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ABSTRACT

This study examined the effectiveness of spaced practice and spaced review when implemented structurally within a computer assisted instruction (CAI) program. The study viewed the comparison of two levels of CAI as instructional treatments. The instructional treatments were developed as structured, which contained spaced practice and spaced review, and unstructured, which did not contain the spacing effects. Treatments were implemented in a pretest-posttest control-group design. The two levels of CAI were measured by recall and retention. Findings indicated a statistically significant different between treatment groups on both recall and retention. Group 1, which received the structured CAI program as treatment, performed better than Group 2, which received the unstructured CAI program as treatment. Findings indicated that the spacing effects of spaced practice and spaced review, when incorporated within CAI programs, enhances learning and memory, and more specifically recall and retention. Findings also indicated that subjects maintained a level of memory due to the structured CAI program, and that subjects did not maintain a level of memory from recall to retention with the unstructured program. Overall, the data suggested that the spacing effects of spaced practice and spaced review would enhance recall and retention. (Author/AEF)

The Effects Of Spaced Practice And Spaced Review On Recall And Retention Using Computer Assisted Instruction

by

Carlous Caple

A dissertation submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the requirements
for the Degree of
Doctor of Education

DEPARTMENT OF OCCUPATIONAL EDUCATION

Raleigh

1996

Approved By:

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ABSTRACT

CAPLE, CARLOUS. The effects of spaced practice and spaced review on recall and retention using computer assisted instruction. (Under the direction of Dr. V. William DeLuca).

The purpose of this study was to examine the effectiveness of spaced practice and spaced review when implemented structurally within a computer assisted instruction program. It was postulated that spaced practice and spaced review would enhance learning and memory when executed in a computer assisted instruction program. The study viewed the comparison of two levels of the independent variable, computer assisted instruction as instructional treatments.

The instructional treatments were developed as structured, which contained spaced practice and spaced review, and unstructured, which did not contain the spacing effects. The researcher implemented the instructional treatments in a pretest-posttest control-group design. The two levels of the independent variable were measured by the dependent variables of recall and retention.

The statistical analysis used was an Analysis of Covariance (ANCOVA), to examine significant differences between groups. The pretest served as a covariate to control for subjects having prior knowledge of the information presented, and to determine statistical equivalence among the groups. A T-test of dependent means was conducted to examine within groups data from recall to retention. A significance level of .05 was established prior to analyses to determine rejection of the tested hypotheses.

Findings indicated a statistically significant difference between groups on both dependent variables of recall and retention. Group I, which received the structured CAI program as treatment, performed better than group II, which

received the unstructured CAI program as treatment. The finding of significance between groups indicates that the spacing effects of spaced practice and spaced review, when incorporated within computer assisted instruction programs, enhances learning and memory, and more specifically recall and retention.

Findings for within groups data, yielded no significant difference from recall to retention for group I, which received the structured CAI program as treatment. This finding indicates that subjects maintained a level of memory due to the structured CAI program. Findings for within groups, yielded a significant difference from recall to retention for group II, which received the unstructured CAI program as treatment. This finding indicates that subjects did not maintain a level of memory from recall to retention with the unstructured CAI program, which further supports the argument for the implementation of spacing effects within computer assisted instruction programs.

Overall, the data suggested that the spacing effects of spaced practice and spaced review would enhance recall and retention. Therefore, the researcher made conclusions and recommendations for the implementation of spaced practice and spaced review. The researcher concluded that spacing effects enhance learning and memory when incorporated within the structure of computer assisted instruction programs, students recall and retain information better when spacing effects are presented in their educational tasks, and spacing effects the design of educational software which would help innovation in the educational software arena. The researcher's recommendations were for educational software developers to incorporate spacing effects in the design and structure of the computer assisted instruction programs they develop. Further recommendations were made for future educational reseach studies, specifically as they relate to the development of software functionality.

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Dedication

to

Mrs. Stella Bennett-Caple

"Grandmother, you saw your dreams through me; my only regret is that you are not here to share it with me. You are here with me in spirit; I miss you."

I further dedicate this body of work to my family; my parents Mr. and Mrs. R.H. and Shirley Caple, and my brother Ray Caple. Your support means the world to me, without it, I have nothing.

Biography

Carlous Caple was born to R. H. and Shirley Marie Watson-Caple on October 25, 1966. He was the youngest of two sons. His brother Ray Caple completed his education at Shaw University in Raleigh North Carolina. For 30 years, Durham, North Carolina was called home. Carlous attended the Durham Public Schools for the most part of his secondary education. Carlous attended Hillside High School where he graduated in 1985. Carlous received a Bachelor of Arts degree from North Carolina Central University in 1989, where he had dual majors in Psychology and Dramatic Art. He later earned a Master of Arts degree in Educational Technology from the same university in 1991. In 1992, he enrolled in the doctoral program in the Department of Mathematics, Science, and Technology Education at North Carolina State University.

Carlous began his career as an academic instructor in 1990. He later began teaching as an adjunct professor at Shaw University, where he taught in the disciplines of Psychology, Mass Communications, and Dramatic Art. Aside from teaching, Carlous's endeavors included professional acting, and singing. Carlous currently resides in Durham, North Carolina.

Acknowledgements

The author wishes to acknowledge and express sincere thanks to the advisory committee members, Chairman Dr. V. William DeLuca, Dr. Herbert Exum, Dr. Richard Peterson, and Dr. Gary Moore. For your support, guidance, time and effort, I am truly thankful. God bless you.

The author wishes to acknowledge and express sincere thanks to the following supportive cast:

My father God, my creator, and his son, my lord and savior Jesus Christ. You are always with me in mind, body, and spirit.

My family, the Caple family, the Hall family, the Stanley family, and the Robinson family, God bless you.

My friends and associates, Mrs. Linda Trogdon, Dr. Barry Goldfarb, Dr. Kwabena F. Ashanti, Dr. Horace Bruce Caple, Dr. Patricia Caple, Dr. Marvin E. Duncan and family, Mr. James E. Osler and family, Mr. Herb DeLancey, Mrs. Stephanie Green, Mr. Lawrence Lovette, Mrs. Vertina Galloway, Mrs. Mary-Louise Center-Grant, Mr. Darryl J. Roberts, Mr. Russell Robinson, Ms. Juone Brown, Mr. Chris Tubbs, Ms. Robin Battle, and others to numerous to mention, but not forgotten, God bless you.

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CHAPTER I

INTRODUCTION

When computer assisted instruction emerged in the 1960's, educational programmers were solving problems by implementing B. F. Skinner's work on behavior modification. B. F. Skinner observed a lateral relationship between his laboratory work and practices that could improve education. B. F. Skinner basically described learning as a change in behavior. However, at that time, cognitive theory, was not being implemented, which would have made it possible to design programs that actually help students learn how to learn, learn how to set cognitive goals, learn how to apply effective strategies for comprehension, learn self monitoring, and learn how to organize knowledge. Cognitive research during the last 15 years, however, has made substantial progress in providing a basis for such programs. Still, today most CAI software is written with the assumption that students already use such cognitive strategies, and so the software does nothing to foster such strategies (Bracey, 1990).

One of the most serious problems in the application of the computer to instruction is that the computer is often employed without any theoretical framework. Teachers often tell their students to run software simply "because it's good" or because students seem to like it, without relating this use to any theoretical principles or specific instructional strategies. This is ironic, because recent years have witnessed a considerable growth in solid research demonstrating the effectiveness of specific instructional strategies. Research indicates that instructional effectiveness is related to the extent that these principles are put into practice (Vockell, 1990).

Vockell, (1990), states that at the present time, research does not comprehensively indicate that computers lead to enhanced instruction. One explanation for the variance in research findings is that computers are more likely to lead to improved instruction when operated within a sound theoretical framework, and are more likely to prove ineffective when they are used in a haphazard or pedagogically unsound manner. There are several well validated principles of instruction that can be integrated with computer use to enhance instruction. One well validated principle is mastery learning, and another such principle is concept learning. By being aware of these principles and guidelines, educators can employ the computer more effectively in their efforts to enhance instruction.

There is a belief that computer technology can enhance the educational process. Innovative uses of the computer in education can renew interest in science and technology, act as a valuable teaching tool, and possibly reach students who are otherwise bored, or simply reject the current educational system (Bishop-Clark and Grant, 1991).

In viewing the role of technology as it applies to the educational system, restructuring has become the operative word in the school reform movement. According to Renee Campoy (1992), restructuring implies a radical change in the schooling process with an emphasis on student centered-learning, which is mostly computer interactive, counter to a textbook-based curriculum.

Several authors investigated specific aspects of student centered-learning. According to George G. Bear (1984), students who experience high success rates do so because their teachers provide frequent drill and practice, monitor each student's individual progress, and provide feedback and remedial instructions when needed. In effective schools, basic skills are practiced to the point that over-learning occurs and higher-level objectives are not emphasized unless the lower-level objectives have already been mastered and over-learned. He continues to state that since microcomputers, with quality software, can provide the reinforcement, monitoring, branching, feedback, and remedial instructions characteristic of effective teaching, it is likely that schools employing them primarily for the drill and practice of basic skills, tutorials, and simulations will be more successful in improving overall school effectiveness (Bear, 1984).

STATEMENT OF THE PROBLEM

Relative to cognitive theory are the learning concepts of spaced practice and spaced review. Both concepts are employed in the development of instructional activities. These concepts have previously been implemented in studies on Alzheimer's Disease, in which they have proven beneficial (Anderson, 1990). Spacing effects can prove to be beneficial in enhancing instruction, enhancing memory and learning for the student, and the instructor. By employing these concepts in the development of educational software, educators can use the computer with more confidence. This study examined two independent variables applied to learning: spaced practice and spaced review. The effectiveness of these concepts was measured by a test of recall and retention.

The researcher manipulated one independent variable, computer assisted instruction with two levels of treatment. The two treatments were: (1) a structured computer assisted instruction program, which contained spaced practice and spaced review in its structural design, and (2) an unstructured computer assisted instruction program, which did not contain spaced practice and spaced review in its structural design. Each instructional treatment was measured by a test of recall and retention.

The purpose and objective of this study was to investigate the spacing effects of spaced practice and spaced review incorporated with computer assisted instruction, to determine whether or not learning and memory are improved. It was postulated that spaced practice and spaced review would enhance learning and memory when executed in a computer assisted instruction program. This study viewed the comparison of two levels of the independent variable as instructional treatments. A structured computer assisted instruction program, and an unstructured computer assisted instruction program were implemented.

RESEARCH QUESTIONS

The research questions that this study proposed to ask and answer were: (a) Will there be a significant difference among the independent variable of computer-assisted instruction (structured), and computer-assisted instruction (unstructured), with respect to recall as measured by a test on African-American Scientists and Inventors? (b) Will there be a significant difference among the independent variable of computer-assisted instruction (structured), and computer-assisted instruction (unstructured), with respect to retention over a given time period of one week, as measured by a test on African-American Scientists and Inventors? (c) Will there be a significant difference within groups from recall to retention for the computer assisted instruction (structured) program? (d) Will there be a significant difference within groups from recall to retention for the computer assisted instruction (unstructured) program?

HYPOTHESES

The following hypothesis statements were tested:

(1) There will be no significant difference (alpha = .05), based upon an analysis of covariance, between a structured computer assisted instruction program, and an unstructured computer assisted instruction

program on the dependent variable of recall, with the pretest as the covariate.

(2) There will be no significant difference (alpha = .05), based upon an analysis of covariance, between a structured computer assisted instruction program, and an unstructured computer assisted instruction program on the dependent variable of retention, with the pretest as the covariate.

(3) There will be no significant difference (alpha = .05), based upon a t-test of dependent means, within a structured computer assisted instruction program from recall to retention.

(4) There will be no significant difference (alpha = .05), based upon a t-test of dependent means, within an unstructured computer assisted instruction program from recall to retention.

DEFINITION OF TERMS

The following terms were used throughout the study. These terms are defined to familiarize the reader with the subject matter. The terms defined are:

CAI - "abbreviation for Computer-Aided Instruction or Computer-Assisted Instruction. See Computer-Assisted Instruction" (Edmunds, 1985).

Computer-Aided Instruction - "an approach to education that utilizes programs to interact with a student. The student can, in effect, carry on a "conversation" with the computer. The computer provides information or asks questions, eliciting a response from the student. If the student responds correctly, the computer will pass on to the next subject. Otherwise, the student may back up and repeat the "conversation", or the computer will display more information on the subject" (Edmunds, 1985).

Computer-Assisted Instruction - "synonymous with Computer-Aided

Instruction" (Edmunds, 1985).

CAI-Structured - "a computer assisted instruction program that has been designed with the spacing effects of spaced practice and spaced review. The CAI-Structured program, used as a treatment in research, was designed to allow the learner to have the opportunity to stop and resume practice sessions without having to go back to the beginning of a tutorial, and to allow the learner to review items previously learned, based on the amount of time which has passed since the learner last responded to that item."

CAI-Unstructured - "a computer assisted instruction program that has been designed without the spacing effects of spaced practice and spaced review. The CAI-Unstructured program, used as a treatment in research, was designed without the capabilities of allowing the learner to have the opportunity to stop and resume practice sessions, and the opportunity of allowing the learner to review items previously learned."

Cognition - "refers to how we know the world through mental processes such as thinking, perceiving, and remembering" (Mischel, 1986).

Cognitive Psychology - "the study of the mind, which, unlike the brain, is not an observable entity. It involves many hidden activities, such as thinking, memory, language, and consciousness" (Ornstein, 1985).

Cognitive Science - "a relatively new field, which attempts to integrate research efforts from psychology, philosophy, linguistics, neuroscience, and artificial intelligence" (Anderson, 1990).

Cognitive Tools - "tools that can assist learners in accomplishing cognitive tasks. These tools have been incorporated into computer systems" (Lajoie, 1993).

HyperCard - "an electronic implementation of a stack of three-by-five cards. Each card in the stack can contain text, pictures, fields, and buttons" (Merrill, et al, 1992).

Instruction - "a specific unit of information loaded into a computer's main storage. An instruction, in effect, tells the computer what to do. Each instruction is set up according to the statements in a program. An instruction is interpreted by the control section of the computer's central processing unit (CPU)" (Edmunds, 1985).

Learning - "a relatively permanent change in behavior or knowledge brought about by practice or experience" (Wingfield, 1979).

Recall - "the process of retrieving information from memory. An experimental procedure for investigating memorial processes whereby the subject must reproduce material previously learned" The Penguin Dictionary of Psychology (1985).

Retention - "the process of holding onto or retaining a thing. Most commonly used with respect to issues surrounding the retention of information, where the basic presumption is that some "mental content" persists from the time of initial exposure to the material or initial learning of a response until some later request for recall or re-performance" The Penguin Dictionary of Psychology (1985).

Spaced Practice - "the degree to which computer drills allow for the spacing of practice sessions. The implications of spaced practice are to allow the learner to specify the appropriate difficulty level at the beginning of each session or provide a mechanism to keep track of the items that a particular learner was working on during the last session" (Salisbury, 1990).

Spaced Review - "the degree to which computer drills allow for the increase of spacing between presentations of the material. The implications of spaced review are to provide a mechanism for gradually increasing spacing between presentations of the material" (Salisbury, 1990).

Technology - "the study of the technical means the human has initiated and utilized for survival" (Lauda & McCrory, 1986).

Tutorials - "a method of teaching that involves a series of screen formats. These screen formats are presented in response to a terminal operator's (student's) request. The operator usually has a number of options available, usually chosen from a "menu", from which to select a desired sequence of screen formats" (Edmunds, 1985).

ASSUMPTIONS OF THE STUDY

For this study the following assumptions were made: (1) that the level of attrition will be low, due to incentive given to subjects for their participation, (2) that the sample size selected will be representative of the population of college and university students, and (3) that students answered all questions asked during testing for recall and retention. The assumption of subjects answering all questions is necessary in determining if spacing effects are meaningful at enhancing memory and learning, and also distinguishing the better of the two instructional treatments.

LIMITATIONS OF THE STUDY

The major limitations of this study were extraneous variables that posed a threat to internal validity. History, refers to numerous outside influences that could possibly effect results. History occurs when a researcher does not have direct control over the setting. The subjects are not insulated from numerous possible distractions as they are in a true experiment. Experimental mortality, or attrition, refers to loss of subjects during the course of the study. To maintain low attrition, incentives were provided. The researcher offered instructors the incentive of both computer assisted instruction programs that were used to conduct the study. The instructors offered their students that participated, the incentive of added grade points toward exams, or the final grade for the semester. To address the limitations of the study, the researcher implemented a pretest-posttest control-group design. According to Walter R. Borg, and Meredith D. Gall (1989), the pretest-posttest control-group design is among the most commonly used experimental designs in educational research. If properly carried out, it effectively controls for the eight threats to internal validity which are history, maturation, testing, instrumentation, regression, selection, mortality and interaction effects (Borg, and Gall, 1989).

SUMMARY

New and innovative uses have developed as a result of cognitive psychology. Great implications for computer assisted instruction have developed with its theory grounded in cognitive psychology. Today, students are using software in schools that make use of cognitive strategies. These programs were developed to enhance the process of learning, and learning how to learn. Students learn by an interactive approach within their computer curriculum. More so, these computer tutorials contain components that may lead to enhanced instruction.

The cognitive components of spaced practice and spaced review have been proven effective at enhancing learning and memory in studies on Alzheimer's Disease, head injuries, visual recognition, and psychomotor activity. These components can prove to be beneficial at enhancing computer assisted instruction programs. The benefit of employing spacing effects with computer assisted instruction can lead to improved learning and memory, and can assist educators with implementing the computer with greater confidence.

At the present time schools are going through a restructuring process where the computer will play a major role in decision making. Computer effectiveness will be a major concern as educational systems move into the 21st century, students change, and technology advances. The components and principles incorporated in the development of computer tutorials will be a determining factor in the advancement of the student, and the way the student learns and memorizes educational material.

The remainder of this dissertation is structured with chapter II as a review of literature, chapter III as a methodology of the research study conducted, chapter IV as the findings of the study, and chapter V as a summary with conclusions and recommendations.

Chapter II

REVIEW OF LITERATURE

Many of the guiding principles of computer assisted instruction were laid down before computers were ever used for instruction. In the 1950's, educational programmers began to seek to solve educational problems by applying the techniques of behavior analysis through programmed instruction. Many authorities date the beginning of this movement to 1954 with the publication of B. F. Skinner's article The Science of Learning and Teaching (Markle, 1964). Unlike most other psychologists at that time, Skinner saw a strong parallel between his activities in the laboratory involving animal behavior, and practices that could improve education. Skinner broadly defined learning as a "change in behavior". He believed that the principles of stimulus and reward, characterized by immediate reinforcement, could bring about learning (Price, 1991).

Although B. F. Skinner's work made foundational contributions to the world of computer assisted instruction, it is the field of cognitive psychology in recent years that has been most influential in the development of computer software programs for educational endeavors. Closely related to the field of cognitive psychology, is the field of cognitive science which provides theory for computers, and computer based instruction.

John R. Anderson, (1990), states that cognitive science is a recently emerged field, which attempts to integrate research efforts from psychology, philosophy, linguistics, neuroscience, and artificial intelligence. This field can be dated from the appearance of the journal Cognitive Science in 1976. The fields of cognitive psychology and cognitive science overlap. It is not profitable to try to define precisely the differences, but cognitive science makes greater use of methods such as computer simulations of cognitive processes and logical analysis, while cognitive psychology relies heavily on experimental techniques that grew out of the behaviorist era for studying behavior (Anderson, 1990).

Three main influences account for the modern development of cognitive psychology. The first was the development of what has been called the information processing approach, which grew out of human factors work and information theory. Human factors refer to research on human skills and performance. This field was given a great boost during World War II, when practical information on these topics was badly needed. Information theory is a branch of communication sciences that provides an abstract way of analyzing the processing of knowledge. The work of the British psychologist Donald Broadbent at the Applied Psychology Research Unit in Cambridge, was probably most influential in integrating ideas from these two fields and developing the information processing approach. He developed these ideas most directly with regard to perception and attention, but the analyses now pervade all of cognitive psychology (Anderson, 1990).

Closely related to the development of the information processing approach were developments in computer science, particularly artificial intelligence, which tries to get computers to behave intelligently. The direct influence of computer based theories on cognitive psychology has always been minimal. The indirect influence, however, has been enormous. A host of concepts have been taken from computer science and used in psychological theories. Probably more importantly, observing how we could analyze the intelligent behavior of a machine has largely liberated us from our inhibitions and misconceptions about analyzing our own intelligence (Anderson, 1990).

The third field of influence on cognitive psychology is linguistics. In the 1950's, Noam Chomsky, a linguist at the Massachusetts Institute of Technology, began to develop a new mode of analyzing the structure of language. His work showed that language was much more complex than had previously been believed and that many of the prevailing behavioristic formulations were incapable of explaining these complexities. Chomsky's linguistic analyses proved critical in enabling cognitive psychologists to fight off the prevailing behavioristic conceptions. George Miller, at Harvard University in the 1950's and early 1960's, was instrumental in bringing these linguistic analyses to the attention of psychologists and in identifying new ways of studying language (Anderson, 1990).

A current theme in the literature is that of "cognitive tools". The metaphor implies that there are tools that can assist learners in accomplishing cognitive tasks. There are at least four types of cognitive tools that can be identified by the functions they serve. They are simulations, diagnostic feedback, student models, and database management. These four tools can: (1) support cognitive processes, such as, memory and metacognitive processes; (2) share the cognitive load by providing support for lower level cognitive skills so that resources are left over for higher order thinking skills; (3) allow the learners to engage in cognitive activities that would be out of their reach otherwise; and (4) allow learners to generate and test hypotheses in the context of problem solving. These four tools are not mutually exclusive. Cognitive tools that serve these functions have been incorporated into computer systems such as Bio-World, a computer-based learning environment that provides high school biology students with practice at diagnosing infections (Lajoie, 1993).

Bio-World is a computer coached learning environment that teaches high school students to diagnose infections. It is not intended to make physicians out of students. Rather, it is intended to provide opportunities for students to scientifically reason about the data that they have available to them in a simulated hospital environment. Bio-World is meant to foster contextualized reasoning.

Susanne P. Lajoie, (1993), states that students in the classroom are taught declarative knowledge about bacterial and viral infections, how infections are transmitted, how different infections affect different parts of the body, and how the body has different defense systems to guard against certain diseases. Students are also introduced to concepts involving diagnostic tests that can identify the presence or absence of infection. Bio-World provides mechanisms for putting this declarative knowledge into practice by providing opportunities for students to use such knowledge in the context of realistic problem-solving tasks, such as diagnosing a disease.

Bio-World was designed to support cognitive processes, as well as memory and metacognition. Bio-World supports cognitive processes by providing students with access to declarative and conceptual knowledge through an on-line medical library. Students can select information from the library in the context of a problem. Bio-World also presents a diagnostic notebook which serves to support memory and metacognition. Memory processes are supported by displaying the learner's previous actions, such as library searches and diagnoses that were made for a patient (Lajoie, 1993).

Researchers examining the effectiveness of computer assisted instruction have shown positive results in a variety of measures. Most of these measures, however, have been specific to the computer program itself. It has been more difficult to demonstrate the effectiveness of a tutorial or simulation program as it relates to the course it accompanies due to the way it is structurally designed.

According to David F. Salisbury, (1990), the computer has many characteristics which allow it to be potentially the most effective means of providing drill and practice. However, many practice programs being produced today are poorly designed from a psychological standpoint, and therefore do not provide drill and practice in the most effective and efficient means possible. Most computer drills, pattern the traditional flashcard strategy that ignores some basic principles derived from research in cognitive psychology (Salisbury, 1990).

Cognitive science addresses the need for mental representations and stresses an analysis of human activity separate from sociology, biology, and neurology. Researchers in cognitive science hold that the computer is an invaluable model of the human mind, and is central to understanding thinking and problem solving (Thorpe, and Turner, 1993). With this understanding, software designers and authors can develop programs which utilize cognitive strategies and components to enhance learning and memory. Cognitive components have been employed in studies on memory retrieval, and recognition. The components of spaced practice and spaced review have been manipulated in studies, and have proven to be effective with improving learning and memory.

Demster & Farris, (1990), states that the spacing effect is important in several respects. First, the spacing effect is one of the most dependable and robust phenomena in experimental psychology. In many cases, two spaced presentations, which may have intervals of one hour or one week's time, are about twice as effective as two massed presentations, and the difference between them tends to increase as the frequency of repetition increases. Moreover, demonstrations of achievement following massed presentations often are only slightly higher than those following a single presentation. Second, the spacing effect is truly ubiquitous in scope. It has been observed in virtually every experimental learning paradigm, and with all sorts of traditional research material. Third, the spacing effect has the distinction of being one of the most respected phenomena in the psychological literature. It was known as early as 1885, when Ebbinghaus published the results of his seminal work on memory, and it gained formal recognition in the form of Jost's Law, published in 1897. This law states that "if two associations are of equal strength but of different age, a new repetition has a greater value for the older one" (Demster, and Farris, 1990).

RESEARCH RELATED TO SPACING EFFECTS

Understanding of cognitive factors such as spacing effects, have proven to provide an advantage in research on learning and memory. While spaced practice, and spaced review, as spacing effects, have been influential in educational settings, they have also made a beneficial influence in medical arenas as well, with studies conducted for further understanding of Alzheimer's Disease (Anderson, 1990), and research on head injury victims.

In a study conducted at the University of New Orleans, four individuals with Alzheimer's Disease were trained to remember and to implement an intention for future action. The training program utilized the spaced retrieval method, which involves active attempts to recall information over expanding intervals of time. All participants learned to select a colored coupon from an array of distractors, and offer it to the experimenter after a one week's delay. Following one week retention of the initial task, a different coupon became the new training target. All participants were able to shift to this new task requirement , and all learned three successive coupon colors successfully. These results indicate that individuals with Alzheimer's Disease can learn a prospective memory task using spaced retrieval practice and can make adjustments for changing task requirements (McKitrick, Camp, and Black, 1992). According to the authors of this study, the results lend further validation to spaced retrieval as a technique of memory enhancement in Alzheimer's Disease patients (McKitrick, Camp, and Black, 1992).

An early study was conducted in 1965 concerning spaced repetitions. The study conducted by Ausubel and Youssef, was concerned with the effect of spaced repetition on the meaningful retention of connected discourse. It seeks to ascertain whether or not such repetitions enhance substantive retention of an unfamiliar learning passage as manifested by greater ability, 48 hours after original learning, to answer multiple-choice questions that test clear and precise understanding of the material. In studying for a forthcoming objective examination, for example, does a student profit from a spaced re-reading of his or her lecture notes or of the textbook material (Ausubel, and Youssef, 1965). In this study, the experimental population consisted of 87 senior undergraduate students in three sections of an educational psychology course at the University of Illinois. The subjects were enrolled in one of nine teacher education curricula at the secondary school level. The experiment was conducted separately in each section as a required laboratory exercise and was performed during regularly scheduled class hours. The learning material consisted of a specially prepared 1400 word passage dealing with the endocrinology of pubescence. It was chosen due to its novelty to the undergraduates in teacher education. Knowledge of the material was tested by a 36 item multiple-choice test with a corrected split-half reliability of .83. Subjects were randomly assigned to the experimental or control group. Each group was stratified by sex to equal out subjects in each group. The experimental group was given 25 minutes to read and study the learning passage, and the control group was similarly allowed 25 minutes to read and study a completely unrelated passage on the history of narcotic drug addiction. Two days later both groups were asked to study the learning passage for 25 minutes. After a 48 hour interval, the multiple-choice test was administered to each group. The results showed a difference between the means of the experimental and control groups was significant beyond the .001 level of confidence for a one tailed test. A significant difference was found between groups based upon treatments. The mean for the experimental group was 24.25, and for the control group, 19.63. In addition to enhancing meaningful learning and retention in these two direct ways, repetition also influences these processes in two indirect ways; through modifications in cognitive structure wrought by the first trial. In the first place, initial contact with the material sensitizes the learner to the meanings it contains when he or she encounters it again (Ausubel, and Youssef, 1965).

Spaced practice and spaced review can be employed universally to all subject matter, as demonstrated in a longitudinal study implementing a foreign language vocabulary. In a 9 year longitudinal investigation conducted by Bahrick, et al (1993), 4 subjects learned and relearned 300 English-foreign language word pairs. Either 13 or 26 relearning sessions were administered at intervals of 14, 28, or 56 days. Retention was tested for 1, 2, 3, or 5 years after training terminated. The longer intersession intervals slowed down acquisition slightly, but this disadvantage during training was offset by substantially higher retention. Thirteen retraining sessions spaced at 56 days yielded retention comparable to 26 sessions spaced at 14 days. The retention benefit was due to spacing, and both variables facilitated retention of words regardless of difficulty level and of the consistency of retrieval during training (Bahrick, et al, 1993).

In a similar study (Durgunoglu, et al, 1993), repeated readings were a recognized method for improving student's memory for text. The researchers investigated the variables that influence the effectiveness of repeated readings. Across four experiments, college students read narrative or expository texts and answered comprehension questions about the texts. The time interval between the repetitions (massed or spaced repetitions), the language of repetitions (same or different), as well as the type of activity between the two repetitions (interfering or non-interfering passages) were manipulated. These variables affected performance only on text-based questions that asked for details rather than on questions that asked for main ideas and inferences. A spaced repeated reading led to better performance than a massed repeated reading. However, a bilingual presentation could overcome the disadvantages of a massed repetition (Durgunoglu, et al, 1993).

Spacing effects have been used in numerous ways in order to study learning and memory. Spacing effects have also been used in tests of visual recognition. In a study conducted by Allyson Cahill and Thomas Toppino (1993), preschool and second grade children studied a list of either pictures or their corresponding labels (words) and, 48 hours later, received a yes/no recognition test involving either the same or the opposite type of stimuli. Some items on the study list were presented twice, with repetitions either massed or distributed (spaced). The results indicated that, when both study and test stimuli were pictures, the children's recognition was better than when study and/or test stimuli were words. The children also recognized distributed repetitions better than massed repetitions (a spacing effect). However, the spacing effect was not altered by the type of stimuli presented for study and/or test. The results suggest that the spacing effect is mediated by a semantic representation and that, under these circumstances, it is produced by relatively automatic processes (Cahill, and Toppino, 1993).

Spacing effects have proven to be effective with psychomotor activity, as presented in a study on free-throw shooting performance (Predebon, and Docker, 1992). This study conducted at the University of Sydney, assessed the effectiveness of preshot routines on free-throw shooting behavior of experienced basketball players. 30 male subjects were assigned to one of three conditions, no routine, standardized physical routine, and imagery/physical routine. Subject's performance was assessed in four sessions spaced over a six week period. In between sessions, subjects were given practice with the preshot routine of their condition. In the first session all subjects attempted the throws using their regular preshot routine, whereas in the remaining three sessions they performed as required by their assigned condition. Over-all, the imagery group performed significantly better than the routine group which in turn performed better than the no-routine group. The last test session's performance of the routine and the physical/ imagery routine groups but not the no-routine group was similar to player's regular preshot routine performance, suggesting that withdrawal of experienced players's regular preshot activity has a relatively long lasting detrimental effect on their free-throw shooting performance (Predebon, and Docker, 1992).

A study on full processing hypothesis of the spacing effect was conducted at the Osaka University of Education by Kitao (1992). The hypothesis stated was: full processing hypothesis of the spacing effect attributes poor recall of massed repeated items to a failure to process the repeated items fully. This study examined the applicability of this hypothesis to sentence free recall task in two experiments. The spacing effect was tested by presenting each sentence with or without intervening ones. The rehearsal procedure was used to enhance the full processing of massed repeated items. In both experiments I and II spaced presentation yielded substantially higher level of recall than did massed presentation. However, when the full processing was enhanced by rehearsal procedure in experiment II, massed presentation yielded the same level of recall as spaced counterparts. These results suggest that the failure of full processing in massed presentation results in the spacing effect of the sentence free recall task (Kitao, 1992).

Another study in which spacing effects were manipulated, was conducted at Northwestern University on unmixing effects of spacing on free recall (Hall, 1992). In three unmixed list free recall experiments, total recall was as high for lists that contained massed repetitions as for those containing spaced repetitions. This finding and differences between spaced and massed lists in the pattern of recall (notably serial position differences) indicate that displaced rehearsal (review of earlier list items) was more prevalent during study of the massed lists. These results imply that displaced rehearsal has a large role in producing the free recall advantage typically observed for spaced compared with massed items in mixed lists and that unmixed list designs generally are to be preferred for spacing experiments. They also imply that intentional free recall experiments are not instructive concerning effects of spaced versus massed study, because rehearsal strategies for free recall result in the spaced study of massed items (Hall, 1992).

According to an article by Michael J. Kahana, and Robert L. Greene

(1993), the spacing effect refers to the advantage in memory for information repeated at separate points of time over information repeated in massed fashion. In research, they conducted three experiments which showed that no spacing effect was found in free recall of lists containing items of high interstimulus semantic similarity. However, spacing effects were found when recognition or frequency discrimination tests were given on these materials. The results supported their hypothesis that several distinct processes underlie the spacing effect (Kahana, and Greene, 1993).

In the studies preceeding, spacing effects have proven beneficial in a number of research opportunities. The effects of spaced practice and spaced review have proven to enhance and improve learning and memory in many research situations. These cognitive components can also prove to be beneficial to computers and computer software programs.

The spacing effect is an extremely robust and powerful phenomenon, and it has been repeatedly shown with many kinds of material. Spacing effects have been demonstrated in free recall, in cued recall of paired associates, in the recall of sentences, and in the recall of text material. It is important to note that these spacing results do generalize to textbook materials, meaning that subjects such as science can be manipulated by spacing effects. Also the effect of spaced study can be very long-lasting (Anderson, 1990).

In an article on computer use in cognitive psychology, Doris Aaronson (1994), states that computers have substantially influenced the theorectical approaches in cognitive psychology. Indeed, the computer itself has been taken as a symbolic model or metaphor for human cognitive processing. Today, both computers and people are viewed as generalized information processors (Aaronson, 1994). Aaronson, continues to state that not only have computers influenced our theoretical thinking, they have also influenced our methodology in cognitive research. The use of computers to conduct psychological experiments has facilitated cognitive research by increasing the variety of research paradigms and the temporal precision with which we can present stimuli and measure responses (Aaronson, 1994).

THE NINE EVENTS OF INSTRUCTION

The events of instruction are designed to make it possible for learners to proceed from "where they are" to the achievement of the capability identified as the target objective. In some instances, these events occur as a natural result of the learner's interaction with the particular materials of the lesson, as, for example, when the beginning reader comes to recognize an unfamiliar printed word as something familiar in his or her oral vocabulary and, thus, receives feedback. However, the events of instruction must be deliberately arranged by an instructional designer or teacher. The exact form of these events, usually communications to the learner, is not something that can be specified in general for all lessons, but rather must be decided for each learning objective. The particular communications chosen to fit each set of circumstances, however, should be designed to have the desired effect in supporting learning processes (Gagne', Briggs, and Wager, 1992).

The HyperCard authoring system allows the software author the ability to integrate curriculum material with the computer for interactive computer study. The HyperCard authoring system allows the author to develop what is called a stack. A stack is a series of cards with buttons for navigation, text, and fields for creative design emphasis. Each card contains information relevant to a concept. HyperCard stack designs can be linear, or have branching incorporated. Branching allows the navigator to explore many areas under one subject area, such as transportation, but more specifically air travel. A linear HyperCard stack only allows the navigator to navigate directly in a straight order. An example of a linear stack might include subject matter on safety precautions for children learning to cross the street. This type of stack would give information pertaining to stopping, looking both ways before crossing, and walking, not running (Goodman, 1990). The HyperCard authoring system is versatile, allowing the author to be creative. Robert Gagne's nine events of instruction can be implemented interchangeably within the HyperCard stack to enhance the instructional application. Creativity can also be expressed with spacing effects to enhance and improve learning and memory of key concepts.

In terms of spacing repetitions, each of the nine events of instruction can be manipulated and placed with strategy in a computer assisted instruction program. It should be realized that the events of instruction do not invariably occur in exact, or consecutive order, although it is their most probable order. Even more important, by no means are all of the events provided for every lesson. Their role is to stimulate internal information processes, not to replace them. Sometimes, one or more of the events may already be obvious to the learner and, therefore, may not be needed. Also, one or more of the events are frequently provided by learners themselves, particularly when they are experienced self-learners. In designing instruction, the list of instructional events usually becomes a checklist. In using the checklist, the designer asks, "Do these learners need support at this stage for learning this task" (Gagne', Briggs, and Wager, 1992)?

The nine events of instruction are: (1) gaining the learner's attention, (2) informing the learner of the objectives, (3) stimulating recall of prerequisite learned capabilities, (4) presenting the stimulus material, (5) providing learning guidance, (6) eliciting the performance, (7) providing feedback, (8) assessing performance, and (9) enhancing retention and transfer. In designing effective computer assisted instruction with the application of the spacing effects of spaced practice and spaced review, the inclusion of Robert Gagne's ninth event, enhancing retention and transfer, becomes important. Provisions made for the recall of intellectual skills often include arrangements for "practicing" their retrieval. Thus, if defined concepts, rules, and higher-order rules are to be well retained, course planning must make provisions for systematic reviews spaced at intervals throughout weeks and months. As for the assurance of transfer of learning, it appears that this can best be done by setting some variety of new tasks for the learner; tasks that require the application of what has been learned in situations that differ substantially from those used for the learning itself. When information or knowledge is to be recalled, the existence of the meaningful context in which the material has been learned appears to offer the best assurance that the information can be reinstated. The network of relationships in which the newly learned material has been embedded provides a number of different possibilities as cues for its retrieval (Gagne', Briggs, and Wager, 1992).

Indirectly related to the nine events of instruction are the components of the nature of computer assisted instruction. The nature of computer assisted instruction can be manipulated by the author or designer of the computer software. The nine events of instruction can be implemented interchangeably with the computer program. According to Vasu, and Vasu (1985), Computer assisted instruction is the most widely used application of computers in instruction. Computer assisted instruction is used to present course content via the computer and can be categorized in five ways: tutorials, drill-and-practice, simulation, instructional games, and problem-solving. Many computer assisted instruction software packages include more than one of these categories in the instruction. That is, the instruction may include a tutorial with opportunity for the user to drill-and-practice the concept, or it might include a simulation designed within a gaming atmosphere (Vasu, and Vasu, 1985).

With spacing effects in regards to the nature of computer assisted instruction, spaced practice and spaced review can be implemented in each of the categories. However, for the benefit of educating the user, spacing effects are best manipulated within the category of drill-and-practice.

Drill-and-practice involves any exercise, physical or mental, that is performed regularly and with constant repetition. It is often associated with rote-memory learning. Many of the modern theories about how learners perform complex tasks, such as reading and computing, suggest that for a learner to learn efficiently, performance of lower-level of subskills must become automatic. This is generally referred to as automaticity of subskills. The more one practices a skill, the more automatic it becomes. As a subskill becomes automatic, it requires less attention and interferes less with other ongoing cognitive processes (Merrill, et al, 1992).

COGNITIVE STRATEGIES

A very special kind of intellectual skill, of particular importance to learning and thinking, is the cognitive strategy. In terms of modern learning theory, a cognitive strategy is a control process, an internal process by which learners select and modify their ways of attending, learning, remembering, and thinking. Many different strategies have been identified that relate to the entire range of cognitive processes of the learner (Gagne', Briggs, and Wager, 1992).

There are a variety of cognitive strategies that can be implemented with computer assisted instruction. Spacing effects are cognitive strategies that have been proven effective with outcomes in learning and memory. The variety of cognitive strategies can be identified in categories. The categories of cognitive strategies are (1) rehearsal strategies, in which the learner engages in their own practice of the material being learned, (2) elaboration strategies, in which the learner makes deliberate associations of the items to be learned, with other readily accessible material, (3) organization strategies, in which the learner arranges the material to be learned into an organized framework, (4) comprehension monitoring strategies, sometimes referred to as metacognitive strategies, pertain to the student's capability of setting goals for learning, estimating the success with which the goals are being met, and selecting alternative strategies to meet the goals, and (5) affective strategies, which are used by learners to focus and maintain attention, to control anxiety, and to manage time effectively. Spacing effects are types of cognitive strategies which support rehearsal strategy. A cognitive strategy is a cognitive skill that selects and guides the internal processes involved in learning and thinking. It is the object of the skill that differentiates cognitive strategies from other intellectual skills. The latter concepts and rules, are oriented toward environmental objects and events, such as sentences, graphs, or mathematical equations. In contrast, cognitive strategies have as their objects the learner's own cognitive processes (Gagne', Briggs, and Wager, 1992).

In relation to spacing effects being implemented in the design of a computer assisted instruction program, one can consider cognitive strategies as learned capabilities that are the outcomes of instruction. According to Gagne', Briggs, and Wager (1992), one might consider cognitive strategies as instructional techniques for use in designing instruction, especially with regard to presenting stimulus materials to the learner. As previously noted, there are a number of different strategies which seem more or less appropriate at different stages in the instructional process. Embedding the strategies into the instructional materials is not the same as teaching the strategies. The embedded strategies serve a specific function, whereas the learned strategies allow the students to provide this function for themselves.

RESEARCH RELATED TO COMPUTER ASSISTED INSTRUCTION

Employing the cognitive strategies of spacing effects to instruction can be further enhanced by implementing them with computer assisted instruction programs. The literature regarding computer assisted instruction has found it largely in comparison to other instructional methods such as the traditional classroom lecture. Research studies have provided support for computer assisted instruction as a viable instructional method, which can be implemented in various settings, such as schools and industry. As previously stated, computer assisted instruction has been compared to other instructional methods as indicated by research studies.

A study conducted at Buffalo State College compared computer assisted instruction and the traditional classroom lecture (Vogler, O'Quin, and Paterson, 1991). The research was a study of the effectiveness of computer assisted instruction as a supplement to a Sociology 100 course. An experimental design using two sections of the same course taught by the same instructor was arranged. Though only one class worked with the computer software, "Student Showcase-Introducing Sociology through the Computer," each class was pretested and posttested to examine attitudes toward computer assignments as an integral part of the course and to determine if the supplemental computer software would have a significant effect on student's knowledge of sociology.

Posttest analyses and comparisons with pretest scores indicated that the computer group's attitudes toward computers as effective teachers and toward their own ability to work with computer assisted instruction were indeed more positive after completing the course. The computer group was also significantly higher in general knowledge of sociology and got higher grades than the non-computer group (Vogler, O'Quin, and Paterson, 1991). As part of a three year effort being funded by a Title III grant, Buffalo State College studied the use of educational software to enhance classroom learning. The college used introductory courses with large freshman enrollments and large class numbers were targeted for computer assisted tutorials and enrichment (Vogler, O'Quin, and Paterson, 1991).

A study in support of computer assisted instruction was conducted at Florida State University. This study, conducted by Yong-Chil Yang (1992), examined the effects of computer based instruction, (CBI), versus print based instruction, (PBI), on motivation, continuing motivation and content recall. A total of fifty-two 11th graders were randomly assigned to either a CBI group or a PBI group. The CBI and the PBI groups studied Lincoln's Decisions on the computer screen and in print text, respectively. After motivation and continuing motivation in both groups were measured with the Instructional Materials Motivation Survey, the immediate and delayed recall was measured with sixteen multiple-choice items. As expected, the results indicated that the CBI group showed significantly higher motivation and higher scores in the immediate recall over those of the PBI group, but the results of delayed recall were not significant between the two groups, and continuing motivation was difficult to interpret. These findings were discussed in terms of the motivational function of computers (Yang, 1992).

Student achievement has been the most evident factor in determining the effectiveness of computer assisted instruction. In an early study conducted, relative to computer assisted instruction, at the University of Santa Clara, differences in student learning achievement was highlighted, as measured by four different types of common performance evaluation techniques, in a college-level computer programming course under three teaching/learning environments: lecture, computer aided instruction, and lecture supplemented with computer aided instruction (Tsai, and Pohl, 1978).

Three samples of students were obtained and matched on relevant variables. The analysis of variance, matched groups design, detected significant differences among treatment groups (teaching/learning environments) on two of the four performance evaluation techniques (Tsai, and Pohl, 1978).

Four particular measuring devices were chosen because they seemed representative of those typically used in introductory level computer programming classes. Also, because of their relatively objective nature in scoring, these four types of instruments minimized subjective evaluation of student performance. In addition, these measuring devices could be easily examined for face validity; probably the most common type of validity criterion used at the collegiate level of classroom testing. The four measuring devices used to evaluate achievement were: (a) hour quizzes, which tested knowledge of specific content of course material, (b) homework assignments, which tested knowledge of new material related to that presented as content of the course, (c) a term project, which tested ability to apply assembly language in digital computer programming as a whole, and (d) a final examination, which tested overall knowledge of all general concepts and principles covered in the text material throughout the course. The design of this study is similar to that referred to by Campbell and Stanley in 1966 as an ex post facto analysis. The phrase "ex post facto experiment" has come to refer to efforts to simulate experimentation through a process of attempting to accomplish a pre-X equation by a process of matching on pre-X attributes. The experimental statistic for this study was the analysis of variance. The results of this study overall demonstrate that differences in learning achievement can be measurement specific. That is, significant differences in learning achievement under different teaching/learning environments may be detected only with certain types of performance evaluation instruments (Tsai, and Pohl, 1978).

As stated earlier, the research conducted in the area of computer assisted instruction in comparison to traditional classroom methods, is vast. However, a study conducted at Tel Aviv University in Israel differs from other studies comparing computerized and paper and pencil performance in that rather than examining the validity of the computer as a testing device, it examines the validity of the decisions made during computer based management of student's CAI work. Computer based management of student's work is a major component in most of the larger CAI systems for individualized drill and practice (D&P), or tutorial programs. Because D&P and tutorials are the most prevalent applications of computers in elementary schools today (Becker, 1987). This study conducted by Hativa (1988), identified differences in student's performance of similar arithmetic tasks in two media: paper and pencil (P&P) and computer assisted instruction (CAI). Performance of elementary school students on P&P was compared with their performance in CAI work in two widely used CAI systems, an Israeli and an American; in two types of practice, either mixed from a variety of types of exercises or of fixed-type exercises; with two types of task arrangement, either strictly or loosely hierarchical; and with two criteria, either level of performance as defined in the CAI curriculum or the percent of correct answers. Results showed that for both CAI systems, for both criteria, for both types of task arrangement, and for either type of practice, the majority of students performed with P&P better than in their simultaneously current CAI work. However, there were students who achieved the opposite results for tasks arranged in loose hierarchy. Both contradictory trends are discussed and explained on the basis of prolonged observations of several students working with the two CAI systems involved (Hativa, 1988).

Another study conducted by Hativa, Sarig, and Lesgold (1991), was done in conjunction between Tel Aviv University, and the University of Pittsburgh. This study is relevant to the research being conducted, in that timing was examined in terms of response time during a computer tutorial. Emphasis was placed upon elementary arithmetic. This study investigated the effects on student's performance of increasing substantially the response time limit in elementary school computer managed drill and practice in arithmetic. Results show that with the longer time limits, all students, but more substantially the low achievers, improved their performance during the first two-month period after the increase. However, there was some decline in this improvement during the second two-month period for the low achievers. The students who benefited the most from the increase in the time limit were those who initially made a relatively large proportion of errors due to this limit. There were minor grade related differential effects of the change in time limit. Limited response time was a positive factor in student's CAI work, but data suggest that limits should be substantially longer than current intuitions suggest (Hativa, Sarig, and Lesgold, 1991).

Support for computer assisted instruction can be found in studies with adult learners as well. The military has long been a foundational ground for computer use. With the advancement of technology, computer hardware and software, the military has made significant gains for the understanding of computer assisted instruction.

In a study conducted examining computer based training simulation systems, the military played a significant role (Shlechter, Bessemer, and Kolosh, 1992). This study investigated the effectiveness of a computer based training simulation system (SIMulation NETworking) combined with a program of role playing activities for helping students to master the conditional knowledge needed for successful field performance. Field evaluations of 746 Armor Officer Basic (AOB) course students who completed the AOB course before SIMNET was implemented (baseline condition) were compared to the field evaluations of 607 students who received SIMNET training. Four hundred seventy of the latter students participated in the role playing phase of this investigation. SIMNET's effectiveness was demonstrated for training military students to apply their newly acquired knowledge in the field exercises. Also, the positive transfer of SIMNET training was seemingly attributable to the student's engaging in appropriate role playing activities during this training. The present findings have affirmed the hypothesized value of using computer based simulation systems for training students to use higher order cognitive constructs. The effectiveness of such instructional systems is seemingly tied to providing students with realistic and safe "learning by doing" opportunities (Shlechter, Bessemer, and Kolosh, 1992).

Further inquiry into studies conducted on computer assisted instruction brought forth the discovery of research which entailed how a subject learns the information given to them. The research found highlighted evidence of cognition and memory. More significantly, the literature found, focused inquiry upon structural components of computer tutorials, such as spacing effects, which have been found to induce and enhance memory. The literature provided a base for the question of whether or not these structural components are solely responsible for computer assisted instruction being the viable alternative to traditional classroom teaching methods?

SPACING EFFECTS AS STRUCTURAL COMPONENTS

A relative study implementing computer assisted instruction with the cognitive strategies of spacing effects was conducted by Edwards and Siegel (1985). In the study, teaching generalizations using a computer based drill strategy was investigated. The more intricate part of the study dealt with increasing ratio review schedules. The major difference between ordinary drills, and increased ratio review drills are, that the increased ratio review presents a drill, however, missed items in the drill are placed in the drill list for review, this is according to the spaced review schedule. This study was designed to answer the following research questions: Is there any effect for increasing ratio review as opposed to immediate review only in drills that teach generalizable concepts? Is there any effect for generalized item generation as opposed to fixed items in a drill to teach generalizable concepts? The design of this study centered around the relationship between equations for curves, specifically parabolas, and their shapes on the cartesian coordinate plane. For the purpose of the experiment, three drill paradigms were used: (a) increasing ratio review with generalized item generation, (b) increasing ratio review with fixed items, and (c) immediate review only with generalized item generation. In increasing ratio review with generalized items, items were randomly selected from the appropriate generalized class for each item presentation, and missed items were reviewed in a one, three, and five later review schedule which presented different items from the same class at each review. The increasing ratio review with fixed items paradigm selected a single item from each class at the beginning of the drill, and this one item was used at each presentation of that concept class. The immediate review only with generalized items drill generated the items in the same manner as in the first drill, but missed items were repeated immediately (one later), until a correct response was given, but then placed at the end of the list. The immediate review only strategy corresponded to the sequencing in the original lesson. These treatments were chosen to answer the preceeding research questions. Subjects in this study were 51 freshmen enrolled in one of three algebra I classes at a university laboratory high school. The same instructor taught all three classes. The entire experiment was carried out in the normal class meeting times on three consecutive days. A 28 item written pretest was administered to all subjects prior to computer instruction. For each problem, a graph was shown, and the student was to provide the equation for the graph. The following day, the computer based instruction was administered to all students. The instruction was controlled by the University of Illinois PLATO IV computer based education system. Upon signing on, each subject was assigned to one of the three treatment groups corresponding to the drill models previously discussed. As a result of the study, the main effect for review schedule was as predicted. Treatments (drill models), were the same in that the subjects in both groups received generalized items and differed only in the review schedule for missed items. For the results, an analysis of covariance was performed. The first group had a spaced review schedule, while the other only reviewed an item immediately following an error before the item was returned to the end of the list. Clearly then, increasing ratio review accounted for the significant difference in delayed task performance. The systematic review of difficult items helped the IRR-GEN subjects to remember the concepts over time better than immediate review treatment helped the IMM-GEN group. The existence of this difference reinforces the findings concerning reviews in the original CFP study and also supports the claim that increasing ratio review techniques can be successful in enhancing traditional drills to teach generalizations (Edwards, and Siegel, 1985).

The spaced practice effect refers to the strong and pervasive positive influence on long-term explicit memory which results from interposing at least one other item between the repetitions of any to be remembered item in a list learning paradigm. Limited prior empirical evidence suggests that spaced practice could also have a similar positive effect on implicit memory performances, as revealed through a tachistoscopic identification task (Perruchet, 1989).

Perruchet's study investigated four experiments involving another implicit memory task, namely a perceptual clarification procedure, conducted to test for the effect of spaced practice with greater methodological control than previously used (1989). Low frequency words were displayed to subjects under a variety of conditions including incidental (experiments 1 and 2), and intentional (experiments 3 and 4), learning instructions. Although spacing regulated to a large extent the performances in subsequent free recall (experiment 2), or recognition (experiments 1,3, and 4), control tasks, the advantage of spaced over massed items in the perceptual classification procedure was always small in magnitude, and only reached significance in the last experiment. Overall, analysis of the data shows with a reasonably high degree of certitude that spaced practice exerts a real but probably slight and fluctuating effect upon implicit memory performance (Perruchet, 1989).

An earlier study that provided a framework relative to the work of Perruchet, was conducted by Madigan (1969), where subjects were examined with 48 words to be recalled later. Some of the 48 words were presented twice, others only once. Subjects recalled twice presented words better than once presented words and the probability that a twice presented word would be recalled was a function of the spacing of the two presentations of the word within the sequence. In other words, the further apart the two presentations of a word in the sequence, the higher was the probability for recalling that word, indicating that retention improves with increased spacing between exposure to the material (Madigan, 1969).

COGNITIVE SCIENCE THEORY

The effectiveness of computer assisted instruction has been shown to greatly enhance the quality of learning in educational settings, and industry. Computer assisted instruction can be implemented with all age groups, and levels of skill. Cognitive science has provided a theory for which the understanding of how we learn to learn is given definition. Out of cognitive science, the spacing effects of spaced practice and spaced review are given definition. In research, spacing effects have been manipulated for the understanding of greater recall and retention of learned items. Research has further provided support for these effects as beneficial to the enhancement of learning and memory. Spaced practice has proven effective at inducing greater recall of learned material, and spaced review has proven effective at inducing greater retention over a period of time. By providing computer assisted instruction with these cognitive components, education as a whole can receive a dual benefit. The benefit of combining computer assisted instruction with the cognitive components of spaced practice and spaced review is enhanced learning and memory, which will provide students with greater learning capabilities, and school performance. Another great benefit of combining computer assisted instruction and these cognitive components, is the creation of improved educational software for educational, as well as recreational learning settings (Thorpe, and Turner, 1993).

SUMMARY

Foundations for computer assisted instruction were laid before computers were ever used for instructional purposes. Programmed instruction, as it was called, was the beginning of educational endeavors with computerization. However, during that period, programmed instruction was developed by applying the techniques of behavioral analysis. Programmed instruction was influenced by psychologist B. F. Skinner. Skinner, recognized a parallel between his work involving animal behavior and practices that could improve education. Skinner defined learning as a "change of behavior".

Since the onset of programmed instruction, many vast improvements have been made. Computer assisted instruction has provided the educator with flexibility in structure and design, and a vast array of software technology. As well, research studies have been conducted to provide further insight upon the use of computers for instruction. The fields of cognitive psychology and cognitive science have given educators and software designers new insight into computer assisted instruction. More specifically, the cognitive components of spaced practice and spaced review have been proven to enhance learning and memory when incorporated in research studies. Research studies have been conducted on patients with Alzheimer's Disease, and head injuries. Studies have also been conducted on visual recognition, psychomotor skills, and performance. The spacing effect has proven to be beneficial for the purpose of inducing improved learning, and greater memory.

Computer assisted instruction has been further developed by the recognition of factors such as those defined by Robert Gagne'. The nine events of instruction were defined specifically for the purpose of designing effective computer assisted instruction. Each of the nine events of instruction, can be manipulated by the author or designer of the computer software. In addition to the nine events of instruction, cognitive strategies can be implemented to manipulate learning outcomes.

Studies have been conducted on computer assisted instruction, showing its effectives as a tool. Cognitive science theory has provided computer assisted instruction with a solid foundation in which to maintain its effectiveness.

In the following chapter, the research study conducted is presented in detail. Chapter III provides the methodology for the research in the area of computer assisted instruction, combined with the cognitive components of spaced practice and spaced review. More specifically, the independent variable is presented with two levels of instructional treatment. Two computer assisted instruction programs, one that is structured with spacing effects, and the other unstructured, without spacing effects is given. Each of the instructional treatments was measured by a test of recall and retention. The researcher has postulated, that the structural components of a computer assisted instruction program, specifically spacing effects, enhance learning and memory.

Chapter III

METHODOLOGY

This chapter discusses the methodology that was implemented to conduct a study on the effects of spaced practice and spaced review on recall and retention using computer assisted instruction. The researcher examined spacing effects that have been embedded as cognitive strategies in a computer assisted instruction program, to determine their effectiveness at enhancing learning and memory. The methodology includes the research design and a full explanation of each treatment. The independent and dependent variables are discussed, as well as a description, which includes validation of the measurement instruments. An explanation of the procedures to be used in the study are given, including a description of the specific instructions received by the treatment groups. Research expectations are discussed as well, regarding the statistical hypotheses.

SUBJECTS

This study was conducted using undergraduate students at North Carolina State University. The sample of subjects were students enrolled in courses under the disciplines of Graphic Communications, Technology Education, and Industrial Engineering. The courses in which the students were enrolled, were GC-200 Applied Cad, GC-120 Foundation of Graphics, TED-115 Wood Processing, TED-122 Metal Technology, TED-221 Construction Technology, TED-384 Computer Applications in Industry, and IE-210 Introduction to Engineering Graphics.

The students from these classes volunteered to participate in the study. The researcher, in conjunction with class instructors, provided incentives for active participation in the study. The researcher offered instructors that allowed their classes to participate in the study, the computer assisted instruction programs that were designed for the study. Incentives of added points to a student's class grade for participation in the study were offered by instructors to the student. At the completion of the study, students received a participation form, with which to present to their instructor for extra credit points.

Thirty-six subjects (N = 36), participated in the study, which were undergraduate students at North Carolina State University. Subjects volunteered to participate in the study, and were assigned to groups by a simple random sampling procedure. Subjects were randomly assigned to treatment groups by a color coding procedure. Twelve computers were used to conduct the study. For each odd numbered computer, a blue color coding was used to indicate that the CAI-unstructured treatment was implemented by the subject. For each even numbered computer, a red color coding was used to indicate that the CAI-structured treatment was implemented by the subject. As subjects signed in to participate, they were randomly assigned to a computer by color coding. To maintain randomization, for the purpose of keeping subjects in a treatment group, the researcher monitored which color coded computer a subject was assigned to.

INSTRUMENTS

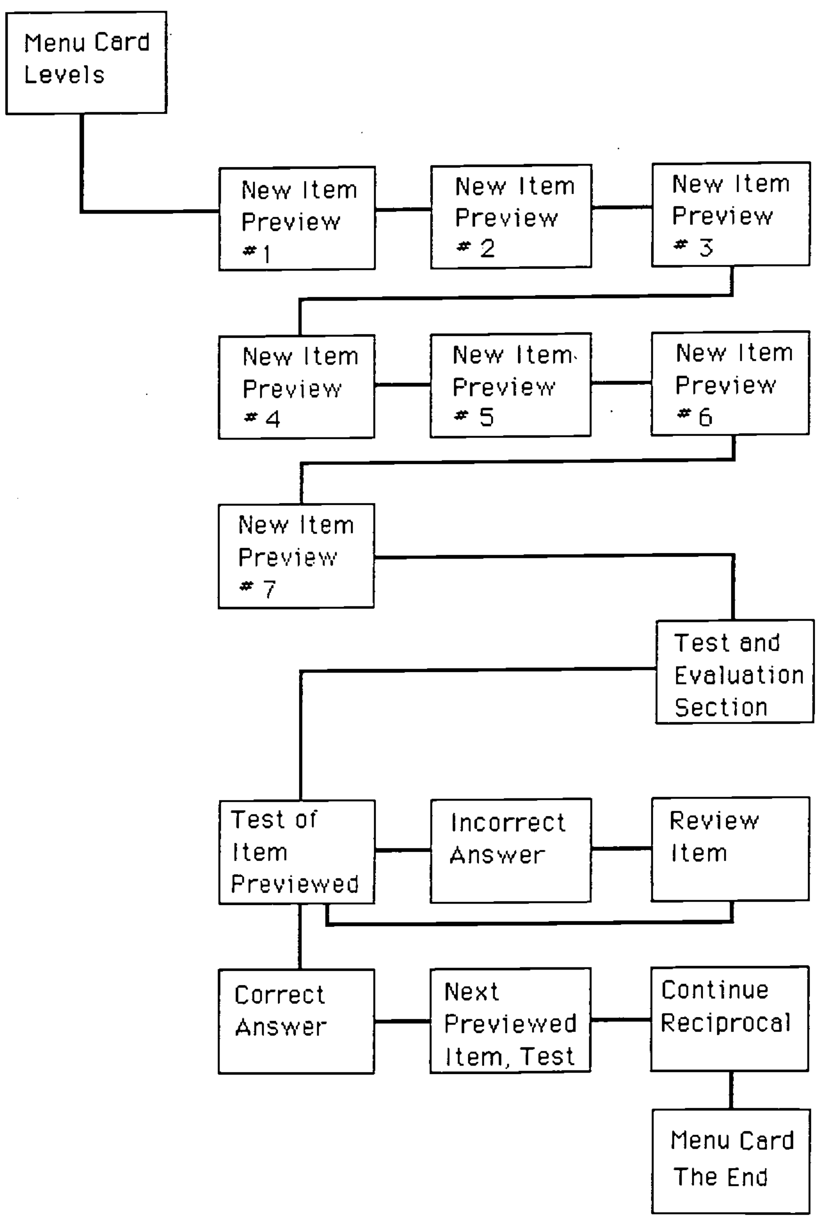
The researcher's major advisor approved instrumentation for the study to be conducted. The major advisor's approval allowed the instrumentation to have face validity. The instrumentation had face validity, due to the fact that it was judged to be structured to evaluate the hypothetical construct of memory, of the subject content being studied. Two computer assisted instruction programs; one with the structural components of spacing effects and one without, were also used.

The computer assisted instruction program, structured with the components of spacing effects was programmed by providing the learner the opportunity to practice items with the inclusion of feedback reinforcement. The structure of this program employed a branching format. Branching allowed the learner to use a menu card, from which the learner could choose a part of the tutorial to go to. After the learner was introduced to the item to be learned, he or she was then presented with an embedded quiz on the items learned. Upon answering the questions, the learner would receive feedback in response to their answer. An incorrect response would send the learner back to the items for practice in a spacing sequence, a correct answer would move the learner forward in the computer program. Practice was signaled by feedback, which allowed the learner to move forward once he or she had mastered an item, or repeated the item until learning had taken place. Review was programmed by repetition of items at the end of the computer program. The learner was able to review learned information before engaging in the embedded quiz at the end of the tutorial which covered all relative items presented in the tutorial. A flowchart of the computer assisted instruction program structured with spacing effects is provided in Figure 1 on the following page.

The computer assisted instruction program, unstructured, without the component of spacing effects was programmed with incorporation of a linear structure. Practice and review of concepts were not provided. However, embedded quizzes and feedback were provided. The major difference with feedback, was that after a feedback presentation had been given, the computer program would not return to a remediation of the item learned. No repetition was provided within the computer program.

Both instructional treatments were developed on African-American scientists and inventors, provided by the researcher, with the computer software programs developed using the HyperCard authoring software system. To implement the computer tutorials for the study, the researcher used reserved computer laboratory facilities at North Carolina State University.

Figure 1. Flowchart of the computer assisted instruction program structured with spacing effects for enhanced learning and memory.



The researcher provided subjects with the computer assisted instruction programs. The researcher also provided the pretest which was designed as a multiple-choice test, on American Inventors. As well, the researcher provided the tests for recall and retention. The tests for recall and retention were the same. The test was made-up of questions in the form of multiple-choice, and matching formats. The pretest was given to control for prior knowledge of African-American Scientists and Inventors, and to determine statistical equivalence among the groups. The test of recall and retention was designed to examine memory and learning. The researcher also provided subjects with a contract of participation for earned incentive. The contract of participation was given to subjects at the completion of the test of retention, at the end of the experiment.

DESIGN AND PROCEDURE

The researcher received volunteers for the study by seeking the cooperation of instructors to allow their students to participate in research. The researcher made announcements of the research study to the various classes. During the announcements, the researcher circulated a sign-up sheet for student volunteers. The sign-up sheet stated specifics which were also announced by the researcher. The dates, time, and location were given during the announcement, and also appeared on the sign-up sheet.

On day one, subjects entered into the computing facility to participate in the study. Subject's names were checked, and they were given instructions. Subjects were assigned to a computer for the purpose of grouping for treatment, then given the pretest. Once subjects had completed the pretest, they were asked to navigate through the computer assisted instruction program. Once subjects had completed the computer assisted instruction program, they were given a test for recall. Upon completion of the test for recall, subjects were given a reminder sheet, which asked them to return in one week's time to complete the study.

On day two, which occured one week from day one, subjects returned to complete the study. Subjects were asked to complete a test for retention. Upon completion of a test for retention, subjects were given a participation form, for which they were to present to their instructors for the incentive of extra credit points toward a class grade. The participation form was signed and dated by the researcher to validate student participation.

A sample of thirty-six subjects (N = 36) participated fully in the study. Subjects were divided equally into two groups of eighteen (n = 18). Attrition did occur between testing period one, and testing period two. A total of forty-five subjects participated in the study initially, however after the first testing period nine subjects dropped. Thirty-six subjects participated on day two of the study, giving each group an equal number of eighteen (n = 18) subjects. Group I received the structured computer assisted instruction program. This program contained the cognitive factors of spaced practice and spaced review. Group II received the unstructured computer assisted instruction program. This program did not contain the cognitive factors of spaced practice and spaced review in its design. The content of African-American scientists and inventors was consistent across treatment methodologies. Testing was also consistent across treatment methodologies. Each group received the identical subject matter. The pretest, test of recall, and test of retention remained the same with each group. The tests were identical for each testing period.

The researcher designed the instructional treatments of computer assisted instruction, structured and unstructured. The researcher also designed the pretest and the posttest. The test for recall of information learned was given immediately after completion of each instructional treatment. The test for retention was given after a period of one week has elapsed from the time the test of recall was given. All treatment periods were the same in timing. The researcher reserved blocks of time for each research period. A computer facility was reserved for a five hour block of time, for day one of the study. A classroom facility was reserved for a five hour block of of time, for day two of the study. Each instructional session was given individually on two individual days, with a one week interval between them.

RESEARCH DESIGN AND STATISTICS

The researcher used a pretest-posttest control-group design. The pretest-posttest control-group design is implemented with the following steps: (1) random assignment of subjects to experimental and control groups, (2) administration of a pretest to both groups, (3) administration of the treatment to the experimental group but not the control group, and (4) administration of the posttest to both groups (Borg, and Gall, 1989). The experimental and control groups were treated alike with the exception of the treatment variable (refer to Figure 2).

The researcher used analysis of covariance (ANCOVA) to conduct the statistical analyses. The analysis of covariance was used to determine significance between groups on the dependent variables, with the pretest as the covariate. The analysis of covariance, with the pretest as the covariate, controlled for prior knowledge of the information learned, and determined statistical equivalence among groups. T-tests of dependent means were also calculated to determine the significant differences within groups on the dependent variables (the posttest scores). Statistical procedures were conducted using the SAS statistical software package. A SAS proc glm, general linear models procedure was used.

Figure 2. The pretest-posttest control-group research design.

R O X O

R O   O

Where: R = Random Assignment
X = Experimental Treatment
O = Observation, either pretest or posttest

DATA COLLECTION

A sample of thirty-six (N = 36) subjects were randomly assigned to a treatment group (n = 18) by color coding of computers. Subjects were either assigned to a red or blue coded computer, which indicated their treatment group. Data was collected by completed tests returned to the researcher by the subject. The tests were separated into treatment group by color code. Those subjects which received the structured CAI program, were placed in the red color coded group, and subjects receiving the unstructured CAI program, were placed in the blue color coded group. Once a subject's group was established, they remained in that group throughout the study.

Data was collected and tabulated. The tests were divided into groups, red and blue. Each member of a group had taken a pretest, a test for recall, and a test for retention. Each test was graded for a total score. Each test question was worth a total of five points. The highest possible score that a subject could earn was one hundred.

THE INDEPENDENT VARIABLE

The independent variable was computer assisted instruction which had two levels of instructional treatment. The two instructional treatments were: a structured computer assisted instruction program containing spaced practice and spaced review in its design, and an unstructured computer assisted instruction program, designed without the spacing effects of spaced practice and spaced review.

THE STRUCTURED CAI PROGRAM

The computer assisted instruction program, structured treatment, authored by the researcher, through HyperCard, was developed around the concept of African-American Scientists and Inventors. The structured CAI program contained the cognitive factors of spaced practice and spaced review. Spaced practice influences greater recall by allowing the learner to stop and resume practice sessions in a CAI program. Spaced review influences greater retention by allowing the learner to review items previously learned based on the amount of time which has passed since the learner last responded to that item.

THE UNSTRUCTURED CAI PROGRAM

The computer assisted instruction program unstructured treatment, authored by the researcher, through HyperCard, was also developed around the concept of African-American Scientists and Inventors. However, the CAI unstructured treatment did not contain the cognitive factors of spaced practice and spaced review.

THE DEPENDENT VARIABLES

The dependent variables of recall, and retention were measured by a test on the items learned. The test given was consistent across treatments, meaning the same test was given for recall and retention. Recall and retention were measured to determine if learning and memory were enhanced.

RECALL

Recall, according to the Pinguin Dictionary of Psychology (1985), is the process of retrieving information from memory. An experimental procedure for investigating mental processes whereby the subject must reproduce material previously learned. This dependent variable was measured by a test on African-American scientists and inventors.

RETENTION

Retention, according to the Pinguin Dictionary of Psychology (1985), is the process of holding onto or retaining a concept. It is most commonly used with respect to issues surrounding the retention of information, where the basic presumption is that some "mental content" persists from the time of initial exposure to the material or intial learning of a response until some later request for recall or re-performance. This dependent variable was measured by a test on African-American scientists and inventors.

THE CONTROL VARIABLES

The researcher controlled for interference by providing subjects with novel material. Interference refers to factors influencing long-term, and short-term memory. The two types of interference are proactive, and retroactive.

INTERFERENCE

By providing novel material, the researcher can control for interference.

The two types of interference are: (a) proactive interference, where old linkings interfere with the formation of new ones, and (b) retroactive interference, where new linkings interfere with old linkings.

The most noticeable form of interference is the detrimental effect of new learning on the retention of older memories. This is called retroactive inhibition. If retroactive inhibition were the only source of interference, memory loss might not be as rapid as it is. There is also interference from prior learning on the retention of newer material. This forward acting interference is referred to as proactive inhibition. While logically distinct, retroactive and proactive inhibition in everyday forgetting, ordinarily form two sides of the same coin of interference. Indeed, even in the laboratory, it is sometimes hard to isolate their independent effects unless we have very strict control over all prior learning of the subject, (Wingfield, 1979).

The organization of the remaining chapters follow the design and procedure section of this chapter. Chapter IV descibes the findings and results of the study conducted. Statistical analysis gives the effects of the levels of independent variable on the dependent variables, and the effects of the pretest. Analysis also determines if spacing effects made a significant impact with the enhancement of memory and learning, by determining the outcomes of each hypothesis statement. Chapter IV also makes generalizations based upon the sample studied, to the population that the sample was taken from.

Chapter V is a discussion and summary of the study. The outcome of the study is discussed, along with conclusions and recommendations for practice and implementation, and for future studies in the area of computers and cognition.

Chapter IV

FINDINGS

Thirty-six subjects (N = 36), divided into two groups (n = 18), participated in this study. The subjects were from the disciplines of graphic communications, technology education, and industrial engineering. The following chapter provides a summary of the findings.

The focus of this study was the examination of spacing effects. Spaced practice, and spaced review were examined to determine if they had an effect on recall and retention. The treatments of this study were measured by the dependent variables of recall and retention. Two computer assisted instruction programs were implemented. The structured CAI program contained the spacing effects of spaced practice and spaced review in its structural design. The unstructured CAI program was designed without the spacing effects of spaced practice and spaced review. The methodology consisted of subjects taking a pretest, followed by implementing their asigned treatment computer assisted instruction program, and taking the test of recall and retention. After a period of one week, subjects were asked to complete the study by taking the test of recall and retention once again. The pretest was used as a covariate to control for prior knowledge, and to determine statistical equivalence among the groups. A T-test of dependent means was conducted to further examine significant difference within groups on the dependent variables. An alpha level of .05 was preset throughout the study for statistical analysis. Descriptive statistics were calculated from raw data scores from each group on the pretest, and the posttest, once for recall, and once for retention. Descriptive statistics were calculated before other statistical analyses to examine mean score differences among the groups. (Refer to table 1).

Table 1

Descriptive statistics for each group.

	Recall			
	N	Mean	Pretest-Mean	SD
Group I	18	91.38	45.27	7.43
Group II	18	81.38	44.72	13.26

	Retention			
	N	Mean	Pretest-Mean	SD
Group I	18	87.77	45.27	7.11
Group II	18	69.16	44.72	11.53

Note. Table 1 shows the means and standard deviations for each group. Each group was represented by an even number of 18 subjects. Means were calculated for the pretest scores of each group, and for the posttest scores of each group. The means and standard deviations for group I on both recall and retention indicate less variance by subjects that received the structured CAI program.

HYPOTHESIS I

Hypothesis I stated, " There will be no significant difference (alpha = .05), based upon an analysis of covariance, between a structured computer assisted instruction program, and an unstructured computer assisted instruction program on the dependent variable of recall, with the pretest as the covariate." The data indicate significance was found between the groups on the dependent variable of recall, where the calculated F-value (7.63) was greater than the criterion F-value (4.17) at the .05 alpha level. Based upon this finding, hypothesis statement one was rejected. (Refer to table 2).

Table 2

Analysis of covariance (ANCOVA) table for the dependent variable recall, with the pretest as the covariate (Alpha = .05).

Source of variation	DF	SS	MS	F
RECALL				
Between Groups (Treatments)	1	822.38	900	
Within Groups (Error)	33	3887.93	117.82	*7.63
Total	34	4710.31		

Note. Table 2 shows that *7.63 was the calculated F statistic, which was greater than the criterion F value of 4.17 (1, 34), for alpha set at .05. This finding indicates a significant difference between groups, and statistical equivalence between the groups on the dependent variable of recall.

HYPOTHESIS II

Hypothesis II stated, "There will be no significant difference (alpha = .05), based upon an analysis of covariance, between a structured computer assisted instruction program, and an unstructured computer assisted instruction program on the dependent variable of retention, with the pretest as the covariate." The data indicate significance was found between the groups on the dependent variable of retention, where the calculated F-value (33.35) was greater than the criterion F-value (4.17) at the .05 alpha level. Based upon this finding, hypothesis statement two was rejected. (Refer to table 3).

Table 3

Analysis of covariance (ANCOVA) table for the dependent variable retention, with the pretest as the covariate (Alpha = .05).

Source of variation	DF	SS	MS	F
RETENTION				
Between Groups (Treatments)	1	3149.28	3117.36	
Within Groups (Error)	33	3083.99	93.45	*33.35
Total	34	6233.27		

Note. Table 3 shows that *33.35 was the calculated F statistic, which was greater than the criterion F value of 4.17 (1, 34), for alpha set at .05. This finding indicates a significant difference between groups, and statistical equivalence between groups on the dependent variable of retention.

HYPOTHESIS III

Hypothesis III stated, "There will be no significant difference (alpha = .05), based upon a t-test of dependent means, within a structured computer assisted instruction program from recall to retention." The data indicates that no significant difference was found within group one, which received the structured computer assisted instruction program, from recall to retention. Hypothesis statement three was not rejected (accepted). The calculated-t (1.49) was less than the critical-t (2.0423), at the .05 alpha level, with the degrees of freedom equal to 34 (Refer to table 4).

Table 4

T-test of dependent means for Group I, Recall to Retention.

	N	Mean	SD	Calculated T-score
Recall	18	91.38	7.43	
Retention	18	87.77	7.11	*1.49

Note. Table 4 shows that the calculated t-score (*1.49) was less than the critical t-score (2.0423). This finding indicates that subjects receiving the structured CAI treatment retained a level of knowledge between testing periods from recall to retention.

HYPOTHESIS IV

Hypothesis IV stated, "There will be no significant difference (alpha = .05) based upon a t-test of dependent means, within an unstructured computer assisted instruction program from recall to retention." The data indicates a significant difference from recall to retention within group two, which received the unstructured computer assisted instruction program. Hypothesis statement four was rejected. The calculated-t (2.95), was greater than the critical-t (2.0423) at the .05 alpha level, with the degrees of freedom equal to 34 (Refer to table 5).

Table 5

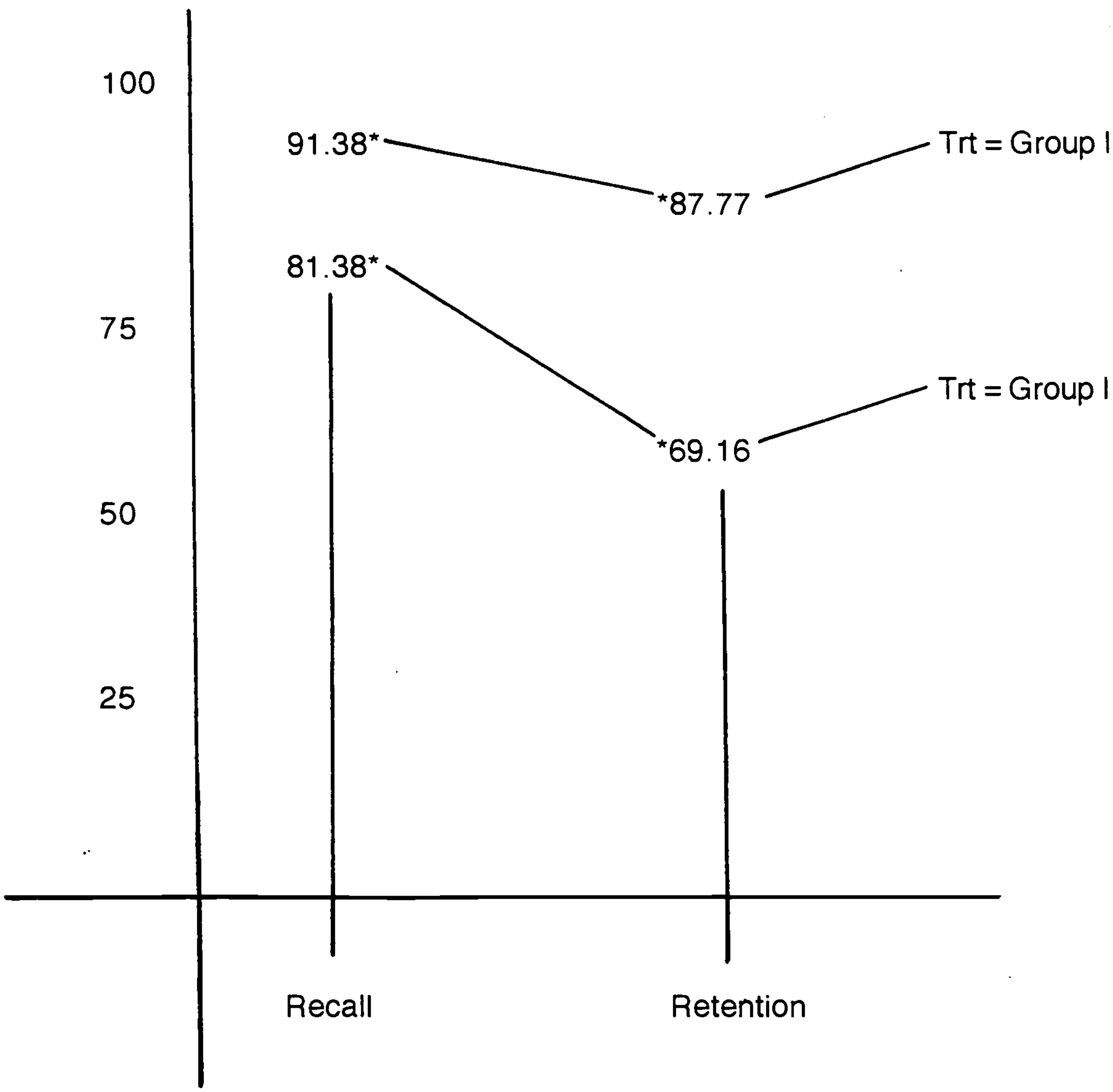
T-test of dependent means for Group II, Recall to Retention.

	N	Mean	SD	Calculated T-score
Recall	18	81.38	13.26	
Retention	18	69.16	11.53	*2.95

Note. Table 4 shows that the calculated t-score (*2.95) was greater than the critical t-score (2.0423). This finding indicates that subjects receiving the unstructured CAI treatment had a significant drop in level of knowledge retained between testing periods from recall to retention.

The non-significant findings of hypothesis three, when observed in comparison to the significant findings of hypothesis four, further support the researcher's postulation, that spaced practice and spaced review can enhance learning and memory, and more specifically recall and retention, when implemented within a computer assisted instruction program.

Figure 3. Diagram of descriptive data, for within groups analysis showing the means of each group for the dependent variables of recall and retention.



The remaining chapter V is a discussion and summary of the study. The outcome of the study is discussed, along with conclusions and recommendations for practice and implementation, and for future studies in the area of computers and cognition.

Chapter V

SUMMARY, CONCLUSIONS, RECOMMENDATIONS

SUMMARY

The purpose of this study was to investigate the effects of spaced practice and spaced review implemented in a computer assisted instruction program. The researcher postulated that spaced practice and spaced review would enhance recall and retention when applied to the design and structure of a computer assisted instruction program.

The problem this research focused on, was the use and implementation of spaced practice and spaced review in the development of educational software. The cognitive factors of spaced practice and spaced review have both been employed in instructional activities, and implemented in studies, such as those conducted on Alzheimer's Disease in which they have been proven beneficial. By employing spaced practice and spaced review in the development of educational software, educators can employ the computer with greater confidence. This study examined spaced practice and spaced review to determine their effectiveness within computer assisted instruction programs. Their effectiveness was measured by a test of recall and retention.

The researcher developed testable hypothesis statements from which to conduct the study. The hypothesis statements identified the independent and dependent variables. The levels of the independent variable were the Structured, and Unstructured computer assisted instruction programs. The Structured computer assisted instruction program contained the cognitive factors of spaced practice, and spaced review within its developmental structure. The Unstructured computer assisted instruction program did not contain the cognitive factors of spaced practice, and spaced review within its developmental structure. The dependent variables were recall and retention, which were measured by a test on African-American scientists and inventors. The hypothesis statements helped to format the experimental design relative to the problem investigated, which was a pretest-posttest control-group design.

Cognitive theory has provided a foundation for the advancement of computer assisted instruction. Cognitive research has provided support in the areas of learning how to learn, effectiveness of computer programs, and teaching. Chapter I places specific emphasis on the educational system and its use of computer assisted instruction, the need for effective computer assisted instruction, and innovative ways of enhancing the learning process. The use of cognitive tools to enhance instruction, and assist learners in accomplishing tasks was also emphasized. A description of a successful computer assisted instruction program, Bio-World, was given. Cognitive psychology, and cognitive science were discussed as theoretical foundations to effective computer assisted instruction and the enhancement of learning.

BACKGROUND

A review of literature revealed the evolution of principles guiding computer assisted instruction. B. F. Skinner and his theory of behaviorism were highlighted as a foundation to the improvement of education. B. F. Skinner is noted for his research on behavior modification, where he found a parallel between his laboratory work and practices that could improve education. The theory of cognitive science now provides the basis for computers in education. This theory combines the disciplines of psychology, philosophy, linguistics, neuroscience, and artificial intelligence. The review of literature further revealed research related to spacing effects. These research studies guided thought in support of the postulation developed by the researcher. Robert

Gagne's "nine events of instruction" provided a structural compostion of effective computer assisted instruction programs. Understanding of the "nine events of instruction" was further influenced by the conceptualization of cognitive strategies and their effectiveness with computer assisted instruction programs. Research related to computer assisted instruction provided support for need toward educational arenas. The conclusion of the review of literature provided support for the research study conducted. Spacing effects were observed as structural components to computer assisted instruction, and cognitive science theory provided theoretical support.

METHODOLOGY

The methodology of the research study provided a detailed description of the subjects that participated as volunteers to the study. Subjects were volunteers from the disciplines of Graphic Communications, Technology Education, and Industrial engineering. The researcher received volunteers for the study through instructors teaching courses in each discipline. As a way to reduce attrition, the researcher in conjunction with the instructors offered subjects an incentive for their participation. Subjects were assigned to groups by simple random sample procedure. When subjects entered the testing site, they were assigned to a computer and given a pre-test. The computers were color-coded red or blue, indicating to the researcher which treatment was provided. Upon completing the pre-test, subjects were instructed to navigate through the computer assisted instruction program. Once a subject had completed their CAI program, they were given the test on African-American scientists and inventors, to test for recall. After a one week period subjects returned to complete the study, by taking the test on African-American scientists and inventors once again, this time for retention.

The researcher used the following instruments as materials to conduct the study. Two computer assisted instruction programs were implemented. Each was developed by the researcher with the HyperCard authoring software system. The first CAI program was structured, and contained the spacing effects of spaced practice, and spaced review. The structured CAI program held implications for each of the spacing effects. The second CAI program was unstructured, and did not contain spacing effects or their implications. A pretest was utilized as a control, and to determine if subjects were statistically equivalent. A test for recall and retention was also used. The test for recall was given directly after the subjects received the treatment. The same test was used to test for retention one week later.

The data were collected and analyzed with the SAS software program. An analysis of covariance was conducted to determine a significant difference between groups, and to further determine statistical equivalence between groups. A probability value of .05 was established prior to data analysis to determine the rejection decision of the hypotheses statements. The methodology also revealed a detailed explanation of the independent variable, the dependent variables, and the control variables.

RESULTS AND FINDINGS

The research questions provided direction and focus to the study. The hypotheses statements were formalized based upon the research questions that the researcher asked initially. Hypothesis I stated, "There will be no significant difference (alpha = .05), based upon an analysis of covariance between a structured computer assisted instruction program, and an unstructured computer assisted instruction program on the dependent variable of recall, with the pretest as the covariate." The findings were significant, therefore rejecting hypothesis statement I. Hypothesis II stated, "There will be no significant difference (alpha = .05), based upon an analysis of covariance between a structured computer assisted instruction program, and an unstructured computer assisted instruction program on the dependent variable of retention, with the pretest as the covariate." Findings were significant for the dependent variable of retention between groups, therefore rejecting hypothesis statement II.

Further statistical analyses were conducted using the t-test of dependent means, which examined significant differences within groups based upon the posttest scores. The findings for group I were not significant, where the calculated-t (1.49) was less than the critical-t (2.0423), therefore accepting the hypothesis statement three. However, the findings for group II were significant, where the calculated-t (2.95) was greater than the critical-t (2.0423), therefore rejecting hypothesis statement four. These findings further support the researcher's postulation that spacing effects do enhance learning and memory, and more specifically recall and retention.

CONCLUSIONS

The findings of the study appear to justify the following conclusions.

(A) Based upon the significant finding between groups, arguments toward the cognitive factors of spaced practice and spaced review validate the researcher's postulation. The researcher postulated that the spacing effects of spaced practice and spaced review could enhance recall and retention when implemented structurally within a computer assisted instruction program. The study revealed significance, which supported the researcher's postulation. According to research studies on spacing effects, the cognitive factors of spaced practice and spaced review have proven beneficial at enhancing learning and memory.

(B) Based upon the significance of the finding for the treatment group, with regard to the dependent variable of recall, arguments toward the cognitive factor of spaced practice is validated. The instructional treatment with the implications for spaced practice (structured CAI), did enhance learning and memory for immediate recall. The subjects were provided spacing of practice sessions. This allowed the subject the capability of stopping and resuming a practice session without having to return to the beginning of the drill. The unstructured CAI program did not allow for such practice sessions, therefore not rendering the same effect.

According to David F. Salisbury (1990), the reason spaced practice is considered to be more effective than massed practice is that the learning context on each occasion is somewhat different thus causing the information to be encoded somwhat differently each time. Research on spaced practice suggest that learning environments in which computer drills and tutorials are used should accommodate and encourage the spacing of practice sessions. Also, computer drills and tutorials should include the capability of allowing the learner to stop and resume practice sessions without having to go back to the beginning of the drill. In other words, the learner should be able to resume a drill picking up with the same items that he or she was working on during the previous session (Salisbury, 1990).

(C) Based upon the significance of the finding for the treatment group, with regard to the dependent variable of retention, arguments toward the cognitive factor of spaced review are validated. The instructional treatment with the implications for spaced review (structured CAI), did enhance learning and memory for retention over a period of one week. Subjects were provided increased spacing between exposure to the material. According to David Salisbury (1990), the further apart the two presentations of a word in a sequence, the higher was the probability for recalling that word, indicating improvement or strengthening of retention.

David F. Salisbury (1990), also states that spaced review has been shown to be a significant means of enhancing retention of learned material. In a study conducted by S. A. Madigan (1969), subjects were presented with 48 words to be recalled later. Some of the 48 words were presented twice, others only once. Subjects recalled twice presented words better than once presented words, and the probability that a twice presented word would be recalled was a function of the spacing of the two presentations of the word within the sequence. The further apart the two presentations of a word in the sequence, the higher was the probability for recalling that word, indicating that retention improves with increased spacing between exposure to the material (Salisbury, 1990).

According to Benjamin Kleinmuntz (1967), in the recall of individual items, long recall intervals may be permitted and the characteristics of recall over these extended periods observed. The experiment consisted of presenting a single item, say a trigram, having the subject engage in some irrelevant verbal activity for a few seconds, and then asking for recall of the item. There was good evidence that the after effects of previous tests were competing at the time of recall with the most recently presented item, since recall of the first item was significantly better than recall of succeeding items. Furthermore, letters from the immediately preceeding test item frequently intrude in recall of the current item. The experiment can be conceptualized in terms of memories from previous tests occurring during the recall interval while the subject is attempting to discriminate the most recently presented item. If there were no decrease in the availability of traces as the experiment progressed, then the subject would be presented with an increasingly difficult task as the memory traces from previous presentations accumulated over the experiment. However, the evidence indicated that interference from previous tests, levels off after the first few test in the session. This, added to the finding that intrusions show a strong recency effect, and suggests that either the traces from preceeding presentations became less available with time and/or the action of intervening events, or the subject was better able to discriminate intrusions as the time after their presentation increased (Kleinmuntz, 1967).

The significant findings of the analysis of covariance supports the theories of retroactive interference, and proactive interference. With regards to recall, the theory of retroactive interference is notable. According to Norman E. Spear, and David C. Riccio (1994), in regards to free recall lists, extinction of responses in the first list would occur because producing these responses would be incorrect during learning of the interpolated list. Understanding of retroactive interference requires analysis of this extinction factor, which is frequently referred to as "unlearning" (Spear, and Riccio, 1994).

In regards to retention, the theory of proactive interference is notable. The accumulation of proactive interference can have devastating consequences for long-term retention. This was illustrated by an experiment that involved a simple procedure. Subjects learned 10 pairs of common words until they could correctly state the response to each stimulus on a given trial. Recall was tested 48 hours later. After this test a second list was learned and this too was tested 48 hours later; then a third was learned and tested 48 hours later; and so forth, for 36 lists. In spite of a progressive improvement in rate of learning the lists (learning to learn), a dramatic decline occurred in recall, from 70 percent accuracy on the first list to only 4 percent on the 36th. In the face of such massive proactive interference, virtually nothing was remembered about a set of words that had been learned perfectly only 2 days earlier (Spear, and Riccio, 1994).

Based upon the findings, it is concluded that the cognitive factors of spaced practice and spaced review can induce, and enhance greater recall and retention. Spacing effects are effective when implemented within the design and structure of computer tutorials. Students recall and retain information better when spacing effects are presented within their educational tasks. Spacing effects enhance the design of educational software, and could help innovation in the educational software arena, by providing positive feedback from students, parents, teachers, and administrators. Spacing effects can improve educational endeavors, specifically related to computers in education, and interactive environments as a whole.

RECOMMENDATIONS

Based upon the conclusions, the following recommendations are made in order to establish a relationship between educational software developers, interactive computer programs with spacing effects, and researchers interested in cognitive science and its application to technology. More specifically, a relationship of understanding of the spacing effect and its strength, for software developers, instructors, administrators, and students.

Recommendations for practice and implementation are that software developers implement spacing effects, and the theory of cognitive science in the development of software for school systems, homes, business and industry. The implementation of spacing effects would allow developers the powerful insight of psychology, and how the human cognitive mind operates. The same application of cognitive psychology would allow software developers to reap greater benefits from their instructional programs, by the enhanced buying power of the consumer market. Computer software programs that are effective at achieving a high degree of learning, are in higher demand by consumers.

It is recommended that educators seek educational software that provides spacing effects for the benefit of enhanced, or a higher degree of learning. The practice of implementing well developed educational software, allows educators the advantage of teaching effectiveness, which has a direct influence on students and their performance in school. This practice would also increase self-esteem in students. School administrators would also benefit from the implementation of educational software using spacing effects. This fact would manifest itself in census data on individual school districts or systems. Effective school administrators are a direct result of effective teachers that have students performing at optimum levels in given school districts or systems.

It is recommended that parents implement similar software in the home. This would allow students to gain advantage in learning edeavors. Parents can offer their children a competitive edge by implementing software that fosters better learning and memory within the home.

The researcher also recommends that further studies be conducted on the implementation of spaced practice and spaced review with computer assisted instruction for the purpose of enhancing recall and retention in educational endeavors. Based upon the conclusions, the following recommendations are offered.

(A) It is recommended that further research be conducted, implementing the spacing effects of spaced practice and spaced review with computer assisted instruction, however, with the additional examination of the effects of visual images in CAI programs. The purpose in a study of this nature would be to examine learning outcomes of subjects based upon the incorporation of spacing effects and the interaction of visual data, as compared to textual data. Variables that might be investigated with a study of this nature, would be the age of the subject, and learning styles. J. Piaget's theories of developmental psychology could be applied for the understanding of the learner.

Further support for a study of this nature is identified. According to Farough Abed (1992), communication through images is a fundamental teaching strategy which has received a great deal of attention from researchers in educational technology. While specific picture variables have been studied (e.g., color, amount of detail, shading), much of the research to date has proceeded on the assumption that most pictures would function identically in a given setting. The theory proposed here adopts an alternative view, assuming that various types of pictures have different effects on the learner. The main impetus for this type of study is the creation of memorable images which will increase the probability that picture information will be retained over a long period of time. Of interest in this regard is interactive imagery (Abed, 1992).

Farough Abed (1992), further states in essence, that complex interactive illustrations engage the learner in visual problem-solving dialogue by not immediately communicating the message. This encourages the learner to be an active participant in the learning process, rather than a passive receiver of information. Initially capturing the attention of the learner is a crucial step that interactive illustrations are capable of achieving (Abed, 1992).

Further support for visual learning is expressed by Rudolf Arnheim (1993), who states that without separating the intellect from sensory experience, visual thinking makes the mind work as a whole. It gives intelligence to vision and adorns the concepts of abstraction with all the colors and shapes of visual experience. Visual learning relies not only on how much ability and willingness pupils bring to their studies. Much depends also on how well the materials and conditions offered in the learning situation are suited to a ready grasp of the things to be seen and understood (Arnheim, 1993).

(B) It is recommended that further research be conducted by examining the implementation of spacing effects. It is suggested that an increase in the complexity of content be examined, as well as the intervals of spacing effects be increased. This would allow for a closer examination of the power of spacing effects, which in turn would determine the strength of the effects with regard to time spent with the computer application. The factors of time and intervals would be examined closely, determining the power of spacing effects.

Further recommendations include the extended developement of the computer assisted instruction program. The improvement of the tutorial as a whole could enhance the chances for significant outcomes in the research. Factors such as timing and scoring, scripted into the structure of the CAI program, color, extended memory for the inclusion of extra material, and size of screen could possibly derive greater benefits. These factors can be found in advanced authoring software packages, such as Hyperstudio, SuperCard, and Macromedia Director, an object-oriented design software. The most important factor would be memory, in terms of computer capacity, which would allow the author endless opportunity to design an appropriate program.

Additional support can be extended toward research for spacing effects with computer assisted instruction, by collaborative efforts of educational software designers, instructors, administrators, parents, and students. As well, the arenas of business and industry, outside of academia can have input, and provide inspiration and support to the cause of enhancing and inducing greater recall and retention with educational endeavors.

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APPENDICES

AFRICAN-AMERICAN INNOVATION AND INVENTION - TEST

Instructions: please read each question carefully and answer all questions in each section of the test.

Part I - True/False. Place a "T" or an "F" on the line next to the statement.

1.______ Jan Matzeliger is responsible for inventing the "third rail" track used by present-day subway trains.

2.______ Granville T. Woods was given the name, "The Black Edison".

3.______ Frederick McKinley Jones was a self-taught engineer.

4.______ Elijah McCoy began his career as an inventor while working on railway systems with engines.

5.______ Valerie L. Thomas invented high definition television.

Part II - Multiple Choice. Circle the correct answer.

1. Elijah McCoy's Locomotive Lubricator used this substance to keep a train's engine running smoothly.

   a. oil
   b. graphite
   c. axle grease

2. This inventor developed the multiple effect evaporation which revolutionized the sugar industry.

   a. Norbert Rillieux
   b. Andrew J. Beard
   c. John L. Morton

3. This self-taught engineer revolutionized the trucking industry with his cooling unit.

   a. Lewis Temple
   b. Lewis H. Latimer
   c. Frederick Mckinley Jones

4. Television has been improved due to inventor Valerie L Thomas and her invention of .

   a. High definition television
   b. The illusion transmitter
   c. The satellite dish

5. The traffic signal that is responsible for our modern day traffic lights was invented by.

   a. James E. Shepard
   b. Garrett A. Morgan
   c. Thomas Edison

6. Hand-lasting shoes was replaced by the Lasting Machine, which was invented by

   a. Frederick McKinley Jones
   b. Louis Wright
   c. Jan Matzeliger

7. Granville T. Woods was given the name, the "Black Edison" due to .

   a. comparison to Thomas Edison
   b. working with Thomas Edison
   c. his relation to Thomas Edison

8. He had an early career as a sewing machine repairman, which led to a as a tailor.

   a. Garrett A. Morgan
   b. Ernest Just
   c. Granville T. Woods

9. He was born on a plantation in New Orleans, LA, but spent most of his life in Paris, France.

   a. Frederick McKinley Jones
   b. Jan Matzeliger
   c. Norbert Rillieux

10. He was born in the South American country of Surinam (Dutch Guiana).

    a. Norbert Rillieux
    b. Jan Matzeliger
    c. Elijah McCoy

Part III - Matching. Match the inventor with the invention.

A. Granville T. Woods

B. Frederick McKinley Jones

C. Valerie L. Thomas

D. Lewis Temple

E. Elijah McCoy

F. Jan Matzeliger

G. Garrett A. Morgan

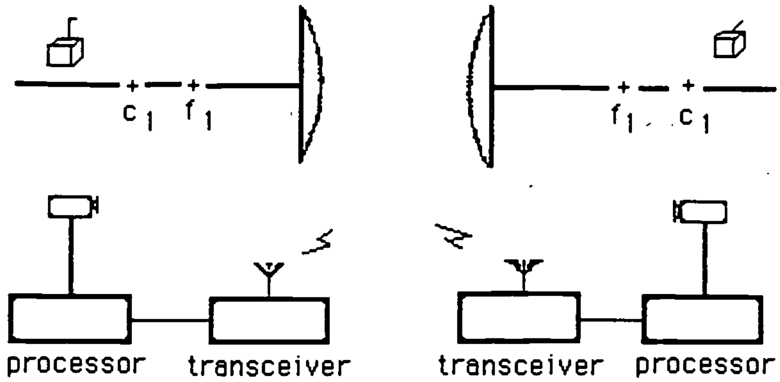
H. Charles Goodyear

I. Joseph Lee

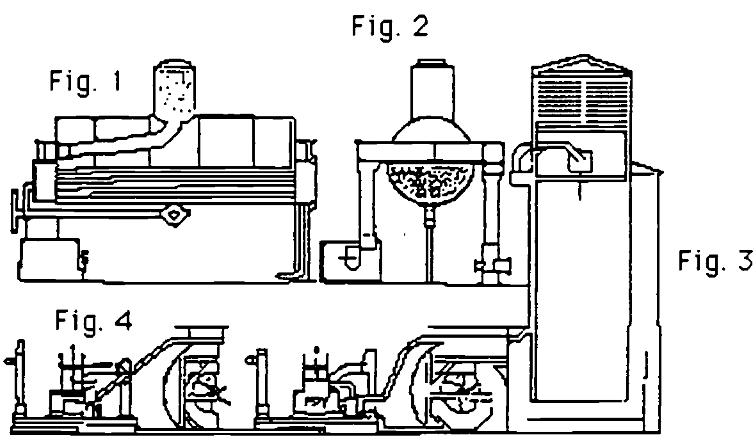
J. Norbert Rillieux

K. Louis Wright

L. Benjamin Banneker



Illusion Transmitter
Patented 1980



Evaporating Pan
Patented 1846

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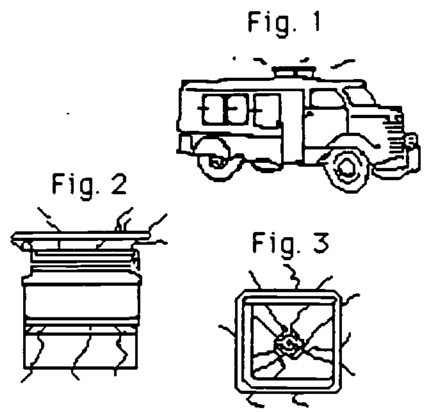


Removeable Cooling Device
Patented July 12, 1949

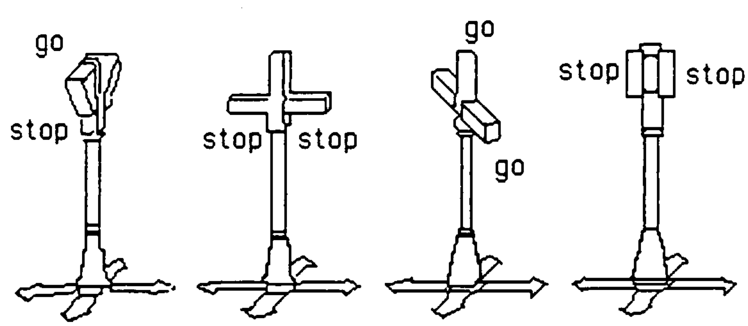
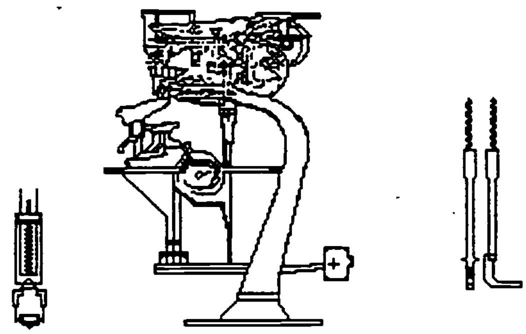
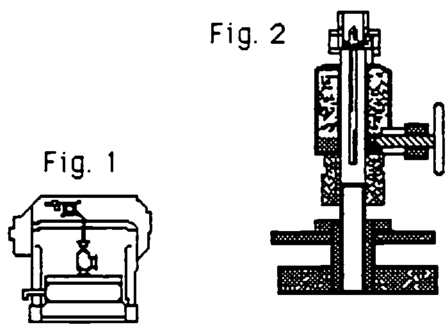


Fig. 1 Fig. 2 Fig. 3 Fig. 4

Three-Way Traffic Signal
Patented November 20, 1923



Lasting Machine
Patented March 20, 1883



Graphite Locomotive Lubricator
Patented 1915

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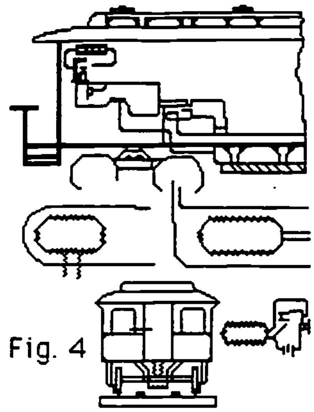
Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5



Railway Induction Telegraph System
Patented November 27, 1887

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