THE EFFECTS OF SHORT-TERM MEMORY TRAINING ON CHILDREN WHO EXHIBIT MATHEMATICS LEARNING DISABILITIES AND SHORT-TERM MEMORY RETENTION PROBLEMS

STEPHANIE JANE MICHAEL

The Effects of Short-Term Memory Training on Children Who Exhibit Mathematics Learning Disabilities and Short-Term Memory Retention Problems

© Stephanie J. Michael, B.A. (Hons.)

A Thesis Submitted to the School of Graduate Studies
in Partial Fulfilment of Requirements for the Degree of
Master of Science

Department of Psychology
Memorial University of Newfoundland

March, 1986

St. John's Newfoundland

ISBN 0-315-31038-3

Abstract

Children who perform poorly on mathematical tasks also tend to do poorly on both auditory and visual short-term memory tasks. The purpose of this study was to compare the relative effectiveness of an intervention package consisting of short-term memory strategy instruction and standard math practice with an intervention package consisting of standard math practice alone. Children who received the combined math and memory instruction were predicted to perform better on subsequent math tasks than those who received only math instruction. Fourteen children (mean age = 10.93 years) of average intelligence, who performed below average on several math and memory tests were randomly assigned to one of two conditions. A control group received math instruction consisting of practical application of the four basic math operations. The experimental group received short-term memory instruction and training in addition to the math practice. Treatment for both groups consisted of six one-hour sessions, spread over the course of two weeks. All children were assessed pre- and post-treatment. Assessment involved both visual and auditory math and memory testing. The experimental group improved significantly from pre- to post-assessment on both math and memory tasks. The math only group did not. For children performing poorly on math and memory tasks, these results strongly demonstrate the effectiveness of a combined math and memory training program.

Acknowledgements

I would like to express sincere thanks to the members of my thesis committee, Christine Arlett (my supervisor), Rita Anderson, and Barbara Hopkins, for their praise, their criticism, and their consistent cooperation. Many thanks also go to Michael Sherrick, for answering my continuous stream of statistical questions and to Jack Strawbridge, who often helped me when my knowledge of the computer system failed. I am grateful to Graduate Studies, for providing me with financial support through a Memorial University of Newfoundland fellowship.

Thanks are due to the Diagnostic and Remedial Unit at Memorial University, for providing an accessible subject population, materials, and working space. Also, I certainly appreciate the parents of the children in my math groups. Besides requesting help for their children, they made sure that they attended every session.

Finally to Gerry, thank you for all those hours you listened, waited, and provided encouragement.

Table of Contents

List of Tables

List of Figures

The generic term, learning disabilities, refers to a heterogeneous group of disorders manifested by significant difficulties in the acquisition and use of listening, speaking, reading, writing, reasoning or mathematical abilities. These disorders are intrinsic to the individual and are presumed to be due to central nervous system dysfunction. Even though a learning disability may occur concommitantly with other handicapping conditions or environmental influences, it is not the direct result of those conditions or influences. Depending on the definition used, estimates of the percentage of school aged children with learning disabilities vary from 2% to 30%, with boys outnumbering girls by a factor of 4 to 1 (Kirk and Kirk, 1983).

Worden (1983) outlined two popular models that are used to explain the basis of learning disabilities. From the perspective of the Developmental Lag Model, children with learning disabilities exhibit a slow rate of development in particular areas and therefore resemble younger normal children. Under this model, cognitive development is seen only as slower than normal, not different in any fundamental way. Learning disabled children will progress through the same developmental stages as normal children, but at a slower rate. This view implies that with maturation, learning disabled children will catch up to their peers. In contrast, from the perspective of the Permanent Deficit Model, children with learning disabilities show mild versions of symptoms typically observed in victims of brain damage. These deficits are permanent ones. Learning disabled children will continue to show the same cognitive profile as adolescents and as adults.

Mathematics Learning Disabilities. Although learning disabilities can be observed in many school related areas, the focus in this study is on mathematics. Englehardt (1983) describes several different approaches that are used to explain the underlying problem(s) associated with a mathematics learning disability. The Intellectual Skills Approach presumes that the learner's problems stem from a deficit in some cognitive ability or process, such as sequential memory or visuospatial abilities. Under the Procedural Approach, learner difficulties are attributed to absent or misordered steps in mathematical procedures. This may be seen when one does not have all the mathematical prerequisites necessary to complete a problem. The Conceptual Approach assumes that difficulties in math reflect the failure to understand various mathematical concepts, principles or procedures.

Two other potential sources of difficulty in addition to those identified by Englehardt can be described. The Mathematical Block Approach assumes that some children may exhibit a block to mathematics, resulting in a lack of motivation and consequently poor math performance. Under the final approach, the Language Approach, children's problems may reflect difficulties in reading and comprehending the wording of a problem.

Each of these approaches could reflect either of the models discussed by Worden (1983). These approaches present a broad spectrum as to the nature of learning disabilities. They are not exclusive, as a child could have difficulties in all or a combination of areas. Whereas all of the approaches can be applied to children who exhibit mathematical difficulties, the focus of this study will be on the first. The Intellectual Skills Approach stresses deficits in cognitive abilities as the underlying problem. Specifically, this study will focus on deficits in the use of short term memory (STM) strategies in mathematics disabled children.

Short-Term Memory. Short term memory (STM), or working memory as it is commonly called, refers to a hypothetical buffer in the information processing system where stimuli are held momentarily for further processing. Hence, STM has been hypothesized to play a central role in a range of important cognitive skills, from speech comprehension to arithmetic and from learning to complex reasoning. Instead of a single unitary STM system, Baddeley (1982) argues that working memory should be regarded as a set of interrelated subsystems. In his model, working memory is divided into three subsystems: a central executive system and two slave systems, the articulatory loop and the visuo-spatial scratch pad.

The central executive forms the control centre of the system and is assumed to select and operate various control processes. It is also assumed to have a limited amount of processing capacity, some of which could be devoted to the short-term storage of information. The central executive is able to offload some of the storage demands to the two subsidary slave systems.

The articulatory loop consists of two subsystems, a phonemic store and an articulatory rehearsal process. The phonemic store is assumed to be responsible for phonemic similarity effects on STM. That is, serial recall is better for sequences of phonemically dissimilar items than for sequences of phonemically similar items. According to Baddeley's model, access to the phonemic store is assumed to be automatic for spoken verbal material, but to require articulation when the verbal material is presented visually. The articulatory rehearsal process is assumed to enhance memory span by refreshing the fading memory trace of items registered within the phonemic store. Without rehearsal, the lifespan of an item in storage is short. The more rapidly a sequence of items can be articulated, the more frequently can its memory trace be refreshed (Baddeley and Wilson, 1985).

The visuo-spatial scratch pad has been regarded as a temporary spatial memory system and has been shown to be involved in manipulating visuo-spatial information. Because this study looks at basic math operations that do not involve the visuo-spatial scratch pad, the characteristics of this system will not be elaborated further.

Developmental Studies of STM. Memory studies conducted in the middle and the late 1960s have revealed that by 8 or 9 years of age, children use numerous strategies as aids in their efforts to remember. They rehearse the names of stimuli (by saying the names repeatedly) and organize stimuli in terms of semantic properties (by grouping). Younger children fail to use these potentially helpful mnemonics. Strategies are first used with some consistency in the early elementary school years. From middle and late childhood and through adolescence, there seems to be a gradual developmental progression in the effectiveness and flexibility with which strategies are implemented (Kail and Hagen, 1982). The acquisition of strategy use occurs with normal development.

Developmental studies have found that when young children fail to use a particular strategy, they can often be trained to do so. Upon instruction they show immediate improvements in utilizing the strategy. In these studies, failure to use a particular strategy does not seem to reflect a limitation in the memory system itself. Instead, it appears to be a failure on the part of the individual to employ the appropriate strategy. Efforts to instruct elementary school children who do not spontaneously use strategies have been successful. Normal children can be taught to use rehearsal strategies and when they do, their performance on STM tasks improves accordingly (Waters and Andreassen, 1983).

Particular groups of children do not spontaneously employ STM strategies appropriate to their developmental level. These include retarded individuals and children exhibiting attention deficit disorder. As outlined below, research evidence suggests that both of these groups can improve on STM tasks once they receive instruction on STM strategies.

Retarded persons are particularly inefficient at using mnemonic strategies that require rehearsal, organization, and elaboration. These individuals do not tend to spontaneously rehearse in situations which call for rehearsal, and thereby lose a great deal of information. As the number of items in a to-be-remembered list of items increases, the performance of retarded individuals deteriorates more than it does for normal individuals. Training retarded persons to rehearse leads to improved performance on STM tasks. In the same manner, preventing normal individuals from rehearsing results in a performance similar to untrained retarded individuals (Robinson and Robinson, 1976). Much of the evidence shows that retarded individuals can maintain mnemonic strategies for considerable periods ranging from two weeks to one year. Although evidence for the generalization of such strategies with this population is sparse, what is available suggests that the effects of training are usually limited to the particular training context (Haywood, Meyers and Switzky, 1982).

Attention deficit disorder children have been observed to have poor school performance, despite the fact that they generally achieve average scores on intelligence tests. Attention deficit disorder children seem to have no particular difficulty storing information, as long as it has been adequately processed. The processing skills and effort required to establish clear, well organized representations of new learning in this group of children frequently appear to be inadequate. They appear to have less mastery of mnemonic devices than normal children. In particular, attention deficit disorder children do not seem to take the trouble to mentally rehearse material that is to be remembered (Douglas, 1983). Attention deficit disorder children do no worse than normal children on memory tasks that provide a built- in strategy for remembering. However, their performance is notably worse when tasks require them to generate their own strategies (Kendal and Braswell 1985).

STM and Learning Disabilities. Much of the work on mathematics disabilities and STM deficits has followed from earlier studies that examined the relationship between reading disabilities and coding efficiency in STM. Conrad's research (1964, 1972) on phonetic coding has shown that it is more difficult for a subject to repeat a string of phonemically similiar consonants (eg. B,C,D,G,P,T,V,Z) than a sequence of consonants that differ from each other in sound or articulation (H,K,L,Q,R,S,W,Y). Conrad interpreted this as evidence that STM uses a speech based coding system. A clear advantage to the dissimilar set emerges by age 8.

Shankweiler, Liberman, Mark, Fowler and Fischer (1979), found that poor readers were less affected by the phonemic similarity of the items than good readers. This was for both visual and auditory presentations. Shankweiler et al concluded that poor readers were deficient in the use of a phonemic code. They go on to suggest that individual variation in coding efficiency may be a relevant factor in learning to read.

Siegel and Linder (1984) also compared the recall of phonemically similar and dissimilar letter strings in groups of children who differed in reading achievement. The normally achieving children recalled significantly more of the phonemically dissimilar letter strings than the phonemically similar ones. The poor readers did not. Like Shankweiler et al, Siegel and Linder concluded that normally achieving children show sensitivity to the phonemic aspects of stimuli during a memory task, but children with a reading disability do not. Furthermore, Siegel and Linder postulated that deficits in STM are a general characteristic of learning disabilities, and are not just limited to reading.

Over the last several years, researchers have examined the relationship between STM skills and mathematical performance. Webster (1979, 1980), Siegel and Feldman (1983), and Siegel and Linder (1984) found that poor performance on STM tasks is associated with mathematics learning disabilities. When asked to recall lists of items, mathematics disabled children performed significantly poorer than normally achieving children. In these studies, lists consisted of letter strings similar to those devised by Shankweiler; Webster used digit strings as well. The lists were presented either auditorally or visually. All children in these studies had average I.Q.'s.

Webster (1979, 1980) found significant differences in STM capacity among three groups of mathematics achievers. His groups were made up of mildly mathematics disabled children, severely mathematics disabled children, and mathematics proficient children, ranging in age from 11 - 12 years. He concluded that the mathematics disabled learners failed to use the same coding mechanism as efficiently as the adequate learners.

The subjects in the Siegel and Linder (1984) study had either a math disability or were achieving averagely in math in school. They ranged in age from 7 - 13 years. For the younger mathematics disabled children (7 - 8 years), no differences were found between the recall of phonemically similar and dissimilar letters. The normal group at this age did demonstrate a difference. The older mathematics disabled children (9 - 13 years), like the normal groups at this age, had a significantly poorer recall of similar as compared to phonemically dissimilar letters. Over all of the ages, performance of the math disabled group was significantly lower than that of the normal group. The younger learning disabled children in the Siegel and Linder study were characterized by a deficiency in phonemic coding. The older learning disabled children appeared to be using a phonemic code, but had a more general deficit in STM. Siegel and Linder (1984) suggest that such data supports a developmental lag model in which disabilities represent a maturational lag rather than a deficit.

Baddeley's (1982) model of working memory assumes that the articulatory loop can store any information, either spoken verbal material or through the articulation of visually presented verbal material. In his research, Webster (1980) found a significant main effect associated with modality of presentation. Visual input was superior to oral input. Siegel and Linder (1984) reported deficits with both oral and visual stimuli. However, while no direct comparisons were made, the deficits were less obvious with auditory stimuli. Although complete comparisons of the modality differences are not available in these studies, the observed differences suggest the importance of testing in both modes.

Math and STM Processes. At least two different theoretical approaches have examined the relation between math and STM processes. Brainerd (1983) described a working-memory model for mental arithmetic in which problem information is first encoded into the short-term store and then retrieved and appropriately processed. Hence, this sequence can be displayed as: numerical encoding — short-term numerical store — retrieval from short-term store — arithmetical processing — response decoding. Such a model allows one to determine where in working memory the errors are occuring. Brainerd's research has demonstrated that the estimated proportion of errors attributable to STM failure is far greater than the estimated proportion of errors attributable to processing failure. The magnitude of this difference, however, is subject to the qualifying influences of encoding format, type of mathematical operation and age level.

Baddeley's (1982) model of working memory, as previously described, consists of the executive system, the articulatory loop, and the visuo-spatial scratch pad. When examining math disabilities in relation to Baddeley's model, one is able to assign elements of math to the components of the model. The articulatory loop may store the arithmetic sign and the numbers of a problem, whereas the executive system may retrieve the algorithm necessary to solve the problem (Siegel and Linder, 1984). In other words, the articulatory loop is responsible for immediate memory demands, such as remembering the numbers of the problem and the function to be performed (eg. addition or subtraction). The executive system comes into play when incoming information (a new problem) is integrated with past knowledge of what to do with it. As math and memory processes have been shown to be related, it seems that inefficient use of the articulatory loop is responsible for the problems witnessed in children who perform poorly on both STM and math tasks. It is this loop that controls the retention of information through rehearsal. Those who make inadequate use of the loop are likely to be poor at math (Baddeley, 1979).

An assortment of memory strategies can be used to aid remembering or to improve memory span performance. Rehearsal, for example, can be as simple as spontaneous overt verbalizations. Rehearsal is not a common cognitive activity prior to 8 or 9 years of age, and may not be evident in older children who exhibit poor performance on STM tasks. Another memory strategy involves aiding retention by deliberately organizing stimuli in terms of their membership in conceptual categories. Similar to categorization is the procedure whereby one clusters information into groups. For example, in digit span tasks it helps if one attempts to remember two 3 digit numbers, rather than one 6 digit number. Memory is often improved when children are made aware that they must employ strategies to aid their recall (Kail and Hagen, 1982). Mental rehearsal has been the main teaching strategy in work done with mentally retarded, attention deficit disorder, and learning disabled children.

Proposed Hypotheses. In summary, research has shown that children who exhibit mathematical difficulties may also perform poorly on STM tasks. This relationship has been discussed by Siegel and Linder (1984). Such a deficit falls under the Intellectual Skills Approach model described by Englehardt (1983). At the same time, work with normal, mentally retarded, and attention deficit disorder children has shown that instruction in strategies such as rehearsal are effective in improving their performance on STM tasks.

Torgesen (1980) and Torgesen and Goldman (1977) suggested that it should be possible to improve the performance of learning disabled children on at least some kinds of reading tasks by teaching them to use more efficient memory learning strategies. "Expected differences between disabled and normal children on the basic task would be significantly reduced if both groups were given external support in the use of verbalization as a mnemonic strategy" (Torgesen and Goldman, 1977, p.59).

The present research focuses on children who are of average intelligence, but who perform below average on mathematics and STM tasks. Given the apparent relationship between mathematics disabilities and STM, instruction designed to improve performance on STM tasks should lead to an improvement in their mathematical performance.

Children who receive both STM and math instruction will be compared to children who receive math instruction alone. It is hypothesized that those children who receive STM instuction will subsequently improve on STM tasks. Those who do not receive this training will not show an improvement on the STM tasks. Furthermore it is hypothesized that those children who receive the combined treatment (memory plus math) will show a significant improvement on math tasks over the children who were only instructed on math. The STM strategy instruction will be instrumental in improvements seen over the testing sessions.

Several considerations must be made when developing a memory/math instruction program. By taking into account the suggestions of many authors, I developed a program that I felt best suited the aims of this project.

As suggested by Waters and Andreassen (1983), a researcher should manipulate the basic task (ie. use of STM strategies) by presenting it in a variety of forms. These authors also suggest that to ensure task familiarization, practice should be incorporated and explicit verbal instruction be given. As applied to teaching the use of strategies, these suggestions imply that a variety of types of strategies should be explored. There are several different ways to present the concept of strategic use of STM, and thereby encourage strategy use. These include rehearsal, chunking, and categorization. I decided to give extensive practice with the rehearsal technique as this has been the main teaching strategy with other groups of memory-deficient children (Kail and Hagen, 1982; Robinson and Robinson, 1976; and Waters and Andreassen, 1983). Practice with this technique involved both auditory and visual modalities. The digit strings presented were of varying lengths. Instructions were repeated many times to the children.

Kennedy and Miller (1976) suggested that persistent use and utility of a newly acquired strategy (rehearsal) may depend, at least in part, on having a rationale for engaging in such activity. They found that feedback given to children on how well they rehearsed helped their performance. By demonstrating effective strategy utilization, I was able to give the children knowledge about how the memory system operates and its role in strategy generalization (ie. metamemory). Strategy training must be linked with use and with an understanding of the system. Training on STM tasks should therefore include information about the strategy, how it can help, practice with the strategy, and feedback, all of which were incorporated in the present study.

To test for the specific effectiveness of memory training, two groups were utilized. Each group received the same attention to math. Only one group received the memory training.

Method

Subjects

Subjects were selected from the population of children referred to the Diagnostic and Remedial Unit within the last several years. This Unit, within the Education Department at Memorial University of Newfoundland, is a referral centre for school aged children from the province of Newfoundland who are either experiencing learning problems or are facing an issue regarding their academic placement at school. Examination of the 350 current files at the Diagnostic and Remedial Unit yielded a list of 30 children whose files contained information meeting the following five criteria: (a) the children had a mathematics problem as defined by below average math scores on a diagnostic math test or a specific request for math remediation from the school; (b) the children had some indication of a memory problem as defined by below average memory scores on a standard test or poor retention observed by school personnel; (c) the childrens' intelligence was within average limits; (d) the children were between 9 and 12 years of age (inclusive); and (e) the children lived within a reasonable driving distance of Memorial University. The parents of children who met all criteria were contacted by phone, informed of the proposed study, and asked if they would like their child to participate in the group. Fifteen families indicated interest, with 14 children actually completing the program. One child did not return after the initial assessment.

Fourteen children, between the ages of 9 years, 2 months, and 12 years, 8 months participated in this study, (mean age = 10.93 years). These included 12 males (mean age = 11.02 years), and 2 females (mean age = 10.38 years). Subjects were assigned to one of two groups, the STM group or the math group. Because all 14 children could not be run at once and holidays and camps interfered with scheduling, two successive sets of groups were set up, one each during July and August, 1985. Group assignment took place in several stages.

Eight children were initially available to start the program in July. These children were divided according to sex and paired on the basis of age, making 4 pairs. Pairs were matched again on the basis of age forming 2 sets of 2 pairs of children. One pair from each set was randomly assigned to each group. Each group had two pairs of children.

The second set of children were tested during August. These children were also paired in the same fashion and assigned to a group. As there were 6 subjects (3 pairs) in this group, 1 pair was assigned to each group. The remaining pair was assigned to the STM group as a female was in it. The only other female (from group 1) had been assigned to the math group. Overall there were 8 children (7 males and 1 female) in the STM group, and 6 children (5 males and 1 female) in the math group.

In addition to the children who participated throughout the study, four pilot subjects were used to help develop the treatment procedures. None of these children had learning problems.

Materials and Administration Procedures

Specific assessment techniques were selected for each of the relevant functions important to this study.

General Intelligence. Two subtests from the Wechsler Intelligence Scale for Children - Revised (WISC-R) (Weschler, 1974) were administered to ensure that for both normative and comparision purposes, all children were of average intelligence. The WISC-R is the most commonly used test to assess children's intelligence. It consists of 12 subtests (two of which are optional) - 6 verbal, and 6 non-verbal or performance task subtests. The two subtests used in this study were the Vocabulary and Block Design subtests. This short form of the WISC-R has been shown to be valid for screening purposes (Silverstein, 1974, 1983).

Memory Tasks. Two memory tasks were used, one dealing with auditory STM, the other with visual STM. The auditory STM task consisted of the Digit Span subtest from the WISC-R. This subtest requires that the individual repeat number strings read aloud by the examiner, in both forward and backward order. The number strings increase in length from 2 to 9 digits. The test begins with the presentation and forward recall of digit strings. String length is increased by one digit until children make two consecutive errors on digit strings of the same length. When this criterion is reached, the strings to be repeated backwards are presented in the same way. From this, the examiner obtains a raw score consisting of the total number of correctly repeated strings. Based on age norms, this number is converted into a standard score with a mean of 10 and a standard deviation of 3.

The visual STM task was the Visual Attention Span for Letters subtest from the Detroit Tests of Learning Aptitude (Baker and Leland, 1967). The Detroit Tests of Learning Aptitude is a diagnostic test comprised of 19 subtests, designed to examine children's learning problems. It has normative data for children between the ages of 3 and 19. The Visual Attention Span for Letters subtest consists of letter strings that are presented simultaneously on cards. When the cards are removed, the subject must recall the proper sequence of the letters. These strings vary in length from 4 to 8 letters, beginning with the letter strings with 4 letters. All of these strings must be repeated in forward order. The test is complete when children make four consecutive errors. Based on how many letter strings the children remember correctly (raw score), a standard score is obtained by comparing the raw score to normative age data.

Math Performance Tasks. As with the memory tasks, two math tasks were chosen for administration. Both were taken from the KeyMath Diagnostic test (Connolly, Nachtman, and Pritchett, 1976), which is an individually administered test designed to provide a diagnostic assessment of skill in mathematics. KeyMath test items are divided into 14 subtests organized into 3 major areas: content, operations and applications. The mental computation section from the KeyMath test was used to tap auditory math performance. This section is made up of 10 mental math questions designed to become increasingly difficult over the length of the test. The mental math questions are presented orally and have to be answered orally. This section is discontinued after 3 consecutive errors. A standard score is obtained by comparing the total number of correct answers (raw score), with the normative data.

Visual math performance was examined using the written computation section from the KeyMath Test. This section is divided into 4 subsections, each dealing with a specific operation (addition, subtraction, multiplication and division). There are between 12-15 problems in each subsection, all presented on paper. Children are given the problem sheets and asked to solve them in writing. For each subsection, a standard score is obtained through the same procedure used for the mental math problems.

Other materials used in this study included math sheets and math problems, as designed by the examiner. Examples of these are presented in Appendix A and Appendix B respectively. Other activities and games used during the treatment sessions are listed under Appendix C.

Procedure

Each subject was individually assessed twice during the program, once before treatment began, and again at the conclusion of treatment.

Pre-assessment. Pre-assessment consisted of an individual session with each child. During this session, the child was screened for intellectual ability, using the Vocabulary and the Block Design subtests from the WISC-R. Then the child was assessed on the two memory tests, the Digit Span subtest from the WISC-R (auditory memory) and the Visual Attention Span for Letters subtest from the Detroit Tests of Learning Aptitude (visual memory), followed by the two math tests, the mental computations section from the KeyMath Test (auditory math) and the written computations section from the KeyMath Test (visual math). A child would not have been included in this study if he or she had not performed below average on at least one of each of the STM and math tasks. In fact, all children performed below average on all of the tests. At the completion of all pre-testing, the parents were called and given the date and time of their child's first session.

<u>Intervention.</u> Treatment consisted of strategy instruction and/or math practice. The STM group received instruction on STM strategies, practice using these strategies, and math practice. The math practice was aimed at incorporating the memory strategies into the math problems. The math only group received math practice identical to the STM group with the exception that all reference to STM or memory strategies was eliminated. In both groups, during math practice, the children were corrected if they made errors due to improper use of math rules. Pairs of children met for the actual treatment sessions. This enabled the examiner to watch the progress of each child closely, and to provide each child with individualized instruction. A pair remained together for the length of the program. The treatment extended over a two week period, with sessions held three times a week, for an hour at a time.

An outline of the program as designed by the examiner is given in Table 1. The children in each condition received the same amount of math practice time.

Table 1

Program Outline

STM Group	Math Group
Session 1. (60 mins.) -introduction to memory -memory examples -memory strategies and practice -memory game	Session 1. -math facts (10 mins.) -math sheets (20 mins.) -activity (30 mins.)
Session 2. (60 mins.) -review of memory strategies -memory practice -memory game	Session 2. -math facts (10 mins.) -math sheets (10 mins.) -activity (35 mins.) -math game (5 mins.)
Session 3. -memory practice (5 mins.) -math facts (15 mins.) -math sheets (25 mins.) -math game (15 mins.)	Session 3. -math facts (10 mins.) -math sheets (10 mins.) -math game (5 mins.) -activity (35 mins.)
Session 4. -memory practice (5 mins.) -math facts (15 mins.) -math sheets (25 mins.) -story problems (15 mins.) -math game (if time)	Session 4. -math facts (10 mins.) -math sheets (10 mins.) -story problems (10 mins.) -activity (30 mins.)
Session 5. -memory practice (5 mins.) -math facts (15 mins.) -math sheets (20 mins.) -story problems (10 mins.) -math game (10 mins.)	Session 5. -math facts (10 mins.) -math sheets (20 mins.) -story problems (15 mins.) -math game (15 mins.)
Session 6. -memory practice (5 mins.) -math facts (15 mins.) -math sheets (30 mins.) -story problems (10 mins.) -math game (if time)	Session 6. -math facts (10 mins.) -math sheets (30 mins.) -story problems (15 mins.) -math game (10 mins.)

While the STM group received memory practice, the Math Only group were engaged in activities that did not deal with math or memory (see Appendix C).

For the STM group, memory strategies involved mainly training in rehearsal (subvocally repeating things to oneself), but also in chunking (breaking items into groups). Strategy practice also included games designed to concentrate on memory. I began the first session by focusing on memory. I asked the children what memory is and what they do if they want to remember something. I asked them to think of ways to remember things (eg. "How do you remember spelling and history? What about a phone number?"). We then discussed their ideas.

Next, the children were given examples of applying memory strategies. The first example used Visual Memory Cards (from Developmental Learning Materials). I gave the children 2 sets of pictures to remember, one set at a time. The first set was scrambled on the table. It included pictures of a pipe, dog, key, milk carton, light, line, and fork. The second set was presented in an orderly fashion, the cards were lined up in pairs, and each pair had a similar feature. These included pictures of hammer and scissors, chair and lamp, boy and girl, and tree and flower. Although each set had 8 pictures, every child found the second set easier to remember. They were asked why. We talked about organization, grouping things that are similar, and remembering small groups of information at a time.

The other memory example dealt with number strings. I presented each child with a number string (5 digits) to remember. One child in the pair was not given an opportunity to rehearse (I asked him or her questions). The other child in the pair was helped by me saying the digits out loud over and over. This led us to talking about having to concentrate in order to remember, and the advantages of being able to say something over and over to yourself in order to help you remember, i.e. the rehearsal technique.

The next stage of memory training involved actual practice with rehearsal. I began by placing index cards that had number strings written on them in front of each child alternately. A total of 150 cards with number strings varying in length from 3-8 digits on them were used. The strings were generated from random number tables. We began with the 3 digit cards (eg. 528). "Here are some numbers that I want you to remember. Let's say them out loud, 528, 528, 528, 528, 528, 528. O.K., I'll take the card away, and let's see if you can remember the numbers." Starting in this manner, the children would always get the strings correct. They were congratulated and were shown the card.

After a few items I would stop vocalizing the string, but encourage the child to continue. Later, I asked them to say it over and over just inside their head. As the children became proficient at the task, I increased the number string length, and shortened exposure time.

We went through the same routine with auditory number strings, starting with 3 digits and working upwards to a maximum of 8. After every example, the children were told whether they were correct or incorrect and were always shown the card so that they could see for themselves.

For cards with 5-8 digits, I also introduced chunking, or breaking these longer number strings into smaller groups. For instance, 634254 became 63, 42, 54, or 634, 254.

At the beginning of every session, time was spent reviewing and practicing the rehearsal technique.

Math practice for both groups consisted of written and mental computations. This was divided into several sections: (a)Math facts, such as the times tables, (b) math sheets, (c) story problems, with both verbal and written answers, and (d) verbal math questions, such as "what is 2+4+8= ?". All practice involved the four basic operations. The children practiced on addition first, and then, subtraction, multiplication, and division. This follows the standard organization of teaching math.

Post-assessment. At the completion of the program, the children were once again seen individually. This assessment took place the day immediately following the final session, and the children were administered the four tests (2 math and 2 memory). Following the completion of the program, a letter was written to the parents of the children, giving information on how their child performed throughout the program, results from pre- and post-testing, and suggestions for continued remediation.

Results

The results obtained through this study clearly demonstrate several findings. First, as predicted the children in the STM group improved significantly on the memory scales. The math only group did not. Secondly, and more important to the focus of this study, children who received both STM instruction and math practice improved significantly more over time on math tasks than did those children who received the math practice alone.

General Intelligence and Age Comparisons. At pre-treatment there was no significant difference between the ages of the children in the two groups; $t(12) = 0.35$. The mean ages were 11.02 years for the STM group and 10.82 for the math group. No significant differences were found between the two groups of children on measures of I.Q.: Vocabulary, $t(12) = 0.75$, and Block Design, $t(12) = 0.30$. On Vocabulary the mean scores were 9.5 for the STM group and 8.8 for the math group. On the Block Design subtest the STM group had a mean score of 9.7 and the math group had a mean of 9.5.

Overview of Analysis. Both the raw and the standard scores for each measure were analyzed. Because the results were virtually identical, only the results from the analysis of standard scores will be reported. The standard scores refer to an age or grade level. All raw scores are presented in Appendix D, all standard scores in Appendix E. The results of the statistical analyses performed on the standard scores can be seen in Tables 2-5. Analyses of the raw data are

Table 2

The Digit Span Subtest - Analysis of Variance on Standard Scores

Source of Variation	SS	df	MS	F
Between Subjects				
A (groups)	2.678	1	2.678	0.738
Subjects within groups	43.500	12	3.625	
Within Subjects				
B (time)	30.035	1	30.035	37.939
AB	12.964	1	12.964	16.376
B X Subjects within groups	9.499	12	0.791	

Table 3

The Visual Attention Span for Letters Subtest - Analysis of Variance on Standard Scores

Source of Variation	SS	df	MS	F
Between Subjects				
A (groups)	6.785	1	6.785	6.462
Subjects within groups	12.600	12	1.050	
Within Subjects				
B (time)	6.270	1	6.270	12.658
AB	3.192	1	3.192	6.444
B X Subjects within groups	5.944	12	0.495	

Table 4

The Mental Computations Subtest - Analysis of Variance on Standard Scores

Source of Variation	SS	df	MS	F
Between Subjects				
A (groups)	7.832	1	7.832	2.950
Subjects within groups	31.851	12	2.654	
Within Subjects				
B (time)	21.262	1	21.262	20.164
AB	7.893	1	7.893	7.485
B X Subjects within groups	12.653	12	1.054	

Table 5

The Written Computations Subtest - Analysis of Variance on Standard Scores

Source of Variation	SS	df	MS	F
Between Subjects				
A (groups)	33.820	1	33.820	1.072
Subjects within groups	378.482	12	31.540	
Within Subjects				
B (time)	250.203	1	250.203	97.153
AB	59.337	1	59.337	23.040
B X Subjects within groups	30.904	12	2.575	

presented in Appendix F. The means and standard deviations for each set of data, raw and standard scores are presented in Appendixes G and H, respectively.

For each of the four tests, the standard score for each child was submitted to an analysis of variance where groups (STM and Math, and Math only) was a between subjects factor and test (pre- and post-) was a within-subjects factor. For each analysis, when significant interactions were noted, four multiple comparisons were performed using the Scheffe method. To determine if any differences existed between the STM and math only groups at the start of testing, performance on the pre-tests for each group was compared. To determine whether the math only group improved over time, a second comparison examined performance at both pre- and post-testing. Similarly, to determine whether the STM group improved over time, their performance was compared at pre- and post-testing. Finally, to determine if any differences existed between the STM group and the math only group at the end of testing, performance on the post-tests for each group was compared. Unless otherwise noted, all significant effects were reliable at the .01 level or beyond.

Auditory STM Task. The standard scores on the Digit Span subtest of the WISC-R were analyzed. As can be seen in Table 2, a significant main effect of time of testing was found $F(1,12) = 37.94$. As shown in Figure 1, this effect was qualified by an interaction between groups and time of assessment (pre- and post-testing), $F(1,12) = 16.38$. The Digit Span scores only improved at post-testing for subjects who received memory training. Performance of the math only group did not change from pre- to post-testing, however the STM group did show an

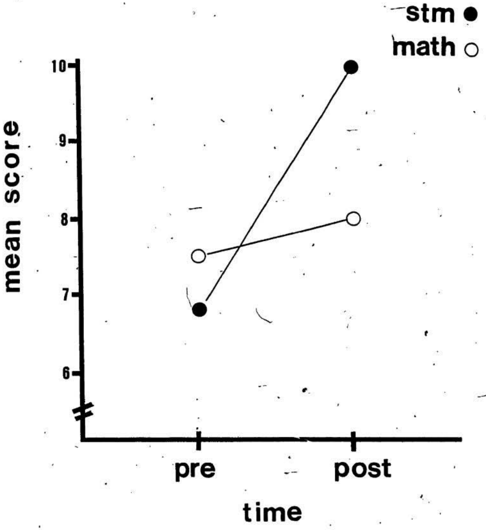

Figure 1. The Digit Span Subtest - Mean Scores at Pre and Post-Testing.

improvement in performance over time, $F(1,12) = 53.3$. Although the STM group recalled more digits than the math only group at post-testing, the effect failed to reach significance.

Visual STM Task. Visual memory was assessed through the administration of the Visual Attention Span for Letters subtest from the Detroit Tests of Learning Aptitude. As shown in Table 3, time of testing was significant as a main effect, $F(1,12) = 12.66$, as was the effect of group, $F(1,12) = 6.46$, $p<.05$. Figure 2 illustrates the significant interaction between groups and time of assessment, $F(1,12) = 6.44$, $p<.05$. Only subjects who received memory training recalled more items at post-testing than at pre-testing on this subtest. Similar to the auditory STM task, the STM group recalled more letter strings at post-testing than at pre-testing, $F(1,12) = 18.87$. In addition, at post-testing students in the STM group recalled more letter strings than students in the the math only group, $F(1,12) = 9.3$, $p<.05$.

Auditory Math Task. The standard scores on the mental computation section of the KeyMath test pertained to auditory math performance. On this dependent measure, as seen in Table 4, a significant main effect of time of testing was found, $F(1,12) = 20.16$. Figure 3 shows the interaction between groups at pre- and post-testing on auditory math performance, $F(1,12) = 7.49$, $p<.05$. Specific comparisons revealed that although the math only group did not improve significantly over the course of treatment on mental math computations, the STM group did improve, $F(1,12) = 27.21$. At post-testing the STM group correctly answered more of the auditory math questions than did the math only group. This

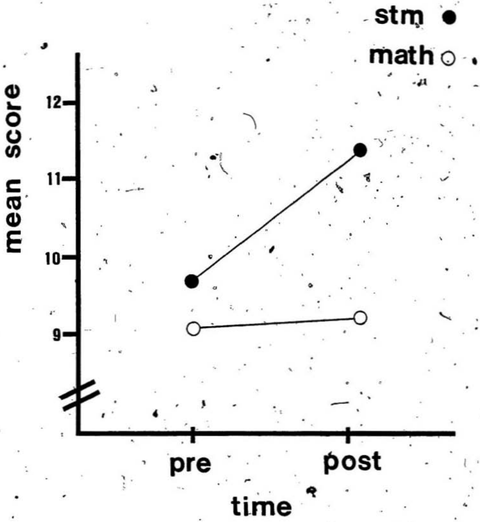

Figure 2. The Visual Attention Span for Letters Subtest - Mean Scores at Pre and Post-Testing.

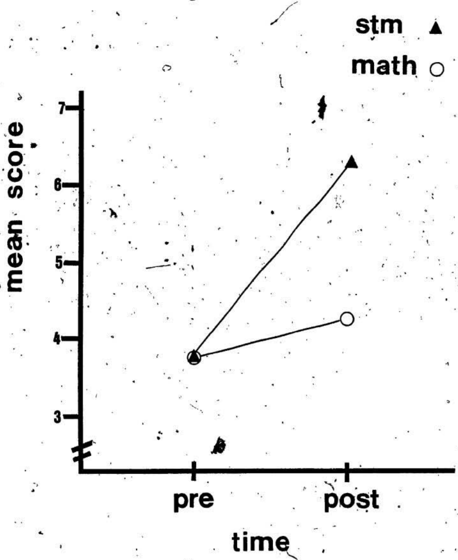

Figure 3. The Mental Computations Subtest - Mean Scores at Pre and Post-Testing.

difference approached significance but failed to reach the required levels.

Visual Math Task. The final dependent measure involved an analysis on the standard scores of the written computation section from the KeyMath test. As seen in Table 5, a significant main effect of time of testing was found, $F(1,12) = 97.15$. Figure 4 illustrates the interaction between groups and time of assessment, $F(1,12) = 23.04$. This interaction reflected the significant improvement of the STM group from pre- to post-testing on written math computations, $F(1,12) = 113.50$.

Other Analyses. The written computation section of the KeyMath test was comprised of four sub-sections. Performance on the addition, subtraction, multiplication and division sections was examined individually. In order to determine the differences between the two groups on each operation, four individual anovas and sets of means comparisons using the Scheffe method were performed.

No significant interactions were found between the two variables, groups and time of assessment, for addition, $F(1,12) = 1.34$, or for subtraction, $F(1,12) = 1.73$. For each operation however, a significant main effect of time of testing was found. For addition, $F(1,12) = 6.00$, $p < .05$, and for subtraction, $F(1,12) = 36.29$.

A significant main effect of time of testing was found in the analysis of the multiplication problem standard scores, $F(1,12) = 17.64$. This analysis also revealed a significant interaction between groups and time of testing, $F(1,12) =$

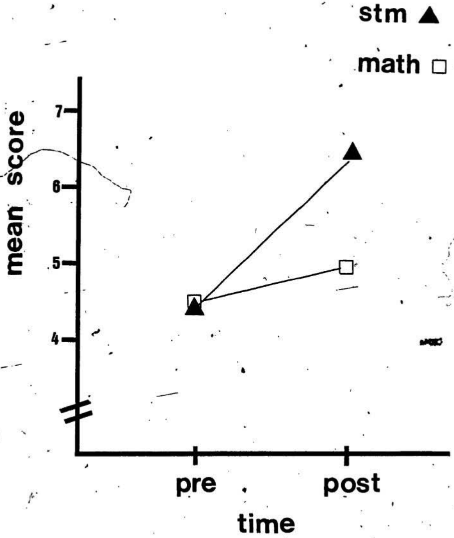

Figure 4. The Written Computations Subtest - Mean Scores at Pre and Post-Testing.

16.89. Only the STM group improved over time on multiplication problems, $F(1,12) = 58.97$.

The final analysis examined the standard scores from the division problems. A significant main effect of time of testing was found, $F(1,12) = 51.40$. An interaction was found between groups and time of assessment, $F(1,12) = 30.42$. Although the math only group did not improve from pre to post-testing, the STM group did, $F(1,12) = 80.78$.

Pre- to Post- Age and Grade Differences. All subjects who took part in this study were performing below average on both math and memory tasks. Over the treatment program from pre- to post-treatment, children in the STM group reached the normative scores, whereas children in the math only group did not. The gains made in all task areas are displayed in Table 6.

Table 6

Mean Scores for Groups at Pre and Post-Testing on all Subtests

		Digit Span	Visual Attention Span for Letters	Mental Computations	Written Computations
Math Group	norm	10.00	10.82	4.8	4.8
	pre	7.50	9.05	3.7	4.4
	post	8.00	9.08	4.2	5.0
STM Group	norm	10.00	11.02	5.1	5.1
	pre	6.75	9.67	3.7	4.2
	post	10.00	11.34	6.3	6.3

Discussion

Research has been generated over the past few years linking poor performance on math related tasks with poor performance on STM tasks. Children who are not retaining given units of information in memory will be unable to perform on tasks that require average memory skills. When children have to work out a mathematics problem for instance, they have to remember the operational sign and the various numbers involved. Retaining this information becomes more difficult when the problems are longer, involve more numbers, more complex computations, and possibly more written or verbal directions. Children who for some reason are not rehearsing these units of information effectively will quickly forget them.

Since the relationship between poor performance on math and STM tasks has been made, the purpose of this research, was to examine the relative effectiveness of memory instruction on children who are poor at both math and memory tasks. Children falling into this category received either standard math remediation consisting of practice with the mathematical operations or memory strategy instruction in addition to the math practice.

The results of this study strongly demonstrate the advantage of incorporating STM instruction into a standard math remediation procedure. First, consider the effect of memory instruction on memory performance. As predicted, children who received STM strategy instruction improved significantly on memory tasks over time. These results repeat those reviewed by many authors (eg. Robinson and Robinson, 1976; Waters and Andreassen, 1983). Providing instruction in memory strategies will improve performance on tasks reflecting use of that strategy.

Second, consider the effect of memory instruction on math tasks. This study demonstrated that children who received the combined treatment did make significant gains from pre- to post-testing on standard math tasks, while the math only group did not. And, although most of the comparisons between the performance of the STM and math only groups on post-testing did not achieve significance, the STM group always performed better. For children who demonstrate both math and memory deficiencies, a remediation program offering math practice in close association with STM instruction far outweighs the merits of traditional math practice alone.

The visual math problems presented to the children during testing sessions included all four basic operations of addition, subtraction, multiplication, and division. Performance on these operations were analyzed separately and significant interactions were found between groups and time of testing only on the multiplication and division sections. Despite the fact that the math only group made some degree of improvement on addition and subtraction, they made no headway with division and multiplication problems. The effects of STM training were only apparent on more complex operations.

Multiplication and division involve more steps than do addition and subtraction, and are decidedly more complex. They are an expansion of the addition and subtraction operations, as for example, a multiplication problem can not be completed without a knowledge of addition. Considering this, it follows that children who display poor memory performance will also have greater difficulty recalling and completing all the steps required when performing multiplication and division procedures. Those proficient at remembering are likely to make fewer mistakes on these complex operations. In this study, children given instruction in memory were better able to perform on the types of problems that demanded good memories.

The children included in this study were performing below average on all administered math, and memory tasks. At post-assessment, the STM group performed at or above age-appropriate levels on all tasks. The math only group did not. This shows that through appropriate instruction, learning disabled children can be brought up to the same performance level as their normal peers.

Learning disabled children, like other groups that show performance deficiencies, do not spontaneously employ appropriate task strategies in a variety of situations. Thus, their low performance on many tasks can be attributed to failure to engage in certain kinds of goal directed activities rather than to structural or capacity limitations. Research has shown that learning disabled children are slow to develop in their use of efficient encoding strategies, such as verbal rehearsal. The performance of learning disabled children has been shown to improve significantly following instructions to use a verbal rehearsal strategy on a recall task. Such improvement in performance suggests that failure to apply the strategy spontaneously may have been an important factor leading to the originally deficient performance on the task (Torgesen, 1980).

Siegel and Linder (1984) have described the STM difficulties associated with mathematical problems as reflecting a maturational lag. That is, children with learning disabilities develop slower in terms of employing STM strategy use. They believe that these children will achieve normal levels over time. Children with learning disabilities are deficient in certain areas. If a deficiency is identified as dependent on the strategic use of the memory system, it should be modifiable. A deficit or a structural deficiency would not be so. The distinction lies in the ease with which improvement can be brought about through training. With retarded individuals for instance, the inference of a rehearsal deficiency in the memory process does not suggest a structural limitation, but instead a failure to employ the appropriate process. Training retarded individuals (or learning disabled) to rehearse eliminates the difference between their performance and that of normal persons. This suggests a production deficiency, a failure to spontaneously employ rehearsal, not a structural deficit (Robinson and Robinson, 1976). The results of this study suggest that learning disabled children can perform on tasks similar to normal children, once given instruction. This follows a maturational lag model, not a structural deficit model.

For the tasks administered to the children, both auditory and visual modes were used. According to Baddeley's model, any information presented which can be articulated will be stored in the articulatory loop section of working memory. Therefore, both auditory and visual information, if articulated, reach this loop. The two STM tasks given to the children were not strictly comparable. The digits on the auditory STM task were presented sequentially. The letters on the visual task were presented simultaneously. Therefore, differences between auditory and visual STM performances could not be analyzed. This limitation prevents a comparison between the results found in this study and previous studies that found a modality difference (eg. Webster, 1980). This does not affect the important conclusion that the same pattern of improvement was seen in each modality.

It is difficult to decide upon and plan a program that aims to improve both math and memory performance. Given the strong results obtained with this study however, various other factors could be examined in future studies. The first point relates to generalization and maintenance of effects. In this research, only math was examined, and only math was tied into the memory practice. Trying to generalize memory strategies beyond the math process may have an added benefit. One must also wonder as to the long term gains of such a short term treatment. However, as the effect of the combined method of teaching has been shown, sustaining such a program with these children should enable them to continue to perform on math and STM tasks at age appropriate levels.

It does seem necessary, for STM/math disabled children, to incorporate the memory instruction with the math instruction, as a conjoint package. The effects of receiving memory instruction only were not controlled for in this study. Without this control, it is not known what the subsequent performance on math tasks would be for the child who received only the memory instruction. As extra math practice is a common occurrence in academic settings, it would make more sense to the student to incorporate new strategies into the problem area.

Although not examined in this study, it would be interesting to analyze the types of errors made and base memory instruction on it (see Young and O'Shea, 1981). Children making errors on long addition for instance, may benefit from receiving instruction on grouping - remembering 14 and 32 instead of 1,4,3,2. Children making errors on word-problems may be helped by rehearsing only the main elements of the problem.

In summary, the results obtained from this research study clearly indicate several conclusions. For children who are performing poorly on STM and mathematics tasks, a combined STM/math instruction package will far outweigh the merits of math instruction by itself. One must address the deficit which as expressed throughout this paper, may not be just math. It is important therefore to examine the math process, to determine why errors are occuring. With this knowledge, one can provide a mathematics learning disabled child with a program that will help him or her to achieve at age-appropriate levels.

References

Baddeley, A. (1979). Working memory and reading. In P. A. Kolers; E. W. Rolstal, & H. Bouma (Eds.), *Processing of visible language* (Vol. 1). New York: Plenum Press, pp. 355-370.

Baddeley, A. (1982). Reading and working memory. *Bulletin of the British Psychological Society*, **35**, 414-417.

Baddeley, A. & Wilson B. (1985). Phonological coding and short-term memory in patients without speech. *Journal of Memory and Language*, **24**, 490-502.

Baker, H.J. & Leland, B. (1967). *The Detroit Tests of Learning Aptitude*. Indiana: Test Division of Bobbs-Merril Company, Inc.

Brainerd, C. (1983). Young children's mental arithmetic errors: A working memory analysis. *Child Development*, **54**, 812-830.

Connolly, A.J., Nachtman, W., & Pritchett, E.M. (1976). *KeyMath Diagnostic Arithmetic Test*. Minnesota: American Guidance Service Inc.

Conrad, R. (1964). Acoustic confusions in immediate memory. *British Journal of Psychology*, **55**, 75-84.

Conrad, R. (1972). The developmental role of vocalizing in short-term memory. *Journal of Verbal Learning and Verbal Behavior*, **11**, 521-533.

Douglas, V.I. (1983). Higher mental processes in hyperactive children. In R. M. Knights & D. J. Bakker (Eds.), *Rehabilitative treatment and management of learning disabilities*. Baltimore: University Psychology Press, pp.65-92.

Englehardt, J.M. (1983). Instructional strategy for the learning disabled child in mathematics - An introduction. *Focus on Learning Problems in Mathematics*, **5**, 1-3.

Haywood, H.C., Meyers, C.E., & Switzky, H.N. (1982). Mental retardation. *Annual Review of Psychology*, **33**, 309-342.

Kail, R. & Hagen, J. (1982). Memory in childhood. In B. Wolman (Ed.), *Handbook of developmental psychology*. Englewood Cliffs: Prentice Hall Inc., pp. 350-366.

Kendal, P. & Braswell, L. (1985). *Cognitive-behavioral therapy for impulsive* *children*. New York: The Guilford Press.

Kennedy, B. & Miller, D. (1976). Persistent use of verbal rehearsal as a function of information about it's value. *Child Development*, **47**, 566-569.

Kirk, S., & Kirk, W. (1983). On defining learning disabilities. *Annual Review of Learning Disabilities*, **1**, 17-18.

Robinson, N. M. & Robinson, H. B. (1976). *The mentally retarded child: A psychological approach*. New York: McGraw-Hill.

Shankweiler, D., Liberman, I., Mark, L., Fowler, C., & Fischer, F. (1979). The speech code and learning to read. *Journal of Experimental Psychology: Human Learning and Memory*, **5**, 531-545.

Siegel, L. & Feldman, W. (1983). Nondyslexic children with combined writing and arithmetic learning disabilities. *Clinical Pediatrics*, **22**, 241-244.

Siegel, L. & Linder, B. (1984). Short term memory processes in children with reading and arithmetic learning disabilities. *Developmental Psychology*, **20**, 200-207.

Silverstein, A. B. (1974). A short form of the WISC-R for screening purposes. *Psychological Reports*, **35**, 817-818.

Silverstein, A. B. (1983). Full scale I.Q. equivalents for a two subtest short form of the Wechsler Preschool and Primary Scale of Intelligence and the Wechsler Intelligence Scale for Children - Revised. *Psychological Reports*, **53**, 16-18.

Torgesen, J. (1980). Conceptual and educational implications of the use of efficient task strategies by learning disabled children. *Journal of Learning Disabilities*, **13**, 364-371.

Torgesen, J. & Goldman, T. (1977). Verbal rehearsal and short-term memory in reading disabled children. *Child Development*, **48**, 56-60.

Waters, H. & Andreassen, C. (1983). Children's use of memory strategies under instruction. In M. Pressley and J. Levin, (Eds.) *Cognitive strategy research: Psychological foundations*. New York: Springer-Verlay New York Inc., pp. 3-24.

Webster, R. (1979). Visual and aural short term memory capacity deficits in mathematical disabled children. *Journal of Educational Research*, **72**, 277-283.

Webster, R. (1980). Short term memory in mathematics-proficient and mathematics-disabled students as a function of input modality / output modality pairings. *Journal of Special Education*, **14**, 67-78.

Wechsler,D. (1974). *The Wechsler Intelligence Scale for Children - Revised.* New York: The Psychological Corporation.

Worden, P. (1983). Memory strategy instruction with the learning disabled. In M. Pressley & J. Levin, (Eds.) *Cognitive strategy research: Psychological foundations.* New York: Springer-Verlay New York Inc., pp. 129-154.

Young,R. & O'Shea, T. (1981). Errors in children's subtraction. *Cognitive Science*, **5**, 153-177.

Appendix A

Math Sheets

The following are the math sheets given to each child in both the STM group and the math only group.

name ______________________ 48

654 + 243	362 + 283	463 + 298
297 + 658	765 + 987	268 + 787
629 + 592	1257 + 532	1698 + 924
2395 + 627	4962 + 387	5526 + 789
9276 + 953	7265 + 997	8762 + 7555

20 - 12	48 - 21	72 - 38
36 - 13	87 - 54	96 - 63
74 - 68	132 - 21	165 - 48
232 - 121	654 - 98	843 - 72
397 - 308	463 - 291	593 - 468

24	27	409
56	40	246
92	89	32
+ 40	+ 50	+ 89

254	476	987
448	231	543
206	578	217
+ 500	+ 870	+ 569

654	769	602
269	540	498
013	794	24
+ 547	+ 116	+ 68

98702	537809	678280
− 584	− 42854	− 2643

name: ______ 51

12 + 17	15 + 18	19 + 17
21 + 17	36 + 22	29 + 36
54 + 87	63 + 54	92 + 26
123 + 52	254 + 49	312 + 19
541 + 63	923 + 48	452 + 16

name: ________________

679 -497	754 -99	690 -478
976 -799	1253 -821	1364 -253
4765 -532	5976 -823	9276 -983
3482 -994	4653 -829	5365 -2974
7265 -4954	8293 -2717	7542 -1659

name: ____________________

46 -21	91 -53	836 -374	733 -699
8746 -5927	7411 -3989	62371 -49240	30739 -29846
349 +568	217 +989	621 843 +795	421 3765 + 562
5632 - 749	4329 -3176	70000 -43121	36200 - 9767
4385 +9271	58456 215 + 3671	912 49754 + 50021	

name:________________

21	40	18	44
46	32	22	52
52	51	56	70
+94	+17	+35	+15

59	17	53	17
24	81	26	15
66	63	74	13
+70	+20	+88	+18

16	43	22	94
15	79	33	39
14	14	44	72
+13	+13	+55	+18

name: ____________

55

298 726 + 52	64390 - 74	236950 49320 + 60809
90500 - 499	72688 4365 + 200	765 294 +876
72000 - 439	1437 - 564	2000 - 99
4639 - 999	649 - 77	33000 - 9999
7654 2680 7887 +5111	731 53 19 + 9	53144 677 50 + 101
500 - 33	4006 - 887	5555 -4568

name: ______________

7 ⟌42　　5 ⟌25　　3 ⟌18

4 ⟌24　　9 ⟌18　　2 ⟌14

5 ⟌40　　6 ⟌36　　3 ⟌30

5	7	6	2	4	3	8	9
× 3	× 3	× 9	× 8	× 7	× 4	× 7	× 4

3 ⟌9　　5 ⟌20　　6 ⟌42

name: ____________

$5\overline{)25}$ $3\overline{)90}$ $7\overline{)343}$

$8\overline{)656}$ $40\overline{)480}$ $12\overline{)4{,}356}$

5 × 8	7 × 4	31 × 26	98 × 76
12 × 14	30 × 17	51 × 5	85 × 30

$7\overline{)287}$ $6\overline{)432}$ $5\overline{)130}$

$8\overline{)64}$ $5\overline{)365}$ $7\overline{)546}$

name: ____________________

$4\overline{)376}$ $10\overline{)660}$ $2\overline{)942}$

$7\overline{)4921}$ $6\overline{)252}$ $5\overline{)175}$

$4\overline{)132}$ $3\overline{)279}$ $8\overline{)576}$

$\begin{array}{r} 17 \\ \times\ 5 \\ \hline \end{array}$ $\begin{array}{r} 62 \\ \times\ 50 \\ \hline \end{array}$ $\begin{array}{r} 24 \\ \times\ 17 \\ \hline \end{array}$

$\begin{array}{r} 624 \\ \times\ 5 \\ \hline \end{array}$ $\begin{array}{r} 7690 \\ \times\ 9 \\ \hline \end{array}$ $\begin{array}{r} 4369 \\ \times\ 7 \\ \hline \end{array}$

name: ______________

59

$11\overline{)143}$ $4\overline{)144}$ $8\overline{)630}$

$32\overline{)768}$ $12\overline{)2436}$ $7\overline{)595}$

$$\begin{array}{r} 56 \\ \times\ 4 \\ \hline \end{array} \quad \begin{array}{r} 253 \\ \times\ 6 \\ \hline \end{array} \quad \begin{array}{r} 254 \\ \times\ 32 \\ \hline \end{array}$$

$$\begin{array}{r} 26 \\ \times 26 \\ \hline \end{array} \quad \begin{array}{r} 49 \\ \times 33 \\ \hline \end{array} \quad \begin{array}{r} 325 \\ \times\ 83 \\ \hline \end{array}$$

$$\begin{array}{r} 55 \\ \times 55 \\ \hline \end{array} \quad \begin{array}{r} 677 \\ \times\ 51 \\ \hline \end{array} \quad \begin{array}{r} 8053 \\ \times\ 37 \\ \hline \end{array}$$

name: ____________________ 60

8631 × 50	7730 × 341	534 × 99
433567 × 88	589139 × 809	788990 × 90899

Appendix B

Math Problems

1. Math facts:

   A. Children were asked to repeat their times tables (both orally, and by writing them on paper).

   B. Children were asked facts such as:

      2+2= ? , 3+5= ? , 12-6= ? , 4X6= ? , 25÷5= ?

      3+4= ? , 7+4= ? , 14-8= ? , 5X8= ? , 30÷6= ?

      9+1= ? , 7-2= ? , 15-6= ? , 6X7= ? , 42÷7= ?

   C. Children were asked to mentally compute the following type of math problem:

      2+2+2= ? , 7+3-1= ? , 2X2+3= ? , 6X5-10= ?

      4+3+2= ? , 4+7-6= ? , 3+2X5= ? , 6+3-5X4= ?

      3+9+4= ? , 9+9-8= ? , 5-2X7= ? , 15 5X3+2= ?

2. Story problems:

   A. Short story problems presented orally, such as:

      Bob won 5 medals and Peter won 2 medals. How many medals did they win altogether?

      Anne and Bernice went to the store. They both had $2.00 to spend. Together how much money did they have to spend?

Gerry had $10.00 to spend. He spent $4.00 at the Drug Store and $2.00 at the Corner Store. How much money did he spend? How much money did he have left?

Mary's baby drinks 2 bottles of milk a day. How many bottles does the baby drink every week?

Mrs. Smith bought 30 marbles. She wanted to divide them equally among her two children. How many marbles did each child receive?

B. Long story problems (presented orally allowing students to write down key information and completing sums on paper):

For the last 2 weeks, Debbie has been bowling in her phys-ed class. During that time, her scores were 102, 99, 109, 114, 116, and 119. Her total sum for these games was 659. Three of her friends had the following totals; Cathy 604, Betty 768, and Mary 599.

What is the difference between Debbie's total and Cathy's total?

What is the difference between Betty's and Debbie's totals?

What is the difference between Debbie's and Mary's totals?

After a school dance, several friends decided to have a pizza party. The large pizzas will serve 4 people and the medium pizzas will serve 2 people.

How many people will 13 large pizzas serve?

How many people will 18 medium pizzas serve?

How many people will 3 large pizzas and 5 medium pizzas serve?

Appendix C

Games and Activities

Math Games (both groups)

1. Pirates Gold (James Galt and Company Limited)

A game for 2-4 players where the object is to reach Treasure Island by correctly answering mental addition and subtraction math problems.

2. Teacher's Quiz (Waddington)

A quiz game for 2-6 players where players have to correctly answer questions in several categories (History/Geography, Facts and Fantasy, Spelling, Math, Science, and Words) to reach the 100 mark on the playing board.

NOTE: Only 4 categories were used at a time (always including math). If one of the other 2 categories was landed on, a math question would be asked.

3. Tens (Waddington)

An addition exercise. This game has 72 triangular pieces, each piece divided into 3 segments made of a certain color and with a number from 0-10. The object of the game is to get rid of all one's triangles by strategically placing them so that adjacent numbers add up to 10, and colors match.

Memory Games (for STM group only)

1. Remember, Remember (James Galt and Company Limited)

This game has 120 picture cards that form pairs. To begin all cards are turned face down. Players take turns turning two cards over. To win a player must remember where the cards were to gather the most pairs.

2. Memory Game using Playing Cards

This is a modified version of Remember, Remember using regular numbered playing cards, instead of the pictures.

Other Activities (for math group only)

1. Jiggle (James Galt and Company Limited)

This game has various coloured forms made up of 1-5 squares. A player must fill up his or her board by throwing dice to determine what forms can be laid. The object is to fill one's board first, without having any forms of the same colour touching.

2. Puzzle Grams (various)

Using geometric shaped blocks, players must fit them together to form a shape identical to one presented to them on a card.

Appendix D

Raw Scores

subject	Digit Span	Visual Attention Span for Letters	Mental Computations	Add.	Sub.	Mult.	Div.
STM 1							
pre	10	[illegible]-2	6	11	6	5	4
post	12	5-3	9	11	12	9	8
STM 2							
pre	10	5-2	7	11	11	6	6
post	17	6-2	9	15	13	10	7
STM 3							
pre	7	5-3	2	9	5	5	5
post	9	6-3	8	12	11	9	7
STM 4							
pre	9	5-2	7	12	6	5	2
post	10	6-1	7	11	10	9	5
STM 5							
pre	9	5-3	2	9	8	5	4
post	11	5-2	9	11	9	6	6
STM 6							
pre	7	4-4	3	9	9	5	2
post	12	5-2	6	12	12	8	5
STM 7							
pre	10	5-2	5	12	9	7	4
post	13	7-1	10	13	11	9	7
STM 8							
pre	8	5-3	5	12	10	6	4
post	11	6-3	8	12	11	9	7
Math 1							
pre	9	5-2	6	12	8	8	4
post	10	5-3	3	12	11	8	4
Math 2							
pre	9	5-1	3	13	8	5	4
post	8	5-1	6	13	11	7	4
Math 3							
pre	11	5-2	5	12	11	8	4
post	11	5-2	6	12	11	8	4
Math 4							
pre	9	4-4	3	8	5	5	4
post	10	5-1	3	11	7	5	4
Math 5							
pre	7	5-1	2	7	6	4	2
post	8	4-4	4	8	8	5	2
Math 6							
pre	11	5-3	8	12	10	8	5
post	12	5-4	9	12	12	8	6

Appendix E

Standard Scores

subject	Digit Span	Visual Attention Span for Letters	Mental Computations	Add.	Sub.	Mult.	Div.
STM 1							
pre	7	9.09	4.4	4.6	2.7	3.9	4.1
post	9	10.03	7.3	4.6	7.8	7.0	7.7
STM 2							
pre	8	9.09	5.2	4.6	6.6	4.5	5.9
post	14	11.09	7.3	8.2	9.5	8.7	6.6
STM 3							
pre	5	10.03	2.0	3.5	2.1	3.9	5.0
post	7	12.03	6.1	5.5	6.6	7.0	6.6
STM 4							
pre	7	9.09	5.2	5.5	2.7	3.9	2.4
post	9	11.03	5.2	4.6	5.6	7.0	5.0
STM 5							
pre	7	10.03	2.0	3.5	3.9	3.9	4.1
post	10	9.09	7.3	4.6	4.7	4.5	5.9
STM 6							
pre	6	8.09	2.9	3.5	4.7	3.9	2.4
post	11	9.09	4.4	5.5	6.6	6.2	5.0
STM 7							
pre	8	9.09	4.0	5.5	4.7	5.3	4.1
post	11	13.06	7.3	6.4	6.6	7.0	6.6
STM 8							
pre	6	10.03	4.0	5.5	5.6	4.5	4.1
post	9	12.03	6.1	5.5	6.6	7.0	6.6
Math 1							
pre	7	9.09	4.4	5.5	3.9	6.2	4.1
post	8	10.03	2.9	5.5	6.6	6.2	4.1
Math 2							
pre	7	9.03	2.9	6.4	3.9	3.9	4.1
post	6	9.03	4.4	6.4	6.6	5.3	4.1
Math 3							
pre	8	9.09	4.0	5.5	6.6	6.2	4.1
post	8	9.09	4.4	5.5	6.6	6.2	4.1
Math 4							
pre	8	8.09	2.9	2.9	2.1	3.9	4.1
post	9	9.03	2.9	4.6	3.2	3.9	4.1
Math 5							
pre	6	9.03	2.0	2.5	2.7	2.5	2.4
post	7	8.09	3.5	2.9	3.9	3.9	2.4
Math 6							
pre	9	10.03	6.1	5.5	5.6	6.2	5.0
post	10	10.09	7.3	5.5	7.8	6.2	5.9

Appendix F

Analysis of Raw Data

The Digit Span Subtest

Source of Variation	SS	df	MS	F
Between Subjects				
A (groups)	3.65	1	3.65	0.71
Subjects within groups	61.35	12	5.11	
Within Subjects				
B (time)	28.00	1	28.00	22.12
AB	11.81	1	11.81	9.33
B X Subjects within groups	15.19	12	1.27	

The Visual Attention Span for Letters Subtest

Source of Variation	SS	df	MS	F
Between Subjects				
A (groups)	26.30	1	26.30	6.52
Subjects within groups	48.42	12	4.03	
Within Subjects				
B (time)	24.14	1	24.14	13.37
AB	12.19	1	12.19	6.75
B X Subjects within groups	21.67	12	1.81	

Appendix F

Analysis of Raw Data

The Mental Computations Subtest

Source of Variation	SS	df	MS	F
Between Subjects				
A (groups)	17.65	1	17.65	3.25
Subjects within groups	65.10	12	5.43	
Within Subjects				
B (time)	38.89	1	38.89	16.32
AB	15.00	1	15.00	6.29
B X Subjects within groups	28.60	12	2.38	

The Written Computations Subtest

Source of Variation	SS	df	MS	F
Between Subjects				
A (groups)	47.25	1	47.25	0.99
Subjects within groups	572.75	12	47.73	
Within Subjects				
B (time)	371.57	1	371.57	100.39
AB	82.01	1	82.01	22.16
B X Subjects within groups	44.42	12	3.70	

Appendix G

Raw Scores - Means and Standard Deviations for each Subtest

The Digit Span Subtest

Group	Time	Mean	Standard Deviation
Math	pre	9.33	1.37
Math	post	9.83	1.46
STM	pre	8.75	1.20
STM	post	11.88	2.26

The Visual Attention Span for Letters Subtest

Group	Time	Mean	Standard Deviation
Math	pre	5.50	0.96
Math	post	5.83	1.34
STM	pre	6.13	0.93
STM	post	9.13	2.42

The Mental Computations Subtest

Group	Time	Mean	Standard Deviation
Math	pre	4.50	2.06
Math	post	5.17	2.11
STM	pre	4.63	1.93
STM	post	8.25	1.20

The Written Computations Subtest

Group	Time	Mean	Standard Deviation
Math	pre	7.23	1.55
Math	post	8.08	1.32
STM	pre	7.01	0.92
STM	post	9.58	0.91

Appendix H

Standard Scores - Means and Standard Deviations for each Subtest

The Digit Span Subtest

Group	Time	Mean	Standard Deviation
Math	pre	7.50	0.96
Math	post	8.00	1.29
STM	pre	6.75	0.97
STM	post	10.00	1.94

The Visual Attention Span for Letters Subtest

Group	Time	Mean	Standard Deviation
Math	pre	9.50	0.48
Math	post	9.67	0.67
STM	pre	9.81	0.46
STM	post	11.34	1.26

The Mental Computations Subtest

Group	Time	Mean	Standard Deviation
Math	pre	3.72	1.32
Math	post	4.23	1.50
STM	pre	3.71	1.20
STM	post	6.38	1.10

The Written Computations Subtest

Group	Time	Mean	Standard Deviation
Math	pre	4.41	1.15
Math	post	5.08	1.07
STM	pre	4.23	0.70
STM	post	6.35	0.92