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The Effects of a Cumulative Review Procedure Upon the Acquisition and Retention of Basic Addition Facts Under Mastery Learning Conditions

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THE EFFECTS OF A CUMULATIVE REVIEW PROCEDURE UPON
THE ACQUISITION AND RETENTION OF BASIC ADDITION FACTS
UNDER MASTERY LEARNING CONDITIONS

by

Michael Jeffrey Harshman

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THE EFFECTS OF A CUMULATIVE REVIEW PROCEDURE UPON
THE ACQUISITION AND RETENTION OF BASIC ADDITION FACTS
UNDER MASTERY LEARNING CONDITIONS

Michael Jeffrey Harshman, Ed.S.
Western Michigan University, 1982

The effects of cumulative review upon the acquisition and retention of basic addition facts were examined within a modified multielement baseline design. Subjects were two second graders enrolled in a tutorial program. After training (memorization to specific criteria) involving drill with flashcards, facts were practiced according to one of two procedures. One procedure (Inter-spersal Only) involved practice of newly trained facts mixed with facts known on a pretest. The other procedure (Cumulative Review) involved practice of newly trained facts mixed with facts learned during prior training sessions. The Cumulative Review condition was found to be more effective in terms of overall retention. However, contrary results across subjects were obtained with respect to acquisition.
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CHAPTER I

INTRODUCTION

In the area of early arithmetic instruction, memorization of basic addition facts is essential to the rapid and accurate use of the computational procedures necessary in later problem solving (Ashlock, 1971; Davis, 1978; Rathmell, 1978). Several authors (e.g., Davis, 1978; Engelmann & Carnine, 1982; Silbert, Carnine, & Stein, 1981) contend that cumulative review is an important component of instruction on academic tasks especially where memorization is involved. The present study was designed to examine the effects of cumulative review upon the acquisition and retention of the basic addition facts.

The National Council of Supervisors of Mathematics (1977) issued a position paper delineating ten interrelated and overlapping skill areas to clarify the basic mathematical skills needed by students to successfully participate in society. These ten skill areas would serve as a basis for the direction and rationale of mathematics education. The goal of such education would be to prepare the individual to function effectively in everyday situations which demand an accurate and efficient use of mathematics. Computational skills were included as one of the ten basic skill areas. The other areas included problem solving; the application of mathematics to everyday situations; alertness to the reasonableness of results; estimation and approximation; geometry; measurement; using tables, charts, and graphs; using mathematics to predict; and computer literacy.

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Trafton and Suydam (1975) consider computational skill as a major component of functional competence in those situations where the application of mathematics is involved. Essential to this skill in computation is mastery of the basic number facts.

Ashlock (1971) defines the basic facts of arithmetic as 390 simple closed number sentences that are used in computational procedures. There are 100 basic facts for each of the operations of addition, subtraction, and multiplication. There are 90 basic division facts as 10 facts are eliminated due to the impossibility of dividing by zero. The 100 basic addition facts are statements in the form of "addend+addend=sum" and include all the possible pair-wise combinations in which each of the addends is a whole number under 10 (Silbert et al., 1981). See Appendix A for the complete list of basic addition facts.

Complex addition facts, as distinguished from the basic addition facts, involve the addition of a single digit number to a two digit number. Providing the missing sum in a complex fact (e.g., 23+8=□) constitutes a more difficult task area than with basic facts. Since more preskills are involved such as renaming (regrouping) and adding a series of single digit numbers, the tasks usually require the use of some kind of algorithm to facilitate the series of computations necessary to arrive at the missing sum.

Essential to rapid and accurate use of an algorithm such as the Hutchings low-stress algorithm for addition is the rapid recall of the basic addition facts along with the accurate recording of component operations and regroupings (Hutchings, 1976). Computational forms
should, however, be distinguished from mathematical sentences
(Lichtenberg, 1978). For example, the sentence \(2 + 6 = \square\) is not equivalent to the expression \(+6\). The "\(\square\)" is called a vinculum or bar which means "reduce to the simplest term" while the equals sign ("\(=\)") means several possibilities, only one of which is "reduce to the simplest term."

Lichtenberg (1978) points out that there are different names for numbers and a number sentence is an equation which "asserts that two expressions are names for the same number" (p. 13). Therefore according to Lichtenberg, a basic addition fact is a number sentence such as \(6 + 7 = 13\) and memorization of this fact entails learning that "\(6 + 7\)" and "\(13\)" are names for the same number. Mastery of a basic addition fact is defined by Silbert et al. (1981) as "the student's being able to respond instantaneously to the fact question" (p. 238). Alessi (Note 2) and Silbert et al. (1981) consider the saying of a correctly completed basic fact sentence within two seconds as an acceptable performance criterion for mastery.

Instruction which focuses upon memorization of the basic addition facts usually follows extensive experiences with the manipulation of concrete materials (Engelhardt, 1976). Using concrete materials during the initial instruction for the addition operation is done to promote the children's understanding of the operation and to facilitate the development of verbal repertoires which are necessary for appropriate use of the language and symbolism associated with addition (Rathmell, 1978). Swenson (1973) suggests that learners should "have a good understanding of the meanings of the facts, their application, and their relationships one to another" (p. 75) before emphasis is
placed upon memorization. The types of instructional activities
detailed by Ashlock (1971) include activities for understanding facts
which are followed by activities for relating facts (e.g., classifying
facts with the same sum) and activities for mastering facts (viz.,
practice to strengthen recall of missing numbers in the basic number
sentence). Ashlock states that a child understands a basic addition
fact if he or she is able to write the equation representing the
record of an activity with diagrams or physical objects, and modeling
the activity represented by the basic fact. Essential to this under­
standing is knowledge of numbers as demonstrated by counting aloud,
counting objects, identifying a numeral in a group of numerals when
told the name, and saying the name of a given numeral (Johnson &
Bailey, 1974; Thiele, 1938). Other skills prerequisite to instruction
for memorization of the basic addition facts include correctly identi­
fying and using mathematical symbols (Davis, 1978); counting forwards
by ones and twos (Swenson, 1973); counting forward and backwards to
demonstrate knowledge of one more and one less (Myers & Thornton,
1977; Thiele, 1938); and regrouping by place value and quickly adding
a single digit number to 10 to demonstrate knowledge of what two-digit
numerals or "teens" represent (Nelson & Leutzinger, 1980; Swenson,
1973).

Once the learners have acquired the prerequisite skills,
instruction directed towards the memorization of the basic facts
should begin. Engelhardt (1976) states that teachers typically provide
various activities requiring the use of the basic facts based upon the
assumption that extensive use of the basic facts will result in the
learners memorizing them. Although drill with flashcards is commonly used, Engelhardt suggests games and activities which provide problem solving experiences with the use of open number sentences. Instruction that utilizes the manipulation of concrete materials and drill may include some interesting games and activities but Rathmell (1978) points out that immediate recall of the basic facts (i.e., memorization) is not necessarily the outcome. Rathmell indicates that the acquisition of thinking strategies from the instructional activities and the subsequent use of those strategies may be the salient factors determining whether or not a child is successful in providing the missing numeral in a basic fact sentence. Some of these thinking strategies involve the manipulation of physical objects such as counting on fingers or making and counting tally marks or dots while other strategies involve using known facts or verbal rules to figure out unknown facts.

Brownell and Chazal (1935/1970) describe a study that examines the effects of drill upon arithmetic performance. The drill procedure consisted of repeated random order presentation of basic fact combinations through flashcard activities, games, rapid exposure devices, and one-step problems. In the study, when a child did not know a basic fact during practice, the answer was immediately provided. Brownell and Chazal found that the drill and incidental use of addition facts increased the speed and accuracy of the particular strategy used by the children during the testing situation whether the strategy involved recall of a memorized fact, indirect solutions, or counting. However, drill was found to have little impact upon the development of more effective thinking strategies. Rathmell (1978) suggests that
some children will discover new thinking strategies on their own but drill such as that described by Brownell and Chazal (1935/1970) may be insufficient to facilitate the acquisition and use of more effective strategies.

Davis (1978) recommends that children should not use finger counting or tally mark counting during drill on basic facts. Engelhardt (1976) states that if a learner lacks sufficient mastery of the basic facts, alternative and often time-consuming and distracting methods will be utilized to figure out the missing numerals in basic fact sentences. Ashlock (1971) points out that a learner may have difficulty developing computation skills if it is necessary for that learner to utilize tangential and elaborate procedures for figuring out basic facts. A possible result is that such children may fall far enough behind in mathematics to eventually develop low estimates of their own math skills, avoid opportunities to develop and use their math skills, or even be officially labelled because of their skill deficits (Alessi, Note 2). If a learner is to develop proficient computational skills for use in problem solving and as a tool for further exploration of "new and interesting topics in mathematics," it is obligatory that she or he master the basic facts (Ashlock, 1971, p. 363).

Rathmell (1978) suggests that teaching thinking strategies may be an effective way to facilitate the memorization of the basic addition facts. The strategies include counting by ones or twos; using the identify element for addition (adding zero); the commutative property and doubles; finding one more or one less than a known fact; and adding to ten. Myers and Thornton (1977) and Silbert et al. (1981)
suggest that children should be explicitly taught these relationships and strategies. Even though research (e.g., Carnine & Stein, 1981; Thiele, 1938; Thornton, 1978) supports the teaching of thinking strategies to figure out basic facts, Myers and Thornton (1977) state that an examination of current instructional practices and of mathematics texts reveals that many of the relationships among facts, and various thinking strategies are not emphasized during instruction. The learner is to "discover" them on his or her own. Some learners, however, do not discover the relationships and thinking strategies that facilitate the mastery of the basic facts.

While inadequate fact mastery may be attributed to the failure of a learner to develop thinking strategies, Engelmann and Carnine (1982) suggest another approach. Instead of assuming that the learner is responsible for not learning, Engelmann and Carnine propose that the focus be placed upon an analysis of the instruction instead of upon the learner. This would "require us to rule out the possibility that instructional variables could account for learner failure" (p. 16).

Adequate mastery involves the immediate recall of the basic facts and instruction for mastery usually involves large amounts of practice to increase the rate and accuracy of responding. Ashlock (1971) states that "practice that is to strengthen the immediate recall of missing numbers will involve recall and not just figuring them out" (p. 363). Many important instructional variables are included in the guidelines for teaching children to master the basic arithmetic facts that were derived by Davis (1978) from common effective teaching practices. Some of the guidelines were reported to have a basis in research findings.
The ten guidelines or principles are as follows:

1. Children should attempt to memorize material they reasonably understand.

2. Have children begin to memorize basic arithmetic facts soon after they demonstrate an understanding of symbolic statements.

3. Children should participate in drill with the intent to memorize.

4. During drill sessions, emphasize remembering—don't explain.

5. Keep drill sessions short, and have some drill almost every day.

6. Try to memorize only a few facts in a given lesson, and constantly review previously memorized facts.

7. Express confidence in your students' ability to memorize—encourage them to try memorizing and see how fast they can be.

8. Emphasize verbal drill activities and provide feedback immediately.

9. Vary drill activities and be enthusiastic.

10. Praise students for good efforts—keep a record of their progress (Davis, 1978, pp. 51-60).

These principles closely correspond with many of the essential aspects of instructional procedures included within the ambit of the Direct Instruction model. Becker and Carnine (1980) state that the key assumptions of this model are: "(1) that all children can be taught (the teacher is responsible); (2) that to "catch up," low-performing students must be taught more, not less; and (3) that the task of teaching more requires a careful use of educational technology and of time" (p. 433, emphasis supplied). Silbert et al. (1981) describe eight steps necessary for devising an effective direct instruction program for mathematics. The steps include: Specifying objectives;
devising problem solving strategies; determining necessary preskills,
selecting teaching procedures; designing formats; selecting examples;
and providing practice and review (p. 3).

Silbert et al. (1981) state that a program to facilitate the
memorization of basic facts should include a specific criterion of
performance and intensive practice on newly introduced facts. Carnine
(Note 4) compared two fact presentation procedures. One group of
children was trained according to a cumulative introduction procedure
in which a fact was introduced to a set only when the learners made
a specified number of correct responses (twice the number of facts
in the current set). The other group received a simultaneous intro­
duction of facts with the facts randomly presented until the learners
made consecutive correct responses to each of the entire set of facts.
The children trained with the cumulative introduction procedure reached
the criterion of consecutive correct responses to each of the entire
set of facts in significantly fewer trials. The cumulative introduction
of facts follows a mastery learning approach (Becker & Carnine, 1980)
and the results by Carnine (Note 4) suggest that only a few facts
should be introduced initially. The introduction of new facts should
continue during training only when the learner reaches a specified
standard of performance on the previously introduced facts and reaching
this mastery criterion should involve intensive practice. After pro­
viding intensive practice on newly introduced facts, Silbert et al.
(1981) suggest that practice on previously taught facts should be pro­
vided. They state that "unless earlier introduced facts are systemati­
cally reviewed, students are likely to forget them" (p. 238).
Silbert et al. (1981) consider inadequate review as the greatest shortcoming of commercial arithmetic programs especially in the area of basic fact instruction.

Within the context of this study, mastery of the basic addition facts involves memorization. In such activities, a person "is behaving under contingencies designed to maximize the probability of recall" (Skinner, 1968, p. 205). Engelmann (1977) and Engelmann and Carnine (1982) describe a "memory sequence" designed to facilitate memorization in situations where a learner who is capable of producing a response (e.g., has solved addition problems by finger-counting) cannot recall (produce) the correct response in the context of the memorization tasks.

Engelmann and Carnine (1982) suggest a systematic interruption of the task trials by interspersing familiar but interfering tasks between trials. The interspersal tasks are made more difficult by creating more interference involving interspersal of longer periods of time and larger numbers of interspersal tasks, or by making the interspersal items more similar to the learning tasks and more difficult with respect to response and attentional requirements. Engelmann and Carnine (1982) state that this sequence ensures that a learner will receive a great deal of reinforcement because of the increased opportunities to make a larger number of correct responses on the familiar tasks and also ensures that the learner will receive the practice and feedback necessary to reach a high level of performance on the new tasks.
Two studies reported by Neef, Iwata and Page (1977, 1980) examined an interspersal procedure within spelling instruction. A procedure involving the interspersal of known items during the training of new spelling tasks was compared with a condition in which high density social reinforcement was administered contingently "on such task-related behaviors as paying attention, writing neatly, and trying hard" (Neef et al., 1980, p. 154). Neef et al. (1977, 1980) found that the interspersal procedure was more effective in promoting acquisition. Neef et al. (1980) also found that interspersing items once they were mastered increased the retention both during and following training. Neef et al. (1980) suggest that the effectiveness of the interspersal procedure may be attributed to (1) the facilitation of attentional responses to critical stimulus relationships as a result of the high levels of reinforcement accompanying the large number of correct responses on the known interspersal items, and (2) less interference of the attending responses by emotional responses to errors since the interspersal procedure facilitated more correct responding.

Monteiro (Note 5) examined the effects of two procedures upon the acquisition and retention of basic sight words. The Trial and Error procedure involved the training of sets of sight words to criterion while the Errorless procedure incorporated the use of echoic primes and the interspersal of items with the training items after training to criterion. Monteiro found that the Errorless procedure with the additional interspersal practice was superior with respect to retention. The Errorless procedure did, however, require more training time per session but with fewer sessions.
Wright (Note 6) examined the effects of cumulative review on the acquisition and retention of basic sight words. The study compared two conditions in which known words and those just previously taught were interspersed with newly introduced words. The Interspersal Only condition involved the interspersal of items known on a pretest and the Cumulative Review condition involved the interspersal of items that were learned and mastered during training. The results showed that cumulative review increased the rate of acquisition of new sight words for all subjects but did not improve retention in terms of percent correct. However, the absolute number of words known on the retention probes was found to be higher for the Cumulative Review condition.

Wright suggests that the Cumulative Review condition facilitated acquisition because of increased task requirements with respect to attention. That is, a subject possibly attended more closely to the critical features of the words in the Cumulative Review condition since the training words and interspersal words were both relatively new.

Alessi (Note 3) describes a procedure that can be used by teachers to teach basic sight words within the classroom setting. The procedure utilizes peer and cross-age tutors and a "word-bank" comprised of the basic sight words printed on flashcards. Within this procedure, basic sight words are trained to a mastery criterion level and are subsequently reviewed during later training sessions. A similar procedure that teachers can use to teach basic addition facts within the classroom setting is described by Alessi (Note 2). This procedure
utilizes the peer and cross-age tutors and "fact-banks" for each respective operation of arithmetic. The use of flashcards, structured practice, mastery learning criteria, and systematic review are also incorporated into the "fact-bank" procedure. The Errorless procedure use by Monteiro (Note 5), the Cumulative Review procedure used by Wright (Note 6), and the Cumulative Review procedure used within the present study are all modifications of the same basic procedures delineated by Alessi (Note 2) and Alessi (Note 3).

The present study was a systematic replication of the procedures examined by Wright (Note 6) and explored the effects of cumulative review on the acquisition and retention of basic addition facts. The independent variable was the method for the selection of interspersal items (i.e., selection from items known on the pretest versus selection from those facts learned during training). The dependent variables included the number of responses and number of errors to mastery during training and interspersal; the number of probes to mastery; the total number of sets and individual facts mastered; the duration of training sessions; the score on the Mastery Probes and the total number and percent correct on the Final Day and Follow-Up retention probes.

To compare the two conditions, a multielement baseline design (Ulman & Sulzer-Azaroff, 1975) incorporated within a modified multiple-probe design (Horner & Baer, 1978) was used. As with other within subject designs, the essential characteristic of the multielement baseline design is "the repeated measurement of a behavior under alternating conditions of the independent variable" (Ulman & Sulzer-Azaroff, 1975, p. 379). A distinctive stimulus (eventually
discriminative) is associated with each experimental condition with conditions alternated independently of any changes in behavior. A demonstrated effect as shown by differential performances for different treatment conditions leads to quite believable statements about functional relationships between independent and dependent variables.

Ulman and Sulzer-Azaroff state that the merits of the multielement baseline design over traditional within subject designs are readily shown in situations (especially in educational situations) where the experimental treatments produce irreversible changes in behavior and in situations where a return to baseline conditions is inadvisable as with the elimination of disruptive behaviors or the development of academic behaviors. Since experimental conditions are alternated independent of changes in behavior, the problem with unstable baselines does not arise with a multielement baseline design. Ulman and Sulzer-Azaroff further suggest that this design is especially suited for a component analysis (as in the present study) since behavior changes consistently related to corresponding changes in experimental treatments increase the believability of possible functional relationships. The authors suggest that these relationships tend to be observed in fewer sessions than with other designs since stability criteria are unnecessary. Also, sequence effects appear to be minimized when conditions are presented only briefly (one per session) since minimal exposure to one condition lessens the chances that carry-over effects will develop.
CHAPTER II

METHOD

Subjects

Three male subjects were selected from students enrolled in Project Help, an educational service which is affiliated with Western Michigan University and which provides school-aged children with remedial instruction from tutors enrolled in an educational psychology course. Both grade level and performance on the addition problems on the arithmetic section of the Wide Range Achievement Test, utilized by Project Help as a pre- and posttest, were used to screen potential subjects. Selection of the subjects for participation in the study was based upon overall performance on a basic addition facts pretest. The complete pretest was administered to three pupils, all who were in the eighth month of the second grade. Bob (age 9-3 years), Ken (age 7-8 years), and Bill (age 9-11) correctly responded to an average of approximately 40 of the 100 facts on the pretest (range: 35-43). During the pretest Ken and Bill were observed using a finger counting strategy in attempts to verify their responses while Bob was observed using a guessing strategy. Bill and Bob had previously attended Project Help for several semesters while Ken was a new client.

Prior to the initiation of the study, approval of the research was received from both the Psychology Department Human Subjects Review Committee and the University Human Subjects Institutional Review
Board. The parents of the subjects signed informed consent forms prior to the participation of the subjects in the study. A copy of the letter and informed consent form sent to the parents is included in Appendix B.

On the seventh day of data collection, Bill was dropped from the study because the lengths of his training sessions were inordinately long. The experimenter and Project Help staff felt that the long training sessions would impede progress in his reading instruction.

Setting

The subjects received remedial instruction in decoding and language comprehension during two individual tutoring sessions. The tutoring occurred within university classrooms between 4:00 and 6:00 p.m., Monday through Thursday, except holidays. The experimental sessions were conducted once for each subject during each tutoring session. To minimize the interruptions of the tutoring in progress and also to prevent distractions during training, these experimental sessions were conducted within one of the five partitioned offices in a room adjacent to the classrooms where the tutoring occurred.

Materials

Colored blocks were used as the objects in the prerequisite skills check. The experimental training sessions were recorded on a cassette tape recorder for accuracy and reliability purposes. A Casio PW-80 Pocketwatch electronic calculator with a repeater timer function and electronic buzzer was used to signal the trial intervals during the
probes, training, and interspersal of addition facts.

The 100 basic addition facts (see Appendix A) were printed on 140# white index cards cut to 3 inches by 5 inches. The numerals were printed in black ink with the use of a No. 72 Pickett template with 1/2 inch Neon characters. Each uncompleted fact sentence (hereafter referred to as "fact") was printed lengthwise on one side of the 3X5 inch index card in the form of "'addend'+'addend'='sum'" and each completed fact was printed on the opposite side in the form of "'addend'+'addend'='sum'".

The experimenter used a pencil and data sheets to record the responses of the subjects during the sessions. A screen was fashioned from a manilla folder to prevent the subjects from observing the recording of the responses by the experimenter. Sessions were timed with the use of a wristwatch.

The experimenter gave the subjects 15 "points" during each training session for working hard. An equivalent number of points could be earned by the subjects for work during a comparable amount of time in their tutoring sessions. The points were recorded on their Project Help point cards. With these points, subjects could buy items such as sugarless candy, small toys, games, etc., from the Project Help Store.
Procedure

Measurement

Pretest

A prerequisite skills check was made prior to the administration of the basic addition facts pretest. The experimenter considered a subject as having the necessary preskills if the subject was able to:

a. count aloud to 18.
b. count 18 objects.
c. tell how many objects were in a set (cardinal number).
d. identify a numeral (from 0 to 18) in a group of numerals.
e. say the name of a given numeral.
f. correctly identify (read) the symbols "+" and "=".
g. model a given addition statement with a set of objects.
h. write the addition statement which represented an activity demonstrating a basic addition fact.

To be considered as a subject, a student must also have demonstrated inadequate mastery of the basic addition facts. A student's mastery skill level was indicated by performance on a basic addition facts pretest administered after the prerequisite skills check. Mastery of a basic addition fact is defined by Silbert et al. (1981) as "the student's being able to respond instantaneously to the fact question" (p. 238). Alessi (Note 2) and Silbert et al. (1981) consider the saying of an entire correctly completed basic fact sentence in
approximately two seconds as an acceptable performance criterion for mastery. The task requirements presented by saying a large number of complete fact sentences successively during a timed pretest were likely to be highly demanding for most subjects. Therefore, the selected mastery criterion was relaxed to approximately 3 seconds which remained consistent with that suggested by Alessi (Note 2) and Silbert et al. Inadequate mastery would be demonstrated if the subject responded correctly to between one-third and one-half of the 100 basic facts. This would allow adequate samples from which known and unknown facts could be later selected for interspersal and for training respectively.

The pretest consisted of the 100 basic addition facts (see Appendix A). The 100 fact cards were randomly sorted into stacks of 10 facts each. The following instructions were presented at the beginning of the pretest:

Now we are going to see how well you can do on your addition facts. I will show you some flashcards that have the addition facts without the answers. For each one I want you to say the whole fact with the answer before the buzzer sounds. Okay? Remember, say the whole thing before the buzzer sounds. What are you going to do?....

The electronic calculator was set to signal with the buzzer at 4 second intervals. The experimenter had 1 second to present a flashcard and the subject had approximately 3 seconds to respond.

The experimenter ran through each stack one fact at a time. Each response was recorded as correct or incorrect. If a subject made no response or if a response was not made before the buzzer approximately 3 seconds from the presentation of the fact by the experimenter, the
response was recorded as incorrect. Self-corrects, e.g., "6+4=8...10", were counted as incorrect. Producing extra sounds or slurring sounds between the "equals" and the correct answer were counted as correct if the subject did not produce a whole syllable. For example, "8+7=sessssss...fifteen" was scored as correct while "8+7=six...fifteen" was scored as incorrect. If the subject said a fact incorrectly but then said the entire fact correctly before the time limit, it was scored as correct. A response occurring on the buzzer was scored as correct if at least the first syllable of the answer occurred before the buzzer sounded (e.g., "9+8=seven"-(buzzer sounds)-"teen" was scored as correct). Three seconds after the fact was presented the buzzer sounded and the experimenter said "Next fact" and moved on through the stack. Each stack was recycled three times.

The subjects received no feedback on the correctness of their responses but were praised for paying attention and for working hard. A fact was considered as known if a subject answered correctly on all three presentations or correctly on the last two presentations. All other facts were considered as unknown and were candidates for training items if all three subjects didn't know them. Following the suggestions by Wright (Note 6), this procedure allowed the experimenter to present the same facts to all subjects during treatment, thus controlling for the possibility that one fact was more difficult than another across subjects. No more than 30 facts (three stacks) were presented during one session. The prerequisite skills check and basic addition facts pretest took approximately two days to complete for each subject. The unknown facts were randomly sorted into two
training files, one for each condition. One pair of unknown facts was to be trained during each session so care was taken to prevent the two facts in the pair from having a same response minimum difference (e.g., 6+5=11; 3+8=11).

**Dependent Measures**

Acquisition and retention of the basic addition facts trained and mastered comprised the dependent variables. Assessing a possible effect of an experimental treatment upon acquisition would entail measuring several factors. For a treatment to be considered more effective, a greater number of facts would have to be mastered more quickly (smaller mean number of probes to mastery) in fewer trials (smaller mean number of responses to mastery) with fewer errors (smaller number of errors to mastery). Evaluating retention would entail measuring how well the facts were remembered over the passage of time. A treatment would be considered more effective if a larger percentage of the individual facts trained and mastered were remembered during the retention probes at the end of training and after four and eight weeks had elapsed since training. Measurement of the dependent variables entailed data collection on the following:

(a) the score on the Mastery (retention) Probe for each set of facts introduced. A set of facts was defined as two facts introduced and trained as a pair. Only one pair or set of facts was trained during any one session. Probes were conducted at the beginning of each session and a score of 0, 1, or 2 was recorded for each fact set probed. The criteria for a fact to be considered learned (known)
were correct responses to all three of the presentations during the probe or on the last two presentations. Meeting the above criteria on both facts in a set corresponds to a score of 2. Meeting criteria on only one fact in the set corresponds to a score of 1. Failing to meet the criteria on either fact corresponds to a score of 0 (zero).

(b) the number of facts introduced under each condition.

(c) the number of sets mastered within each condition. The mastery criterion for a set to be considered mastered was defined as a score of 2 on the retention probe for three consecutive sessions for a set of facts under a specific condition.

(d) the total number of individual facts mastered under each condition. The total number of facts introduced upon which a subject met the mastery criterion of three consecutive probes with correct responses on all three presentations of the fact or correct responses on the last two presentations of the fact during each probe.

(e) the total number and percent correct on the Final Day retention probe and on each of the Follow-Up retention probes.

(f) the mean number of unprimed responses (responses not preceded by an echoic prime by the experimenter) to mastery during training and during interspersal for the total number of individual facts mastered within each condition.

(g) the mean number of errors made to mastery during training and during interspersal for the total number of individual facts mastered within each condition.

(h) the mean number of total responses (training plus interspersal) to mastery and the mean number of errors to mastery for the total
number of individual facts mastered within each condition.

(i) the average number of sessions for a subject to meet the mastery criterion of three consecutive probes with a score of 2 for the sets mastered and the average number of sessions to meet the criteria for having learned a fact for three consecutive probes for the total number of individual facts mastered under each condition (number of probes to mastery/number of sets or facts mastered).

(j) the mean session duration including probes, training, and interspersal for each condition.

(k) the mean duration of training and interspersal (time between the discriminative stimulus in Step 2 and the end of the session after Step 13) of basic facts during each condition (from tape recording of sessions).

**Accuracy/Reliability of Dependent Variable Measurement**

Each session was recorded on cassette tape. From this tape recording, the experimenter obtained an estimate of the accuracy of the measurements of each subject's responding. Response-by-response correspondence was obtained through a comparison of the data collected with the tape recording of the subject's responses during the sessions. The accuracy estimate was calculated by adding the number of agreements, dividing by the number of agreements plus agreements, and then multiplying by 100.

Reliability estimates were also obtained on a random selection of 25 percent of the sessions. A comparison of the observations of a subject's responding on tape by an independent observer with the
within session data was made in a manner similar to that described above for the accuracy checks. Percent reliability as a response-by-
response reliability estimate also was calculated by dividing the number of agreements by the number of agreements plus disagreements and then multiplying by 100.

Independent Variables

The independent variable was the method used in the selection of items (three per session) that were interspersed with the two facts within the set being trained to mastery, either from (1) the facts known on the pretest or (2) the facts mastered during prior training sessions.

Accuracy/Reliability of the Procedure Implementation

The accuracy to which the experimenter followed the training procedures for each condition (interspersal only versus cumulative review) was estimated through the use of an accuracy check on all sessions recorded and through the use of a reliability observer on a random selection of 25 percent of the sessions. A checklist similar to that used by Wright (Note 6) was used in conjunction with the tape recordings of the sessions. An example of the checklist is presented in Appendix C. The checklist items correspond to the steps for training and interspersal described below under the Training Procedures section. The item-by-item reliability/accuracy estimate was calculated by dividing the number of sessions an item was observed by the number of sessions observed and then multiplying by 100.
Design

A multielement design (Ulman & Sulzer-Azaroff, 1975) was utilized to compare the interspersal of known facts with newly trained facts (Interspersal Only condition) and the interspersal of facts mastered during prior training sessions with newly trained facts (Cumulative Review condition). This design differs from other standard within subject designs in that there are no treatment phase changes, but rather an alternation of treatment conditions from one session to another. Both treatment conditions were presented daily in random order with one condition being presented during each session. The sessions were approximately 10 minutes in length and were held twice daily, Monday through Thursday, except holidays.

Fact sets comprised of two basic facts were probed and trained under each condition. An adaptation of the multiple-probe technique developed by Horner and Baer (1978) was included to determine whether any improvement in performance could be attributed to learning other than that accomplished within the training sessions. Each fact set trained was probed just before training on that set began.

Mastery Probes

The first session began with a preview probe. Within this probe, the facts to be taught were presented alternately three times each to determine whether or not the facts had been learned since the pretest. The criteria for correctness of responding and whether a fact was considered as known were the same as those utilized in the pretest. During the mastery probes, no feedback was provided to the subjects.
regarding the correctness of responses. However, the subjects were praised for paying attention and for working hard.

On the second day of the study and every day thereafter, a retention probe was conducted. These determined whether or not the subject retained the fact set taught on the previous day(s). These probes were similar to the preview probe—the facts within a set were presented alternately until the subject responded to each fact three times. A fact was considered learned (known) if the subject correctly responded to the fact on all three attempts or on the last two. A score of 2 on the retention probe was recorded if the subject met the above criteria for having learned both facts. If the subject met the criteria on only one fact in the set, then a score of 1 was recorded. If the subject did not meet the criteria for either fact then a score of 0 (zero) was recorded. If the subject demonstrated having learned the facts (i.e., earned a score of 2 on the retention probe), then training was not conducted on those "learned" facts but new facts were probed until two facts were found that were not known and then these were trained.

Each fact set previously trained was probed on successive sessions until the subject met the mastery criterion of correctly identifying both facts in the set (score of 2) on the retention probes for three consecutive sessions. If the subject did not achieve the mastery criterion on one or more of the fact sets probed then the one taught earlier was trained during the session and on subsequent sessions until the mastery criterion was met.
Training Procedures

Interspersal Only Condition

This condition was in effect during one session daily. A set of facts consisting of two unmastered facts were trained at one time following the steps listed below:

Step 1. The experimenter recorded the time to indicate the beginning of the session. A preview or retention probe was conducted to determine the two facts to be trained.

Step 2. The experimenter provided a clear discriminative stimulus for the interspersal only condition by saying: "After we learn (work on) these two facts, we will practice them with facts you already know."

Step 3. Training began with the experimenter presenting a fact card by placing it on the subject's desk with the completed fact side showing. The experimenter provided the subject with an echoic prime (Skinner, 1968) and then asked the subject to echo the response (e.g., "My turn, '2+4=6'. Your turn, say the whole thing."). Correct responses were confirmed (e.g., "yes, 2+4=6") during training and interspersal.

Step 4. The card was then removed for approximately 3 seconds and replaced with the uncompleted fact sentence (referred to as "fact") showing. The experimenter then provided the directive, "Your turn, say the whole thing."

Step 5. The other member of the fact set was placed next to the first card with the completed fact side showing. The experimenter
provided the echoic prime and then asked the subject to echo the response ("My turn,...Your turn, say the whole thing.").

Step 6. The second member of the fact set was then removed for approximately 3 seconds and replaced with the fact side showing. The experimenter then provided the directive, "Your turn, say the whole thing."

Step 7. The two cards were removed for approximately 3 seconds and replaced in the same order with the fact side showing. The experimenter again provided the echoic prime for one fact at a time, asking the subject to say the whole thing.

Step 8. The two cards were removed again for approximately 3 seconds and then replaced in the opposite order. For each fact the subject was asked to say the whole thing ("Your turn, say the whole thing.") without the prime. If an error occurred, the card was turned over to display the completed fact while the experimenter modeled the correct response and then asked the subject to repeat it. The experimenter returned to Step 3, beginning with the fact card on which the error occurred.

Step 9. The cards were presented randomly with the fact side showing until the subject responded correctly to a criterion of five consecutive trials. A trial consisted of the presentation of both facts with an intertrial interval of 4 seconds. The electronic calculator was used to signal intervals of 4 seconds. The experimenter had approximately 1 second to present the card and the subject then had approximately 3 seconds to respond before the buzzer sounded. When the buzzer sounded the experimenter said "Next fact" and
presented the other fact card.

Errors were corrected during this and subsequent steps by the experimenter modeling the correct response and then requiring the subject to repeat it. Errors occurring because the subject failed to respond with the complete fact before the buzzer sounded were corrected by the experimenter prompting the subject to respond just as the card was presented. This was followed by the model-test correction. Responses throughout training were recorded during the intertrial intervals as either correct or incorrect using the same criteria as on the pretest. In step 9, the subject was required to respond in less than 3 seconds for a response to be considered correct. The subjects were praised for working hard and nearly all of the correct responses were confirmed, e.g., "Yes, 2+4=6."

Step 10. After training the facts to the criterion of five consecutive correct trials, the interspersal of three known facts with the two newly trained facts began. The experimenter again provided the subject with a clear discriminative stimulus for the Interspersal Only condition by saying, "Now we will practice these facts with facts you already know."

Step 11. During interspersal a stack of facts known on the pretest was used. A fact was randomly selected from the stack and the three facts (one known, two newly trained) were presented according to the procedure in Step 9 except that a trial consisted of the presentation of three facts and only five trials were presented regardless of whether errors were made or not. If an error was made on a known fact, the subject was corrected by the experimenter modeling the
correct response and then requiring the subject to repeat it.

Steps 12-13. These steps were conducted according to the procedures delineated in Step 11 except that one more fact was selected from the stack of known facts and included within the presentation during each step. Thus there were four and five facts presented in Steps 12 and 13 respectively with a trial consisting of four and five facts respectively. At the completion of Step 13, the session was stopped and the time recorded.

Cumulative Review Condition

This condition was in effect during one session daily and was conducted in a fashion similar to the Interspersal Only condition except with respect to the manner in which interspersal items were selected. In the Cumulative Review condition when the first fact set was trained, the three interspersal items were selected from those known on the pretest. After the second set was trained, only one interspersal item was selected from the facts known on the pretest with the others selected from the first set trained. A fact trained under the Cumulative Review condition was considered as an interspersal item if the subject met the criterion for that individual fact on the probe (which was correct responses to three consecutive presentations of an individual fact or two of the last three presentations correct). Not until after the third fact set was trained were all interspersal items selected from the previously trained items. It was not until the fifth session that cumulative review began for both subjects.
Also, within the Cumulative Review condition the discriminative stimuli provided by the experimenter at Steps 2 and 10 differ from those in the Interspersal Only condition. During Step 2 within the Cumulative Review condition the experimenter stated "After we learn (work on) these two facts, we will practice them with facts we are learning at Project Help." During Step 10 the experimenter stated "Now we will practice these facts with facts we are learning at Project Help."

The days a fact was trained, mastered and reviewed were recorded. As more sets were trained, each of the review (interspersal) items was selected if (1) it had not been reviewed in a while, (2) it was difficult for the subject to learn, and/or (3) it was recently trained (Engelmann & Carnine, 1982).

Final Day and Follow-Up Retention Probes

An overall retention probe was conducted on the last day of training and follow-up retention probes were made after the fourth and eighth weeks following the last day of training to determine the extent of the subject's retention of the facts mastered during training. All the facts that were introduced under both conditions were randomly sorted into equal piles. The probes then followed the procedures developed for the pretest. The total number known (three trials correct or last two correct being the criteria for a fact to be considered known) for facts introduced and for individual facts mastered, and the percent correct for facts introduced and for individual facts mastered were recorded.
CHAPTER III

RESULTS

Accuracy/Reliability of Dependent Variable Measurement

Accuracy checks by the experimenter on the measurement of the correctness of responding on item presentation during probes, training, and interspersal under each condition were made on 15 of 16 sessions for Bob and on all 16 sessions for Ken. The overall accuracy estimate for the recording of Bob's data was 99.8% for the Interspersal Only condition and 100% for the Cumulative Review condition. For the recording of Ken's data, the overall accuracy estimate was 99.7% for the Interspersal Only condition and 99.4% for the Cumulative Review condition.

Reliability observations on a random selection of 25% of the sessions for each condition were made by an independent observer. The overall reliability estimate for the recording of Bob's data was 99.7% for the Interspersal Only condition and 99.7% for the Cumulative Review condition. The overall reliability estimate for the recording of Ken's data was 99.6% for the Interspersal Only condition and was 99.8% for the Cumulative Review condition.

Accuracy/Reliability of the Procedure Implementation

The accuracy of the implementation of the two procedures was estimated through the use of an accuracy check by the experimenter on
recordings of 15 of 16 of the sessions for both conditions for Bob and on all of the sessions for Ken. For Bob, the overall accuracy estimates on checklist items were 94.8% (range: 73.3 to 100%) for the Interspersal Only condition and 95.5% (range: 73.3 to 100%) for the Cumulative Review condition. The overall accuracy estimates for Ken were 93.3% (range: 68.75 to 100%) for the Interspersal Only condition and 91.8% (range: 68.75 to 100%) for the Cumulative Review condition.

On a random selection of 25% of the sessions, an independent observer completed the checklist with the recordings of the sessions. The overall reliability estimates were 96.2% for both the Interspersal Only condition and the Cumulative Review condition for Bob. The reliability estimates for Ken's sessions were 96.2% for the Interspersal Only condition and 94.2% for the Cumulative Review condition.

**Session Durations**

Bob's average overall session duration (including probes, training and interspersal) for the Interspersal Only condition was 10 minutes 25 seconds and his average overall session duration for the Cumulative Review condition was 9 minutes 45 seconds. The Interspersal Only condition required 6.8% more time per session.

The overall session durations included the probes which could vary in the number of sets probed (and thus vary in the amount of time in which to conduct them). The training (Steps 2-9) and interspersal (Steps 11-13) parts of the procedure required the subject to respond to an equal number of trials during each session for each condition unless errors were made (especially in Step 9 where the subject was required
to correctly respond to five consecutive trials) so the duration of those parts of the procedure were measured. From the recordings of Bob’s sessions, the average duration of item training and interspersal (time between the first discriminative stimulus and the end of the session) was 8 minutes 11 seconds for the Interspersal Only condition and was 7 minutes 50 seconds for the Cumulative Review condition. Therefore, training and interspersal during the Interspersal Only condition required 4.5% more time per session.

Ken's overall session duration averaged 10 minutes 33 seconds for the Interspersal Only condition and averaged 11 minutes 23 seconds for the Cumulative Review condition. The Cumulative Review condition required 7.9% more time per session.

From the recordings of Ken's sessions, the average duration of item training and interspersal was 8 minutes 42 seconds for the Interspersal Only condition and was 9 minutes 14 seconds for the Cumulative Review condition. Therefore, training and interspersal during the Cumulative Review condition required 6.1% more time per session.

Number of Facts Introduced and Mastered

The number of facts introduced, the number of sets mastered, and total number of individual facts mastered are presented in Table 1.

For Bob, more facts were introduced (12 vs. 10), more sets were mastered (5 vs. 3), and more individual facts were mastered (10 vs. 6) under the Interspersal Only condition than under the Cumulative Review condition. However, for Ken, more facts were introduced (10 vs. 6), more sets were mastered (2 vs. 1), and more individual facts were
mastered (7 vs. 4) under the Cumulative Review condition than under the Interspersal Only condition.

Table 1
Number of Facts Introduced and Mastered for Each Condition

<table>
<thead>
<tr>
<th>Subject</th>
<th>Condition</th>
<th>Facts Introduced</th>
<th>Sets Mastered</th>
<th>Total Individual Facts Mastered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bob</td>
<td>Cumulative Review</td>
<td>10</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Interspersal Only</td>
<td>12</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Ken</td>
<td>Cumulative Review</td>
<td>10</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Interspersal Only</td>
<td>6</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

Mean Number of Sessions to Mastery

The mean number of sessions to meet the mastery criteria on the Mastery Probes for the basic addition facts under each condition is presented in Table 2 for sets mastered and for individual facts mastered.

The mastery criteria for sets mastered are scores of 2 on the Mastery Probes for three consecutive probes/sessions and the criteria for individual facts mastered are correct responses on all three presentations of an individual fact or correct responses on the last two presentations during the Mastery Probes for three consecutive probes/sessions.
Table 2
Mean Number of Sessions to Meet Mastery Criteria for Sets and Individual Facts

<table>
<thead>
<tr>
<th>Subject</th>
<th>Condition</th>
<th>Sets Mastered</th>
<th>Total Individual Facts Mastered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bob</td>
<td>Cumulative Review</td>
<td>7.7</td>
<td>6.5</td>
</tr>
<tr>
<td></td>
<td>Interspersal Only</td>
<td>6.2</td>
<td>5.5</td>
</tr>
<tr>
<td>Ken</td>
<td>Cumulative Review</td>
<td>9.5</td>
<td>8.4</td>
</tr>
<tr>
<td></td>
<td>Interspersal Only</td>
<td>11</td>
<td>9.8</td>
</tr>
</tbody>
</table>

On the average, Bob took approximately 20% fewer sessions to meet the mastery criteria under the Interspersal Only condition for sets mastered (6.2 vs. 7.7) and took approximately 15% fewer sessions for the total individual facts mastered (5.5 vs. 6.5). Ken, however, took approximately 14% fewer sessions to meet the mastery criteria under the Cumulative Review condition for sets mastered (9.5 vs. 11) and approximately 14% fewer sessions to meet criteria for the total individual facts mastered (8.4 vs. 9.8).

Mean Number of Responses and Errors to Mastery

Table 3 shows the mean number of responses during training and interspersal from the introduction of a fact into training until the mastery criterion was reached under each condition for each subject.
<table>
<thead>
<tr>
<th></th>
<th>Bob Cumulative Review</th>
<th>Bob Interspersal Only</th>
<th>Ken Cumulative Review</th>
<th>Ken Interspersal Only</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Training</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean # Responses</td>
<td>24</td>
<td>19</td>
<td>34</td>
<td>49</td>
</tr>
<tr>
<td>(12-37)</td>
<td>(12-28)</td>
<td>(12-61)</td>
<td>(31-60)</td>
<td></td>
</tr>
<tr>
<td>Mean # Errors</td>
<td>0.3</td>
<td>2</td>
<td>4.7</td>
<td>5.3</td>
</tr>
<tr>
<td>(0-2)</td>
<td>(0-6)</td>
<td>(0-14)</td>
<td>(0-9)</td>
<td></td>
</tr>
<tr>
<td><strong>Interspersal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean # Responses</td>
<td>74</td>
<td>35</td>
<td>77</td>
<td>71</td>
</tr>
<tr>
<td>(35-120)</td>
<td>(30-60)</td>
<td>(40-105)</td>
<td>(45-105)</td>
<td></td>
</tr>
<tr>
<td>Mean # Errors</td>
<td>2.2</td>
<td>0.8</td>
<td>16.9</td>
<td>14.8</td>
</tr>
<tr>
<td>(0-7)</td>
<td>(0-3)</td>
<td>(0-22)</td>
<td>(0-20)</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean # Responses</td>
<td>98</td>
<td>54</td>
<td>112</td>
<td>121</td>
</tr>
<tr>
<td>Mean # Errors</td>
<td>2.5</td>
<td>2.8</td>
<td>21.6</td>
<td>20</td>
</tr>
</tbody>
</table>
Also presented are the mean number of errors during training and interspersal, the mean number of total responses to mastery, and the mean number of total errors to mastery for each condition.

Bob, on the average, reached the mastery criterion in approximately 45% fewer total responses (54 vs. 98) under the Interspersal Only condition with approximately 12% more errors (2.8 vs. 2.5 errors). During the training part of the procedure, Bob required approximately 21% fewer responses (19 vs. 24) to meet the mastery criterion under the Interspersal Only condition but was less accurate (2 vs. 0.3 errors). During the interspersal part of the procedure, Bob required approximately 53% fewer responses (35 vs. 74) under the Interspersal Only condition to reach mastery, with fewer errors (0.8 vs. 2.2 errors).

Ken, on the other hand, reached the mastery criterion in approximately 7% fewer total responses (112 vs. 121) under the Cumulative Review condition but with approximately 8% more errors (21.6 vs. 20). During training, Ken required 31% fewer responses (34 vs. 49) to meet the mastery criterion under the Cumulative Review condition with approximately 11% fewer errors (4.7 vs. 5.3 errors). During interspersal, Ken required somewhat more (approximately 8%) responses (77 vs. 71) to meet the mastery criterion under the Cumulative Review condition, with approximately 14% more errors (16.9 vs. 14.8 errors).

Performance on the Mastery Probes

The scores made by the subjects on the Mastery Probes for the facts introduced in each condition are depicted in Figures 1 and 2. The scores on the Mastery Probes for both conditions are graphed on each panel for
Figure 1. Bob's Performance on Mastery Probes for Each Fact Set Introduced, Trained, and Mastered During the Interspersal Only and Cumulative Review Condition.
FIGURE 1. BOB

- CUMULATIVE REVIEW, TRAINING
- CUMULATIVE REVIEW, NO TRAINING
- INTERSPERSONAL ONLY, TRAINING
- INTERSPERSONAL ONLY, NO TRAINING

8+7=15
2+6=8
4+6=10
3+9=12
6+8=14
5+7=12
9+5=14
5+6=11
8+8=16
3+8=11
7+6=13
9+7=16
5+9=14
9+8=17
6+9=15
8+4=12
4+8=12
6+7=13
5+8=13
2+7=9
6+5=11
4+9=13

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Figure 2. Ken's Performance on Mastery Probes for Each Fact Set Introduced, Trained, and Mastered During the Interspersal Only and Cumulative Review Conditions.
FIGURE 2.  

- CUMULATIVE REVIEW, TRAINING  
- CUMULATIVE REVIEW, NO TRAINING  
- INTERSPERSAL ONLY, TRAINING  
- INTERSPERSAL ONLY, NO TRAINING

- 8+7=15  
  2+6=8  
- 4+6=10  
  3+9=12  
  x 8+7=15  
  6+8=14  
- 7+2=9  
  6+8=14  
- 9+5=14  
  5+6=11  
- 5+7=12  
  8+8=16  
- 7+6=13  
  9+7=16  
- 3+8=11  
  5+9=14  
- 9+8=17  
  4+8=12

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each successive set of facts. The order of introduction of fact sets was the same for each subject (except for the fact 7+2=9 on which Bob met the criteria during the first probe on that fact so that fact was dropped as a training item for Bob). Dropping only one fact under these circumstances indicates that little or no memorization of the basic addition facts occurred between the pretest and the time the facts were introduced.

The sets of facts introduced are indicated in the legend to the right of the respective axes for each set of facts taught under each condition. On the graph, data points for probes on facts taught under the Cumulative Review condition are shown by circles while the data points for probes on facts taught under the Interspersal Only condition are shown by triangles. An open data point indicates that training occurred for that set of facts during that session.

Throughout the study, Mastery Probes were conducted at the beginning of each session. One session of each condition was presented on each day of the study with the order of the conditions alternated randomly. Figure 1 shows Bob's scores on these Mastery Probes and also shows when each fact set was introduced, trained, and mastered. For example, on the probes for the first fact set (8+7=15; 2+6=8) trained under the Cumulative Review condition, Bob failed to meet the criteria for having learned (known) the facts for sessions 1-4. Therefore, that fact set was trained during those sessions. During sessions 5-7, Bob met the criteria for having learned the fact set and thus met the mastery criterion of three consecutive probes with a score of 2. During session 5, since the first fact set was known, another fact set (6+8=14;
5+7=12\) was probed under the Cumulative Review condition and was trained. This fact set was subsequently trained during sessions 5–9 and 11 since Bob failed to meet criteria on the probes. A third fact set \((8+8=16; 3+8=11)\) was probed and trained during session 11 since Bob met the criteria on the probe for the second fact set. During session 12, the third fact set was probed but not trained since Bob failed to meet criteria on the probe for the second fact set. Other subsequent probes followed in this manner.

For the first fact set \((4+6=10; 3+9=12)\) trained under the Interspersal Only condition, Bob failed to meet criteria on the first probe so training on that fact set occurred. However during sessions 2–4, Bob did meet criteria and the first set was considered mastered. During sessions 2–3, a new fact set \((9+5=14; 5+6=11)\) was subsequently probed and trained. Bob met criteria on the first two fact sets during session 4 so another fact set was probed and trained. Other subsequent fact sets were probed and trained in this fashion.

Figure 2 similarly shows the scores on the mastery probes, and when each fact set was introduced, trained, and mastered for Ken. For example, the first fact set \((8+7=15; 2+6=8)\) trained under the Cumulative Review condition was probed and was introduced into training during session 1. It was subsequently probed and trained during sessions 2 and 4 and was mastered by session 7. During session 2 under the Cumulative Review condition, one fact from each of the first two sets were inadvertently trained together. This is depicted by the X's on the top two panels in Figure 2. The mix-up was corrected by session 3. The first fact set \((4+6=10; 3+9=12)\) trained under the Interspersal Only
condition was introduced during session 1 and was trained during sessions 1, 2, 3, 6, 8, 10, 13, and 16. Ken failed to meet the mastery criterion for this fact set during the study since the mastery criterion of three consecutive probes with a score of 2 was not met. However, other fact sets were probed, trained and mastered.

Figures 3 and 4 show the cumulative number of facts mastered across sessions. Note the separation of the curves for the two conditions. In Figure 3, the Interspersal Only condition was superior for Bob in terms of cumulative number of facts mastered. However, in Figure 4, the Cumulative Review condition was superior for Ken.

Final Day and Follow-Up Retention Probes

Table 4 shows the number of facts known (subject met criteria of correct responses on three consecutive presentations of a fact or correct responses on the last two presentations) on the Final Day and on two Follow-Up retention probes.

On the Final Day retention probe, Bob met criteria on six of ten (60%) facts introduced during the Cumulative Review condition and on four of six (67%) of the facts mastered under the Cumulative Review condition. This performance was superior to that made on facts under the Interspersal Only condition. On facts under the Interspersal Only condition, Bob met criteria on four of twelve (33%) facts introduced and on three of ten (30%) facts mastered.

Ken also showed somewhat better performance on the Final Day retention probe for facts introduced and mastered under the Cumulative Review condition. He met criteria on six of ten (60%) facts introduced
FIGURE 3.

Figure 3. Cumulative Number of Facts Mastered by Bob Across Sessions for the Interspersal Only and Cumulative Review Conditions.
Figure 4. Cumulative Number of Facts Mastered by Ken Across Sessions for the Interspersal Only and Cumulative Review Condition.
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<td>6/10 (60%) 4/7 (57%)</td>
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and on four of seven (57%) facts mastered under the Cumulative Review condition. He met criteria on three of six (50%) facts introduced and on two of four (50%) facts mastered under the Interspersal Only condition.

On the 4-Week Follow-Up retention probe, both subjects showed an overall drop in retention of the basic addition facts introduced and mastered throughout the study. Bob met criteria on four of ten (40%) facts introduced and on three of six (50%) facts mastered under the Cumulative Review condition. He met criteria on two of twelve (17%) facts introduced and on one of ten (10%) facts mastered under the Interspersal Only condition. Bob's retention of facts trained under the Cumulative Review condition remained superior to his retention of facts trained under the Interspersal Only condition.

Ken, however, showed somewhat better retention on facts introduced and mastered under the Interspersal Only condition although his retention of facts trained under both conditions (as shown by the Final Day and the 4-Week retention probes) was very similar overall (with somewhat higher retention of facts under the Cumulative Review condition on the Final Day retention probe). On the 4-Week retention probe, Ken met criteria on two of six (33%) facts introduced and on two of four (50%) facts mastered under the Interspersal Only condition. He met criteria on three of ten (30%) facts introduced and on two of seven (29%) facts mastered under the Cumulative Review condition.

On the 8-Week Follow-Up retention probe, both subjects showed better retention on those facts introduced and mastered under the Cumulative Review condition. Bob met criteria on three of ten (30%)
facts introduced and on two of six (33%) facts mastered under the Cumulative Review condition. He met criteria on three of twelve (25%) facts introduced and on three of ten (30%) facts mastered under the Interspersal Only condition.

On the 8-Week retention probe, Ken met criteria on five of ten (50%) facts introduced and on four of seven (57%) facts mastered under the Cumulative Review condition. He met criteria on two of six (33%) facts introduced and on two of four (50%) facts mastered under the Interspersal Only condition.

Across retention probes, Bob's overall retention of facts trained under the Cumulative Review condition was superior to his retention of facts trained under the Interspersal Only condition. Ken's overall retention of facts trained under the Cumulative Review condition was generally greater than his retention of facts trained under the Interspersal Only condition although the results are somewhat mixed across retention probes.
CHAPTER IV

DISCUSSION

The purpose of this study was to examine the effects of cumulative review upon the acquisition and retention of basic addition facts. The findings indicate that the Cumulative Review condition was somewhat more effective with respect to overall retention of the basic facts even when the Interspersal Only condition was more superior for one subject in terms of acquisition. These results are consistent with those reported by Neef et al. (1980) who found that interspersal training with cumulative review led to high levels of retention in spelling. The present findings concerning overall retention for Bob are contrary to those reported by Wright (Note 6) who found little difference between the Cumulative Review and Interspersal Only conditions in terms of percent of sight words retained. The findings concerning retention for Ken appear to be more consistent with those found by Wright, with Ken's overall retention of facts trained under the Cumulative Review condition being somewhat greater than his overall retention of facts trained under the Interspersal Only condition. However, the small number of facts mastered by Ken made interpretation difficult.

Engelmann and Carnine (1982) state that a learner may require a large number of practice trials before an acceptable performance level can be reached on difficult or highly unfamiliar tasks. The "memory sequence" provides a large amount of massed practice trials. With

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massed trials the learner is expected to reach the mastery criteria in less time than if the same number of practice trials were distributed over a number of sessions. However, Engelmann and Carnine state that massed practice is less efficient. Kryzanowski and Carnine (1980) report that recall of letter-sound correspondences was higher under a condition where practice was distributed or spaced throughout the training sequence as compared to recall under a condition where the practice was massed within the training sequence. Both conditions in the present study provided a means for presenting a large amount of massed practice on newly introduced items. Without systematic review during instruction, learners may forget earlier introduced items (Silbert et al., 1981). Distributed practice was included in the Cumulative Review condition and was expected to result in increased retention. Also since the mastery criteria required high performance on the Mastery (retention) Probes across three consecutive sessions where training did not occur, better acquisition was expected if the distribution of practice trials as cumulative review facilitated better recall on the Mastery Probes.

The results of the present study showing higher performance across follow-up retention probes for facts trained under the Cumulative Review condition provide some evidence in support of the incorporation of cumulative review into instructional sequences for such academic tasks as the memorization of basic addition facts. However, the incongruous results found with respect to acquisition which may be attributed to extraneous factors suggest that further research be conducted in this area.
The results with respect to both acquisition and retention should be viewed in light of several factors which may have had some influence upon the outcome of the study. Learning history and the use of a specific strategy when figuring out basic facts should be addressed more carefully in future research on cumulative review with basic facts.

Bob, for instance, had considerable experience with direct instruction procedures (which are designed to facilitate responding with few errors) especially statement repetition tasks. He tended to make few errors throughout the study. Ken, however, was a new student in Project Help and had little exposure to direct instruction procedures. He tended to make a large number of errors. Also, during the pretest, Bob was observed utilizing a guessing strategy when figuring out basic facts while Ken was observed on many occasions attempting to verify his responses with a finger counting strategy. It is possible that, as Bob learned the new strategy of memorizing facts, he practiced the newly memorized facts during school arithmetic tasks while Ken may have continued to use his finger counting strategy. These extraneous variables may have had some influence on the subjects' acquisition and retention of the basic facts memorized during the study.

One issue which may have influenced the number of facts introduced was the criterion used to determine mastery (a score of 2 on the Mastery Probes for three consecutive probes/sessions). Wright (Note 6) utilized the additional criterion that if a set was not mastered in four sessions it was dropped from the study. In the present study, that additional criterion was not used because of the possibility of a loss of data. However, it was possible for a subject to meet the...
criteria of having learned a fact by correctly responding to all three presentations or to the last two presentations of one fact in a set during a probe for three consecutive probes long before the subject met those mastery criteria for the entire set. Neef et al. (1980) used a criterion which allowed individual members of a set to be replaced when the mastery criteria were met. With this additional criterion it would be possible to introduce more facts into training thus increasing the opportunity for more facts to be mastered.

Another factor involves the length of the study. Basic addition facts are typically taught throughout the first three grades of school particularly during the second grade. If a child has not developed a strategy for figuring out addition facts by the third grade, some strategy should be taught (Silbert et al., 1981). Silbert et al. state that memorizing facts "may require months and months of practice" (p. 246). If the cumulative review of basic addition facts were conducted over the course of a school year, it would seem logical that retention would be greatly increased. The length of the study and the part of the school year in which it was conducted may be important variables to consider during future research.

With respect to acquisition, the results show incongruous effects across subjects. Bob mastered more facts in fewer sessions under the Interspersal Only condition while Ken mastered more facts in fewer sessions under the Cumulative Review condition. Wright (Note 6) found that the Cumulative Review condition was more effective in terms of greater acquisition of basic sight words. Wright suggests that the subjects may have been required to attend more closely to the words in
the Cumulative Review condition since both the training and the interspersal items were relatively new to the subjects. Such an interpretation fails to fully account for the incongruous effects found in the present study. Other variables may have had some influence upon acquisition. These variables include the number of corrections, and the degree of confusion or interference which results from incompatible responses and juxtapositions of minimally different examples.

One consistency in the findings across subjects was that, on the average, more errors were made on facts trained under the condition which was generally superior with respect to acquisition. Monteiro (Note 5) suggests that an errorless procedure (similar to the Cumulative Review procedure in the present study) would be more likely to result in greater opportunity to obtain reinforcers. Also, Neef et al. (1980) suggest that consequences following errors could possibly elicit emotional responses which would interfere with a subject's attending behaviors making it less likely that the subject would attend to the critical features of the stimuli. These suggestions fail to fully explain the present contradictory findings. Other factors may be involved. Although the subjects reached mastery in fewer unprimed responses in fewer sessions under the conditions where more errors were made, these sessions also took longer. The duration of the training and interspersal parts of the procedures reflect the increase in the amount of time necessary for corrections. It is possible that the use of the model-test correction procedure, followed by the experimenter's confirmation of the correct response on the test, may have provided the subjects with "extra" practice in making correct responses thus strengthening those responses
in the subjects' repertoires. The dependent measure of mean number of unprimed responses to mastery does not reflect the increase in responses due to the correction procedure.

Skinner (1957) considers the saying of the sum in the presence of the incomplete fact sentence to be a form of verbal behavior called intraverbal behavior. Skinner distinguishes intraverbal behavior from other forms of verbal behavior also controlled by prior verbal stimuli in that there is no point-to-point correspondence between the stimuli and resulting response-product of intraverbal behavior. With echoic behavior and writing from copy there is formal point-to-point correspondence in that the stimuli and response-product are of the same modality (visual or auditory) and have similar physical patterns or sequences of sounds and letters. With textual behavior and taking dictation there is point-to-point correspondence between the sequence or patterns of stimuli and those sequences or patterns of the response-product even though the stimuli and response-product may be of different dimensions (e.g., visual stimuli and auditory response-product). Even with the basic sight words used by Monteiro (Note 5) and Wright (Note 6), there was at least partial point-to-point correspondence between the pattern of letters of the stimuli and the pattern of sounds of the response-product. However, in the present study there was no point-to-point correspondence between stimuli and responses since the responses being strengthened were intraverbally related to the stimuli.

In the present study, the subjects were required to "say the whole thing" thus adding auditory stimuli to help occasion a specific response. The problem of interference arises because the subject emits a series
of responses as a chain of intraverbals. Skinner states that "(a)ny one link in a chain of intraverbal responses is not under the exclusive control of the preceding link" (p. 72). This is illustrated by the subjects' error patterns. The most prevalent incorrect response made to the stimuli "4+6=" was "eight" which shows the intraverbal relationship of counting by twos. Skinner also states that different stimuli may gain control over a single response while different responses may be controlled by a single stimulus. That is, different stimuli (e.g., "3+9="; "6+6=") strengthen the same response; or part of the stimuli of an incomplete basic fact sentence strengthen several responses (e.g., "2+" strengthens at least ten responses).

Any feature of the stimuli present when a particular verbal response is reinforced will gain control over that response to some extent (Skinner, 1957). Skinner states that a process called "abstraction" is used by the verbal community to sharpen stimulus control by the critical or relevant stimulus features while decreasing the control exerted by irrelevant features. To accomplish this, the verbal community reinforces a response only in the presence of the critical features and does not reinforce the response when the critical features are absent. Engelmann and Carnine (1982) describe several principles, such as the sameness or difference principles, which guide the juxtapositioning of examples in a teaching sequence. Proper sequencing of examples will enhance the critical features of the examples for the learner and will allow the learner to rapidly learn to ignore irrelevant features.

The proper sequencing of examples is especially important when the learners are naive or are learning relatively new skills. However, in
the present study, the subjects were not naive learners. They showed an understanding of what the numerals in the basic fact sentences "stood for" during the prerequisite skills check. They also probably had many trials in school making correct responses in the presence of incomplete fact sentences using a finger counting or some other strategy so sequences enhancing the critical features would be superfluous since the subjects demonstrated that they could respond to the critical features. Engelmann and Carnine (1982) suggest that for more sophisticated learners the principles guiding example sequencing can be relaxed. However, to facilitate the most rapid learning, Silbert et al. (1981) recommend that facts still be introduced systematically to avoid possible confusion.

Problems with interference or confusion are compounded when the stimuli are minimally different. Monteiro (Note 5) and Wright (Note 6) used stimuli that were maximally different. However, in the present study, unknown facts were randomly assigned to each condition. Differential effects may have resulted from greater interference and confusion occurring among the training and/or interspersal items under one condition than under another. In the present study, the training items and thus cumulative review items tended to be from facts that began with 6's, 7's, 8's, or 9's while the known items used as interspersal items for the Interspersal Only condition tended to be from facts that began with 0's, 1's, 2's, 3's, 4's, or 5's. When designing cumulative reviews, Engelmann and Carnine (1982) suggest that an interspersal item most similar to the training item be included in the review set to increase the difficulty of the memory requirements of the tasks. The "memory
sequence" is used when a learner cannot remember the correct response in the context of the memorization task. Engelmann and Carnine (1982) state that if a learner can produce a response (e.g., can arrive at a missing sum through finger counting) but not within the specified task context (e.g., memorization) then the instruction should focus on shaping contexts. Engelmann and Carnine state that a "context-shaping procedure sequences contexts of varying difficulty" (p. 30). A sequence of a series of the same task is an easy sequence for a learner to respond to. However, it is possible that a learner will begin to respond echoically to previous responses if the example stimuli do not change. According to Greeno (1964), the repetition of a task is a relatively ineffective teaching sequence especially when the repetitions closely follow one another. The purpose of the "memory sequence" is to systematically interrupt trials of the particular task being taught thus increasing the difficulty of the memory task by interpolating an increasing number of familiar but interfering (interrupting) tasks within the sequence. However, in the present study, the Cumulative Review condition may have been excessively more difficult than if more systematic sequencing of items were used. More systematic sequencing could either lessen the interference and confusion resulting from the minimally different stimuli and competing responses, or systematically enhance the relationships among stimuli and responses thus increasing the effectiveness of the Cumulative Review procedure with respect to acquisition.

If the goal of the instruction is to teach the "names" of the numerals equated in the fact sentences then a sequence should be used
which introduces new members that are familiar but not highly similar to those most recently introduced (Engelmann & Carnine, 1982). However, if the goal is to teach relationships then Engelmann and Carnine suggest that a different sequence be used which enhances the relationships through the systematic sequencing of examples according to specific principles. These relationships are precisely what some authors (e.g., Carnine & Stein, 1981; Thiele, 1938; Thornton, 1978) suggest should be stressed when teaching basic addition facts. These strategies and verbal rules constitute a "generative set" which consists of the "minimum number of component skills that can be joined in various combinations to yield the maximum range of competence in the subject area" (Alessi, Note 1, p. 1). The generative set for basic addition facts is illustrated in Appendix D. If further research on cumulative review is conducted, special attention should be given to the sequencing of training and interspersal items.

The present study found that the Cumulative Review condition was somewhat more effective in terms of overall retention. However, the incongruous results with respect to acquisition suggests that further research be conducted in this area. More cogent findings would be expected if the further study of the effects of cumulative review upon the acquisition and retention of academic skills would place special attention upon more systematic sequencing of items. Other factors described above as possible having some influence upon the experimental effects should also be addressed.
REFERENCE NOTES


REFERENCES


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APPENDIX A

Basic Addition Facts

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APPENDIX B

Informed Consent Forms

_____ is enrolled in the Project Help tutorial program for Spring session 1982 and is in the Decoding A and Language II programs. While the major focus is to further develop your child's reading and language skills, Project Help may also work to develop other skill areas.

Two procedures have been developed to systematically teach the basic addition facts using flash cards. Each procedure requires 10 minutes of instruction time every day your child attends Project Help this semester. One procedure will consist of having your child practice newly learned addition facts with facts already known. The other procedure is designed to help your child learn new facts while continually reviewing those facts learned during training.

The goal of these training procedures is to teach rapid and accurate recall of the basic addition facts of arithmetic. Knowledge of these basic facts is an important pre-requisite in the development of computational skills for use in problem solving. Proficiency in this area will provide a firm basis for further exploration of new and interesting topics in mathematics.

I would like permission to teach your child the basic addition facts with these two procedures during this semester. If you agree to your child's participation, I will keep daily records regarding how long it takes to teach each new fact. These records will be kept on file in the Project Help office and will be accessible only to the director of Project Help and myself. If at any time you wish to see these records or observe a session, you are welcome to do so. At the completion of this part of the program, a final report will be sent to you summarizing the progress made in learning the basic facts.

If you wish to withdraw your child from this part of the program or obtain the records of your child's participation, you may do so by contacting me at Project Help.

This project was developed under the supervision of Dr. Galen Alessi, the coordinator of the School Psychology Program; and Kathleen Wright, M.A., the director of Project Help. I have worked as a tutor and as the Educational Technologist in Project Help and I currently hold both a bachelor's and a master's degree in Psychology. This project is part of my degree requirements for the Education Specialist degree in School Psychology. The results of this project will be written in report form and all participants will remain anonymous. At no time will your child's
name or any other identifying information be associated with the project. If you would like a copy of my final report, I will be happy to furnish you with one.

Sincerely,

Michael Jeffrey Harshman, M.A.

Please return this form indicating your decision regarding your child's participation in the project.

I have read the attached description and do (circle one) agree / not agree to have my child participate in this project. It is my understanding that if my child does participate, I will receive a final report describing the progress my child made with the basic addition facts. I may withdraw my child from this part of the program at any time I so wish.

______________________________  ________________
signature                      date
APPENDIX C

Session Checklist

+ performed correctly
- performed incorrectly
or not accomplished
o not observed

Checklist completed by: ____________________  Day: ______________
Subject: ____________________  Condition: ____________________

1. E presents facts for retention probe (one fact at a time; no corrections or prompts provided; 4 sec for each fact; 3 trials—a trial consists of the presentation of both facts; approximately 4 sec intertrial intervals). 

2. E provides clear S\(^D\): "After we learn (work on) these two facts, we will practice them with facts":
   a) "you already know" (Interspersal Only)
   b) "we are learning at Project Help" (Cumulative Review)

3. E places 1st fact on the table, provides echoic prime and requests echoic response from S.

4. E removes card for approximately 3 sec; replaces it requesting response from S (errors are corrected).

5. E adds 2nd fact, provides echoic prime and requests echoic response from S (1st fact card present but no response required; errors are corrected).

6. E removes 2nd card for approximately 3 sec; replaces it requesting response from S (errors are corrected).

7. E removes both cards for approximately 3 sec; replaces them in same order; provides echoic prime and requests response from S for each fact (errors are corrected).

8. E removes cards for approximately 3 sec; replaces them in reverse order; requests response from S for each fact (errors are corrected; return to step 3 error fact first).

9. E removes and replaces both cards in an unpredictable order requiring S to respond to each fact within 4 sec until criterion of 5 consecutive trials correct is reached (1 trial consists of the presentation of both facts).
10. E repeats S^D: "Now we will practice these facts with facts":
   a) "you already know" (Interspersal Only)
   b) "we are learning at Project Help" (Cumulative Review) 

11. E adds one fact (interspersal for 5 trials--a trial consists of the presentation of 3 facts); E places cards in unpredictable order for each trial and requires S to respond to each fact within 4 sec; approximately 4 sec intertrial interval; E records responses and corrects all errors. 

12. E adds 2nd interspersal fact for 5 trials (trial--4 facts). 

13. E adds 3rd interspersal fact for 5 trials (trial--5 facts). 

APPENDIX D

Generative Set for Basic Addition Facts

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- +0 — identity element for addition and commutative property
- +1 — plus-one facts and commutative property
- +2 — plus-two facts and commutative property
- D — doubles
- D+1 — double plus-one
- S — sharing a number to make a double
- +9 — sharing a number to make a plus-ten fact

(last six facts) — last six facts and commutative property

(adapted from Myers & Thornton, 1977).


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