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NAME OF AUTHOR/NOM DE L'AUTEUR Cornelius P. Rea

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NAME OF SUPERVISOR/NOM DU DIRECTEUR DE THÈSE Dr. Vito Modigliani, Associate Professor, S.F.U.

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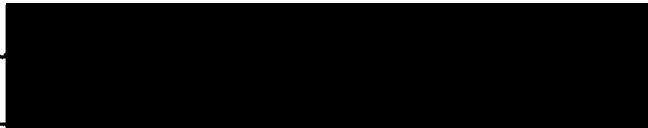
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**LA THÈSE A ÉTÉ
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A PRACTICAL APPLICATION
OF THE SPACING EFFECT
TO CLASSROOM LEARNING

by

Cornelius P. Rea

B.A. Simon Fraser University, 1978

THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF ARTS
in the Department
of
Psychology



Cornelius P. Rea 1982

SIMON FRASER UNIVERSITY

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APPROVAL

Name: Cornelius P. Rea

Degree: Master of Arts

Title of Thesis: A Practical Application of the Spacing
Effect to Classroom Learning

Examining Committee:

Chairperson: Dr. Bernard Lyman

Vito Modigliani

Roger Blackman

Ron Marx
External Examiner
Associate Professor
Department of Education
Simon Fraser University

Date Approved: 26 Feb 1982

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Author:

(Signature)

Cornelius P. Rea

(Name)

April 20 1982

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ABSTRACT

It has been demonstrated in the laboratory that it is possible to structure practice of to-be-remembered material in such a way that the probability of retention is maximized. Distributed practice typically leads to superior performance in most memory tasks compared to massed practice. Specifically, distributed practice with inter-test intervals of an expanding nature has been shown to be an optimal sequence. A series of experiments was carried out in order to develop a practical educational application of these research findings. The first two experiments were aimed at discovering an appropriate methodology for use in a school situation. The final study consisted of a direct application of these findings. The hypothesis tested was that materials (multiplication tables and spelling lists) which are presented in an expanded distributed practice series will induce greater retention than massed repetitions. The subjects were 44 grade three students and the study consisted of two parts. In part one of the study (Experiment IIIA) the subjects were seen on an individual basis utilizing a slide-tape presentation of material. The results of this part of the study demonstrated a significant difference between the distributed practice group and the massed practice group. In the math condition the former remembered almost twice as much as the latter, both on an immediate oral test and a

subsequent written test. In the spelling condition the distributed practice group performed better than the massed practice group, and while the difference was not as great as in the math condition, it was still statistically significant. The second part of the study (Experiment IIIB) involved a whole class experiment utilizing drill sheets for the distributed and massed practice groups. After three consecutive days of working with the drill sheets students received a test on day 4 and a final surprise test on day 7. An analysis of the data revealed that there was no significant difference between groups on either of the two tests. The results of this series of experiments are discussed in relation to their implications for future research. Certain applications such as adaptation for remedial work and learning centres are indicated. Refinements in procedure aimed at long term retention as well as the development of whole units based on expanding series are outlined.

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TABLE OF CONTENTS

Approval.....ii

Abstractiii

Acknowledgementsv

List of Tablesviii

List of Figuresix

A. Chapter One.....1

 I. Introduction2

 II. Applied versus Basic Research4

B. Chapter Two.....8

 I. Issues in memory research9

 II. Rehearsal and Memory15

 III. The Spacing Effect21

 Encoding Variability theories:24

 Deficient Processing Theories:27

 IV. Applied Studies38

C. Chapter Three.....42

 I. Study I50

 Method50

 Results and discussion53

 II. Study II55

 Method56

 Results and discussion:63

 III. Study III73

 IV. Experiment IIIA75

Method	75
Results and discussion	80
V. Experiment IIIB	87
Method	87
Results and discussion:	89
D. Chapter Four.....	92
I. Discussion	93
Experiment IIIA:	94
Experiment IIIB:	95
Implications for Future Research	98
Appendices	106
References.....	128

LIST OF TABLES

- Table 1. Means and Standard Deviations for the Pre-timed and Self-timed groups on tests 5, 6, and 7, as a function of condition, A1, A2, B, and C. 65
- Table 2. Comparison between Pre-timed and Self-timed groups on total time taken in seconds from beginning of sequence to the end of test 6, including distractors, for condition A1, A2, B, and C. 68
- Table 3. Average time, in seconds, taken per fact on P and each test trial (T1 to T6) for each condition A1, A2, B, and C, for the Self-timed group. (The Pre-timed groups' times are in brackets). 69
- Table 4. Mean scores and Standard Deviations on the oral and written tests of math facts by group, level and and class 81
- Table 5. Mean scores and Standard Deviations on the oral and written tests of spelling facts by group, level and class. 84
- Table 6. Mean and percent scores on spelling and math tests one and two for the distributed and massed practice groups. 90

LIST OF FIGURES

Figure 1. Percent recall on tests 5, 6, and 7 as a function of condition (A1, A2, B, and C) for the Pre-timed and Self-timed groups.

64.

A. Chapter One

I. Introduction

An important objective for educational research is to facilitate the acquisition of knowledge and skills in an efficient manner. Traditionally psychologists have been active in contributing to ways of achieving this goal, e.g., Thorndike (1913); Skinner (1968). The development of effective and efficient instructional methods and materials has been aided by psychological research in areas such as motivation, developmental psychology, assessment, learning and cognition, to name only a few. More specifically, psychological research in memory has important implications for education. It is difficult to think of any educational objective for which the ability to retain information is unimportant. If students can be aided in remembering more effectively, educational gains will follow. The purpose of this thesis was to extend recent findings in basic memory research to a practical educational situation involving typical classroom material, i.e., multiplication tables and spelling lists.

One of the most powerful variables affecting memory is repetition. The fact that repetition improves retention has been established empirically in numerous studies (Hintzman, 1976). Although repetitive drill is less common in schools than it once

was, it is still an important component in learning certain types of material e.g., multiplication tables, spelling lists. It is noteworthy that continuous successive repetitions (massed practice or MP) are less effective for memorization than repetitions which are spaced apart in time (distributed practice or DP). This phenomenon, commonly referred to as the spacing or MP-DP effect, has been demonstrated in laboratory studies involving a wide variety of memory tasks (Hintzman, 1974). The present study applies the spacing effect results obtained in the laboratory to the learning of multiplication tables and spelling lists by third grade students. This research, therefore, is of an applied nature and for this reason it is important to discuss, at the outset, the general issue of applied versus basic or theoretical research in educational psychology.

II. Applied versus Basic Research

Educational psychology has been defined as a distinct discipline whose main focus is the study of human behavior in educational or learning settings, and which is primarily concerned with understanding and improving the teaching/learning process (Gage & Berliner, 1975). Two strategies have been employed in the application of the science of psychology to education. The first involves deriving concepts and laws about learning and human nature from basic experimental work in psychological laboratories. The second is concerned with direct experimentation with learning in school settings (Anderson & Faust, 1973).

Navarick (1979) has suggested that dividing research into two categories, basic and applied, is useful but misleading. For many psychologists interested in educational phenomena, the boundaries between the two have become increasingly blurred (Glaser, 1978). Sharp distinctions between projects often cannot be made. To take into account the complex relationships involved in educational research, Hilgard (1964) suggested conceptualization of the psychology of learning as a series of six graded steps leading from basic research at one extreme to political and industrial activity at the other.

Ausubel (1978) stated that educational psychology is an applied science and as such the discipline is not concerned with general laws in themselves. Rather, its focus is on those properties of learning that can be related to effective ways of deliberately bringing about stable cognitive changes. A major problem, according to Ausubel, has been that research in learning theory has been undertaken by psychologists unconnected with education, investigating problems quite remote from the type of learning that goes on in the classroom. The focus has been on animal learning and rote or non-verbal learning rather than on the learning of organized bodies of meaningful material. Ausubel notes that the emphasis on the extrapolation of rote learning theory to school learning has not been productive.

On the other hand, Anderson and Faust (1973) have outlined a number of problems associated with research in classroom settings. They pointed out that educational investigators have been trying to apply the methods of science to obtain dependable answers to practical questions about school learning, e.g., whether small classes are better than large classes; whether the discovery method is better than the expository method; whether televised lectures are better than live lectures, etc. Unfortunately, the authors conclude that research attempting to answer such practical questions has been almost uniformly inconclusive. Applied research in the classroom has also suffered as a result of such factors as lack of agreement over

what is meant by a given method, bias as a result of teachers being asked to teach according to two different methods, or premature implementation of methods not fully developed. (Anderson & Faust, 1973).

Ausubel's (1978) position is that the principles governing the nature and conditions of learning can be discovered only through an applied or engineering type of research. However, the inconclusiveness of the results of applied research (Anderson & Faust, 1973), as well as the problem of translating general concepts about learning discovered in the laboratory into workable instructional techniques, poses serious problems.

A move toward resolving this issue has gained some impetus in recent years. For instance Glaser, (1978) suggested that developments in the field of instructional psychology might serve as the bridging or intermediary activity required for ongoing contact between theory and application. He pointed out that there is an interaction involved, with theory being changed by application and attempts at application influencing the shape of psychological knowledge and theory. Thus, an approach involving a search for basic laws of learning in both the laboratory and the classroom and which instigates the necessary research to implement them in school settings would appear to be most productive. Theory and research can contribute to the development of optimal ways for acquiring knowledge and skill and, as Glaser (1978) pointed out, much progress has been made

toward the integration necessary for building a psychology of instruction.

Some areas where this trend is evident are task analysis, behavior modification, psychological assessment and text comprehension. It is notable that the area of memory research has not been conspicuous in making major contributions to efforts aimed at educational improvements. This issue will be discussed next.

B. Chapter Two

I. Issues in memory research

The processes of memory and the results of memory research have important implications for education and educational psychology. It is not clear, however, that whatever knowledge about human memory we have, has been utilized to achieve educational goals. It is apparent from a review of the literature that certain procedures do produce marked improvements in remembering over others. It is also apparent that very few of the tasks in which improvements have been demonstrated can be regarded as educational. For example, Howe and Ceci (1979) have noted a number of problems related to this issue. First, they pointed out that in the majority of memory experiments there is a deliberate intention to remember on the part of the participants. In many school situations, where information is learned and retained, this intention is not emphasized. In other words the instructions given in the classroom in relation to materials to be learned are rarely the same as the instructions given in an experiment. Although reasoning and comprehension require retention of information, students are seldom explicitly told to try to memorize. Memorization would seem to occur as a result of other factors and is accomplished in the context of additional activities. These contextual factors are frequently missing in memory

experiments and exactly what contributions they make to the learning process is not clear. Second, the tasks involved in memory experiments are not, in practical terms at least, the type of tasks that are normally encountered in school classrooms, nor are the materials the same as those that are typically used in the schools. Third, the nature of psychological experiments require that all variables are held constant except for those of interest to the investigator. This methodology narrows the focus so that material, while ostensibly educationally relevant, tends to be very restricted (Howe & Ceci, 1979).

Despite these constraints, research in memory still has a worthwhile contribution to make to education, since much of what is learned in educational settings involves memory processes. Primary graders must memorize the alphabet and thousand of words in the process of learning to read; and numbers and multiplication tables when they learn mathematics. Throughout the average school career students continue to memorize new words, key terms, ideas, concepts and to commit hundreds of facts to memory. Comprehension, computation and reasoning all depend upon memory.

While this discussion is primarily concerned with the educational implications of memory research, there are conceptual problems in restricting discussion to memory. Separating memory from other types of performance is arbitrary

inasmuch as memory systems are intricately involved in many processes and play a role in every psychological activity (Jones, 1979). Thus, while it can be truthfully said that there is no such thing as a non-memory task, tasks do vary in the degree of reliance placed on the mechanisms of storage and retrieval.

In certain basic tasks such as remembering a name or telephone number or learning a shopping list, the role of memory is fairly obvious. Reasoning tasks, such as correctly performing the Luchin's water jar problem also depend to a large extent, on both temporary and long term retention of various items of information (Atwood & Polson, 1976). Memory requirements may be a major source of difficulty in many situations that contribute to a person's education. As pointed out by Howe and Ceci (1979), individual and developmental differences in remembering are influenced in large part by three factors: (1) metamemorial processes, (2) the learner's state of knowledge about the materials to be remembered, and (3) strategies that are adopted by the learner. While these three factors usually combine to influence memory, the last is more central to the present study.

The term metamemory is used to describe the learner's awareness of the processes and activities that lead to effective remembering (Flavell, 1971). Use of rudimentary metamemorial processes begins in early childhood at approximately age three. These processes and their complexity continue to increase with

age (Kreutzer, Leonard & Flavell, 1975).

When items of information have to be recalled, the basic store of knowledge already possessed by the individual is an important determinant of success. Some researchers have suggested that increased knowledge and information about material to be remembered is the main factor involved in age-related improvements in memory (e.g., Huttenlocher & Burke, 1976). For instance some knowledge of the numbering system would be of obvious benefit to a child learning the multiplication tables. Other researchers have suggested that, in addition to metamemory and knowledge, use of appropriate strategies as children get older is a determinant of developmental increases in memory (Flavell, Beach & Chinsky, 1966; Howe, 1976).

Strategies are those control processes in which individuals engage when faced with a task that requires retention of information (Morris, 1979). Such activities as labelling, use of visual imagery, organization of items, use of mediators, mnemonics, and rehearsal are all examples of strategies. Strategies can be involved in retention of both rote and meaningful material and may be used consciously or without awareness (Howe & Ceci, 1979).

Ordinarily, there are few problems in remembering organized meaningful material. This is not surprising since to claim that something is meaningful and organized implies that it fits with past experiences and can be easily analysed by the cognitive

system (Morris, 1979). Meaningfulness is perhaps one of the most overused words in education. This undoubtedly reflects the importance of this factor in relation to retention and understanding of material encountered in the classroom. The highly desirable emphasis on the importance of children understanding what they learn does not mean that everything that needs to be learned can be automatically or naturally acquired in a meaningful way. It would therefore seem sensible, when warranted by the nature of the material, to find ways of supplying meaning, organization and cues. Mnemonic devices are strategies that can serve that function (Morris, 1979). Such mnemonics as the phonic translation system, the peg or hook system, the method of loci, use of visual images, and the link method are all examples that have been demonstrated to be effective. (see Bower, 1973; Morris & Reid, 1971; Raugh & Atkinson, 1975).

One problem with mnemonics is that the information may remain encapsulated in them and not become integrated into the general store of knowledge (Morris, 1979). Another problem is the amount of effort required to master mnemonics in the first place. For the average person this expenditure of energy is probably the major obstacle in the acquisition of these memory aids. Moreover, such evidence as there is suggests that mnemonics become unnecessary as knowledge of the information they convey increases. While they are useful in aiding the initial acquisition of material, with continued use they become

less necessary (Atkinson, 1975).

One of the strategies that has been studied extensively is rehearsal. The fact that rehearsal can be consciously controlled makes it relatively accessible for investigation. Rehearsal has played a major role in the explanation of learning and memory and has been controlled in nearly all experimental paradigms (Johnson, 1980). Rehearsal is of direct relevance to the present research and will be discussed next in some detail.

II. Rehearsal and Memory

Repetition is a common strategy used to remember information and is one variety of rehearsal. Rehearsal and repetition, however, are not equivalent concepts. In rehearsal the repetition is internally generated by the learner rather than externally imposed. Johnson (1980) acknowledged this in his definition of rehearsal as "those preparatory learning activities that occur when re-exposures and/or new encodings are internally generated by the learner rather than by additional presentations external to the learner" (p.265). This definition differentiates rehearsal from outside reexposures to the task and refers to preparatory learning activity involving the contents of the rehearser's own memory. As Johnson pointed out, an externally initiated repetition may induce rehearsal if the learner imposes knowledge from his/her own memory on the repeated information. While the concept of rehearsal is theoretically straightforward, its operational definition and detection are much less so.

Some researchers assume that subjects rehearse whenever there is an opportunity (e.g., Shaffer & Shiffrin, 1972). Others have attempted to assess covert rehearsal through various means. Electromyograph potentials and lip reading have proven useful but limited, (e.g. Locke & Ginsberg, 1975). The use of pupillary

size as an index of covert rehearsal is complicated because these responses are known to be influenced by other factors (Kahneman & Wright, 1971). The amount of time taken to study an item has also been used to assess rehearsal. When subjects are allowed to pace the presentation of material, the pauses may be taken as an indication that rehearsal is occurring (Belmont & Butterfield, 1971). A subject paced study by Shaughnessy, Zimmerman and Underwood (1972) showed that better recall was related to time spent studying the material. Other studies, however, have found that duration of pauses were not closely related to accuracy of recall (e.g., Belmont & Butterfield, 1971; Zimmerman, 1975).

In order to avoid the methodological problems of covert rehearsal a number of researchers have attempted to directly observe rehearsal by asking subjects to verbalize aloud (Izawa, 1976; Rundus, 1971; Whitten & Bjork, 1977). This technique does, however, raise the issue of whether overt and covert rehearsal can be equated. Johnson (1980) reviewed a number of studies which compared overt and covert rehearsal. Because of the complexity of the different conditions involved (e.g., type of rehearsal strategy, stimulus materials) the results of the review were equivocal. Johnson concluded "that it cannot be assumed that overt rehearsal is a mirror image of covert rehearsal" (p.263).

Not only are there difficulties in measuring rehearsal, but the converse experimental manipulation, that of preventing rehearsal, also presents methodological problems. The effectiveness of the various methods employed is difficult to assess. Some researchers have used rapid presentation rates in order to reduce rehearsal time (e.g., Wenger, 1979). However this method does not preclude the subject from rehearsing some part of the material. A more common strategy is to have subjects engage in some cognitive operation on an interpolated task. Petrusic and Jamieson (1978) found that the most forgetting occurred as a result of shadowing as an interpolated task and that increasingly less forgetting occurred as a result of such tasks as listening to vocal music, listening to instrumental music, or leaving the interval blank. Thus, it would appear that in most situations the difficulty of the interpolated task is directly related to recall of previously presented material. However, changes in the level of recall may not accurately reflect the occurrence of rehearsal. Poor recall does not necessarily mean a lack of rehearsal, and elevated levels of retention need not be assumed to be the result of more rehearsal (Dark & Loftus, 1976). A dimension other than difficulty may be involved. Ideally, interpolated tasks should be neutral with respect to the material to be remembered. Lack of neutrality may cause interference with memorization rather than merely preventing it (Neimark, Greenhouse, Law & Weinheimer, 1965). Thus, it is not

always clear whether it is the difficulty of the interpolated task or interference which cause changes in levels of retention (Johnson, 1980).

Longer rehearsal periods usually result in higher levels of performance (e.g., Hockey, 1972; Penney, 1975; Rundus & Atkinson, 1970), although some instances have been reported where this is not the case (e.g., Glenberg, Smith & Green, 1977; Shaffer & Shiffrin, 1972). Increases in study time have been shown to affect immediate recall but not delayed recall (Modigliani & Seamon, 1974; Woodward, Bjork & Jongeward, 1973). Variables such as type of material and modality of presentation appear to play an important role. For instance, the task of remembering words was enhanced by longer rehearsal intervals, but this was not the case with remembering pictures (Hintzman & Rogers, 1973; Ternes & Yuille, 1972).

Craik and Lockhart (1972) in their depth-of-processing model, postulate the existence of two different types of rehearsal. Type I or maintenance rehearsal maintains the to-be-remembered item at a superficial level. Thus, increased maintenance rehearsal does not improve recall. Type II or elaborative rehearsal involves the creation of more meaningful associations at a deeper level of analysis and consequently would benefit from longer rehearsal time. While there is evidence in support of the notion of two types of rehearsal (e.g., Craik & Watkins, 1973) other researchers have argued to

the contrary (e.g., Dark & Loftus, 1976; Evans, 1977).

Lack of empirical support for the existence of Type 1 rehearsal may be due to problems in definition. An important point made by Dark and Loftus (1976) was that Type 1 rehearsal is not the same as rote repetition. The latter can produce either Type 1 or Type 11 rehearsal effects. The issue of the existence of different types of rehearsal would appear to be unresolved. In addition to the above factors, modality effects have been investigated. Auditory presentation compared to visual presentation was found to be consistently superior for short term memory but only for recently presented items (Penney, 1975). Listening comprehension has been shown to be substantially influenced by presentation variables. Webstone and Friedlander (1974) found comprehension performance was lowest for audio cassette and highest for videotape.

We do not yet have a complete understanding of the effects of rehearsal on retention, as its effectiveness varies as a function of type of material, presentation mode and duration. However, there is little question that most forms of rehearsal increase memory and that continued investigation of this process is warranted.

One of the variables that has attracted attention in recent years is the length of the time interval between presentation and rehearsal of to-be-remembered information. Contrary to common intuition, it appears that longer intervals between

presentation and the first opportunity to rehearse leads to better performance than if there is no delay. This is the spacing effect referred to earlier (e.g., Melton, 1970).

III. The Spacing Effect

Many of the variables studied in traditional memory research in psychology laboratories are not easily manipulated by the teacher in a classroom situation. One exception to this generalization may be related to the spacing effect. This refers to the finding that items are better recalled if repetitions are spaced apart in time (distributed practice or DP) rather than massed (massed practice or MP) (Melton 1970; Underwood 1970). This phenomenon has been demonstrated in a wide variety of laboratory memory tasks and conditions (see Hintzman, 1974). The spacing effect has been found in paired-associate learning (e.g., Schwartz, 1975) free recall (e.g., Melton, Reicher, & Shulman, 1966), and recognition memory (e.g., Hintzman & Block, 1970). Materials have included words (e.g., Whitten & Bjork, 1977), sentences (e.g., Underwood, 1970), pictures (Hintzman & Rogers, 1973), nonsense syllables (e.g., Kintsch, 1966), second language vocabulary (Bloom & Shuell, 1981), spelling lists (Reith, Axelrod, Anderson, Hathaway, Wood, & Fitzgerald, 1974) and telephone numbers (Landauer & Ross, 1977). Some of the dependent variables used have been frequency judgements (e.g., Proctor, 1980), probability of recall (Shaughnessy, 1977), recognition and recognition latency (Johnson & Uhl, 1976). The

effect has been found in auditory and visual modalities as well as mixed modalities in the same list (Hintzman, Block & Summers, 1973). The spacing effect is found over various presentation rates (Whitten & Bjork, 1977) and occurs in within-list spacings (Maskarinec & Thompson, 1976) as well as between list spacings (Underwood, 1969). Although the spacing effect has been demonstrated with long intervals between repetitions and/or re-presentations (up to 24 hours, Bloom & Shuell, 1981) and with more than two presentations (Landauer & Bjork, 1978), most laboratory studies have employed a relatively restricted set of conditions. For instance Hintzman (1974) excludes from his definition of the MP-DP effect intervals which exceed 15 seconds. The usual paradigm in laboratory experiments involves two presentations and a test (P1, P2, and T). Performance typically improves as the P1-P2 interval increases from zero to approximately fifteen seconds, and then asymptotes. The length of the P2 to test (T) interval is usually held constant, and only the P1-P2 interval is varied (Hintzman, 1974). Crowder (1976), in his discussion of the spacing effect, noted that performance is better when at least some other items intervene between two repetitions. He pointed out that performance steadily improves as a function of the number of intervening items, not simply the length of the interval. The spacing effect obtained with intervals over 15 seconds which involve intervening items has been referred to as the lag effect or

Melton Lag (Hintzman, 1974). D'Agostino and De Remer (1972, 1973) have shown that the Melton lag (intervals over 15 seconds) is unique to free recall, and in addition provided some empirical support for the view that the effects of short and long (Melton lag) P1 - P2 intervals may be a result of different processes.

Hintzman (1974) noted that the spacing effect is a real and omnipresent phenomenon and that in experiments where it is not demonstrated the possibility of sampling error, ceiling effects or some flaw in experimental design should be suspected. The research interest in this phenomenon stems from the fact that it appears to be a theoretical anomaly. Underwood (1970) pointed out that the MP-DP effect violates the Total Time Law. This law postulates that retention is a function of total study time and not how time is distributed. Consequently it does not account for superior memory performance for DP items, over MP items, where the amount of study time is the same regardless of spacing (Underwood, 1970). The law of recency would predict that the more recent items would be remembered better. In both MP and DP the time interval between P2 and T is held constant. Consequently, P1 is more recent with respect to T in MP schedules, where it occurs next to P2, than it is in DP schedules where it is separated by an interval. But, in contradiction to the law of recency, massed practice typically results in lower retention levels.

Although it is still unclear why distributed practice facilitates memory, several theoretical interpretations have been formulated (Bloom & Shuell, 1981). Although the present research is not concerned with testing theory, per se, a brief discussion of the various hypotheses will follow. Hintzman (1976) provided a useful organizational scheme for discussing these explanations. He suggested that they be classified under two headings; encoding variability theories and deficient processing theories.

Encoding Variability theories:

Semantic Variability: Two versions of the encoding variability theory have been identified: semantic variability and contextual variability. The former focuses on the fact that verbal items are to some extent ambiguous and can be interpreted in more than one way. Further, the more different meanings an encoded item has, the easier it is to retrieve. This hypothesis assumes that the semantic meaning given an item at P2 will be the same as that assigned at P1 if the repetitions are massed. When the interval is long as in distributed practice there is a greater likelihood that the P2 interpretation will change. Thus, DP is assumed to produce greater retention than MP because there are more ways to retrieve items encoded in distributed practice (Melton, 1970). Hintzman (1976) pointed out that there is very

little empirical support for this hypothesis and a considerable body of evidence against it. For example, if P1 and P2 encodings are different then recognition of P2 as having been seen previously should lead to poorer retention (Martin, 1972). The available data suggests that the opposite is true (Crowder, 1976). Bellezza, Winkler & Andrasik (1975) reported that words recognized as "old" on P2 (and thus assumed to be encoded in the same way) led to better recall on the final test than those not recognized on P2, a direct contradiction of the hypothesis. A recent study (McFarland, Rhodes, & Frey, 1979) offered some support for a modification of the semantic variability hypothesis which stressed variations in features within a single semantic concept rather than independent semantic interpretations. Their results, however, were not conclusive enough to rule out other interpretations of the spacing effect, such as the inattention hypothesis (see below).

Contextual Variability: A second version of the encoding variability hypothesis follows from Anderson and Bower's (1972) theory of retrieval. The contextual variability hypothesis proposes that encoding and storing items involves associations established between the meaning and attributes of to-be-remembered items and a conglomeration of contextual elements such as adjacent list words, the subject's conscious thoughts and environmental factors (Hintzman, 1976). The more contextual information that is available at retrieval the more

likely it is that an item was presented previously. Thus the spacing effect is explained by the assumption that two presentations of an item that are spaced apart in time will involve a different set of contextual elements than if they are presented successively (Crowder, 1976).

The most convincing evidence for this hypothesis would be data that would clearly show that the spacing effect could be attenuated or eliminated by induced variation in context of P1 and P2 during massed practice. Experiments manipulating this variable have not supported the hypothesis (McFarland et al., 1979). For example, Wells and Kirsner (1974) found that switching the input modality between P1 and P2 does not reduce the effect. Hintzman, Summers, Eki and More (1975) varied two conditions in the spacing of presentations of pictures. In one condition, an effective incentive tone occurred along with P2 while P1 was accompanied by silence; in the second condition both P1 and P2 were presented without the tone. Again, the MP-DP effect was not altered. Similarly, Shaughnessy (1976) found that the MP-DP effect was not influenced when an orienting task was different with P1 and P2. These and similar findings (e.g., Maskarinec & Thompson, 1976; Schwartz, 1975) pose serious problems for the contextual variability hypothesis.

Deficient Processing Theories:

Under this general heading it is possible to categorize four different hypotheses: (1) consolidation (2) habituation (3) rehearsal, and (4) attention. Hintzman (1976) noted that the processes involved in rehearsal and attention can be assumed to be under voluntary control while habituation and consolidation are involuntary processes.

Consolidation: The essence of this hypothesis is that consolidation of memory traces takes place over time and uninterrupted consolidation will result in better recall than consolidation which is incomplete (Crowder, 1976). During massed practice, when P2 occurs immediately after P1, the consolidation processing of P1 is interrupted by P2. In distributed practice, on the other hand, the consolidation of P1 is assumed to be complete by the time P2 occurs. Thus, the superior recall associated with DP is a result of more complete consolidation (Landauer, 1969, 1974). The usual assumption is that the short term trace is the source of consolidation and that information is continually transferred from the short term state to the more permanent long term state (Hintzman, 1974). It follows that if the same consolidation mechanism is involved in processing both occurrences of an item, then during massed practice there would be competition for its use and consequently a weaker long term trace. Given this assumption, manipulations that interfere with

the short term retention of P1 should interrupt consolidation and create poorer long term retention. A study by Tzeng (1973) presented evidence which argued against the consolidation hypothesis. By varying the difficulty of the task that intervened between P1 and P2 but keeping the difficulty of the P2 - T task constant, Tzeng (1973) found that recall was directly related to task difficulty. In other words, recall was superior when the intervening task was difficult as opposed to when it was easy. These results add support to earlier and similar findings which provided evidence against consolidation as an adequate explanation of the spacing effect (e.g., Bjork & Allen, 1970). Evidence presented which demonstrates that the locus of the spacing effect is at P2 (e.g., Hintzman, Block & Summers, 1973) rather than at P1 as the consolidation hypothesis would suggest, is not necessarily evidence against the hypothesis. Rather, as Hintzman (1976) suggested, the hypothesis can be altered to its converse, i.e., the continuing consolidation of P1 interferes with consolidation of P2.

A slightly altered version of the consolidation hypothesis proposes that differences in learning are due to two or more activity traces being consolidated into one single structural encoding during massed practice, whereas during spaced practice there are several separate structural encodings (Tarpay & Meyer, 1978). A serious problem for this theory is that the time taken for consolidation to occur has not been conclusively determined.

As a result of electroconvulsive shock studies with animals, Baddeley (1976) has suggested that the time may range from 15 seconds to more than an hour. However, learning studies have typically produced the spacing effect for periods of less than 15 seconds between P1 and P2.

It may be the case that consolidation is involved in the spacing effect but formulations and testings to delineate the underlying process or processes have not been very productive. It would appear that it is lack of supportive rather than presence of contradictory evidence that poses difficulties for the consolidation hypothesis (Hintzman, 1976). Another reason that the hypothesis has not been favored by most researchers concerned with the spacing effect may be due to the lack of success in confirming the existence of a consolidation process in animal research (e.g., Miller & Springer, 1973).

Habituation: Like the consolidation hypothesis this is an involuntary processing model but with the locus of the spacing effect occurring during P2. The poor performance of MP compared to DP is assumed to be a result of insufficient processing of the second occurrence of an item (Crowder, 1976). As long as the subject is devoting attention to P1, the process responsible for encoding continues to habituate or adapt, and only begins to recover when the subject stops. During DP, recovery from habituation is complete by the time P2 occurs, whereas with MP, P2 occurs before recovery is complete, thus impairing retention

(Hintzman, 1974). In an experiment by Hintzman, Summers and Block (1975), degree of habituation was manipulated by varying the exposure time of P1. It was felt that the greater the habituation, the slower the recovery process, and that some predictable evidence of the spacing effect could be obtained. The results, however, indicated that neither increasing the duration of P1 beyond 2.2 seconds (Experiment 1), nor presenting pictures several times in close succession (Experiment 2) had the predicted effect on the spacing curve (Hintzman et al., 1975). The results of this study suggest that habituation would have to asymptote in less than 2.2 seconds for this hypothesis to be supported.

When materials that the subject cannot rehearse are used, the recovery process should be a temporal function and not dependent on the nature of the interpresentation task. It has been demonstrated that complex visual scenes are not rehearsed (Shaffer & Shiffrin, 1972). Thus, the results of a study by Hintzman & Rogers (1973) demonstrated that the effects of spacing on picture memory were a function of time and independent of whether the P1 - P2 interval involved other items or was blank, supporting the habituation hypothesis.

When materials that a subject can rehearse are used, rehearsal should act to maintain habituation and inhibit full recovery. The habituation hypothesis would predict that the more difficult the intervening task between P1 and P2, the less

rehearsal there would be, which would result in more complete recovery by the second presentation. In other words, a difficult task intervening between P1 and P2 should produce greater retention than if the interval is blank or filled with an easy task. Contrary to this prediction, Proctor (1980; Experiment 5) found that the spacing effect was eliminated when a difficult task intervened between P1 and P2. Earlier studies by Bjork and Allen (1970) which obtained contrary results, have been criticized by Pollatsek and Bettoncourt (1976) as having little applicability to the spacing effect except in those studies using the Brown-Peterson task. Overall, it would appear that there is little empirical support for the habituation hypothesis. The consolidation and habituation hypotheses imply processes of an involuntary nature. The next two hypotheses deal with voluntary process.

Rehearsal: The rehearsal hypothesis states that subjects will rehearse P1 information and that the longer the P1-P2 interval, the more rehearsal time is available (Atkinson & Shiffrin, 1968). As in the consolidation hypothesis, then, the locus of the spacing effect is assumed to be at P1 rather than P2 and the emphasis is on the relation between total processing and long term storage strength (Crowder, 1976). Unlike the consolidation hypothesis, however, the rehearsal hypothesis assumes that the critical processing is under the subject's voluntary control. An experiment by Rundus (1971) which

investigated the overt rehearsal patterns of subjects tended to support the hypothesis. Similarly, Glenberg (1977) has provided evidence for voluntary rehearsal strategies as an explanation for the lag effect. He assumes that massed repetitions tend to be grouped together during rehearsal, while spaced ones are not, and that the probability of recall, in a free recall situation, is a function of the number of different groups in which the item is stored. DP produces superior recall because the subject has created more groups for these items than for MP items. Glenberg's (1977) results provide support for differential rehearsal strategies being involved in the lag effect (i.e., long P1 - P2 intervals with up to 40 intervening items). However, as Hintzman (1974) has argued, the lag effect in free recall may be the result of different processes than the spacing effect (short P1 - P2 intervals). Proctor (1980) supported this notion and suggested that while the lag effect may be due to voluntary rehearsal strategies, the spacing effect may be due to involuntary organizational processes. In a series of experiments he demonstrated that the spacing effect is not simply a result of differential rehearsal patterns. Earlier studies which involved manipulations affecting rehearsal did not influence the spacing effect in the way the hypothesis would predict (e.g., Elmes, Greener & Wilkinson, 1972; Hintzman & Rogers, 1973). It has also been shown that in studies involving incidental learning, where the subject has no reason to rehearse, there is

just as great an effect as when intentional learning is involved (e.g., Rowe & Rose, 1974; Shaughnessy, 1976). Finally, in contradiction to the notion implicit in the rehearsal hypothesis, that the locus of the spacing effect is at P1, studies by Hintzman et al. (1973) have demonstrated that the critical processing is at P2.

In summary, it would appear that there is a considerable body of evidence against the rehearsal hypothesis as an explanation of the spacing effect, but some support in its favor in relation to the lag effect.

Inattention: This hypothesis proposes that subjects choose to pay less attention to P2 when it occurs adjacent to P1 than when they are spaced apart in time (Underwood, 1969; 1970). Thus, there is assumed to be less functional study time in massed practice than distributed practice and a resulting decrement in probability of recall. A number of assumptions underlie this hypothesis. The first assumption is that there is a central limited capacity mechanism which is responsible for encoding, and that successive presentations must compete for its use. The second is that the amount of processing given P2 is under voluntary control (Hintzman & Stern, 1977). A third assumption is that the total time law (i.e., that effective study time determines the amount learned) is correct. Because DP items are better recalled than MP items, even though they are equivalent in exposure time, there must be less effective study

time in MP schedules. Further, information is more redundant for MP items than for DP items, because the information being presented is still available in memory. This could account for the attenuation of attention for MP items (Shaughnessy, Zimmerman & Underwood, 1974). Evidence in favor of this hypothesis accrues from studies where subjects are allowed control of the presentation of items (e.g., Zimmerman, 1975). When time spent studying each item was measured it was found that subjects spent less time on P2 when it followed P1 without a delay than when there was one. Similar findings have been reported in other studies using subject-paced procedures (e.g., Shaughnessy, Zimmerman & Underwood, 1972). A recent study by Wenger (1979) adds further support for the inattention hypothesis and extends the generality of earlier findings by Waugh (1970). Using a paired-associate memory task and comparing two rates of presentation, fast (1.3 seconds) and slow (4 seconds), Wenger demonstrated that while there was a clear MP - DP effect at the slower rate, the spacing effect was eliminated at the fast rate. The implication is that because subjects had difficulty encoding words sufficiently for recall at the fast rate, they were more likely to pay attention to both presentations in the MP condition. These data support the prediction of the inattention hypothesis that when subjects are forced to pay attention to both occurrences of a massed repetition, there would be no attenuation of attention and

consequently the MP - DP effect would be eliminated.

Studies which tested the idea that a limited-capacity central processing mechanism is involved in the spacing effect have produced results supporting this notion. Elmes, Greener and Wilkinson, (1972) examined recall of the words which occurred immediately following P2. Those in the MP repetitions were recalled better than those in the DP repetitions. This finding suggests that because less effort is expended in processing MP items there is more capacity available for the next item in the list and consequently better recall of those items. Similarly Johnston and Uhl (1976) reported that when auditory signals accompany P2 there is less likelihood that subjects will detect the signal as the P1 - P2 interval increases. The implication of this finding is that subjects have more capacity available during MP when less effort is being made to encode P2, than they do during encoding of P2 in DP.

While the above findings favor an attenuation of attention explanation, a critical test for the hypothesis would clearly demonstrate the existence of voluntary processes underlying the spacing effect. Hintzman, Summers, Eki and Moore (1975), attempted to manipulate the degree of attention that subjects paid presentations, but were unsuccessful in eliminating the spacing effect. Their conclusion was that the underlying mechanism is not under voluntary control. Likewise, Elmes, Sanders and Dovel (1973), in a free recall experiment, tried to

allocate subjects' attention to the second occurrence of items regardless of spacing, through use of the isolation or von Restorff effect. The critically selected items were in either a highly distinctive voice (auditory list) or distinctive typeface (visual list). Elmes et al. (1972) showed a facilitative effect of isolation on the recall of spaced items compared to massed items. This clearly demonstrated that the spacing effect was not diminished by isolation, a contradiction to the hypothesis that voluntary processes underlie the MP - DP effect.

A similar finding was reported by Hintzman (1976) where monetary incentives were used in order to manipulate subjects' attention. Again the spacing effect was not attenuated. While these studies are not conclusive, they fail to confirm an obvious prediction of the inattention hypothesis.

Other studies have presented additional problems for the inattention hypothesis (e.g., D'Agostino & DeRemer, 1973, Experiment I; Hintzman & Stern, 1977; Maskarinec & Thompson, 1976). For example Underwood, Kapelak, and Malmi (1976) attempted, in a number of experiments, to discover situations in which the size of the MP - DP effect varied as a function of other factors. Four different situations were examined: (1) recognition of letters, (2) verbal discrimination, (3) short free recall lists, and (4) recall of twice presented MP items with intervening items inserted to promote forgetting. The spacing effect was demonstrated in all studies and Underwood et

al. (1976) pointed out that their data cannot be accounted for by any of the current MP-DP theories. In particular, their Experiment IV poses serious problems for the attenuation of attention hypothesis. Attenuation results when the material being presented becomes redundant if it is still available in memory. Underwood et al. (1976) attempted to produce an equivalent recall level for both DP and MP items by inducing forgetting for P1 under both schedules. Their results showed that this manipulation did not influence the spacing effect as the attention hypothesis would predict. Their Experiment III produced similar results utilizing multiple presentations of an item (Underwood et al., 1976).

The above discussion makes it evident that there is no one adequate explanation for the spacing effect; it remains a theoretically elusive phenomenon. The reasons why distributed practice facilitates memory are not clear and while several theoretical accounts have been proffered none appears to be totally satisfactory. Despite its theoretical elusiveness, however, the spacing effect is one of the most robust phenomena discovered in memory research. It could be expected, therefore, that there would be a considerable body of research investigating the spacing of repetitions or rehearsals of to-be-remembered information in applied settings. This is not so.

IV. Applied Studies

The current trend in educational practice is to deemphasise memory (possibly because of its rote memorization connotation). It is obvious, however, that memory plays an important role. Since the spacing effect has been demonstrated in a large variety of laboratory tasks it seems that the spacing of to-be-remembered information in a classroom setting would help children remember it better. A review of the literature, however, has produced very few studies in which the MP - DP phenomenon has been utilized effectively to promote learning in educational or real life settings (Bloom & Shuell, 1981; Landauer & Ross, 1977; Reith, Axelrod, Anderson, Hathaway, Wood & Fitzgerald, 1974). It may be that, because massed practice is a frequently used rehearsal strategy, its effectiveness is overestimated. While it is not very effective, massed practice is probably used because it keeps the target item in mind while it is being rehearsed, and the procedure logically follows from the correct assumption that increased frequency of repetitions improves retention. Also, use of MP, while producing poorer recall, may nevertheless result in greater confidence in being able to remember (Landauer & Ross, 1977). Repetitions, however, should be distributed to be most effective.

In one study where teachers were asked to judge the instructional effectiveness of prose passages they gave higher ratings to texts in which critical information was massed than to those where it was spaced, contrary to actual effectiveness (Rothkopf, 1963; Rothkopf & Coke, 1966).

A more direct application involved the use of distributed practice in learning spelling lists in grade school (Reith et al., 1974). Their results demonstrated that DP (receiving a portion of the words each day) produced superior performance on a weekly spelling test compared to the normal method of presenting all the words at the beginning of the week. A similar result was obtained with foreign language vocabulary lists (Fenge, 1976).

In a study investigating the acquisition of basic sight words, Gargagliano (1974) found that five one-minute sessions (DP) were more effective for overall learning than one five-minute session (MP).

A more recent study (Bloom & Shuell, 1981) provided further support for the efficacy of distributed practice in practical situations. High school students learning French vocabulary lists were assigned to either a DP condition or an MP condition. The former involved three ten-minute units on each of three days while the latter consisted of all three units being completed in one thirty-minute period on a single day. A test given four days later showed that the DP group recalled 35% more than the MP

group, a dramatic difference.

An interesting finding in this study was that, on a test given to both groups at the end of the third unit, there was no significant difference between the groups, indicating that learning was equivalent for both groups. Thus, it would appear that DP and MP during the acquisition phase have equivalent effects on the learning of vocabulary words. Bloom & Shuell (1981) reasoned that because the two groups were comparable at the start of the retention interval the difference on the final test was a function of storage processes rather than acquisition processes. Because a decrement in retention occurred, they suggested that the differential forgetting in the two groups was due to the massed or distributed conditions of learning. It would appear that distributed practice affected learning and memory in different ways, indicating that separate and distinct process may be involved.

It has also been demonstrated that spacing of the reviews of previously learned material can be helpful. Reynolds and Glaser (1964) found that spaced reviews of information learned by programmed instruction improved retention of the material, whereas successive repetitions were not as effective.

While laboratory studies have typically employed interpresentation intervals of very brief duration (i.e., 15 seconds) the few studies discussed above involved much longer intervals (up to 24 hours). Nevertheless, the spacing effect was

still obtained. As indicated earlier, there is a mass of evidence in support of the omnipresence of the phenomenon in controlled laboratory settings. However, the paucity of studies providing empirical support for direct practical application points to the need for research in this area, if the goal of improving educational experience is to be achieved. As Bloom and Shuell (1981) pointed out, virtually no research has been carried out to determine if distributed practice works under normal classroom conditions.

C. Chapter Three

Most of the literature on the spacing effect is concerned with the spacing between two presentations of to-be-remembered material followed by a test. A similar, though much smaller body of literature, deals with the effect of the spacing of tests, following the initial presentation, on retention. Typically the paradigm includes a presentation (P) of an item followed by a first test (T1) and then a second test (T2). Additional tests may follow T2, although this is not common. The questions of interest are (1) does T1 affect performance on T2, and (2) do the intervals between P and T1 and between T1 and T2 affect recall on a later test of retention?. First, it has been clearly demonstrated that test trials increase memory as measured in later trials (Landauer & Eldridge, 1967; Izawa, 1971, 1978, 1981; Modigliani, 1978, 1980; Wenger, Thompson, & Bartling, 1980; Whitten & Bjork, 1977; Whitten & Leonard, 1980). This phenomenon has been referred to as the potentiating effect of test trials (Izawa, 1971). Second, Landauer and Bjork (1978) have provided compelling evidence for not only for the potentiating effect of recall tests, but also for increased effectiveness with spaced schedules of testing (in which several tests follow presentation) compared to other schedules. Their study has provided the model for the present application to the learning of multiplication tables and spelling lists by third grade pupils, and will therefore be examined in some detail.

Landauer & Bjork (1978) conducted two experiments concerned with optimal scheduling of recall tests following a single presentation of material. In the first experiment, the initial presentation (P) was followed by three tests (T1, T2, T3), and a final retention test (T4) thirty minutes after T3. The material presented was the first and last names of fictitious persons. A test was comprised of the presentation of the first name and a request to recall the last name that had accompanied it on the initial presentation. The distraction intervals (D1, D2, and D3) between P, T1, T2, and T3 were filled with intervening items consisting of other presentations and tests. Thus, the sequence was P, D1, T1, D2, T2, D3, T3, with the value of D1, D2 and D3 varying according to a number of different patterns and with T4 always following thirty minutes after T3. The number of intervening items in the three intervals were arranged in three different patterns.

The uniform series had intervals with an equal number of intervening items in D1, D2, and D3. The expanding series had an increasing number of items in each interval. That is, $D1=0$, $D2=3$, and $D3=10$. The contracting series had the same values but in the reverse order, i.e. $D1=10$, $D2=3$, and $D3=0$ intervening items. These last two patterns therefore differed in the scheduling of distraction periods between P and T3, but the total elapsed time between these two events was kept constant. In addition to these three patterns of tests, a P only condition

was included which involved the initial presentation, but no tests prior to T4. In this condition subjects were allowed to determine their own rehearsal strategies between P and T4.

The results showed that the probability of recall at T3 was .4 for the 10, 3, 0 sequence, but .6 for the 0, 3, 10 sequence. Thus, the latter resulted in 50% greater recall than the former. The most relevant finding was that the expanding pattern (0, 3, 10) produced almost 100% more correct responses on T4 than the P only condition. In addition, the expanding series was significantly superior to the uniform and contracting patterns in all phases of the study.

The reason for the greater effectiveness of the expanding series seems fairly obvious. If the initial distracting interval (D1) is very short, then the first recall at T1 is likely to be successful. Since a successful recall has a potentiating effect, it is probable that after D2, the second recall will also be correct, even though D2 is longer than D1. The second recall will likewise have a potentiating effect, increasing the likelihood of a successful third recall even though D3 was longer than D2, and so on. The main feature of an expanding test series is that the subject is very likely to experience success at every step due to this particular scheduling of distracting periods and tests.

The second experiment by Landauer and Bjork also demonstrated the effectiveness of an expanding series of tests,

using similar materials. As a result of the first experiment, two schedules of tests were used. In each schedule a single presentation was followed by 4 tests and a final delayed test (T5) 30 minutes after T4. In the uniform series the distracting period was as follows, $D1=D2=D3=D4=3$ intervening items. In the expanded series the distraction period was, $D1=0, D2=1, D3=3, D4=8$ intervening items. Note that the mean value of D in the expanding series was 3, which meant that the total number of items intervening between P and T4 was the same in the two series. As was the case in experiment one, a P only condition was included where subjects were allowed to choose their own rehearsal strategies and were tested at T5 only.

Again, the expanding series produced superior recall in all phases of the study compared to the uniform series and to the P only condition. On T5, the expanded pattern, with the same average spacing, produced significantly superior recall compared with the uniform series, with 66 and 56 percent recall respectively. Also, the largest difference between the expanded (0, 1, 3, 8) series and the uniform series occurred at T1, supporting the hypothesis that the length of the first distracting period (following P) is most important in determining the success of later recall. A third point is that there was very little loss of retention between T4 and T5 (in either the uniform or expanded series) indicating that the first four tests engendered a strong memory of the material. Finally, both the uniform and

the expanded series produced vastly superior recall on the final test compared with the P only group. The uniform series produced 150% greater recall, and the expanded series 200% greater recall than the P only group, a very substantial improvement.

In addition to the above, Landauer and Bjork also looked at the effect of repetitions of the items rather than of test trials. In other words, T1, T2, T3, and T4 became P1, P2, P3, and P4 and a test followed thirty minutes after P4. Again, the series compared were uniform (3, 3, 3, 3), expanded (0, 1, 3, 8) and P only. The results indicated that the level of recall on T5 was impressively high in both uniform and expanded conditions; 58 and 62 percent respectively, but the difference was not significant. However, the interaction between test-type and pattern was significant. This led to the conclusion that an expanded distribution of practice is better than a uniform distribution of practice for test trials, but that they are equally effective for re-presentations of material. It may be, as Landauer and Bjork have assumed, that with the expanded series, successful trials are better than repetitions because they induce a greater effort at encoding, and additionally shape the response behavior required for the final test performance.

In summary, Landauer and Bjork's results provide a compelling demonstration that (a) test trials have a potentiating effect; i.e. they engender strong memory of to-be-remembered material; (b) the scheduling of tests has a

significant effect on how much will be remembered; and (c) expanded series of tests are optimal.

An important aspect of Landauer and Bjork's procedure is that, since it entails only a single presentation followed by a number of tests, it would seem ideally suited to teaching basic materials such as multiplication facts and spelling lists to pupils in elementary grades. Furthermore, the procedure can be used with individuals or groups. Thus, it would be possible to adapt this procedure to teach basic facts in either individualized programs (e.g. remedial math, learning centres, etc.) or as a group instructional method in a regular classroom situation.

The main purpose of this thesis was to use an expanded test series to teach grade three pupils multiplication facts and spelling lists. The hypothesis was that presentation of material in this way would induce greater retention than other currently used instructional methods which typically involve massed repetitions. Three studies were conducted. Study I was a direct application of the procedure developed by Landauer and Bjork (1978). Grade 3 students were taught (on an individual basis) 4 multiplication facts in either an expanded series or the more common unexpanded method, using an audio cassette and a pre-recorded tape. The lack of learning which was evident in either condition suggested the need for further refinement in the methodology. Thus, Study II was conducted in the laboratory

with college students, in order to explore various procedures with the aim of finding one or more that would be adaptable to the classroom situation. As a result of the information obtained from both these studies, Study III was carried out in a school situation with grade 3 students using an improved methodology compared to Study I. This final experiment involved two parts; an individual study and a whole class study. The materials taught in both parts were multiplication facts and spelling lists.

I. Study I

In this study, an attempt was made to teach four multiplication facts to third grade pupils using the methodology developed by Landauer and Bjork (1978). The hypothesis was that the students taught the facts using an expanded test series would remember more than those taught using the more common massed practice series.

Method

Subjects and design: Twenty four grade three students (from one classroom) at Miller Park Elementary School, Coquitlam, B.C. were randomly assigned to one of the two groups. Group one was presented with the material in a manner which reflected a typical classroom method of presentation, i.e. massed practice, and group two received the same material but in an expanded-test series (distributed practice).

Materials and procedure: The material used for the study was seven facts from the seven times multiplication tables. The four target facts were 7×3 , 7×4 , 7×5 , and 7×6 , and the three additional facts used as distractors were 7×1 , 7×2 , and 7×7 . A pre-test determined that the only facts the majority of

students could answer correctly were 7×1 and 7×2 . Group one was presented with the facts in the following manner:

Presentation of fact one	(P1F1)	$7 \times 1 = 7$
Test one of fact one	(T1F1)	$7 \times 1 = ?$
Test two of fact one	(T2F1)	$7 \times 1 = ?$
Test three of fact one	(T3F1)	$7 \times 1 = ?$
Test four of fact one	(T4F1)	$7 \times 1 = ?$
Test five of fact one	(T5F1)	$7 \times 1 = ?$

After a seven second pause, fact two (7×2) was similarly presented and tested, and so on for the remaining facts (7×3 through 7×7 , in that order). Sixty seconds after the conclusion of this sequence, a final test of all seven facts was given. The whole sequence, including the test, was presented using a pre-recorded tape on an audio-cassette player. Presentation of each fact and the test of each fact took 2 seconds and response time allowed was 4 seconds. Thus the total time for the learning sequence was 4 minutes 26 seconds. The test questions on the final test took 2 seconds each, and the response time allowed for each was 6 seconds, for a total of 56 seconds.

For group two, the expanded series was presented as follows:

	Presentation of fact one	(PF1)	$7 \times 1 = 7$
	Test one of fact one	(T1F1)	$7 \times 1 = ?$
	Presentation of fact two	(PF2)	$7 \times 2 = 14$
	Test one of fact two	(T1F2)	$7 \times 2 = ?$
	Presentation of fact three	(PF3)	$7 \times 3 = 21$
*	Test one of fact three	(T1F3)	$7 \times 3 = ?$
	Test two of fact one	(T2F1)	$7 \times 1 = ?$
*	Test two of fact three	(T2F3)	$7 \times 3 = ?$
	Presentation of fact four	(PF4)	$7 \times 4 = 28$
*	Test one of fact four	(T1F4)	$7 \times 4 = ?$
*	Test three of fact three	(T3F3)	$7 \times 3 = ?$
*	Test two of fact four	(T2F4)	$7 \times 4 = ?$
	Test two of fact two	(T2F2)	$7 \times 2 = ?$
	Test three of fact one	(T3F1)	$7 \times 1 = ?$
*	Test three of fact four	(T3F4)	$7 \times 4 = ?$
*	Test four of fact three	(T4F3)	$7 \times 3 = ?$
	Presentation of fact five	(PF5)	$7 \times 5 = 35$
*	Test one of fact five	(T1F5)	$7 \times 5 = ?$

(and so on, for all seven facts)

(see Appendix A for complete sequence)

As can be seen from the above, the target facts (*) were tested in an expanded manner. The number of intervening items between successive tests were 0, 1, 2, 4 and 8, and consisted of both familiar facts and target facts. Again, presentation and test time were 2 seconds each, and response time allowed was 4

seconds. As with group one, the total sequence took 4 minutes 26 seconds. This group was given the same final test as group one, 60 seconds after completion of the learning sequence.

Presentation of all the material and tests was auditory, using a pre-recorded tape (female voice), and played on a cassette player. The students' responses were recorded for later analysis. Students were seen individually in a small room and were seated at a table beside the experimenter. They were verbally given a standard set of instructions (see Appendix B) and were then played a brief practice tape of known facts (i.e., $2 \times 2 = 4$; what is 2×2 ?, etc.) to familiarize them with the procedure. Next they were played the learning sequence. During the 60 second distraction period following this, they were asked a few conversational questions, e.g. "Do you like school?"; and "What is your favorite subject?", and were then given the final test. Students were thanked for assisting with the test, and for attempting to memorize a difficult sequence of facts. Subjects for each group were run using an AB,BA sequence. The experiment was conducted over four days during the normal math period.

Results and discussion

The results were not as expected; there was an average recall of only .66 facts for both groups. The only correct recalls, however, were due to responses given by subjects run

toward the end of the study. Thus, even this small level of retention may have been due to prior knowledge of the nature of the experiment on the part of the last few subjects run in both groups. If these subjects are excluded, the mean retention level falls to nearly zero. This floor effect may have been due to a number of procedural factors. Perhaps too many facts were presented in a series; speed of presentation may have been too rapid, or the overall length of the learning sequence may have been too long. Perhaps the strictly auditory mode of presentation was inadequate, given that the children usually see the material to be memorized. The vocalization on the tape may not have been varied or lively enough to induce the necessary attention for learning to take place. The students had been informed that some testing would be taking place and that they would be working individually with the experimenter. Thus, test anxiety may have created a stressful situation which interfered with performance.

It is also possible that in spite of the expectation, the procedure was too difficult to follow. The essentially nil results of this study indicated that application of laboratory findings to the classroom situation was not as straightforward as had been imagined. Consequently, a second study was planned, to be carried out in the laboratory, in an effort to discover procedures that would be more effective when used with children.

II. Study II

In an attempt to clarify some of the issues raised in the initial study and to refine the methodology, a second experiment was conducted in the laboratory using college students. Practical constraints precluded using children in this study. It was felt, however, that sufficient valuable information could be obtained using a college population, which would allow a return to the classroom with a more refined and workable system. Therefore, of prime interest in this study were procedural matters. First, an examination of teaching machines (e.g. Speak 'n Math, Speak 'n Spell) and computer assisted learning programs (e.g. Apple) indicated that an audio visual mode of presentation would probably be most effective. This would encourage the transfer of learning across sensory modalities, possibly inducing overall superior retention (Wetstone & Friedlander, 1974). It was therefore decided to use audio visual presentation of material for this study. Second, three conditions were used in an attempt to discover the optimal type of sequence for efficient and effective learning. The to-be-remembered material was fifteen facts, the square roots of four digit random numbers.

Condition A was essentially the same pattern as the expanded test series in the first study. By using the tests of

the target facts as distractors (D), this sequence took half as much time to present as either of the other two conditions described next. Condition B was also an expanded test series, but each fact was presented singly, and expanded with familiar square roots as distractor items. This series was expected to be easier to learn than A. Condition C was equivalent in length to B, and had the same number of distractors (D), but the repetition of tests was massed. Each of the above conditions was given to one of two groups, a pre-timed group and a self-paced group. The pre-timed group received the material according to a predetermined schedule of presentations and tests (automatically controlled by electronic pulse cues on the tape). The self-timed group received the same material, but was allowed to control presentation and response rates. This latter group was included in order to gather time related information such as the length of time students took to spontaneously rehearse an item after its initial presentation, the amount of time taken to respond, as well as any data which might aid in developing an appropriate methodology for a practical educational application.

Method

Subjects: Thirty six male and female undergraduates at Simon Fraser University were randomly assigned to one of the two between-subjects groups. The subjects were paid \$4.00 each for

their participation in the study.

Design: The design was a 3 x 2 factorial. Condition (A, B, C) was a within-subject factor, and time (pre-timed vs. self-timed) was a between subject factor. In the pretimed group, presentation, test rate and response time were predetermined, while in the self timed group these factors were under the control of the subject. To avoid any effect of order, the three conditions were counterbalanced across subjects within both groups.

Materials and procedure: Each of the three within-subject conditions contained five target facts. These facts were the square roots of four digit random numbers (e.g. the square root of 5794 = 76.12). It was felt that this material was in some sense of equivalent difficulty for college students to memorize as unfamiliar multiplication facts would be for grade three students. The distracting task material was the square root of familiar numbers (e.g. the square root of 36 = 6). A description follows.

Condition A: This was an expanded series, and was equivalent to the experimental condition used in Study I. This sequence was an extrapolation of Landauer and Bjork's procedure and provided a time-efficient manner of presentation of material. The sequence was as follows:

Exposure and
Response time

Presentation of fact one	(PF1)	4 seconds
Test one of fact one	(T1F1)	6 seconds
Presentation of fact two	(PF2)	4 seconds
Test one of fact two	(T1F2)	6 seconds
Test two of fact one	(T2F1)	6 seconds
Distraction one	(D1)	4 seconds
Test two of fact two	(T2F2)	6 seconds
Presentation of fact three	(PF3)	4 seconds
Test one of fact three	(T1F3)	6 seconds

(and so on for all five facts)

(see Appendix C for complete sequence)

The number of intervening items between tests was 0, 1, 2, 4 and 8. That is, between T1 and T2 there was one intervening item, between T2 and T3 there were two intervening items, between T3 and T4, four intervening items, and between T4 and T5, eight intervening items. As can be seen above, the intervening items were the presentation of new facts, tests of these facts and some familiar distractors. Thus, in Condition A there were two kinds of items used to expand the series; tests of the target facts and tests of known facts (e.g., what is the square root of 81 ?) The presentation of each fact took 4 seconds, the test of a fact 2 seconds, and the response time allowed was 4 seconds. The distraction tasks (familiar items) took 4 seconds each, i.e.

1 1/2 seconds for the question and 2 1/2 seconds for the response. The total learning time for this sequence was 4 minutes 20 seconds. A test (T6) of all five facts (in the same order as presented) was given 10 seconds after T5F5. This last test took 45 seconds total (3 seconds for each test question and 6 seconds for each response). Thus the total time for Condition A was 5 minutes 20 seconds. Immediately after test 6, subjects were given the same sequence a second time (A2). Consequently, Condition A (A1 plus A2) took approximately 10 minutes 40 seconds to administer, making it just slightly longer than Conditions B and C (9 minutes 25 seconds each).

Condition B: This was also an expanded series, but the five facts were presented singly and expanded with only familiar distractors. The material was presented and tested as follows:

	<u>Exposure and</u>	
	<u>Response time</u>	
Presentation of fact one	(PF1)	4 seconds
Test one of fact one	(T1F1)	6 seconds
Distractor one	(D1)	4 seconds
Test two of fact one	(T2F1)	6 seconds
Distractors 2 - 3	(D2-D3)	8 seconds
Test three of fact one	(T3F1)	6 seconds
Distractors 4 - 7	(D4-D7)	16 seconds

Test four of fact one	(T4F1)	6 seconds
Distractors 8-15	(D8-D15)	32 seconds
Test five of fact one	(T5F1)	6 seconds

There was a 5 second delay following response to T5F1 and then fact two was presented in a like manner, and so on until all five facts were presented. As was the case with Condition A, this series contained 0, 1, 2, 4 and 8 intervening items between tests, and was also followed by a sixth test of all five facts 10 seconds after T5F5. The whole sequence took 9 minutes 25 seconds.

Condition C: This condition was the same length as B, contained five facts, and was equivalent to the control condition in Study I. The material was presented and tested as follows:

Distractors 1 - 7	(D1-D7)
Presentation of fact one	(PF1)
Test one of fact one	(T1F1)
Test two of fact one	(T2F1)
Test three of fact one	(T3F1)
Test four of fact one	(T4F1)
Distractors 8-15	(D8-D15)
Test five of fact one	(T5F1)

A delay of five seconds occurred after response to T5F1 and then the next sequence containing fact two began, and so on until all five facts were presented. A sixth test of all five

facts followed 10 seconds after T5F5. As can be seen from the above, testing of the facts was massed for the first four tests, followed by 8 intervening items before T5. This allowed a direct comparison with Condition B on a test of retention at T5, as well as a test of all items on the sixth test (T6). It was assumed that this condition mimicked usual memorization practices. For example, a child attempting to learn the spelling of a new word may look at the letters in the word, repeat them and then test herself three or four times before feeling she has learned the material.

Finally, after all 3 conditions had been presented, a written test (T7), which was comprised of a separate sheet for each condition, was administered. (see Appendix D for sample). This followed 10 seconds after T6 and occurred (in the pre-timed group) approximately 30 minutes after the start of the experiment and was an untimed paper and pencil test of all facts for each condition, with test order of conditions counterbalanced within T7.

The stimulus materials were presented on slides with accompanying vocalization on audio cassette, on a Singer Caramate rear screen slide viewer. Each subject was seen individually, and after a standard set of instructions (See Appendix E), was tested in a sound proof booth. A brief practice slide/tape sequence was played for familiarization purposes. For the self-timed group, this practice session provided an

opportunity for using the self-paced apparatus. This consisted of a hand held button which, when pressed, advanced the tape and changed the slide. Release of the button stopped the tape, thus allowing the subject to hold the slide on the screen for as long as desired. Times between offset and onset of the button press were recorded. For the pre-timed group slide changes, presentation rate, and response time were automatically controlled by cue pulses on the tape. All subject responses were recorded for later analysis. Following the written test a brief questionnaire was completed by all subjects (see Appendix F). The object of the questionnaire was to gather further information regarding the different conditions, the type of strategies used, preference for a particular condition, the most difficult condition, etc.

To summarize, this study was carried out in an attempt to discover a workable methodology which would allow the practical application of the spacing effect in a school situation. An expanded series of tests for each to-be-learned fact (Condition B) was compared with a massed practice series (Condition C) in order to determine which condition would be more effective for retention when tested at three different times (T5, T6 and T7). Condition A was a direct extrapolation of Landauer and Bjork's (1978) procedure, was similar to the experimental condition in Study I, and consisted of an expanded series containing all the to-be-learned facts. Condition A contained the same number of

target facts as B and C, but, since tests and presentations of facts served as distractors for other facts, took approximately half as much time to present. Considering the time factor only, it was thus possible to present Condition A twice in a total time comparable to that taken in either B or C.

Results and discussion:

Recall data: Statistical analyses confirmed what is fairly evident from the data shown in Figure 1. (Means and Standard Deviations are summarized in Table 1; see Appendix G for overall analysis of variance). First, there were no significant differences between the pre-timed and the self-timed groups on any of the three tests in either Condition B or C. Additionally, there was no within group difference between B and C on any of the three tests for either group.

Second, for both groups in Condition B and C, there was an equivalent, and rather dramatic loss of information from T5 to T6, and less so from T6 to T7.

Third, the self-timed group was generally superior to the pre-timed group in the A condition. This superiority was statistically significant for A1 at both T5 and T6, $F(1,34)=6.05$ and 4.50 , respectively, $p < .05$ in both cases, as well as for A2 at T7, $F(1,34)=6.25$, $p < .01$.

Figure 1

Percent recall on tests 5, 6, and 7, as a function of Condition (A1, A2, B, and C) for the pre-timed and self-timed groups.

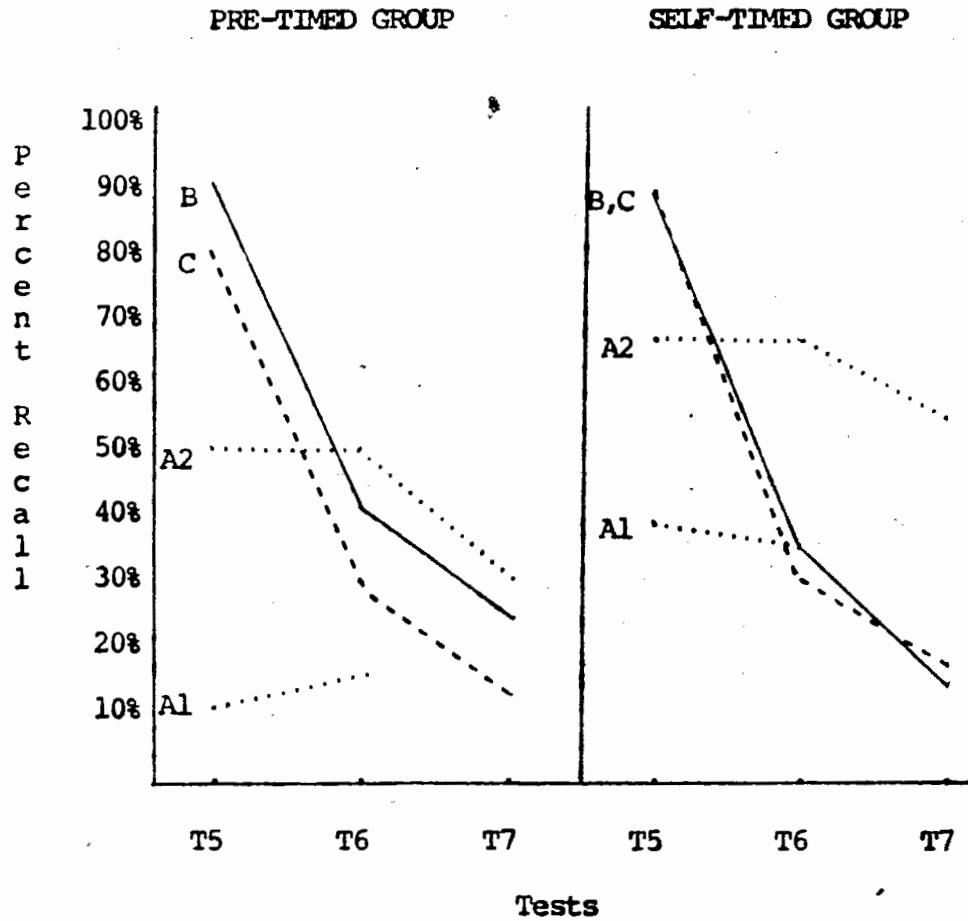


TABLE 1

Means and Standard Deviations for the Pre-timed and Self-timed groups on tests 5, 6, and 7, as a function of condition, A1, A2, B, and C.

		Pre-timed	Self-timed
		group	group
A1	Test 5	M .61	1.89
		SD .78	1.75
	Test 6	M .78	1.73
		SD .81	1.74
A2	Test 5	M 2.50	3.33
		SD 1.50	1.41
	Test 6	M 2.44	3.33
		SD 1.29	1.75
	Test 7	M 1.50	2.67
		SD 1.15	1.60
B	Test 5	M 4.50	4.39
		SD .86	.70
	Test 6	M 2.05	1.72
		SD 1.30	1.02
	Test 7	M 1.22	.72
		SD 1.52	1.07

C	Test 5	M	4.05	4.39
		SD	1.00	.84
	Test 6	M	1.44	1.50
		SD	1.42	1.54
	Test 7	M	.55	.78
		SD	.86	1.11

Fourth, unlike the results of Conditions B and C, there was no loss of information between T5 and T6 in either A1 or A2, but there was a comparable loss between T6 and T7 for both groups.

Fifth, recall was superior on both T6 and T7 in Condition A2 compared to B and C, for both the pre-timed and self-timed groups. In the pre-timed group, however, the difference between A2 and B on either T6 or T7 was not significant. The difference between A2 and C was significant at both T6 and T7 for this group, $t(17)=2.46$ and 2.58 , respectively, $p < .05$ in both cases, Bonferroni corrected t-statistic (Dunn, 1961). For the self-timed group, A2 was significantly superior to both B and C on T6 and T7, all t-test values ($df=17$) $>$ than 3.90 , $p < .01$, Bonferroni corrected t-statistic (Dunn, 1961).

Finally, as can be seen from Figure 1, Condition A produced some interesting results. After receiving the second presentation of the material (A2), subjects in both groups improved their recall on T5 and T6 quite dramatically compared to their performance after one trial (A1).

Time data (self-timed group): Table 2 shows the total time taken by the self-timed group in each condition compared to the time allowed for the pre-timed group. In all cases, the self-timed group took significantly longer than the pre-timed group, all t-test values ($df=17$) $>$ 3.80 $p < .01$, Bonferroni corrected t-statistic (Dunn, 1961).

TABLE 2

Comparison between Pre-timed and Self-timed groups on total time taken in seconds from beginning of sequence to the end of test 6, including distractors, for Conditions A1, A2, B, and C.

Pre-timed Group	Self-timed Group	t	p
A1 325 secs	505 secs	4.86	.001
A2 325 secs	415 secs	4.78	.001
B 565 secs	677 secs	4.18	.001
C 565 secs	715 secs	3.80	.01

TABLE 3

Average time, in seconds, taken per fact on P and each test trial (T1 to T6) for each condition A1, A2, B, and C, for the Self-timed group. (The Pre-timed groups' times are in brackets).

P	T1	T2	T3	T4	T5	T6
A1	16.6 (0)	4.1 (4)	6.8 (4)	6.7 (4)	8.5 (4)	7.6 (4) 10.2 (6)
A2	10.4 (0)	3.5 (4)	4.6 (4)	5.5 (4)	5.1 (4)	6.9 (4) 6.1 (6)
B	16.4 (0)	3.3 (4)	3.9 (4)	3.3 (4)	2.9 (4)	3.1 (4) 18.5 (6)
C	20.9 (0)	2.8 (4)	2.5 (4)	3.6 (4)	2.9 (4)	6.6 (4) 15.2 (6)

Table 3 shows the average time, in seconds, taken on each event (P, T1 through T6) for each condition by the self-timed group. The times allotted the pretimed group for the same events are shown in brackets.

The most noteworthy feature of the data in Table 3 is that in all conditions the self-timed group spent a considerable amount of time during the initial presentation (P) engaging in continuous and massed rehearsal of the to-be-remembered material. Interestingly, the recall data showed that the extra time did not help the self-timed group compared to the pre-timed group in the B and C Conditions, but did so in the A condition.

Questionnaire Data:

An examination of the questionnaires showed that in response to the question regarding which condition felt most comfortable, Condition B was preferred by 50% of the subjects. These subjects also reported that they felt they had learned more in Condition B. Approximately 25% of the subjects preferred Condition A, and reported that receiving the sequence twice was helpful. The 25% who preferred condition C felt it was best because it reflected their normal method of memorization.

When subjects were asked which condition they found the most difficult, 50% reported that A was hardest. The main reason would appear to be the lack of a discernible pattern of

presentations and tests. Thirty-three percent reported that C was the most difficult and the remaining 17% felt that B was the hardest.

Sixty-one percent of subjects in the pre-timed group reported that they would like to have had more time to think before answering. Thirty-nine percent felt that the time allowed was adequate.

Conclusions: The main purpose of this study was to explore different procedures in the hope of finding one or more methods that would be more adaptable to the classroom situation than the one used in Study I. The results of Study II pointed out a number of important factors in this regard.

First, regarding mode of presentation, the behavior and comments of subjects indicated that the chosen audio-visual mode worked very well. It was clear that it was a vast improvement over the method used in Study I. The use of this method was therefore continued in Study III.

Second, the time information provided by the self-paced group offered a more realistic foundation for determining suitable presentation rates and response intervals. It was decided to use a pre-timed mode of presentation in Study III, mainly for practical considerations. The presentation and response rates were modified with respect to those used in Study I, as a result of the information obtained in the self-paced part of the study.

Third, in the pre-timed group, Condition A was not significantly superior to Condition B. Since Condition B was perceived as the easiest in Study II, it was decided to use this sequence of spacing in Study III. Condition C was again used as a control.

Fourth, the difference between performance in Condition B and C was not significant in either group. As Melton (1970) pointed out, the spacing effect is a robust phenomenon and when not demonstrated, methodological or other factors should be suspected. On the basis of subjects' comments the present results were probably due to the the distracting task not being of sufficient difficulty to prevent rehearsal in Condition B.

Finally, ~~the~~ loss of retention between T5, T6 and T7, due to unsuccessful trials, pointed to the need to provide feedback to subjects after each test, with the aim of reducing such a loss. A feedback procedure was therefore incorporated in the series used in Study III.

In sum, this study, carried out in a laboratory setting, provided very valuable suggestions for procedures to be used in applied research with school children.

III. Study III

Study III was carried out in a school situation with grade three students and was comprised of two experiments run over a two week period. Experiment IIIA was a direct application of the methodology and results of Study II. Subjects were tested individually and the materials (multiplication facts and spelling lists) were presented audio-visually. A comparison was made between subjects who received distributed practice (expanded series) and subjects who received massed practice series. The expanded series was similar to Condition B in Study II. The difference was that in the present case, subjects were given feedback after each test. In the previous study there was a single presentation followed by an expanded series of test trials. It became apparent that if a subject forgot an item on any test there was a very high probability that it would not be retrieved on subsequent tests. In order to counteract any memory loss due to unsuccessful trials and to provide immediate feedback to the subject, a brief re-presentation followed the test trials in the present study. The massed practice sequence was like Condition C in Study II, but again with feedback following each test.

Experiment IIIB was run in an attempt to determine whether

the procedures of Experiment IIIA would be effective in a group situation. Having gained access to a school population for experimental purposes it was felt that use of this opportunity to try out a group procedure should not be missed. Experiment IIIB involved whole class instruction. Again, the distributed series was compared with a massed practice method of learning and the material was multiplication facts and spelling words. Students received drill sheets which reflected either a massed or expanded series of presentations and tests. It was planned from the beginning that the group study would be run before Experiment IIIA in order to avoid possible methodological confounds resulting from all subjects having individual contact with the experimenter. However, because IIIA is methodologically and procedurally related more directly to Study II, it will be discussed first.

IV. Experiment IIIA

Method

Subjects: Subjects in this study were 44 male and female students (average age 8.5 years) from two grade three classes at Cedar Drive Elementary School, Port Coquitlam, B.C. Their teachers were asked to rank the students on two variables, math and spelling ability, and on this basis two groups were formed (distributed practice and massed practice) each for math and spelling.

Design: the design involved the comparison of two groups (expanded versus massed practice) with each of two different types of material, multiplication facts and spelling lists. Half the students received the math condition first and half the spelling condition first. The math facts and spelling words were presented to all the subjects in the same order, but two orders of testing the material were used, counterbalanced across subjects. Thus, subjects learned the material sequentially, 1 to 5, but were tested in order one, i.e., 3,2,5,4,1, and in order two, the opposite (1,4,5,2,3). In each group (massed and expanded) the order of testing subjects followed an AB, BA

pattern. There were two tests, an oral test one minute after the learning session and a written test immediately after completion of the first test. Subjects who received order one in the oral test, received the same order in the written test, and likewise for order two.

Materials: A pretest was administered to all the students for both math facts and spelling words, in order to generate a list of stimulus materials. As a result of this, five multiplication facts and four words were selected on the basis of their difficulty for these students. The material used for the distraction tasks were all familiar multiplication facts and known spelling words.

The resulting materials were (a) five multiplication facts (8 x 5 to 8 x 9) and (b) four spelling words (brought, happily, machine, police). As was the case in Study II, both types of material were presented on slides with accompanying vocalization on audio cassette (female voice), on a Singer Caramate rear screen slide viewer. There was a single order of presentation in both conditions. Slide changes, presentation rate and response time were automatically controlled by electronic cue pulses on the tape. The oral test was the same format as the learning session (i.e., slide-tape) and subjects responses were tape recorded. The written test was a single sheet containing all five facts in the math condition (Appendix H). In the spelling condition the written test was presented orally on a prerecorded

cassette tape and the subjects wrote their responses on a blank sheet of paper.

Procedure: Each subject was seen on an individual basis in a small room. After receiving a standard set of instructions (see Appendix I) the subject was seated facing the screen with the experimenter positioned behind. A brief practice session was then given for familiarization purposes. Subjects in the expanded series group received the following sequence:

		<u>Exposure and</u>	
		<u>Response time</u>	
		<u>Math</u>	<u>Spelling</u>
Presentation one of fact	P1	5 secs	10 secs
Test one of fact	T1	6 secs	10 secs
Presentation two	P2	4 secs	5 secs
Distractor one	D1	5 secs	5 secs
Test two	T2	6 secs	10 secs
Presentation three	P3	4 secs	5 secs
Distractor two	D2	5 secs	5 secs
Distractor three	D3	5 secs	5 secs
Test three	T3	6 secs	10 secs
Presentation four	P4	4 secs	5 secs
Distractor four	D4	5 secs	5 secs
Distractor five	D5	5 secs	5 secs

Distractor six	D6	5 secs	5 secs
Distractor seven	D7	5 secs	5 secs
Test four	T4	6 secs	10 secs
Presentation five	P5	4 secs	5 secs

This was followed by an interval (15 seconds in spelling and 10 seconds in math) after which the next fact or word was presented in the same sequence. There were a total of 5 math facts and 4 spelling words. There was a one minute distraction interval at the end of the learning sequence during which students were asked a few conversational questions while the tape and slide trays were changed. The oral test was administered after this one minute distraction period. Subjects were allowed 10 seconds response time for each math fact and 12 seconds for each word in the spelling condition, again automatically timed. Responses were tape recorded for later analysis. Upon completion of the oral test, subjects were given the untimed written test. In the math condition this involved a sheet containing all five facts. Subjects were instructed to take their time and attempt to remember as many facts as they could without resorting to working the answers out. In the spelling condition the subjects listened to the test questions on the tape and wrote their answers on a blank sheet of paper. Advancement of the tape was under experimenter control and thus each question was answered or attempted before the next one was presented. Again the subjects were instructed to take their time

and attempt to remember what they had learned. The purpose of the written test was to allow an additional opportunity to respond without time constraints. The total time for the learning sessions was 7.5 minutes for math and 8 minutes for spelling with the oral tests taking 50 seconds and 60 seconds respectively.

The massed practice groups received exactly the same conditions, the only exception being the sequence of distractors, tests, and presentations. Under the massed condition all seven distractors occurred first followed by a sequence of presentations of facts, tests and re-presentations, as follows:

Distractors one to seven	D1-D7
Presentation one	P1
Test one	T1
Presentation two	P2
Test two	T2
Presentation three	P3
Test three	T3
Presentation four	P4
Test four	T4
Presentation five	P5

Exposure time, response time, inter-item intervals and tests were all of the same duration as in the distributed practice condition. As can be seen from above, this sequence

corresponds to Condition C in Study II. Both groups in this study received exactly the same material, the same number of presentations, tests and distractors, and were thus equivalent in every way except in the sequencing of test trials and presentations. Subjects were not informed concerning the correctness of their responses on the tests but were thanked for taking part and told that they had done well on a very difficult task.

Results and discussion

The results of the math and spelling conditions were analysed separately.

Multiplication facts: Mean scores and Standard Deviations as a function of group (distributed versus massed), class, and level (top half of the class versus bottom half) obtained on the oral and written tests for are shown in Table 4. A 2(group) X 2(class) X 2(level) analysis of variance was performed on the data for the oral and written tests separately (See Appendix J). For the oral test there was a significant main effect for group ($F(1,36)=15.69, p < .001$). Subjects who learned the material in an expanded series of test trials (overall mean=2.04) recalled twice as much on the oral test as those who learned the same material with a massed practice series (overall mean=1.01).

TABLE 4

Mean scores and Standard Deviations on the oral and written tests of math facts by group, level and class.

		Class One		Class Two		Group Mean
		Level 1	Level 2	Level 1	Level 2	
		(High)	(Low)	(High)	(Low)	
ORAL TEST						
DP Grp.	M	1.17	1.80	3.20	2.00	2.04
	SD	.41	.84	.45	1.10	
	n	6	5	5	6	
MP Grp.	M	.60	.67	2.17	.60	1.01
	SD	.55	.52	1.33	.55	
	n	5	6	6	5	
WRITTEN TEST						
DP Grp.	M	1.50	2.00	3.80	3.33	2.66
	SD	.84	1.00	.84	1.03	
	n	6	5	5	6	
MP Grp.	M	.80	1.17	2.83	.80	1.40
	SD	1.10	.75	1.47	.84	
	n	5	6	6	5	

Similarly, there was a significant difference of almost the same magnitude between the two groups' scores on the written test, ($F(1,36)=14.99$, $p < .001$), with overall means of 2.66 and 1.40 for the distributed and massed groups, respectively.

On both the oral and written test there was a significant main effect for class (Oral test: $F(1,36)=15.69$, $p < .001$; written test: $F(1,36)=19.96$, $p < .001$). It can be inferred from this data that class two was superior to class one in math ability, at least as measured by this test.

On the oral, but not the written test there was a significant main effect for level ($F(1,36)=4.30$, $p < .05$). This finding suggests that those students ranked in the top half of the class on math ability, tended to perform better on a timed verbal test (but not on an untimed written test) than those ranked in the bottom half.

There was an interaction between class and level on both the oral and written tests. Higher ranked students in class one did not do as well as those ranked low, in either the massed or distributed conditions. This interaction would seem to indicate that the teacher's ranking of the students in this class may not have reflected their performance potential, at least on a memorization task.

A t-test showed that both groups did significantly better on the written test than on the oral test ($t(42)=3.55$, $p < .001$). This difference may have been due to the lack of time

constraints on the written test. Further, the children may have performed better because the written test reflects the normal method of testing. Alternatively, the possibility cannot be ruled out that the children may have computed some answers, contrary to the instruction to rely on memory.

Spelling: Means and Standard Deviations on both the written and oral tests for each group are shown in Table 5. A 2(group) X 2(class) X 2(level) analysis of variance (see Appendix K) showed that there was no main effect for class in either the oral or written tests. Thus, as far as spelling ability was concerned there was no difference between the two classes. There were, however, main effects for both group and level. As can be seen from Table 4, the expanded series group correctly recalled 89.8% ($M=3.59$) of the words on the oral test, compared to 79.5% ($M=3.18$) for the massed practice group; a significant difference ($F(1,36)=4.24, p < .05$). On the written test both groups improved their performance. The expanded series group had an average of 95.5% correct responses ($M=3.82$), compared to 87.5% ($M=3.5$) for the massed practice group. This again was a significant difference ($F(1,36)=4.15, p < .05$). These results make it clear that an expanded series of tests is a more effective way to learn spelling than the more commonly used massed practice, even at high levels of performance.

TABLE 5

Mean scores and Standard Deviations on the oral and written tests of spelling facts by group, level and class.

		Class One		Class Two		Group Mean
		Level 1 (High)	Level 2 (Low)	Level 1 (High)	Level 2 (Low)	
ORAL TEST						
DP Grp.	M	3.83	2.80	4.00	3.67	3.59
	SD	.41	1.10	.00	.52	
	n	6	5	5	6	
MP Grp.	M	3.60	2.67	3.67	2.80	3.18
	SD	.55	.82	.52	.84	
	n	5	6	6	5	
WRITTEN TEST						
DP Grp.	M	4.00	3.40	4.00	3.83	3.82
	SD	.00	.89	.00	.41	
	n	6	5	5	6	
MP Grp.	M	3.80	3.50	3.67	3.00	3.50
	SD	.45	.55	.52	.71	
	n	5	6	6	5	

There was also a significant main effect for level on both the oral ($F(1,36)=15.13$, $p < .001$) and written test ($F(1,36)=6.86$, $p < .01$). Those students ranked high on spelling ability performed better than those ranked low, thus confirming their teachers' assessment.

A t-test showed that there was a significant difference between scores on the written and oral tests ($t(42)=3.62$, $p < .001$). As had been the case with multiplication facts, children performed significantly better on an untimed written test than on a timed oral test. This result is not surprising since tests in spelling are typically in written form with fairly long response times.

The main result, i.e., that distributed practice works better than massed practice for learning to spell, is an important finding. The emphasis on a massed practice approach to spelling, as advocated in many spelling texts (e.g., The Canadian Basic Spelling Program 3), may not be the most productive in light of these results. Instructions which direct the student to distribute practice and review would be more beneficial.

The results of Study IIIA make it clear that the benefits of spaced practice need not be confined to a laboratory situation. These findings provide strong evidence that a practical application of the spacing effect can substantially increase the amount of material students learn in school. A

sizeable and striking effect was achieved with multiplication tables and a somewhat lesser effect with spelling words.

V. Experiment IIIB

As mentioned previously this part of the study was carried out in an effort to determine whether procedures from Experiment IIIA could be effectively adapted for a group or whole class situation using typical classroom material, i.e., drill sheets.

Method

Subjects: The same subjects were used in both parts of the study. The composition of the two groups was changed, however, in order to eliminate possible carry-over effects from one study to the other. Thus, half the subjects who received distributed practice in Experiment IIIA received massed practice in Experiment IIIB and vice versa. The teachers' rankings (i.e., level) were still used, so that each group had an equal number of high level and low level students.

Design: Two groups, expanded practice and massed practice, were compared on performance on two written tests after whole class training with drill sheets over a three day period. Two types of material were used, multiplication facts and spelling words, and the composition of the groups for each condition varied according to teachers rankings of students' math and

spelling ability. Thus, as was the case in IIIA, the design was a simple two group comparison on two tests, for each condition, math and spelling.

Material: The material for this experiment consisted of drill sheets containing either multiplication facts or spelling words. In the math condition the distributed practice group received a drill sheet consisting of 6 target facts (7 x 4 to 7 x 9) which were tested four times each with an expanding number of distractors (familiar facts) between each test. For the massed practice group the drill sheet was essentially the same except that the target facts were tested successively with zero intervening items. A similar design was followed for the spelling list and in this condition five words were used (guess, suddenly, earth, through, circus). Examples of drill sheets for each condition are in Appendices L and M.

Procedure: For both spelling and math, the drill sheets were distributed during the regular language arts or math periods on three consecutive days. Students' names were written on the drill sheets so that subjects assigned to either group (expanded or massed) received the appropriate material without calling attention to the fact that there were two different conditions. Thus it was possible for the teacher to give a standard set of instructions to all students in her class. For the spelling drill the five target words were introduced in the normal manner on day one (i.e., written on the chalkboard,

spelled out letter by letter, given a definition and used in the context of a sentence). The instructions given to the students were to learn the words by working through the drill sheets. The students were informed that there would be a test on day four but were not informed regarding the test on day seven. At the end of the drill session the sheets were collected and on the two subsequent days the same procedure was followed but without the introduction. A similar program of training was carried out with the multiplication facts.

Results and discussion:

The data from this experiment did not show the predicted spacing effect. There were no significant differences between the two groups in either the math or spelling conditions on either test one or test two. Table 6 shows the mean and percent recall scores for the two groups on each test in both conditions. In the math condition the results of test one showed that the distributed practice group on average recalled correctly 3.85 of the 6 facts (64%) compared to the massed practice group's 3.25 (54%), a non-significant difference. On a surprise test three days later recall for the DP group was 57% compared to 59% for the massed practice group, again a non-significant difference.

TABLE 6

Mean and percent scores on spelling and math tests one and two for the distributed practice and massed practice groups.

MATH TEST

	Test One	Test Two
Distributed practice Group	3.85 (64%)	3.40 (57%)
Massed practice Group	3.25 (54%)	3.55 (59%)

SPELLING TEST

	Test One	Test Two
Distributed practice Group	4.48 (90%)	4.33 (87%)
Massed practice Group	4.48 (90%)	4.66 (93%)

A similar pattern of results was obtained in the spelling condition. The massed practice group scored exactly the same as the distributed practice group on test one, an average of 4.48 correct out of 5 (90%). On the delayed test there was very little forgetting; the DP group had an average of 4.33 correct (87%) and the MP group 4.66 correct (93%), a non-significant difference.

In effect, the results of this experiment suggest that while drill sheets are effective for learning, the variables which usually produce the spacing effect are not easily controlled or manipulated with this type of material in a classroom situation. However, the fact that distributed practice with drill sheets did not result in learning benefits is not conclusive evidence that such methods cannot be applied in the classroom. Rather, other approaches such as variations in materials that would allow greater control over rehearsal, or giving explicit instructions to distribute practice, need to be investigated.

D. Chapter Four

I. Discussion

For the purpose of further discussion a brief summary of the results of this series of studies may be helpful. In Study I an attempt was made at a direct application of the procedures developed by Landauer and Bjork (1978) to the teaching of some basic multiplication facts to grade three students. The lack of appreciable results led to the design of another study in order to clarify some methodological issues. Thus, Study II was carried out in the laboratory using college students. This study demonstrated a number of important points such as the utility of an audio visual mode of presentation, and provided valuable direction for further research in a school situation. As a result of the procedural information gained from these two experiments, Study III was conducted with grade three children and involved two parts: an individual study (IIIA) and a whole class study (IIIB). The materials used in both parts were multiplication facts and spelling lists. The results of Study IIIA showed that it was possible to apply laboratory findings to facilitate the acquisition of material by students in a school setting. Children who received an expanded series of test trials recalled almost twice as many math facts, and were significantly superior in spelling, than those who received a massed series.

Experiment IIIA:

The results of Study IIIA were most encouraging. The demonstration that memorization of multiplication tables and spelling lists can be facilitated by distributed practice has important implications for education. Factors to be considered in relation to the present research involve possible direct applications of distributed practice as a remedial aid for children with learning problems in math. If children can be helped to experience success in learning basic facts such as multiplication tables, this will have a facilitative effect on learning more difficult concepts such as long multiplication and division.

The slide/tape mode of presentation proved very effective in the present study and could easily be adapted for small group study with the use of multiple headphones. In addition it could readily be included in learning centres. Slides of different sets of facts or words with accompanying tapes could easily be produced and made available for childrens' use.

If training sessions are also distributed (see the following discussion of Study IIIB) then further learning benefits could accrue. Along this line it should be possible to design whole units which make use of distributed practice and would include an expanded series of spaced reviews. An obvious goal of

future research would be to test the effectiveness of such a program.

With the increasing use of computers as instructional aids (e.g., APPLE programs) the possibility of utilizing distributed practice of drills based on the method used in the present research has obvious potential.

The time interval allowed for presentation, test/response and re-presentations in both math and spelling conditions appeared to be optimal. Observations of students reactions during training confirmed that there were virtually no instances where the time allowed was inadequate for a response. The time allowed in the oral test also appeared to be sufficient. The fact that subjects performed better on the written test than the oral test may have been due to other factors. For instance in the math condition, even though the students were instructed to rely on memory, it is quite possible that they may have worked out some of the answers when given the extra time. Overall, the time factors involved in presentation of materials in this manner appear to be satisfactory.

Experiment IIIB:

In this part of Study III an attempt was made to induce within-list distribution of practice with drill sheets. The idea of using a drill sheet is basically sound, as it is the most

common type of practice material encountered in grade school. If it is possible to incorporate distributed practice in this type of material and give a clear demonstration that it works, it would be a very practical application. However, no differences between distributed and massed practice in Experiment IIIB were found.

The lack of effect could have been due to a number of factors which were not under experimental control. First, in the whole class situation and because of the nature of the drill sheets, there was no control over whether the subjects actually followed the instructions to do the drill in the appropriate sequence. It may be that when students are faced with a drill sheet similar to those normally used, they tend to do all the easy facts first and then attempt the more difficult items. Second, because the target facts were presented on the drill sheets, it is quite possible that the students did all the repeated items at one time. If this was the case, then in essence, both groups received massed practice, which would account for the lack of spacing effect. A third and important uncontrolled factor in a situation of this type is what students do between drill sessions (between days, in the present case). For instance, between drills and prior to the test, the students may engage in rehearsal or individual study which would tend to overshadow or obliterate the beneficial effects of a five minute distributed practice drill. It should be remembered, in this

respect, that performance was relatively good in Experiment IIIB. The control of students' study behavior will probably always pose a methodological problem for research on distributed practice when the time intervals between drills is in the order of 24 hours or more.

A related, and probably major factor, is that both the distributed and massed practice groups received practice over days and, it may well be that the effect of distribution of practice within lists is minor in comparison to distribution of drills with longer interval, i.e., over days. For instance, Bloom and Shuell (1981) found that three 10 minute drills distributed over three days produced superior retention compared to three 10 minute drills on a single day. Thus, in the present study while groups received the distributed/massed difference within drills, both groups also received distributed practice over days, (i.e., 24 hours spacing intervals between drills). This fact alone could have contributed to the equivalence in results for both groups. The fact that considerable learning took place as a result of this type of drill (65% DP, 55% MP in math and 90% MP and DP in spelling), and very little evidence of forgetting on a long term test of retention (recall of 57% DP and 59% MP in math and 87% DP and 93% MP in spelling) lends support to the notion that both groups may have benefitted from distributed practice over days.

Further research needs to be conducted in order to investigate this possibility. As a first step it would be worthwhile to replicate the findings of Experiment IIIA in a whole class situation. To this effect, what is needed is a more tightly controlled experiment with better constructed drill sheets designed to minimize subject initiated practice that tends to reduce the difference between distributed and massed conditions. This experiment should first be carried out without practice over days, i.e., within a single session. After the effects of distributed practice in the whole class situation and within a single session have been confirmed, sessions across days could also be instituted to further improve retention of to-be-remembered material.

The results of the Landauer and Ross (1977) study, in which simple instructions to distribute practice proved effective, may be adapted for use in the classroom. This procedure could be utilized to make children aware of the effectiveness of the strategy and to actively teach them to use it for drill, reviews, etc.

Implications for Future Research

The information gathered in Study II may also have value for future research and practical applications. One sequence that was tested (Condition A) involved an expanded series of

distributed practice in which the distraction interval was filled with test trials of the previously presented target items rather than neutral distractors (i.e., PF1, T1F1, P1F2, T1F2, T2F1,T2F2, etc.). Thus, this series took half as much time to present the 5 facts as in either of the other two conditions used in that study. It will be recalled that subjects did not learn much after a single presentation in the A Condition. After the second presentation in this condition, however, there was a comparatively high level of retention on both an immediate and long term tests of retention.

This suggests a possible way of using this type of series in conjunction with the expanded series used in Study III. For instance, a student attempting to master 5 new multiplication facts could first train for a number of distributed sessions on each of the expanded schedules presenting only one fact each, then switch to the shorter A-type series containing the same five facts but all intermixed. Benefits could be expected with this switch, from such factors as the novelty effect, as well as from presenting the material in a more challenging manner. Furthermore, one feature of the mixed sequence is that since the facts are not presented in any apparent order, the effect of the sequence is likely to better prepare the student for situations in which the facts are tested non-sequentially. As Landauer and Bjork (1978) have pointed out, the expanded series of test trials in this form is probably most effective because it not

only induces greater encoding effort but also more closely approximates the final test performance. The normal instructional method used with multiplication tables is to introduce them in sequence and then through training and practice, teach the student to respond correctly on non-sequential testing. The above outlined program would incorporate the distributed practice effect throughout the learning sequence and would therefore seem to be an effective aid in achieving this goal. A future experiment designed to test the effectiveness of such a program would be of obvious value.

A further refinement of this type of expanded series (i.e., Condition A) is suggested by the results of Study IIIA. In the laboratory study with college students there was a single presentation followed by an expanded series of test trials. One problem with this method was that if a subject forgot an item on any test it was very likely that it would not be retrieved on subsequent tests. Wenger et al. (1980) examined this problem and reported that presentations and test trials were equivalent for recognition memory provided the test trials were successful. Similarly, Landauer and Bjork (1978), in one part of their second experiment, found that re-presentations were as effective as test trials. As may be recalled, this idea was adapted for use in Study IIIA. In order to counteract any loss due to unsuccessful trials a brief re-presentation immediately after the test trial was included in that study. Following from this

it would appear beneficial to design a sequence which had the time efficiency of Condition A but which counteracted the detrimental effects of omission errors. The following sequence would appear to fulfill that requirement.

*	Presentation one of fact one	P1F1
	Test one of fact one	T1F1
	Re-presentation of fact one	P2F1
	Distractor	D1
	Test two of fact one	T2F1
	Re-presentation of fact one	P3F1
*	Presentation one of fact two	P1F2
	Test one of fact two	T1F2
	Re-presentation of fact two	P2F2
	Test three of fact one	T3F1
	Re-presentation of fact one	P4F1
	Test two of fact two	T2F2
	Re-presentation of fact two	P3F2
*	Presentation one of fact three	P1F3
	Test one of fact three	T1F3
	Re-presentation of fact three	P2F3
	Test three of fact two	T3F2
	Re-presentation of fact two	P4F2
	Test two of fact three	T2F3

Re-presentation of fact three P3F3

Test four of fact one T4F1

Re-presentation of fact one P5F1

(And so on until all five facts had been presented and tested.)

As can be seen from the above sequence, success is built in at every step. If a child makes an error he/she gets immediate feedback and is thus likely to be successful on the next test trial. This type of procedure might eliminate at least some of the difficulties encountered by subjects with the Condition A type sequence in Studies I and II. It would certainly be of practical interest to investigate the efficacy of this type of sequence.

Another issue, not addressed in this study, but which has some bearing on how children learn, is that of motivation. A program of incentives or rewards incorporated with the instruction and related to the mastery of sequences of facts would undoubtedly add additional motivation to learn.

An important issue in relation to the acquisition of information in a school situation is the amount of material that should be included in any one unit of learning. The present series of studies generally involved a small number of facts or words which seemed, intuitively at least, to form a basic unit. However the whole versus parts method of learning material has not been settled conclusively (Morris, 1979). The whole method (e.g., learning all the 8 times tables) may benefit by creating

a context for each part so that not only is the full meaning of the whole of the material better understood but perhaps one part can prompt recall of another. Higbee (1977) claimed that continued practice involving all the material improved efficiency especially with more mature and intelligent learners. On the other hand the parts method may have a motivating effect on the learner since several parts may be mastered in the space of time that might only produce relatively minor improvements with the whole method. Breen and Jurek (1975) pointed out that a difficulty with the parts method is in relating the memorized parts and organizing them into a whole. This is an important issue in relation to how best to group material to be learned into efficient units. The optimal size of the unit may vary depending on the type of material involved. Research is needed in order to determine the most efficient approach for the various kinds of information encountered in school learning and this is a necessary first step before implementing a program of spaced practice of items and/or units.

It is important for educational research to aid in the acquisition of knowledge and skills in an efficient manner. Thus, the goal of applying psychological principles, which have been demonstrated to be effective in the laboratory, to practical situations is of obvious value. While in the past there has been a tradition of psychologists being involved in this type of applied research (e.g., Gagne, Skinner, Thorndike),

education and psychology have, over the years, tended to become isolated from each other (Glaser, 1978). Psychology has been attempting to become a true science and has focused primarily on experimental manipulations involving theoretical considerations without reference to realistic educational goals. Education, and especially educational psychology, has been concerned with more practical problems such as teacher training, curriculum development and psychometric testing, and has paid less attention to scientific and theoretical issues. More recently attempts have been made to bridge this gap, and Glaser (1978) expressed some optimism about the trend toward integration of education and psychology, especially in the field of instructional psychology. In relation to the present study it is apparent that memory research in particular has not reached the stage where it can provide answers to all educational questions involving retention of information. Nevertheless there is a real need for the practical application to education of the genuine gains made in laboratory research in memory. It may be that educators do not appreciate the central importance of memory for attaining intellectual and academic competence. The impression is often given that memory proficiency is perhaps antithetical to scholastic excellence. Such misconceptions need to be clarified if memory research is to make a positive contribution to educational goals. On the other hand, researchers in memory may not be fully cognizant of the ways in which their work can

contribute to education and indeed, may not be aware of the possibilities of relating it explicitly to particular educational objectives. The present study has provided some empirical support for the hypothesis that a commonly demonstrated laboratory phenomenon, the massed-distributed-practice effect, can be utilized as a practical and educationally valuable aid in a school setting and as such has contributed in some degree toward an integration of psychology and education.

Appendices

Appendix A

Sequence of facts used for the distributed practice group in Study I.

Presentation of fact one	(PF1)	$7 \times 1 = 7$
Test one of fact one	(T1F1)	$7 \times 1 = ?$
Presentation of fact two	(PF2)	$7 \times 2 = 14$
Test one of fact two	(T1F2)	$7 \times 2 = ?$
Presentation of fact three	(PF3)	$7 \times 3 = 21$
* Test one of fact three	(T1F3)	$7 \times 3 = ?$
Test two of fact one	(T2F1)	$7 \times 1 = ?$
* Test two of fact three	(T2F3)	$7 \times 3 = ?$
Presentation of fact four	(PF4)	$7 \times 4 = 28$
* Test one of fact four	(T1F4)	$7 \times 4 = ?$
* Test three of fact three	(T3F3)	$7 \times 3 = ?$
* Test two of fact four	(T2F4)	$7 \times 4 = ?$
Test two of fact two	(T2F2)	$7 \times 2 = ?$
Test three of fact one	(T3F1)	$7 \times 1 = ?$
* Test three of fact four	(T3F4)	$7 \times 4 = ?$
* Test four of fact three	(T4F3)	$7 \times 3 = ?$
Presentation of fact five	(PF5)	$7 \times 5 = 35$
* Test one of fact five	(T1F5)	$7 \times 5 = ?$
Test four of fact one	(T4F1)	$7 \times 1 = ?$

* Test two of fact five	(T2F5)	7 x 5 = ?
* Test four of fact four	(T4F4)	7 x 4 = ?
Test three of fact two	(T3F2)	7 x 2 = ?
* Test three of fact five	(T3F5)	7 x 5 = ?
Test five of fact one	(T5F1)	7 x 1 = ?
* Test five of fact three	(T5F3)	7 x 3 = ?
Presentation of fact six	(P1F6)	7 x 6 = 42
* Test one of fact six	(T1F6)	7 x 6 = ?
* Test four of fact five	(T4F5)	7 x 5 = ?
* Test two of fact six	(T2F6)	7 x 6 = ?
* Test five of fact four	(T5F4)	7 x 4 = ?
Test six of fact one	(T6F1)	7 x 1 = ?
* Test three of fact six	(T3F6)	7 x 6 = ?
Presentation of fact seven	(PF7)	7 x 7 = 49
* Test one of fact seven	(T1F7)	7 x 7 = ?
Test seven of fact one	(T7F1)	7 x 1 = ?
* Test two of fact seven	(T2F7)	7 x 7 = ?
* Test five of fact five	(T5F5)	7 x 5 = ?
* Test four of fact six	(T4F6)	7 x 6 = ?
* Test three of fact seven	(T3F7)	7 x 7 = ?
Test four of fact two	(T4F2)	7 x 2 = ?
Test eight of fact one	(T8F2)	7 x 1 = ?
Test five of fact two	(T5F2)	4 x 2 = ?

Test nine of fact one	(T9F1)	$7 \times 1 = ?$
* Test four of fact seven	(T4F7)	$7 \times 7 = ?$
test ten of fact one	(T10F1)	$7 \times 1 = ?$
Test six of fact two	(T6F2)	$7 \times 2 = ?$
* Test five of fact six	(T5F6)	$7 \times 6 = ?$

Appendix B

Instructions for Study One.

I'm going to play some multiplication facts on the tape recorder. I want you to try to remember these.

Some of the facts you'll know already and some will be new to you. I want you to try hard to remember these new ones.

First you'll be told the answer, for instance 7×2 is 14. Next you'll be tested. What is 7×2 ?

If you forget the answer, or don't have time to finish, don't worry, just go on to the next one. At the end we'll have a short test to see how much you remembered, o.k.?

To start with we'll have a practice session so that you can see what it is like.

Appendix C

Sequence of facts for Condition A in Study II

1. The square root of 7325 is 85.59.
2. What is the square root of 7325?
3. What is the square root of 4?
4. What is the square root of 7325?
5. The square root of 3586 is 59.88.
6. What is the square root of 3586?
7. What is the square root of 7325?
8. What is the square root of 3586?
9. The square root of 1956 is 44.23.
10. What is the square root of 1956?
11. What is the square root of 3586?
12. What is the square root of 1956?
13. What is the square root of 7325?
14. What is the square root of 9?
15. What is the square root of 1956?
16. What is the square root of 3586?
17. The square root of 6847 is 82.75.
18. What is the square root of 6847?
19. What is the square root of 16?
20. What is the square root of 6847?
21. What is the square root of 1956?
22. What is the square root of 7325?

23. What is the square root of 6847?
24. What is the square root of 25?
25. What is the square root of 3586?
26. The square root of 1180 is 34.35.
27. What is the square root of 1180?
28. What is the square root of 6847?
29. What is the square root of 1180?
30. What is the square root of 1956?
31. What is the square root of 36?
32. What is the square root of 1180?
33. What is the square root of 81?
34. What is the square root of 49?
35. What is the square root of 100?
36. What is the square root of 64?
37. What is the square root of 6847?
38. What is the square root of 1180?
39. What is the square root of 25?
40. What is the square root of 4?
41. What is the square root of 81?
42. What is the square root of 49?
43. What is the square root of 9?
44. What is the square root of 64?
45. What is the square root of 36?
46. What is the square root of 16?
47. What is the square root of 1180?

Appendix D

Written Test for Study II

FINAL TEST SEQUENCE A

WHAT IS THE SQUARE ROOT OF 7325

WHAT IS THE SQUARE ROOT OF 3586

WHAT IS THE SQUARE ROOT OF 1956

WHAT IS THE SQUARE ROOT OF 6847

WHAT IS THE SQUARE ROOT OF 1180

FINAL TEST SEQUENCE B

WHAT IS THE SQUARE ROOT OF 6606

WHAT IS THE SQUARE ROOT OF 8526

WHAT IS THE SQUARE ROOT OF 6357

WHAT IS THE SQUARE ROOT OF 7379

WHAT IS THE SQUARE ROOT OF 9852

FINAL TEST SEQUENCE C

WHAT IS THE SQUARE ROOT OF 5980

WHAT IS THE SQUARE ROOT OF 8868

WHAT IS THE SQUARE ROOT OF 1547

WHAT IS THE SQUARE ROOT OF 6548

WHAT IS THE SQUARE ROOT OF 3217

Appendix E

Instructions for Study Two

This is a memory experiment. Numerical facts will be presented on the screen and at the same time you'll hear them. The facts you have to remember are the square roots of four digit random numbers

For example the square root of 6785 is 81.35. This will be presented once and then you'll be tested a number of times, so try hard to remember these numbers.

You'll also be asked the square root of familiar numbers, for instance what is the square root of 36?

There are three types of sequences of presentations and tests which you'll be exposed to, each one containing five to-be-remembered facts. At the end of each sequence you'll be given a test of the five facts in that sequence. One sequence which is shorter than the other two will be presented twice. After completion of the three series you'll be given a final written test.

Any questions?.

Self-timed Group: During the learning session you'll be able to hold the slides on the screen for as long as you wish. by use of this button. When you press down on it, the tape advances and presents the next slide. To keep the slide on the screen just release the button. When you're ready to go on to the next one, merely press the button again.

There are quite a number of facts to be learned so don't spend too much time on each one.

Any questions?..

O.K., we'll run through a practice session to familiarize you with the procedure.

Appendix F

Questionnaire used in Study Two

QUESTIONNAIRE

You have been exposed to three different sequences of facts in this memory experiment. One consisted of a number of facts presented together in an expanded form and which you were exposed to twice (Condition A). Another one was similar to the above but each fact was presented by itself and was expanded with more familiar items between each test trial of the target fact (Condition B). A third condition involved presentation of single facts but with successive test trials after the initial presentation followed by a number of more familiar facts before the final test (Condition C).

Please indicate which condition felt most comfortable and explain why.

Which condition did you find most difficult and why.

In which condition did you feel you learned most.

What strategy or strategies did you use in order to memorize the facts.

Would you like to have had some feedback regarding the accuracy of your responses and how do you think it might affect your performance.

How frustrating would you rate the total task.

How do you feel about the total amount of information presented.

Would you have liked to have more time to think before answering.

Appendix G

Study II. Analysis of variance of recall scores between the
Pre-timed and Self-timed groups on T5, T6, and T7 as a
function of Condition A1, A2, B, and C.

Source of variance	df	MS	F	p
Group	1	17.12	3.20	.08
Error	34	5.34	-	-
Condition	3	70.61	34.71	.001
CG	3	8.84	4.35	.01
Error	102	2.03	-	-
Test	2	188.60	199.97	.001
TG	2	1.18	1.25	.294
Error	68	0.94	-	-
CT	6	26.64	35.59	.001
CTG	6	1.19	1.60	.149
Error	204	0.75	-	-

Appendix H

Written test of five math facts used in Study Three.

Order One:

7 9 6 8 5
x8 x8 x8 x8 x8

Order Two:

5 8 6 9 7
x8 x8 x8 x8 x8

Appendix I

Instructions used in Study Three.

I'm going to show you some facts on the screen and at the same time you'll be able to hear them. These will be words that I want you to remember how to spell.

(These will be multiplication facts that I want you to remember). First you'll be told how to spell the word, for instance cat is spelled c-a-t and then you'll be tested. Spell cat.

(First you'll be given the answer, for instance 7×2 is 14 and then you'll be tested on that fact. What is 7×2 ?).

Some you'll know already, but some will be new to you and I'd like you to try to remember these new ones.

If you don't know the answer or don't have time to finish, don't worry - just go on to the next one. Later on we'll have a short test to see how much you remembered, O.K.?

To begin with we'll have a practice session so that you can see what it's like.

Appendix J

Study IIIA. Analysis of variance of the math recall scores on the oral and written tests, by group, by class, by level.

Source of variance	df	MS	F	p
Main effects - Math Oral Test				
Group	1	10.02	15.69	.001
Class	1	10.02	15.69	.001
Level	1	2.75	4.30	.05
Two-way interactions				
GC	1	0.37	0.57	.454
GL	1	0.59	0.93	.341
CL	1	8.19	12.83	.001
Three-way interactions				
GCL	1	0.03	0.44	.837
Explained	7	4.57	7.15	.001
Residual	36	0.64	-	-
Total	43	1.28	-	-
Main effects - Math Written Test				
Group	1	15.36	14.99	.001
Class	1	20.45	19.96	.001
Level	1	1.46	1.42	.241

Two-way interactions

GC	1	2.64	2.57	.117
GL	1	1.97	1.92	.174
CL	1	7.73	7.54	.01

Three-way interactions

GCL	1	1.40	1.37	.25
Explained	7	7.29	7.11	.001
Residual	36	1.03	-	-
Total	43	2.04	-	-

Appendix K

Study IIIA. Analysis of variance of the spelling recall scores on the oral and written tests, by group, by class, by level.

Source of variance	df	MS	F	p
Main effects - Spelling Oral Test				
Group	1	1.84	4.24	.05
Class	1	1.11	2.56	.118
Level	1	6.59	15.12	.001
Two-way interactions				
GC	1	0.47	1.09	.303
GL	1	0.13	0.30	.590
CL	1	0.40	0.92	.343
Three-way interactions				
GCL	1	0.27	0.63	.433
Explained	7	1.54	-	-
Residual	36	0.43	-	-
Total	43	0.62	-	-
Main effects - Spelling Written Test				
Group	1	1.11	4.15	.05
Class	1	0.03	0.09	.773
Level	1	1.84	6.86	.01

Two-way interactions

GC	1	0.78	2.89	.098
GL	1	0.03	0.10	.752
CL	1	0.01	0.01	.916

Three-way interactions

GCL	1	0.44	1.63	.211
Explained	7	0.60	2.25	.053
Residual	36	0.27	-	-
Total	43	0.32	-	-

Appendix L

Math Drill Steets used in Study IIIB (Massed Practice).

Name _____ Date _____

4	3	2	4	2	1	8	3	4	4	4	4
$\frac{x7}{28}$	$\frac{x6}{28}$	$\frac{x2}{28}$	$\frac{x5}{28}$	$\frac{x9}{28}$	$\frac{x8}{28}$	$\frac{x2}{28}$	$\frac{x3}{28}$	$\frac{x7}{28}$	$\frac{x7}{28}$	$\frac{x7}{28}$	$\frac{x7}{28}$
5	3	2	5	4	3	6	2	5	5	5	5
$\frac{x7}{35}$	$\frac{x4}{35}$	$\frac{x2}{35}$	$\frac{x2}{35}$	$\frac{x1}{35}$	$\frac{x5}{35}$	$\frac{x6}{35}$	$\frac{x7}{35}$	$\frac{x7}{35}$	$\frac{x7}{35}$	$\frac{x7}{35}$	$\frac{x7}{35}$
6	3	5	2	2	0	3	5	6	6	6	6
$\frac{x7}{42}$	$\frac{x2}{42}$	$\frac{x3}{42}$	$\frac{x5}{42}$	$\frac{x9}{42}$	$\frac{x4}{42}$	$\frac{x5}{42}$	$\frac{x4}{42}$	$\frac{x7}{42}$	$\frac{x7}{42}$	$\frac{x7}{42}$	$\frac{x7}{42}$
7	6	3	4	2	0	4	5	7	7	7	7
$\frac{x7}{49}$	$\frac{x1}{49}$	$\frac{x3}{49}$	$\frac{x3}{49}$	$\frac{x4}{49}$	$\frac{x3}{49}$	$\frac{x2}{49}$	$\frac{x5}{49}$	$\frac{x7}{49}$	$\frac{x7}{49}$	$\frac{x7}{49}$	$\frac{x7}{49}$
8	2	4	3	3	2	4	8	8	8	8	8
$\frac{x7}{56}$	$\frac{x6}{56}$	$\frac{x3}{56}$	$\frac{x1}{56}$	$\frac{x2}{56}$	$\frac{x5}{56}$	$\frac{x4}{56}$	$\frac{x1}{56}$	$\frac{x7}{56}$	$\frac{x7}{56}$	$\frac{x7}{56}$	$\frac{x7}{56}$
9	5	3	2	6	3	2	0	9	9	9	9
$\frac{x7}{63}$	$\frac{x3}{63}$	$\frac{x6}{63}$	$\frac{x5}{63}$	$\frac{x1}{63}$	$\frac{x4}{63}$	$\frac{x8}{63}$	$\frac{x3}{63}$	$\frac{x7}{63}$	$\frac{x7}{63}$	$\frac{x7}{63}$	$\frac{x7}{63}$

Math Drill sheets used in Study IIIB (Distributed Practice).

Name _____	Date _____					
4	4	2	1	8	3	4
$\overline{x7}$	$\overline{x7}$	$\overline{x9}$	$\overline{x8}$	$\overline{x3}$	$\overline{x2}$	$\overline{x7}$
28						
5	5	4	3	6	2	5
$\overline{x7}$	$\overline{x7}$	$\overline{x1}$	$\overline{x5}$	$\overline{x6}$	$\overline{x7}$	$\overline{x7}$
35						
6	6	2	0	3	5	6
$\overline{x7}$	$\overline{x7}$	$\overline{x9}$	$\overline{x4}$	$\overline{x5}$	$\overline{x4}$	$\overline{x7}$
42						
7	7	2	0	4	5	7
$\overline{x7}$	$\overline{x7}$	$\overline{x4}$	$\overline{x3}$	$\overline{x2}$	$\overline{x3}$	$\overline{x7}$
49						
8	8	8	2	3	4	8
$\overline{x7}$	$\overline{x7}$	$\overline{x1}$	$\overline{x2}$	$\overline{x4}$	$\overline{x5}$	$\overline{x7}$
56						
9	9	6	3	2	0	9
$\overline{x7}$	$\overline{x7}$	$\overline{x1}$	$\overline{x4}$	$\overline{x8}$	$\overline{x3}$	$\overline{x7}$
63						

Appendix M

Spelling Drill Sheets used in Study IIIB. (Massed Practice).

SPELLING DRILL

1. fat
2. kill
3. stop
4. duck
5. bang
6. land
7. well
8. suddenly
9. suddenly
10. suddenly
11. suddenly

Spelling Drill Sheets used in study IIIB. (Distributed Practice)

SPELLING DRILL

1. suddenly
2. fat
3. suddenly
4. kill
5. stop
6. suddenly
7. duck
8. bang
9. land
10. well
11. suddenly

References

- Anderson J.R. & Bower G.H. Recognition and retrieval processes in free recall. Psychological Review, 1972, 79, 97-123
- Anderson, R.C. & Faust, G.W. Educational Psychology: The Science of Instruction and Learning. New York: Harper Row, 1973.
- Atkinson, R.C. Mnemotechnics in school language learning. American Psychologist, 1975, 30, 821-828.
- Atkinson, R.C. & Shiffrin, R.M. Human memory: A proposed system and its control processes. In K.W. Spence (Ed.), The Psychology of Learning and Motivation, Volume 2, New York: Academic Press, 1968, (pp 89-105).
- Atwood, M.E. & Polson, P.G. A process model for water jar problems. Cognitive Psychology, 1976, 8, 191-216.
- Ausubel, D.P., Novak, J.D., & Hanesian, H., Educational Psychology: A Cognitive View, (2nd Edition), New York: Holt, Rinehart & Winston, 1978.
- Baddeley A.D. The Psychology of Memory, New York: Basic Books, 1976.
- Bellezza, F.S., Winkler, H.B., & Andrasik, F., Jnr. Encoding processes and the spacing effect. Memory and Cognition, 1975, 3, 451-457.
- Belmont, J.M., & Butterfield, E.C. What the development of short term memory is. Human Development, 1971, 14, 236-248.
- Bjork, R.A., & Allen, T.W. The spacing effect: Consolidation or differential encoding? Journal of Verbal Learning and Verbal Behavior, 1970, 9, 567-572.
- Bloom, K.F., & Shuell, T.J. Effects of massed and distributed practice on the learning and retention of second-language vocabulary. Journal of Educational Research, 1981, 74, 245-248.
- Bower, G.H. Imagery as a relational organizer in associative learning. Journal of Verbal Learning and Verbal Behavior, 1970, 9, 529-533.
- Breen, M.j., & Jurek, J.M. Serial learning as a function of age

- and part versus whole learning procedures. Psychological Reports, 1975, 36, 767-773.
- Craik, F.I.M., & Lockhart, R.S. Levels of processing: A framework for memory research. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 671-684.
- Craik, F.I.M., & Watkins, M.J. The role of rehearsal in short-term memory. Journal of Verbal Learning and Verbal Behavior, 1973, 12, 599-607.
- Crowder, R.G. Principles of Learning and Memory. New Jersey: Erlbaum Associates, 1976.
- D'Agostino, P.R., & DeRemer, P. Item repetition in free and cued recall. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 54-58.
- D'Agostino, P.R., & DeRemer, P. Repetition effects as a function of rehearsal and encoding variability. Journal of Verbal Learning and Verbal Behavior, 1973, 12, 108-113.
- Dark, Y.J., & Loftus, G.R. The role of rehearsal in long-term memory performance. Journal of Verbal Learning and Verbal Behavior, 1976, 15, 479-490.
- Dunn, O.J., Multiple comparisons among means. Journal of the American Statistical Association, 1961, 56, 52-64.
- Elmes, D.G., Greener, W.I., & Wilkinson, W.C. Free recall of items presented after massed- and distributed-practice. American Journal of Psychology, 1972, 85, 237-240.
- Elmes, D.G., Sanders, L.W., & Dovel, J.C. Isolation of massed- and distributed-practice items. Memory and Cognition, 1973, 1, 77-79.
- Evans J.D. On the inconstant effects of study instruction. American Journal of Psychology, 1977, 90, 511-516.
- Feuge, J.E. Massing versus distributing practice with set and non-set foreign language vocabulary lists. Dissertation Abstracts International, 1976, Nov., 37, 5-A, 2693-A.
- Flavell, J.H. First discussant's comments: What is memory development the development of? Human Development, 1971, 14, 272-278.
- Flavell, J.H., Beach, D.R., & Chinsky, J.M. Spontaneous verbal

- rehearsal in a memory task as a function of age. Child Development, 1966, 37, 283-299.
- Gage, N.L., & Berliner, D.C. Educational Psychology. Chicago: Rand McNally College Publishing Co., 1975.
- Gargagliano, C. The effects of massed versus distributed practice on the acquisition and maintenance of basic sight words. Experimental Education Unit, University of Washington, Working Paper No. 35, September, 1974.
- Glaser, R. Advances in Instructional Psychology Vol. 1. New Jersey: Erlbaum Associates, 1978.
- Glaser, R., & Reynolds, J.H. Instructional objectives and programmed instruction: A case study. In C.M. Lindvall (Ed.) Defining Educational Objectives. Pittsburg: University of Pittsburg Press, 1964, 47-76.
- Glenberg, A.M. Influences of retrieval processes on the spacing effect in free recall. Journal of Experimental Psychology: Human Learning and Memory, 1977, 3, 282-294.
- Glenberg, A.M., Smith, S.M., & Green, C. Type I rehearsal: Maintenance and more. Journal of Verbal Learning and Verbal Behavior, 1977, 16, 339-352.
- Higbee, K.L. Your Memory: How it Works and How to Improve it. New York: Prentice Hall, 1977.
- Hilgard, E.R. (Ed.) Theories of Learning and Instruction. Chicago: University of Chicago Press, 1964.
- Hintzman, D.L. Theoretical implications of the spacing effect. In R.L. Solso (Ed.) Theories in Cognitive Psychology: The Loyola Symposium. Potomac, Md.: Lawrence Erlbaum, 1974.
- Hintzman, D.L. Repetition and memory. In G.H. Bower (Ed.) The Psychology of Learning and Motivation. New York: Academic Press, 1976.
- Hintzman, D.L., & Block, R.A. Memory judgements and the effect of spacing. Journal of Verbal Learning and Verbal Behavior, 1970, 9, 561-566.
- Hintzman, D.L., & Block, R.A. Repetition and memory: Evidence for a multiple-trace hypothesis. Journal of Experimental Psychology. 1971, 88, 297-306.

- Hintzman, D.L., & Block, R.A. Memory for the spacing of repetition. Journal of Experimental Psychology, 1973, 99, 70-74.
- Hintzman, D.L., Block, R.A., & Summers, J.J. Modality tags and memory for repetitions: Locus of the spacing effect. Journal of Verbal Learning and Verbal Behavior, 1973, 12, 229-239.
- Hintzman, D.L., & Rogers, M.K. Spacing effects in picture memory. Memory and Cognition, 1973, 1, 430-434.
- Hintzman, D.L., & Stern, L.D. Failure to confirm Elmes, Greener, and Wilkinson's finding on the spacing effect. American Journal of Psychology, 1977, 90, 489-497.
- Hintzman, D.L., Summers, J.J., & Block, R.A. What causes the spacing effects? Some effects of repetition, duration and spacing on memory for pictures. Memory and Cognition, 1975, 3, 287-294.
- Hintzman, D.L., Summers, J.J., Eki, N.T., & Moore, M.O. Voluntary attention and the spacing effect. Memory and Cognition, 1975, 3, 576-580.
- Hockey, R. Rate of presentation in running memory and direct manipulation of input processing strategies. Quarterly Journal of Experimental Psychology, 1973, 25, 104-111.
- Howe, M.J.A. Good learners and poor learners. Bulletin of British Psychological Society, 1976, 29, 16-19.
- Howe, M.J.A., & Ceci, S.J. Educational implications of memory research. In M.M. Gruneberg and P.E. Morris (Eds.) Applied Problems in Memory. New York: Academic Press, 1979.
- Huttenlocher, J., & Burke, D. Why does memory span increase with age? Cognitive Psychology, 1976, 8, 1-31.
- Izawa, C. The test trial potentiating model. Journal of Mathematical Psychology, 1971, 8, 200-224.
- Izawa, C. Vocalized and silent tests in paired-associate learning. American Journal of Psychology, 1976, 89, 681-693.
- Izawa, C. Theoretical and empirical performance differences between anticipation and study-test methods: Retention interval vs. spaced practice effects. Scandinavian Journal of Psychology, 1978, 19, 151-158. (b)

- Izawa, C. Quantitative tests of the retention interval model. Journal of General Psychology, 1981, 105, 273-292.
- Johnson, R.E. Memory based rehearsal. In G.H. Bower (Ed.) The Psychology of Learning and Motivation, Vol. 14. New York: Academic Press, 1980.
- Johnson, W.A., & Uhl, C.N. The contributions of encoding effort and variability to the spacing effect on free recall. Journal of Experimental Psychology: Human Learning and Memory, 1976, 2, 153-160.
- Jones, D.M. Stress and memory. In M.M. Gruneberg & P.E. Morris (Eds.) Applied Problems in Memory. New York: Academic Press, 1979.
- Kahneman, D., & Wright, P. Changes of pupil size and rehearsal strategies in a short term memory task. Quarterly Journal of Experimental Psychology, 1971, 23, 187-196.
- Kintsch W. Recognition learning as a function of the length of the retention interval and changes in retention interval. Journal of Mathematical Psychology 1966, 3, 412-433.
- Kreutzer, M.A., Leonard, C., & Flavell, J.H. An interview study of children's knowledge about memory. Monographs of the Society for Research in Child Development, 1975, 40, (1, Serial No. 159).
- Landauer, T.K. Reinforcement as consolidation. Psychological Review, 1969, 76, 82-96.
- Landauer, T.K. Consolidation in human memory: Retrograde amnesic effects of confusable items in paired-associate learning. Journal of Verbal Learning and Verbal Behavior, 1974, 13, 45-53.
- Landauer, T.K., & Bjork, R.A. Optimum rehearsal patterns and name learning. In M.M. Gruneberg, P.E. Morris, & R.N. Sykes (Eds.) Practical Aspects of Memory. New York: Academic Press, 1978.
- Landauer, T.K., & Eldridge, L. Effects of tests without feedback and presentation-test interval in paired-associate learning. Journal of Experimental Psychology, 1967, 75, 290-298.
- Landauer, T.K., & Ross, B.H. Can simple instructions to use spaced practice improve ability to remember a fact? An experimental test using telephone numbers. Bulletin of the

- Psychonomic Society, 1977, 10, 215-218.
- Locke, J.L., & Ginsberg, M. Electromyography and lipreading in the detection of verbal rehearsal. Bulletin of the Psychonomic Society, 1975, 5, 246-248.
- Martin, E. Stimulus encoding in learning and transfer. In A.W. Melton, & E. Martin (Eds.), Coding Processes in Human Memory, Washington D.C.: Winston, 1972.
- Maskarinec, A.S., & Thompson, C.P. The within-list distributed practice effect: Test of the varied context and varied encoding hypotheses. Memory and Cognition, 1976, 4, 741-746.
- McFarland, C.E., Rhodes, D.D., & Frey, T.J. Semantic-feature variability and the spacing effect. Journal of Verbal Learning and Verbal Behavior, 1979, 18, 163-172.
- Melton, A.W. The situation with respect to the spacing of repetitions and memory. Journal of Verbal Learning and Verbal Behavior, 1970, 9, 596-606.
- Melton, A.W., Reicher, G.M., & Shulman H.G. A distributed practice effect on probability of recall in free recall of words. Paper presented at the Psychonomic Society, St. Louis, October, 1966.
- Miller, R.R., & Springer, A.D. Amnesia, consolidation, and retrieval. Psychological Review, 1973, 80, 69-79.
- Modigliani, V. Effects of initial testing on later retention as a function of the initial retention interval. In M.M. Gruneberg, P.E. Morris, & R.N. Sykes (Eds.), Practical Aspects of Memory. New York: Academic Press, 1978.
- Modigliani, V. Immediate rehearsal and initial retention interval in free recall. Journal of Experimental Psychology, 1980, 6, 241-253.
- Modigliani, V., & Seamon, J.G. Transfer of information from short- to long-term memory. Journal of Experimental Psychology, 1974, 102, 768-772.
- Morris, P.E. Strategies for learning and recall. In M.M. Gruneberg & P.E. Morris (Eds.) Applied Problems in Memory. New York: Academic Press, 1979.
- Morris, P.E., & Reid, R.L. Repeated use of mnemonic imagery. Psychonomic Science, 1970, 20, 337-338.

- Navarick, D.J. Principles of Learning: From Laboratory to Field. Mass.: Addison-Wesley Publishing Co., 1979.
- Neimark, E., Greenhouse, P., Law, S., & Weinheimer, S. The effects of rehearsal-preventing tasks upon retention of CVC syllables. Journal of Verbal Learning and Verbal Behavior, 1965, 4, 280-285.
- Penney, G.C. Modality effects in short-term verbal memory. Psychological Bulletin, 1975, 82, 68-84.
- Petrusic, W.M., & Jamieson, D.G. Differential interpolation effects in free recall. Journal of Experimental Psychology: Human Learning and Memory, 1978, 4, 101-109.
- Pollatsek A., & Bettencourt, H.O. The spaced practice effect in the distractor paradigm is related to proactive interference but not to short term store. Journal of Experimental Psychology: Human Learning and Memory, 1976, 2, 128-141.
- Proctor, R.W. The influence of intervening tasks on the spacing effect for frequency judgements. Journal of Experimental Psychology, 1980, 6, 254-266.
- Raugh, M.R., & Atkinson, R.C. A mnemonic method for learning a second language vocabulary. Journal of Educational Psychology, 1975, 67, 1-16.
- Reith, H., Axelrod, S., Anderson, R., Hathaway, F., Wood, K., & Fitzgerald, C. Influence of distributed practice and daily testing on weekly spelling tests. The Journal of Educational Research, 1974, 62, 73-77.
- Reynolds, J.H., & Glaser, R. Effects of repetition and spaced review upon retention of a complex learning task. Journal of Educational Psychology, 1964, 55, 297-308.
- Rothkopf, E.Z. Some observations on predicting instructional effectiveness by simple inspection. Journal of Programmed Instruction, 1963, 2, 19-20.
- Rothkopf, E.Z., & Coke, E.U. Variations in phrasing and repetition interval and the recall of sentence materials. Journal of Verbal Learning and Verbal Behavior, 1966, 5, 86-91.
- Rowe, E.J., & Rose, R.J. Instructional and spacing effects in judgement of frequency. Paper presented at the meeting of the Canadian Psychological Association, June, 1974.

- Rundus, D. Analysis of rehearsal processes in free recall. Journal of Experimental Psychology, 1971, 89, 63-77.
- Rundus, D., & Atkinson, R.C. Rehearsal processes in free recall: A procedure for direct observation. Journal of Verbal Learning and Verbal Behavior, 1970, 9, 99-105.
- Schwartz, N. The effect of constant vs. varied encoding and massed vs. distributed presentations on recall of paired associates. Memory and Cognition, 1975, 3, 390-394.
- Shaffer, W.O., & Shiffrin, R.M. Rehearsal and storage of visual information. Journal of Experimental Psychology, 1972, 92, 292-296.
- Shaughnessy, J.J., Persistence of the spacing effect in free recall under varying incidental learning conditions. Memory and Cognition, 1976, 4, 369-377.
- Shaughnessy, J.J. Long-term retention and the spacing effects in free-recall and frequency judgements. American Journal of Psychology, 1977, 90, 587-598.
- Shaughnessy, J.J., Zimmerman, J., and Underwood, B.J. Further evidence on the MP-DP effect in free-recall learning. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 1-12.
- Shaughnessy, J.J., Zimmerman, J., & Underwood, B.J. The spacing effect in the learning of word pairs and the components of word pairs. Memory and Cognition, 1974, 2, 742-748.
- Skinner, B.F. The Technology of Teaching. New York: Appleton-Century-Crofts, 1968.
- Tarpy R.M., & Meyer, R.E. Foundations of Learning and Memory. Glenview, Illinois: Scott, Foresman and Company, 1978.
- Ternes, W., & Yuille, J.C. Words and pictures in an STM task. Journal of Experimental Psychology, 1972, 96, 78-88.
- Thorndike, E.L. Educational Psychology: The Psychology of Learning. New York: Bureau of Publications, Teachers College, Columbia University, 1913.
- Tzeng, O.J.L. Stimulus meaningfulness, encoding variability, and the spacing effect. Journal of Experimental Psychology, 1973, 99, 162-166.

- Underwood, B.J. Some correlates of item repetitions in free recall learning. Journal of Verbal Learning and Verbal Behavior, 1969, 8, 83-94.
- Underwood, B.J., A breakdown of the total-time law in free recall learning. Journal of Verbal Learning and Verbal Behavior, 1970, 9, 573-580.
- Underwood, B.J., Kapelak, S.M., & Malmi, R.A. The spacing effect: Additions to the theoretical and empirical puzzles. Memory and Cognition, 1976, 4, 391-400. The Psychological Record, 1976, 26, 487-493.
- Waugh, N.C. On the effective duration of a repeated word. Journal of Verbal Learning and Verbal Behavior, 1970, 9, 587-595.
- Wells E., & Kirsner, K. Repetition between and within modalities in free recall. Bulletin of the Psychonomic Society, 1974, 2, 395-397.
- Wenger, S.K. The within-list distributed practice effect: More evidence for the inattention hypothesis. American Journal of Psychology, 1979, 92, 105-113.
- Wenger, S.K., Thompson, C.P., & Bartling, C.A. Recall facilitates subsequent recognition. Journal of Experimental Psychology, 1980, 6, 135-144.
- Wetstone, H.S., & Friedlander, B.Z. The effects of live, T.V., and audio story narration on primary grade children's listening comprehension. Journal of Educational Research, 1974, 68,
- Whitten, W.B. II, & Bjork, R.A. Learning from tests: Effects of spacing. Journal of Verbal Learning and Verbal Behavior, 1977, 16, 465-478.
- Whitten, W.B. II, & Leonard, J.M. Learning from tests: Facilitation of delayed recall by initial recognition alternatives. Journal of Experimental Psychology, 1980, 6, 127-134.
- Woodward, A.E., Bjork, R.A., & Jongeward, R.H., Jr. Recall and recognition as a function of primary rehearsal. Journal of Verbal Learning and Verbal Behavior, 1973, 67, 770-775.
- Zimmerman, J. Free recall after self paced study: a test of the attention explanation of the spacing effect. American

Journal of Psychology, 1975, 88, 277-291.