (univariate)
Age by Gender by Type of Question

Multiplication

Source of Variance	df	Mean Square	F
Between persons			
age	3	5.85997	2.27
gender	1	0.20276	0.08
age x gender	3	3.32126	1.29
error	82	2.57601	
Within persons			
type	1	1.41392	3.59
type x age	3	0.02541	0.06
type x gender	1	0.03660	0.09
type x age x gender	3	1.44275	3.66*
error	82	0.39403	

* = $p<.05$

TABLE XII

Performance Means and Standard Deviations
Type of Question by Age Group

Division

Age in Years		Type of Question A $\overline{X}$	A SD	B $\overline{X}$	B SD	Total $\overline{X}$	Total SD
	Males	0.62	0.65	0.38	0.65	0.50	0.65
8-11	Females	0.67	0.82	0.67	1.21	0.67	1.02
	Both	0.64	0.70	0.47	0.83	0.56	0.77
	Males	1.25	1.49	1.13	1.36	1.19	1.43
12 & 13	Females	1.88	1.55	1.63	1.41	1.75	1.48
	Both	1.57	1.52	1.38	1.39	1.48	1.46
	Males	2.08	1.26	1.54	1.13	1.81	1.20
14 & 15	Females	1.00	1.35	1.08	1.32	1.04	1.34
	Both	1.54	1.31	1.31	1.23	1.43	1.27
	Males	1.26	1.28	1.53	1.22	1.39	1.25
16+	Females	1.50	1.43	0.80	1.14	1.15	1.29
	Both	1.34	1.33	1.28	1.19	1.31	1.26
Overall		1.29	1.23	1.13	1.16	1.21	1.20

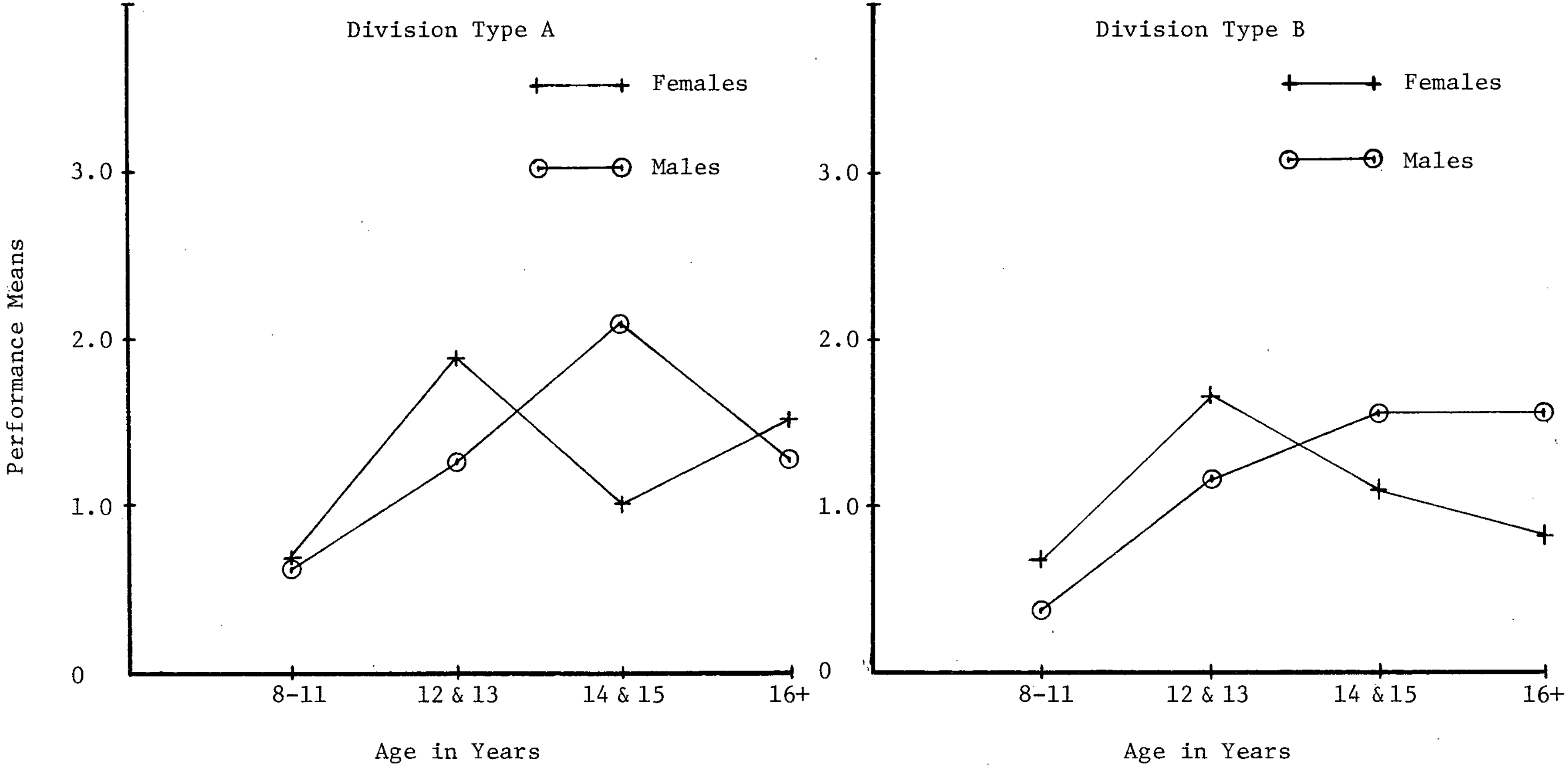

Figure 2: Interaction Graphs, Gender by Age
for Both Types of Question

TABLE XIII

Error Analysis for Division

	Type of Question											
	A				B				Total			
Age Group	Total		Composite*		Total		Composite*		Total		Composite*	
	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)
			25	(55.6)+			22	(45.8)+			47	(50.5)+
8-11	45	(78.9)	4	(8.9)-	48	(84.2)	10	(20.8)-	93	(81.6)	14	(15.1)-
			16	(35.5)×			16	(33.4)×			32	(34.4)×
			1	(4.4)ϕ			1	(3.8)ϕ			2	(4.1)ϕ
12&13	23	(47.9)	13	(56.5)+	25	(54.2)	13	(50.0)+	49	(51.0)	26	(53.1)+
			2	(8.7)-			8	(30.8)-			10	(20.4)-
			7	(30.4)×			4	(15.4)×			11	(22.4)×
			21	(55.3)+			20	(44.4)+			41	(49.4)+
14&15	38	(48.9)	2	(5.3)-	45	(57.7)	10	(22.2)-	83	(53.2)	12	(14.5)-
			15	(39.4)×			15	(33.4)×			30	(36.1)×
			18	(37.5)+			19	(38.0)+			37	(37.8)+
16+	48	(55.2)	4	(8.3)-	50	(57.5)	10	(20.0)-	98	(56.3)	14	(14.3)-
			26	(54.2)×			21	(42.0)×			47	(47.9)×
			1	(0.6)ϕ			1	(0.6)ϕ			2	(0.6)ϕ
Total	154	(57.0)	77	(50.0)+	169	(62.6)	74	(43.8)+	323	(59.8)	151	(46.7)+
			12	(7.8)-			38	(22.5)-			50	(15.5)-
			64	(41.6)×			56	(33.1)×			120	(37.2)×

* = Composite numbers and percentages add up to the total errors (100%) for each age group.

of errors was typical for all age groups except the oldest. They chose (if they made an error) to multiply (54.2%) rather than add (37.5%).

The Type B questions (How many boxes?) were answered incorrectly 169 times (62.6%). The errors were then distributed as follows: 74 questions (43.8%) were added; 56 questions (33.1%) were multiplied; 38 questions (22.5%) were subtracted; and 1 question (0.6%) had no response. Those division questions that were added was the most common error for the three younger groups and the oldest group (16+ years) either multiplied (42%) or added (38%).

For both Type A and B division questions the overall number of students who elected to add and not divide was similar. On the other hand, there was a higher percentage of incorrect response based on subtraction for Type B problems, but the reason is not apparent from the question forms.

Operation By Type - The results of the second analysis are presented in two tables and one graph. The first table summarizes the analysis of variance conducted on the four operations and type of question, treating each factor as a repeated factor. The second table contains the means and standard deviations of each cell corresponding to the interaction between the two factors. The graph also depicts this interaction.

As shown in Table XIV the univariate ANOVA showed that operation, type, and operation by type of question were all significant at the .01 level of significance. The overall mean performance for addition was 2.45; for subtraction - 1.49; for multiplication - 1.35; and for division - 1.21, with the total mean for all four operations being 1.62 (see Table XV). Scheffe's test ($p<.05$) was used to determine significant differences between operation and type of question. The results were as follows:

TABLE XIV

Summary ANOVA (univariate)
Mathematical Operation by Type of Question

Source of Variance	df	Mean Square	F
operation	3	56.94954	50.60**
error	267	1.12557	
type	1	14.16806	24.51**
error	89	0.57817	
operation × type	3	31.27176	40.72**
error	267	0.76801	

** = p<.01

TABLE XV

Performance Means and Standard Deviations
Mathematical Operation by Type of Question

	Type of Question					
	A		B		Total	
Operation	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Addition	2.63	0.69	2.27	1.00	2.45	0.85
Subtraction	0.74	1.18	2.23	1.14	1.49	1.16
Multiplication	1.27	1.23	1.42	1.29	1.35	1.26
Division	1.29	1.30	1.13	1.21	1.21	1.26
Total	1.48	1.10	1.76	1.16	1.62	1.13

Type A	Type B	Total (A and B)
addition>subtraction	addition>multiplication	addition>subtraction
addition>multiplication	addition>division	addition>multiplication
addition>division	subtraction>multiplication	addition>division
multiplication>subtraction	subtraction>division	
division>subtraction		

As might be expected, the performances on addition problems on Type A, Type B, or both types together, were significantly higher than the performances on word problems involving the other three operations. For Type A questions the mean for subtraction problems was significantly lower than the performances on multiplication or division problems. For Type B questions however, the reverse was true - the performance on subtraction problems was significantly greater than that on word problems requiring multiplication or division. The differences between total mean performances on Type A (mean of 1.48) and Type B (mean of 1.76) were not significant.

However, the main effects noted above need to be interpreted in light of the significant interaction between the two factors. Scheffe's test ($p<.05$) was also used to examine significant differences between types of questions. The only significant difference found was between Type A and Type B subtraction problems with the performance on Type B questions significantly exceeding that of Type A questions. This is illustrated in Figure 3. In addition the mean performance for both types of question for each mathematical operation are also shown. The graph of the overall means indicates that the addition mean (2.45) was followed in order by subtraction ($\overline{X}$ = 1.49), multiplication ($\overline{X}$ = 1.34) and division ($\overline{X}$ = 1.21), as discussed earlier. However, the presence of the disordinal interaction indicates that this trend is not consistent across type.

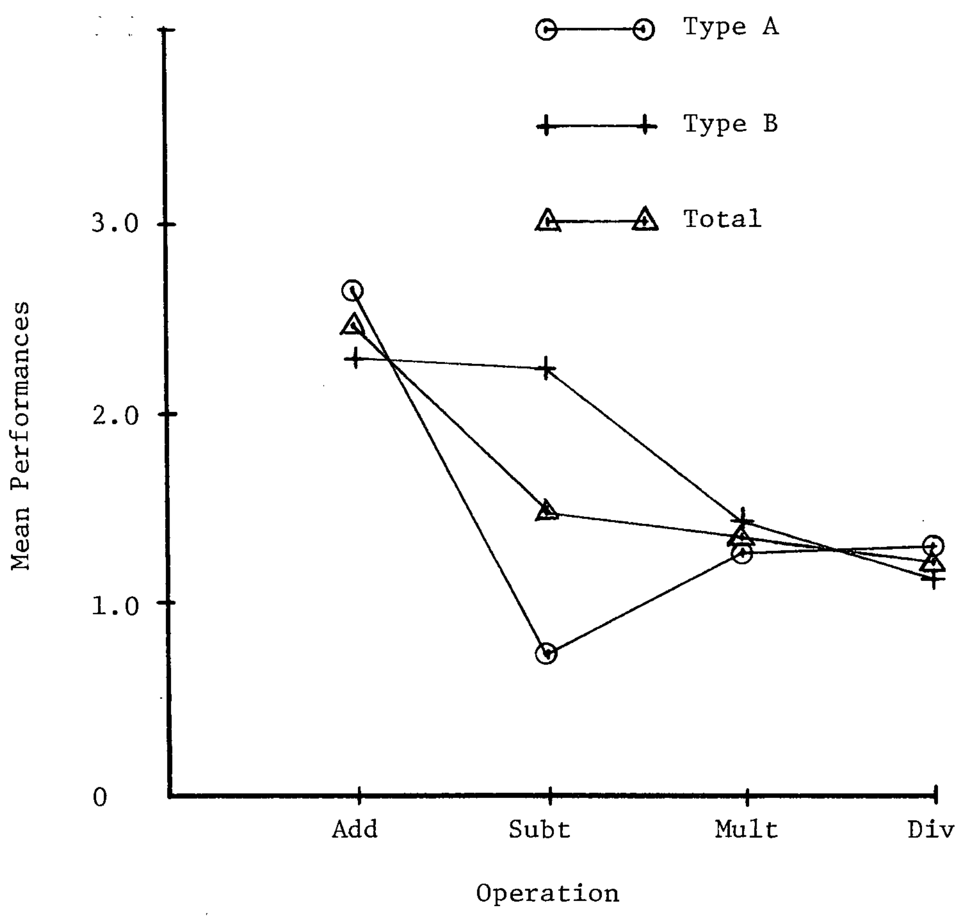

Figure 3: Interaction Graph, Type of Question by Operation

<u>Total Errors</u> - On the entire task 990 (45.8%) of the questions were answered incorrectly. Of these errors 486 (40.9%) were due to addition; 249 (30.5%) were due to multiplication; 128 (15.3%) were due to subtraction; 122 (12.9%) were due to division; and 5 (0.4%) were not answered. The fewest errors were made on the addition questions (18.3% errors) while the most errors were made on division questions (59.8% errors) (see Table XVI).

As a general rule it appears that when confronted with a word problem for which the solution is unclear, students will elect more often to add or multiply rather than subtract or divide. These results must be interpreted with caution. This add or multiply strategy which appears to apply to subtraction and division problems may also occur with addition and multiplication. If this is so, then scores on these latter operations are perhaps inflated. The strategy would result in some correct answers whereas this would not be possible in subtraction and division. This aspect merits further investigation (possibly through an exploration of the reasons given by students for their solution).

TABLE XVI

Total Error Analysis

Operation	Errors Total n	(%)	Composite* n	(%)
Addition	99	(18.3)	29 58 12	(29.3)- (58.6)× (12.1)÷
Subtraction	271	(50.2)	2 122 71 76	(0.7)ϕ (45.0)+ (26.2)× (28.1)÷
Multiplication	297	(55.0)	1 213 49 34	(0.4)ϕ (71.7)+ (16.5)- (11.4)÷
Division	323	(59.8)	2 151 50 120	(0.6)ϕ (46.7)+ (15.5)- (37.2)×
Total	990	(45.8)	5 486 128 249 122	(0.4)ϕ (40.9)+ (15.3)- (30.5)× (12.9)÷

* = Composite numbers and percentages add up to the total errors (100%) for each operation.

CHAPTER V

CONCLUSIONS

I. Summary

This study examined the performance of profoundly hearing impaired students on one-step arithmetical word problems. One hundred sixteen students were administered a computation task and those ninety who met the pass requirement (at least four of the six questions correct for each operation) were selected for the study in which they were given a word problem task. The subjects were divided into four age groups as follows: 8-11 years; 12 & 13 years; 14 & 15 years; and 16+ years.

Statistical treatment of the data showed no significant differences when age and gender were examined for any of the word problems which involved the four operations of addition, subtraction, multiplication, and division. For the word problem requiring the operation of addition however, the type of question was significant. Results revealed that Type A addition problems (i.e. How many toys in all?) were easier to solve than the Type B problems (i.e. How many boxes were there?). Although the percentage of errors for Type B questions was twice that of Type A questions, the distribution of errors was similar. For both types of addition problems, the majority of errors consisted of multiplication in lieu of addition.

The difference in the type of question was also significant for subtraction problems with Type A questions (i.e. How many more toys than boxes?) being uniformly more difficult for all age groups. The interaction between type of question and age was also found to be significant. The mean performances for Type B subtraction problems (i.e. How many toys left?) improved as age increased whereas the means for Type A showed a decrease in performance for the two older groups (14 & 15, 16+ years). Examination of errors showed that for Type A questions younger students added whereas older students multiplied rather than subtracted. For Type B problems, all the age groups with the exception of the 12 and 13 year olds made a greater percentage of errors by adding instead of subtracting. This group made more errors by dividing. Overall the majority of students who made errors tended to add rather than multiply or divide.

Unlike addition and subtraction problems, type of question was not significant for multiplication word problems. Although the performance on these questions improved slightly with increasing age, the differences were not statistically significant. Error analysis for multiplication problems showed that in the majority of cases for both Type A (i.e. How many toys in all?) and B questions (i.e. How many boxes did Susan see?), the students added rather than multiplied.

Type of question was also found not to be significant for division problems. There was, however, a significant interaction between type of question, age, and gender. Both females and males in the three younger age groups (8-11, 12 & 13, 14 & 15 years) performed in a similar manner for both types of questions. The oldest group (16+ years) had the most disparate performance. On Type A questions (i.e How many toys in each box?) the girls from this group scored higher than the boys but on the Type B questions (i.e. How many boxes?) the reverse was true. Also on Type A questions the oldest girls' mean performance was better than the younger girls (14 & 15 years) but on the Type B problems the situation again was reversed. Error analysis for division word problems showed that for both Type A and B questions, a similar number of students elected to add and not divide. For both types of division questions, addition was the most common error strategy for the three younger age groups. The oldest group of students chose to multiply on Type A problems and either multiply or add on Type B questions.

When age and gender were collapsed, a second analysis revealed that operation, type of question and the interaction between operation and type of question were all significant. The mean performances for the total sample population indicated that addition word problems were the easiest to solve followed by subtraction, multiplication, and division in that order. Type A word problems for the four operations appeared slightly more difficult than Type B questions. Performances on addition problems were significantly greater than performances on problems involving the other three operations. For Type A questions the means for subtraction problems was significantly lower than the performances on multiplication or division problems. For Type B questions however, the reverse was true - the mean on the subtraction problems was significantly greater than that on word problems requiring multiplication or division. Analysis of the total errors on the task showed that addition had the lowest percentage of errors (18.3%). The other three groups of problems had similar percentage ranging from 50.2% to 59.8% (more errors than correct responses). It would appear that if an error was made the majority of students either added or multiplied rather than subtracted or divided.

II. Limitations

A factor of concern is the lack of control over many variables in a hearing impaired student population. While the study attempted to control degree of hearing loss and age, other variables such as etiology, educational placement and educational treatment were relatively uncontrolled.

Sample size was small because the study was limited to subjects attending a class under the jurisdiction of the provincial school for the deaf and who satisfied the criteria of the study. Generalization of the results to the deaf population as a whole is not warranted in that there may be an uncontrolled sampling error.

A further limitation is the small number of problems tested for each operation which restricted the reliability of the measurement. However in this pilot study in order not to discourage the students with a lengthy task, greater precision was sacrificed for brevity, hopefully to obtain sustained effort from the students.

III. Educational Implications

Each of a number of factors appeared to play a role in successful problem solving, but no single one seemed to be paramount. Beyond recognition of the fact that intelligence, arithmetical skills, and reading skills are elements involved in problem solving, the conclusions of most studies were not in accord (see Suydam 1967). Statistical treatment on the performance of profoundly deaf students on word problems in this study showed low scores on three of the four operations (subtraction, multiplication, and division). Even though computational skills, syntax and vocabulary were controlled, results indicated that these students had great difficulty in solving seemingly simple one-step arithmetical word problems.

As already discussed, previous studies have indicated that specific training in vocabulary (Lyda and Duncan 1967), and programs of systematic instruction in the reading of word problems (Faulk and Landry 1961) aided student performance. Teachers of the deaf may well consider these approaches and include them in their instruction of arithmetic. Because words may have multiple meanings, as was indicated in this study, vocabulary should be taught in context. "More" does not necessarily mean a greater quantity. Furth (1966b) claims that language and words behind mathematical concepts are not always clear and may run counter to conventional usage in the mind of a young deaf child. For example when asked to find the pile of blocks which "has" more, the child tends to select the pile which "needs" more. Perhaps a contrasting of "wanting" more and "having" more (Ling 1978) may be helpful in developing a fuller understanding of the contextual dependent nature of more. In addition to vocabulary instruction, mathematical punctuation and abbreviations should also be studied.

The two most common question forms for each operation were selected for this study from an elementary mathematics series (Investigating School Mathematics) presently used in British Columbia. Although the students encounter these questions frequently, results showed that generally they do not fully understand what operation was required from the wording of the problem. Teachers should realize that reading skills encountered in literature are not identical with those in mathematics and specialized work on the reading of mathematics is required (Barney 1972). This could be accomplished partially by the student restating or dramatizing the word problem to ensure comprehension of the situation posed in the problem. Borron (1975) stated that to solve problems successfully three prerequisites - reading skill, understanding of mathematical processes and their application, and computational skill - must be met so that the students will be attempting only one new skill - choosing the proper operation to solve the problem. In this study computational skill was controlled therefore it would appear that reading skill and understanding of mathematical processes and their application should be examined as to how these factors affect the performance of hearing impaired students on word problems.

IV. Future Research

As this study examined a restricted sample population, it would be interesting and valuable to investigate how hearing impaired students from various educational placements and instruction would perform on word problem tasks. Factors such as varying degrees of hearing loss and type of communication system used need also to be explored.

One of the shortcomings of many studies, is the use of correct answers as the criterion and corresponding avoidance of looking at the problem solving process. In other words most studies examined error type rather than error cause. A fruitful area of research would consist of an examination of how hearing impaired students reason when they attempt to solve a word problem.

A further consideration for future research involves studies of techniques for teaching hearing impaired students to comprehend the mathematical relationships expressed by the syntax and numerals of a word problem.

In the discussion of educational implications, it was further suggested that a need for research related to the development of measures of specific mathematical reading skills. Hopefully diagnostic tools would be developed from this research to aid teachers of mathematics.

BIBLIOGRAPHY

Alexander, Vincent E. Seventh graders ability to solve problems. School Science and Mathematics, 1960, 60, 603-606.

Balow, Irving H. Reading and computation ability as determinants of problem solving. The Arithmetic Teacher, 1964, 11, 18-22.

Barney, Leroy. Problems associated with the reading of arithmetic. The Arithmetic Teacher, 1972, 19, 131-133.

Borron, Roberta. Helping deaf children learn to solve addition and subtraction verbal problems. American Annals of the Deaf, 1975, 120, 346-349.

Bruner, J.S., Olver, R., and Greenfield, P. Studies in cognitive growth. New York: Wiley, 1966.

Call, Russel J., and Wiggen, Neal A. Reading and mathematics. The Mathematics Teacher, 1966, 59, 149-157.

Carpenter, T.P., Coburn, T.G., Reys, R.E., and Wilson, J.W. Results and implications of the NAEP mathematics assessment: elementary school. The Arithmetic Reader, 1975, 22, 438-450.

Carpenter, T.P., Coburn, T.G., Reys, R.E., and Wilson, J.W. Subtraction: what do students know? The Arithmetic Teacher, 1975, 22, 653-657.

Carpenter, T.P., Coburn, T.G., Reys, R.E., and Wilson, J.W. Notes from the national assessment: word problem. The Arithmetic Teacher, 1976, 23, 389-393.

Carpenter, T.P., Corbitt, M.K., Kepner, H.S., Lindquist, M.M., and Reys, R.E. Results of the second NAEP mathematics assessment: secondary school. The Mathematics Teacher, 1980, 73, 329-338.

Chase, Clinton I. The position of certain variables in the prediction of problem solving in arithmetic. Journal of Educational Research, 1960, 54, 9-14.

Coffing, Esther A. The relationship between silent reading ability and arithmetical ability. School Science and Mathematics, 1941, 41, 10-14.

Conrad, R. The reading ability of deaf school-leavers. British Journal of Educational Research, 1977, 47, 138-148.

Cooper, Robert L., and Rosenstein, Joseph. Language acquisition of deaf children. Volta Review, 1966, 68, 58-67.

Corle, Clyde G. Thought processes in grade six problems. The Arithmetic Teacher, 1958, 5, 193-203.

Days, Harold C., Wheatley, Grayson H., and Kulm, Gerald. Problem structure, cognitive level, and problem solving performance. Journal for Research in Mathematics Education, 1979, 10, 135-146.

Earp, N. Wesley. Observations on teaching-reading in mathematics. Journal of Reading, 1970, 13, 529-532.

Earp, N. Wesley. Problems of reading in mathematics. School Science and Mathematics, 1971, 71, 129-133.

Eicholz, Robert E., O'Daffer, Phares G., and Fleenor, Charles R. Investigating school mathematics. Grades 2-6. Don Mills, Ontario: Addison-Wesley (Canada) Ltd., 1973.

Engelhart, Max D. The relative contribution of certain factors to individual differences in arithmetical problem solving. Journal of Experimental Education, 1932, 1, 19-27.

Erikson, Leland H. Certain ability factors and their effect on arithmetic achievement. The Arithmetic Teacher, 1958, 5, 287-291.

Faulk, Charles J., and Landry, Thomas B. An approach to problem solving. The Arithmetic Teacher, 1961, 8, 157-160.

Furth, Hans G. A comparison of reading test norms of deaf and hearing children. American Annals of the Deaf, 1966a, 111, 461-462.

Furth, Hans G. Thinking without language. London: Collier-MacMillan, 1966b.

Goetzinger, C.P., and Rousey, C.L. Educational achievement of deaf children. American Annals of the Deaf, 1959, 104, 221-231.

Hamp, N.W. Reading attainment and some associated factors in deaf and partially hearing children. Teacher of the Deaf, 1972, 70, 203-215.

Hansen, Carl W. Factors associated with successful achievement in problem solving in sixth grade arithmetic. Journal of Educational Research, 1944, 38, 111-118.

Hargis, Charles H. The grammar of the noun phrase and arithmetic instruction for deaf children. American Annals of the Deaf, 1969, 114, 766-769.

Heddens, James W., and Smith, Kenneth J. The readability of elementary mathematics books. The Arithmetic Teacher, 1964, 11, 466-468.

Henney, Maribeth. Improving mathematics verbal problem solving ability through reading instruction. The Arithmetic Teacher, 1971, 18, 223-229.

Hernandez, Norma G. Word problem skits for the deaf. The Arithmetic Teacher, 1979, 27, 14-16.

Hine, W.D. The attainments of children with partial hearing. Teacher of the Deaf, 1970, 68, 129-135.

Johnson, Harry C. The effect of instructor in mathematical vocabulary upon problem solving in arithmetic. Journal of Educational Research, 1944, 38, 97-110.

Johnson, J.T. On the nature of problem solving in arithmetic. Journal of Educational Research, 1949, 43, 110-115.

Johnson, Kerry A. A survey of mathematical programs, materials, and methods in schools for the deaf. American Annals of the Deaf, 1977, 122, 19-25.

Karchmer, Michael A., Milone, Michael N., and Wolk, Steve. Educational significance of hearing loss at three levels of severity. American Annals of the Deaf, 1979, 124, 97-109.

Kramer, Grace A. The effect of certain factors in the verbal arithmetic problem upon children's success in the solution. Johns Hopkins University Studies in Education, Baltimore: The Johns Hopkins Press, 1933.

Lenore, John. Difficulties in solving problems in arithmetic. The Elementary School Journal, 1930, 31, 202-215.

Lester, Jr., Frank K. Ideas about problem solving: a look at some psychological research. The Arithmetic Teacher, 1977, 25, 12-14.

Ling, Agnes. Basic number and mathematical concepts for young hearing impaired children. Volta Review, 1978, 80, 46-50.

Linville, William J. Syntax, vocabulary, and the verbal arithmetic problem. School Science and Mathematics, 1976, 76, 152-158.

Lyda, W.J. Arithmetic in the secondary school curriculum. The Mathematics Teacher, 1947, 40, 387-388.

Lyda, W.J., and Duncan, Frances M. Quantitátive vocabulary and problem solving. The Arithmetic Teacher, 1967, 14, 289-291.

Messerly, Carol L., and Aram, Dorothy M. Academic achievement of hearing impaired students of hearing parents and of hearing impaired parents: another look, Volta Review, 1980, 82, 28-32.

Meyer, Ruth Ann. Mathematical problem solving performance and intellectual abilities of fourth grade children. Journal for Research in Mathematics Education, 1978, 9, 334-348.

Monroe, Walter S., and Engelhart, Max D. The effectiveness of systematic instruction in reading verbal problems in arithmetic. Elementary School Journal, 1933, 33, 377-381.

Muscio, Robert. Factors relating to quantitative understanding in the sixth grade. The Arithmetic Teacher, 1962, 9, 259-262.

Newcomb, R.S. Teaching pupils how to solve problems in arithmetic. Elementary School Journal, 1922, 23, 183-189.

Olander, Herbert T., and Ehmer, Charles L. What pupils know about vocabulary in mathematics - 1930 and 1968. Elementary School Journal, 1971, 71, 361-367.

Otterburn, Margaret K., and Nicholson, A.R. The language of (CSE) mathematics. Mathematics in School, 1976, 5, 18-20.

Piaget, J. The construction of reality in the child. New York: Basic Books, 1954.

Pitts, Raymond J. Relationships between functional competence in mathematics and reading grade levels, mental ability and age. Journal of Educational Psychology, 1952, 43, 486-492.

Richardson, Lloyd I. The roles of strategies for teaching pupils to solve verbal problems. The Arithmetic Teacher, 1975, 22, 414-421.

Rogers, W. Todd, and Clarke, B.R. Correlates of academic achievement of hearing impaired students. Canadian Journal of Education, 1980, 5, 27-39.

Rogers, W.T., Leslie, P.T., Clarke, B.R., Booth, J.A., and Horvath, A. Academic achievement of hearing impaired students: comparison among selected subpopulations. B.C. Journal of Special Education, 1978, 2, 183-213.

Roling, Pearl, Blume, Clara L., and Morehart, Mary S. Specific causes of failure in arithmetic problems. Educational Research Bulletin, 1924, 3, 271-272.

Rose, Alvin W., and Rose, Helen Cureton. Intelligence, sibling position, and sociocultural background as factors in arithmetic performance. The Arithmetic Teacher, 1961, 8, 50-56.

Schell, Leo M., and Burns, Paul C. Pupil performance with three types of subtraction situations. School Science and Mathematics, 1962, 62, 208-214.

Smith, Frank. The readability of sixth grade word problems. School Science and Mathematics, 1971, 71, 559-562.

Steffe, Leslie P. The relationship of conservation of numerous to problem solving abilities of first grade children. The Arithmetic Teacher, 1968, 15, 47-52.

Stevens, B.A. Problem solving in arithmetic. Journal of Educational Research, 1932, 25, 253-260.

Stevenson, P.R. Difficulties in problem solving. Journal of Educational Research, 1925, 11, 95-103.

Suppes, Patrick. A survey of cognition in handicapped children. Review of Educational Research, 1974, 44, 145-176.

Suydam, Marilyn N. The status of research on elementary school mathematics. The Arithmetic Teacher, 1967, 14, 684-689.

Suydam, Marilyn N., and Weaver, J. Fred. Research on problem solving: implications for elementary school classrooms. The Arithmetic Teacher, 1977, 25, 40-42.

Tomlinson-Keasey, C., and Kelly, Ronald R. The deaf child's symbolic world. American Annals of the Deaf, 1978, 123, 452-459.

Treacy, John P. The relationship of reading skills to the ability to solve arithmetic problems. Journal of Educational Research, 1944, 38, 86-96.

Trybus, Raymond J., and Karchmer, Michael A. School achievement scores of hearing impaired children: national data on achievement status and growth patterns. American Annals of the Deaf, 1977, 122, 62-69.

Underhill, Robert G. Teaching word problems to first graders. The Arithmetic Teacher, 1977, 25, 54-56.

VanderLinde, Louis F. Does the study of quantitative vocabulary improve problem solving? Elementary School Journal, 1964, 65, 143-152.

Vernon, McCay, and Koh, Soon D. Early manual communication and deaf children's achievement. American Annals of the Deaf, 1970, 115, 527-536.

Vernon, McCay, and Koh, Soon D. Effects of oral preschool compared to early manual communication on education and communication in deaf children. American Annals of the Deaf, 1971, 116, 569-574.

Washburne, Carleton, and Osborne, Raymond. Solving arithmetic problems. Elementary School Journal, 1926, 27, 219-226.

Webb, Leland F., and Ost, David H. Real comprehensive problem solving as it relates to mathematics teaching in the secondary schools. School Science and Mathematics, 1978, 78, 197-206.

Webb, Norman L. Processes, conceptual knowledge and mathematical problem solving ability. Journal for Research in Mathematics Education, 1979, 10, 83-93.

Wilson, John W. The role of structure in verbal problem solving. The Arithmetic Teacher, 1967, 14, 486-497.

Wrigley, Jack. The factorial nature of ability in elementary mathematics. British Journal of Educational Psychology, 1958, 28, 61-78.

APPENDIX A

COMPUTATION TASK

Name:______________________________

Birthdate:______________________________

School:______________________________

Teacher:______________________________

Examples:

Circle the right answer.

A) $6 + 4 =$ 2 6 8 10	B) $3 - 1 =$ 1 2 3 4
C) $4 \times 3 =$ 1 7 12 15	D) $10 \div 5 =$ 1 2 5 15

Circle the right answer.

A) 6 + 2 = 3 4 8 12	B) 6 x 3 = 2 3 9 18
C) 3 x 3 = 0 1 6 9	D) 6 ÷ 3 = 2 3 9 18
E) 6 + 3 = 2 3 9 18	F) 9 − 3 = 3 6 12 27
G) 10 ÷ 2 = 5 8 12 20	H) 9 x 3 = 3 6 12 27
I) 10 x 2 = 5 8 12 20	J) 8 x 2 = 4 6 10 16
K) 9 ÷ 3 = 3 6 12 27	L) 6 ÷ 2 = 3 4 8 12

Circle the right answer.

M) 9 + 3 = 3 6 12 27	N) 8 ÷ 2 = 4 6 10 16
O) 3 + 3 = 0 1 6 9	P) 10 - 2 = 5 8 12 20
Q) 8 + 2 = 4 6 10 16	R) 6 - 3 = 2 3 9 18
S) 8 - 2 = 4 6 10 16	T) 10 + 2 = 5 8 12 20
U) 6 x 2 = 3 4 8 12	V) 3 ÷ 3 = 0 1 6 9
W) 6 - 2 = 3 4 8 12	X) 3 - 3 = 0 1 6 9

WORD PROBLEM TASK

Circle the right answer. Name:

A) John had 6 toys. Bill had 2 toys. How many toys in all? 3 4 8 12	B) John had 6 boxes. John had 3 toys in each box. How many toys in all? 2 3 9 18
C) John had 3 boxes. John had 3 toys in each box. How many toys in all? 0 1 6 9	D) John had 6 toys. Bill put 3 toys in each box. How many boxes? 2 3 9 18
E) Susan had 6 boxes. Susan found 3 boxes. How many boxes were there? 2 3 9 18	F) John had 9 toys. John lost 3 toys. How many toys left? 3 6 12 27
G) Bill had 10 toys. Bill had 2 boxes. How many toys in each box? 5 8 12 20	H) Bill had 9 boxes. Susan saw 3 times as many boxes. How many boxes did Susan see? 3 6 12 27

Circle the right answer.

I) John had 10 boxes. John had 2 toys in each box. How many toys in all? 5 8 12 20	J) Bill had 8 boxes. Susan saw 2 times as many boxes. How many boxes did Susan see? 4 6 10 16
K) John had 9 toys. Bill put 3 toys in each box. How many boxes? 3 6 12 27	L) John had 6 toys. Bill put 2 toys in each box. How many boxes? 3 4 8 12
M) Susan had 9 boxes. Susan found 3 boxes. How many boxes were there? 3 6 12 27	N) Bill had 8 toys. Bill had 2 boxes. How many toys in each box? 4 6 10 16
O) Susan had 3 boxes. Susan found 3 boxes. How many boxes were there? 0 1 6 9	P) Susan had 10 toys. John had 2 boxes. How many more toys than boxes? 5 8 12 20

Circle the right answer.

Q) John had 8 toys. Bill had 2 toys. How many toys in all? 4 6 10 16	R) John had 6 toys. John lost 3 toys. How many toys left? 2 3 9 18
S) Susan had 8 toys. John had 2 boxes. How many more toys than boxes? 4 6 10 16	T) John had 10 toys. Bill had 2 toys. How many toys in all? 5 8 12 20
U) Bill had 6 boxes. Susan saw 2 times as many boxes. How many boxes did Susan see? 3 4 8 12	V) Bill had 3 toys. Bill had 3 boxes. How many toys in each box? 0 1 6 9
W) John had 6 toys. John lost 2 toys. How many toys left? 3 4 8 12	X) Susan had 3 toys. John had 3 boxes. How many more toys than boxes? 0 1 6 9