A STATISTICAL ANALYSIS OF LEARNING EXPERIMENTS
INVOLVING AN INTERACTIVE HUMAN-MACHINE SYSTEM

A Thesis

Presented to

the Faculty of the Department of Computer Science

University of Houston

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

---

by

Dona Marie Erb

December 1972

ACKNOWLEDGMENTS

The author is grateful to her patient husband, Bryan, for the recurring advice that "persistence and perseverance made a Bishop of His Reverence."

Dr. Lee Hunt of the Political Science Department generously offered one of his few Statjob Manuals and the counsel of his assistant, Stephen Hartzog. David K. Lowell and Stanley A. Wileman, Jr. of the 360 and 1108 computing centers, respectively, were especially cooperative in providing information towards the solution of the problems relating to the tape translations from one computer to the other and the file building. A most important source of information and assistance was my colleague, Firmo Friere, upon whose work this thesis was largely dependent.

Also, I wish to thank my committee for their personal and professional interest in this thesis. In particular it must be noted that Dr. John J. Lenahan has been a remarkable source of information, inspiration, and red-pencilling from which I have truly benefitted.

A STATISTICAL ANALYSIS OF LEARNING EXPERIMENTS INVOLVING AN INTERACTIVE HUMAN-MACHINE SYSTEM

An Abstract of a Thesis

Presented to

the Faculty of the Department of Computer Science

University of Houston

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

---

by

Dona Marie Erb

December 1972

ABSTRACT

This thesis is a statistical analysis of three learning experiments conducted in the Synnoetics Laboratory at the University of Wisconsin with engineering and vocational students. A comparison is made of the effectiveness of three instruction controls: pre-programmed instruction under machine control, learner control in which students specifically requested subject matter, and collaborative or guided learning which permitted students flexibility in order and amount of subject matter received. When students had acquired the fundamentals, each of the two subsets of instruction control was amplified by one of two methods of feedback for students' problem solving. One method was an incremental schedule in which machine response occurred after attempted partial solutions to problems while an integral schedule reserved machine response until student had attempted a complete solution. The data analyzed consists of scores from post, retention, and standardized tests, and measures of students' intercommunications with the machine and its associated subject-matter base.

Students directing their own learning and solving problems integrally had the lowest rate of processing information while those solving problems incrementally are observed to have high Effective Learning Capacity and high Effective Learning Rate. Students who directed their own learning are observed to make fewest subject-matter accesses once they have begun to problem solve.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure		Page

Figure | | Page

Chapter 1

INTRODUCTION

Nearly fifty years ago, the solution to the problems of mass education was presented in the form of a teaching machine. This panacea has stuck in the throat of the public, as well as the educator. In less than ten years, the very complex technology for the moon landings was accomplished. Why has educational technology not approached its expectations in individualized instruction for the masses?

The challenge remains to develop and validate an interactive human-machine system that will enable many remote teaching terminals utilizing modern media to provide instructional programs in the many content areas at low per unit cost, with high reliability, and so organized that a truly individual instructional strategy is available for each user.

It is the latter difficulty that is the concern of this thesis. While considerable experimental work towards this goal appears to have been done with little thought to any statistically meaningful interpretation of the results, this thesis is a careful statistical analysis of a series of experiments conducted with complete statistical requirements under consideration from the beginning.

1.1 OBJECTIVES

There are four main objectives of this thesis:

(1) To review the literature and studies of computer-assisted instruction over the past years.

(2) To create a computer-based file of student performance data for both batch computation and interactive sleuthing; specifically to organize, reformat, and tape the raw data obtained from a series of three learning experiments conducted at the Synnoetics Laboratory of the University of Wisconsin during 1966-1970.

(3) To perform group analyses of this data; specifically to perform descriptive analyses on the data from Experiment #2, involving nearly 100 students; then to similarly analyze the data from Experiments #3 and #4 combined, involving about 70 students.

(4) To discuss the significant results of each analyses including their major distinctions, and to relate these to other existing evidence.

The general purpose of this thesis is to determine which independent parameters of the quantifiable aspects of the instructional environment contributed positively towards the post test and the retention test scores attained by the students. These parameters include certain standardized scores for the students obtained prior to the instruction, the particular instructional strategy constraining the student, and his record of interactions and times spent within the structure of the program. Those few parameters whose variances account for most of the total variation would provide a basis for a mathematical model of an optimum human-machine interaction strategy for computer-assisted instruction.

1.2 PROGRAMMED LEARNING AND COMPUTER-ASSISTED INSTRUCTION

1.2.1 History of Programmed Learning

Texts

One of the principal differences between the traditional textbook and programmed instruction is that the latter calls for a response by the student to each unit of information presented. Implicit in the early literature on programmed instruction is the assumption that this approach was a behavior-shaping technique utilizing certain behavioristic theories in educational psychology.

It is, however, a question as to whether an overt response is significantly beneficial. One study (Fry, 1959, p. 149) contends that the difference in time spent and test scores achieved was not significantly different between the two groups--one whose responses were written and the other not. Other general findings agree that under a variety of experimental conditions it could not be demonstrated that programmed instruction requiring a response was superior to a textual instruction requiring only reading. In these studies, the student's response as a feedback mechanism plays little or no role. By far the majority of programmed instruction was written "linearly" or "fixed" (see Figure 1-1). Fixed or linear programming means that the whole lesson or a series of steps is kept intact: it is not different from trial to trial or from student to student. Norman Crowder's "scrambled book" is an example of the branched or variable program printed in regular book format (Finch, 1960). Branched or variable programming means that parts of the lesson may be optionally consulted, that parts of the lesson correctly learned may be dropped from review, and so forth. The communication process of these texts was controlled by the use of the feedback. Branching is thus an adaptive mode, i.e., the information is shown to the student. He responds. The next portion of information that is presented to him depends upon his response.

A study (Hartley, 1965) comparing linear as opposed to branched programming schedules indicates that while no significant difference in time was taken to work through the programs, higher ability pupils profited more from branching than from linear programs. A study (Hartley, 1966) to determine if students could reliably choose for themselves sections of a program that they needed or whether the control of this choice should be transferred to the program indicates that the program control is more effective. Lower ability and young subjects fail to act reliably when using learner-controlled branched programs. However, whether these studies are sufficient to counter Mager's view that "learners are

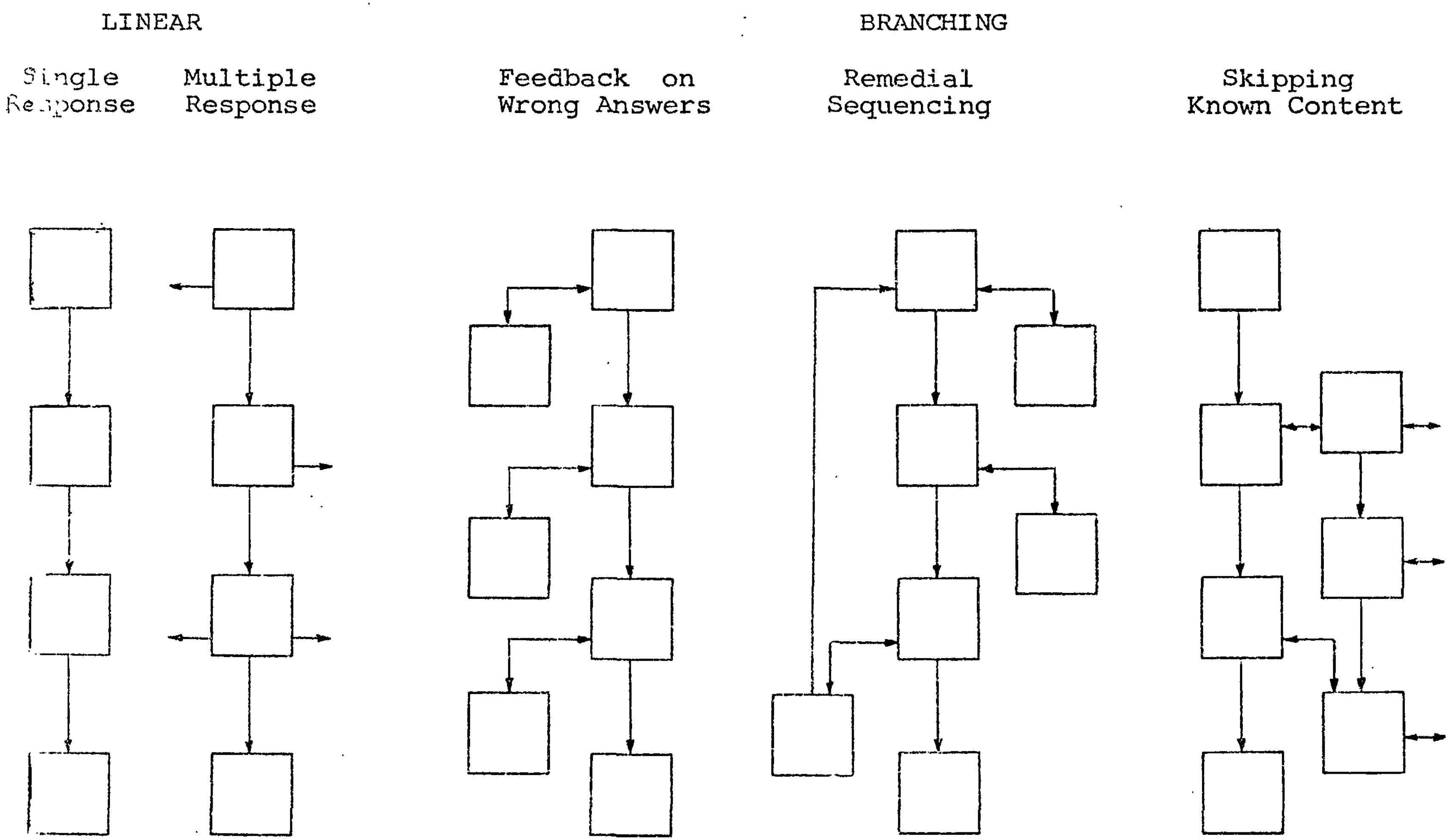


Figure 1-1. Evolution of Programming Strategies

neither as ignorant nor as helpless as we make them out to be and the efficiency of instructional programs may be further improved by learning to take advantage of this fact" (Hartley citing Mager, 1966, p. 5) is also part of the concern of this thesis.

Devices

The founders of the teaching machine movement were B. F. Skinner (Harvard) and Sidney L. Pressey (Ohio State). Pressey did not intend his machines and their self-instructional texts as a replacement for textbooks. His idea was for the student to read the text and then take repeated tests on the machine, studying those things he did not understand well from the text in between, until he could achieve a perfect score. Pressey was not concerned with having the student avoid every error from the first. His stress was placed on the self-organizing properties of the student which his device was to assist. And, incidently, he hoped to remove some of the inefficiencies in group "drill" and of grading papers.

On the other hand, a major tenet of Skinner's view is the avoidance of error by the control of the information increment and of the pacing of information presentation.

A successful program, according to Skinner, leads the student to respond correctly nearly 100 percent of the time--the first time through. The frames in the program utilize "cues" or "prompts" in order to minimize the probability of the student's making an error. Skinner admits that there may be a need for different programs for different students, but he believes that a detailed, one-step-at-a-time program will not harm a fast learner and, in fact, may fill in some unexpected gaps in his knowledge. He further recognizes that there is a difficulty in planning the program so as to get the student to respond correctly later on to reduced cues and to eventually become independent of the program. A related question that needs study is the long-term effects of large amounts of small step or incremental programs on the reading speed and the "skimming" ability of the student.

A major distinction between the machine and the programmed text is that the latter, when "improperly" used, does not constrain the learner to follow the ordered sequence of the program. Thus it would seem that the relatively inexpensive programmed textbook is better at least for review than the programmed machine. However, studies (Goldstein & Gotkin, 1962-66) indicate that no significant difference in subject matter mastery can be shown between programmed machine and text forms of presentation. i.e., It cannot be rejected that programmed texts teach equally well as programmed teaching machines.

Examples of teaching machines. In 1926 Pressey published a description of a "simple apparatus which automatically gives and scores a test, and which will also, automatically, t[illegible] [illegible] and drill material more efficiently, in certain respects, than the human machine [Pressey, 1926, p. 373]." The device consists of a means for threading into the machine a sheet of multi-choice or true-false items. There are two modes, test mode and learning mode. In test mode, the next question is presented at once after each answer. In learning mode, the question is retained until the right answer key is pressed. A second Pressey device could omit a question from further presentation as soon as the student had obtained a certain number of correct answers to it in succession.

The Subject Matter Trainer was developed under the sponsorship of Air Research and Development Command and has been used in the classroom and laboratory studies. While it is most suitable for initial learning of discrete items, it can also present serial learning tasks and problem solving items. A green light flashed if the student's response was correct; otherwise a red light flashed which was followed by a green light over the correct answer. An experiment (Finch citing Mager and Westfield, 1960) comparing the Subject Matter Trainer to regular workbooks produced no indications of its superiority in learning gains except that the students favored it.

A Card-Sort device consisted of up to one hundred items on cards that after presentation would be automatically sorted into a right or a wrong pile while the student was notified by a green or a red light respectively.

Chemo-Cards were specially coated so that the student's pen, using special ink, marking a correct answer would change the marked space to a green color, otherwise it would turn red.

1.2.2 History of Computer-Assisted Instruction

In the decade of the sixties there were numerous approaches taken to the development of computer-aided instruction by American and British researchers. By 1965, the concept of programmed instruction by which a student worked at his own pace through a linear program had given way to instructional sequences that were individualized, i.e., the stimulus is dependent upon the student's previous responses. In Russia, straight linear programming with small steps and frequent feedback had long been rejected in favor of branching programs that have provision for forward and backward branching. The Russians also favor the use of the multi-media approach as part of the programmed instruction.

Weaknesses in the CAI attempts were reviewed in early 1967 by R. T. Filep (1967). He urges CAI researchers and product developers to concentrate on:

(1) the evolution of better teaching strategies needed to utilize fully the capabilities of the computer as a problem-solving device, and also to employ the simulation and data storage attributes.

(2) the design of programs that can record student responses and then present them for analysis in a rapid and intelligible

fashion, thereby providing data on how a wide range of individuals might respond under fixed conditions of instruction.

(3) an assessment of patterns of learning behavior before and after terminal use.

(4) an evaluation of the physical components of teaching terminals and how they aid or detract from the effective use of terminals at remote locations.

(5) a determination of low-cost effective multi-media teaching terminals which will be reliable at remote settings.

(6) an integration of instructional programming languages now in use.

This large, but reasonable set of objectives still separates CAI from its widespread and practical application, but does not preclude the expectations of such application of computer technology in education. This paper is an analysis of research that addresses the first two of Filep's suggestions, although the experiments were developed parallel to rather than in response to Filep's review.

Models of the learning process. In Cybernetic Principles of Learning and Education Design, Smith and Smith (1966) question the validity of the assumption by almost all psychologists that reinforcement is central to learning. The cybernetic alternative to reinforcement is feedback control. This views the human as a self-regulating system relying on sensory feedback or knowledge of results in his effort to maintain goal-directed behavior. The Smiths do not think that cybernetic principles are less applicable to verbal and cognitive behavior than they are to psychomotor behavior. In their view, the thinking process demands precise integration of many intrinsic sources of sensory stimulation and a high degree of vigilance in monitoring the different spatial, sequential, temporal, and kinetic variations in the feedback.

Factors considered in the learning process model. The student is a component of the instructional system. The student's characteristics of motivation, intelligence, perception, and so forth influence the design, operation, and evaluation of any computer-assisted instruction system. A number of studies have confirmed that social factors and the influence of administrative necessities also affect the development and use of programmed instruction.

1.3 INTERACTION STRATEGY

A human working with a computing machine may be referred to as a human-machine system. An Interactive Human-Machine System requires that the human be on-line and directly connected to the machine. An interaction strategy refers to the particular manner in which communication, control, and learning occur between human and machine.

By 1968, instructional programming, previously all linear, had developed several strategies of branched programming: student-controlled systems, program-controlled systems, collaboratively-controlled systems and teacher-controlled systems. The program-controlled systems are the most common. Such systems are, of course, highly developed counterparts of the non-computer teaching machines. Thus there is a one-to-one association between the computer generated stimulus and the student generated response. The logical facilities of the computer select the sequence of stimuli (i.e., information or questions) on the basis of the student's overall performance. These systems have been implemented at the universities of Illinois and Michigan. The subject matter covered has included psychology, number theory, foreign languages, vocabulary drill, grammar, and so forth.

An example of a collaboratively-controlled system has been implemented by Bolt, Beranek and Newman Inc. (Hickey, 1968). It is the Socratic System (which is not to be confused with the Socrates system at the University of Illinois). Associated with each student stimulus there is a set of conditional computer responses. The computer response may depend not only on the current stimulus, but on everything that preceded. The instructional strategies are not fixed but are data provided by the author.

The teacher-controlled systems are multi-student, automated facilities for a classroom of student terminals monitored by a human teacher. Either the student or the computer [illegible] the teacher to a need for special assistance.

The student-controlled system is least used. The student addresses the computer much like one uses a dictionary or encyclopedia. Another simple variation is a program by which a student may vary the coefficients of some function and the computer displays the associated graph.

At the Synnoetics Laboratory of the University of Wisconsin, three of these major system types--the student-controlled, the machine-controlled, and a collaborative student-machine-controlled--were implemented in a common interactive system and studied comparatively in a series of experiments that began in 1966. The first of these experiments (Lenahan and Clatur, 1969) indicated that machine-control yielded the best immediate learning scores but the poorest long-term retention scores.

1.4 INTERACTION STRATEGY MODELS

For the purpose of this study, Interaction Strategy is considered in two dimensions: (see Figure 1-2)

(1) Instruction Control

(2) Design Schedule

The Instruction Control operates in a continuum of two modes:

(a) Learning Control exists when a student's action can represent his intent to control the next machine action.

(b) Teaching Control exists when a student's action cannot represent his intent to choose or control the next machine action or, equivalently, Teaching Control exists when a student's action causes the machine to select its next action.

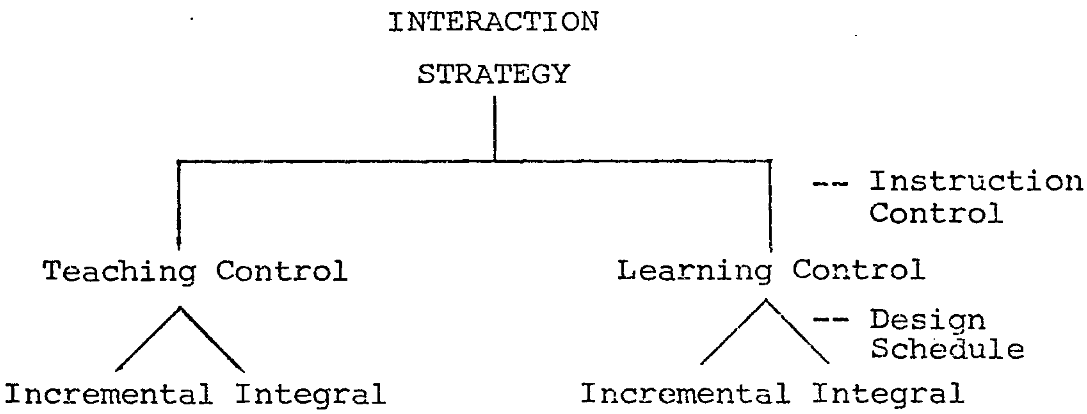


Figure 1-2. Interaction Strategy

The second dimension of this Interaction Strategy is Design Schedule. This is a feedback control plan especially suited to the subject matter of the University of Wisconsin experiments. The subject matter was Sequential Logic Circuit Theory and one of the requirements was to design a logic circuit. The Design Schedule provided two methods by which the students could design their sequential machines.

(1) Incremental or a state-by-state design

(2) Integral design

The Incremental Design Schedule is achieved through a series of intermediate, partial solutions with error feedback available for each partial solution. The size or increment of each partial solution is unspecified and is completely variable from the smallest possible increment to the largest possible increment, i.e., the complete solution. If it should occur that the smallest possible increment is in fact the complete solution, then the schedule is called an Integral Design Schedule. Review of the subject matter is permitted during this design phase.

The three methods of Instruction Control and the two types of Design Schedules provide six possible experimental course combinations that could be randomly assigned to a student. Thus the experiment is factorially designed as shown in Figure 1-3. The three levels of instruction featured a full human control, denoted by ENCY; a full machine control of the interaction, denoted by PPI; and a combination of the strategies, denoted by GL.

INSTRUCTION CONTROL

DESIGN SCHEDULE		ENCY	PPI	GL
	INC	1	2	3
	INT	4	5	6

Legend:
ENCY: Encyclopedia
PPI: Pre-Programmed Instruction
GL: Guided Learning
INC: Incremental
INT: Integral

Figure 1-3. Interaction Strategy of the Experimental Course Combinations

Chapter 2

EXPERIMENTAL SITUATION*

2.1 OBJECTIVES

The Synnoetics Laboratory at the University of Wisconsin was under the direction of Dr. John J. Lenahan in the 1966-1969 period during which an experimental interactive human-machine system and subject matter structure for a course of study were developed and tested. The experimental approach of the Laboratory was to emphasize learning strategy rather than teaching strategy in computer-assisted instruction studies. Learning strategy implies a concern with the individual student styles of acquisition, application, retention, and transfer of the information, whereas teaching strategy implies a concern with the motivation, inductive/deductive presentation, logical/psychological method, and behavioral objectives of the information. Learning strategy also presupposes that a system which requires or allows a student to choose among available information according to his individual needs reveals much more of the student's unique learning characteristics than a system which does not allow such student control. Accumulations of such knowledge

*Most of the ideas and description in this chapter are the work of Dr. John J. Lenahan and Mr. Firmo Friere (Lenahan, 1969; Friere, 1972).

of individual student behavior provide the input for the design of truly individual systems. The development of an Interactive Human-Machine (IHM) system responsive to the individual characteristics of most humans was the main objective of the Synnoetics Laboratory. To this end the interactive system was implemented to study such questions as the following:

1. What is the nature and formulation of communication between human and machine in an IHM system and the adapting, learning, and information processing capabilities required in such systems?

2. How is a system designed in which human, machine, and the interaction between them can be monitored and controlled during learning?

3. To what extent can humans effectively apply and refine their individual interaction strategies?

4. How can human learning behavior be monitored, measured, and to varying degrees, controlled?

2.2 FACILITY

The primary hardware used in this research was an IBM 1710 Control System which was a second generation machine of rather slow speed, variable word length, and flexible communication channels. Extensive modifications made the system capable of real-time data acquisition and control, superimposed on a time-sharing system for the remote terminal.

The software consisted of a real-time control/time-sharing executive and an integrated set of general purpose routines for storage, retrieval and communication. The remote terminals, which were on-line to the system, consisted of typewriters, random-access projectors, audio recorders, video recorders, display monitors and student request keyboards. Each terminal room was equipped with an IBM 1052 keyboard, a rear-projection screen, and various typewritten material in a reference handbook.

The Student Request Keyboard (Figure 2-1) was constructed to facilitate a student operating in any one of the three possible modes of Instruction Control--Encyclopedia, Pre-Programmed Instruction, or Guided Learning (see Chapter 1.4, page 13). The extent to which a student used the NEXT BITE key determined the resulting Instruction Control. If he never used the NEXT BITE key, then his strategy was purely learning strategy and represented by point C on the continuum. The NEXT BITE key provided a way for the student to let the machine select its own next action, without the student's knowledge of what that next action would be. There is also the SELECT BASIC BITE key which allowed the student to select any BASIC BITE in the sequence (a learning strategy interaction). The four keys on the left of the request keyboard allowed the student a higher level of control of the machine than do the keys already described. They allow him to move through the subject matter very rapidly by requesting OVERVIEW and/or PRACTICE on entire segments (AREAS) of the BASIC BITE SEQUENCE. The total capability of the student request keyboard was to allow the student to:

(1) scan through the entire subject matter set by selecting various segments (SELECT AREA) of the BASIC BITE [illegible]

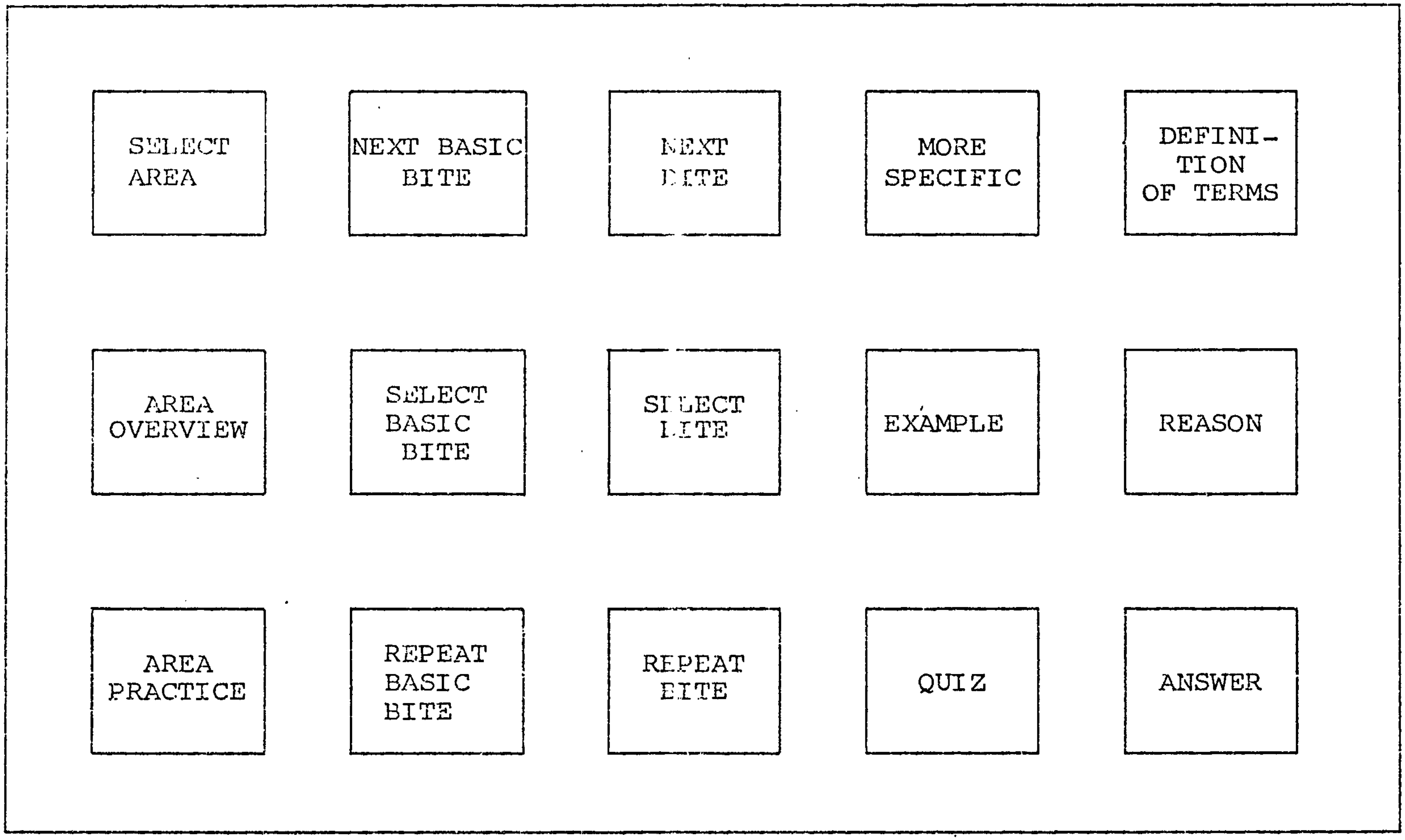


Figure 2-1. Student Request Keyboard Guided Learning Options

obtaining summaries (OVERVIEW) and review (PRACTICE), and to (2) concentrate his efforts (GUIDED LEARNING) in those particular segments of the BASIC BITE SEQUENCE which he did not understand by utilizing the keys SELECT BITE, NEXT BASIC BITE, EXAMPLE, and so forth.

For the two other modes of Instruction Control, PPI and ENCY, the Control Board in Figure 2-1 had all of its keys covered with the exception of the one required to support the mode in question (Figures 2-2, 2-3).

In any of the cases, presentation of the appropriated information would follow the depression of a key.

Both in Guided Learning and Encyclopedia modes of Instruction Control, a BITE was selected by the student (using the Alphanumeric Keyboard) after pressing the SELECT BITE key on the Control Board.

2.3 EXPERIMENTAL DESIGN

2.3.1 The Machine

Supporting the experiment, as part of the MACHINE component of the IHM System, were:

(1) The Subject Matter: consisting of a Data Base capable of being accessed and interrogated by the students. In this experiment, the Subject Matter was Sequential Logic Circuit Theory.

(2) A BUILD Simulator: enabling the student to construct sequential machine states, transitions and outputs [illegible] the [illegible]aly Model.

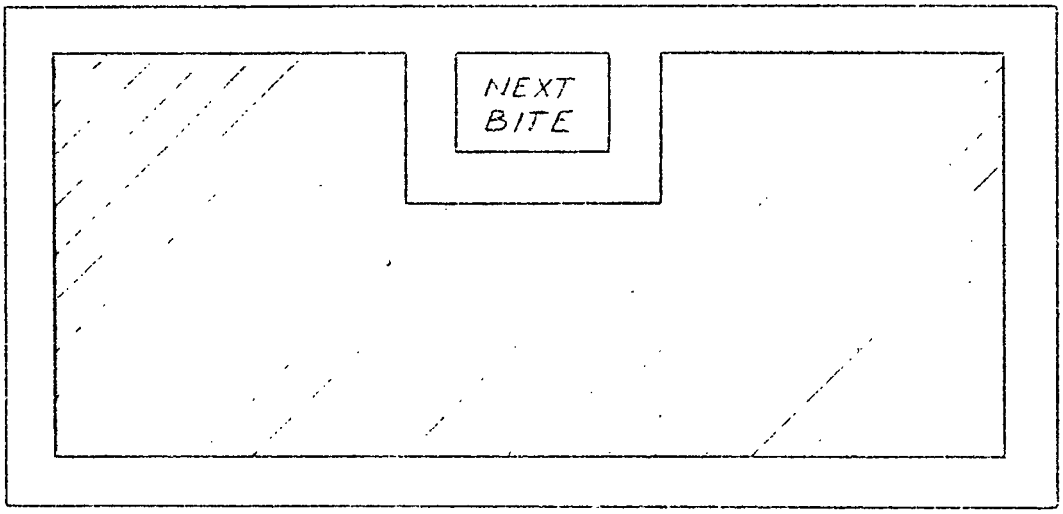


Figure 2-2. Pre Programmed Instruction Control Board

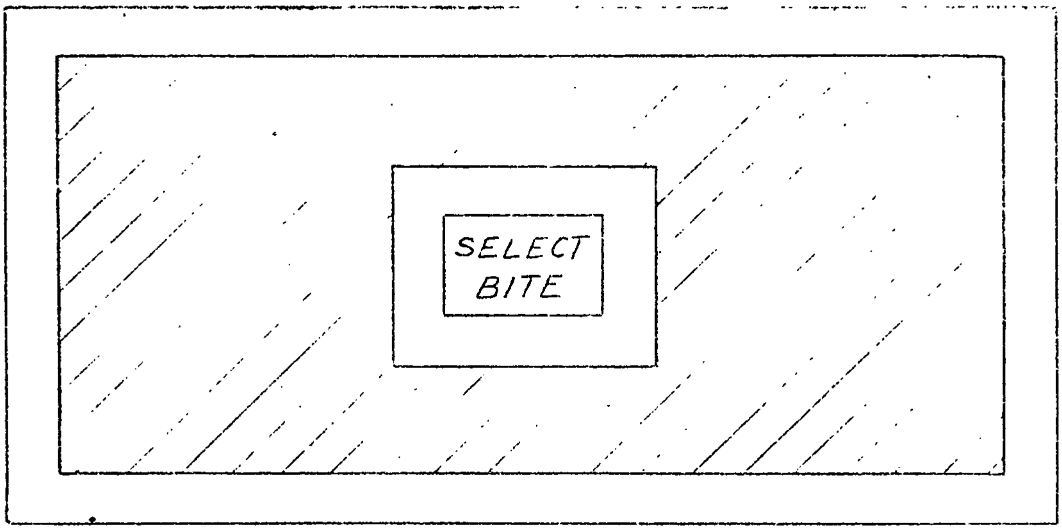


Figure 2-3. Encyclopedia Control Board

(3) A TEST Simulator: permitting the student to test his design. This simulator accepted the input sequences specified by the student, simulated the design, and provided him with the resultant outputs and transitions. This result was compared with a version of the correct design and any discrepancies were recorded and subsequent diagnostics given.

(4) A LOOK Simulator: providing the student with a view of the states, transitions and outputs as they had been constructed by him. This simulator was used to recheck the actual design solution and to provide a permanent record of the design implementation.

2.3.2 Supporting Information Structure

A Information Structure implies the existence of a data base and a set of algorithms to manage this data base. The interest here lies solely on the configuration of the Data Structure.

The basic building block of this Data Structure is called a BITE which is functional information/control unit. The different types of BITES are:

(a) Basic Bites (BB)

(b) Peripheral Bites (PB)

The subject matter to be made available to the student was formed by the two types of BITES above.

The Basic Bites represent those unique ideas which were fundamental to an understanding of the entire subject matter. Related to each Basic Bite was the set of Peripheral Bite types which were classified according to the nature of the information they provided.

The Peripheral Bites Types were:

(a) More Specific (MS)

(b) Example (EX)

(c) Definition of Terms (DF)

(d) Quiz (QU)

(e) Answer (AN)

(f) Reason (RE)

The diagram in Figure 2-4 gives a pictorial representation of the subject matter organization.

2.3.3 Implementation of Interaction Strategies

The Bite Structure organization of the subject matter was used to implement the continuum of Instruction Controls. The Instruction Control PPI involved absolute system control and no student control over what and how material was learned. It was a linear sequence of bites of information with potential branching based on certain pre-set decision functions.

An instructional control which combined teaching control and learning control, GL, gave the student partial control over what and how the material in the Bite Structure was accessed. i.e., The student was free to select any basic bite at any time and to select any type of peripheral bite at any time <u>after</u> accessing its basic bite. One could not directly access a peripheral without first accessing its

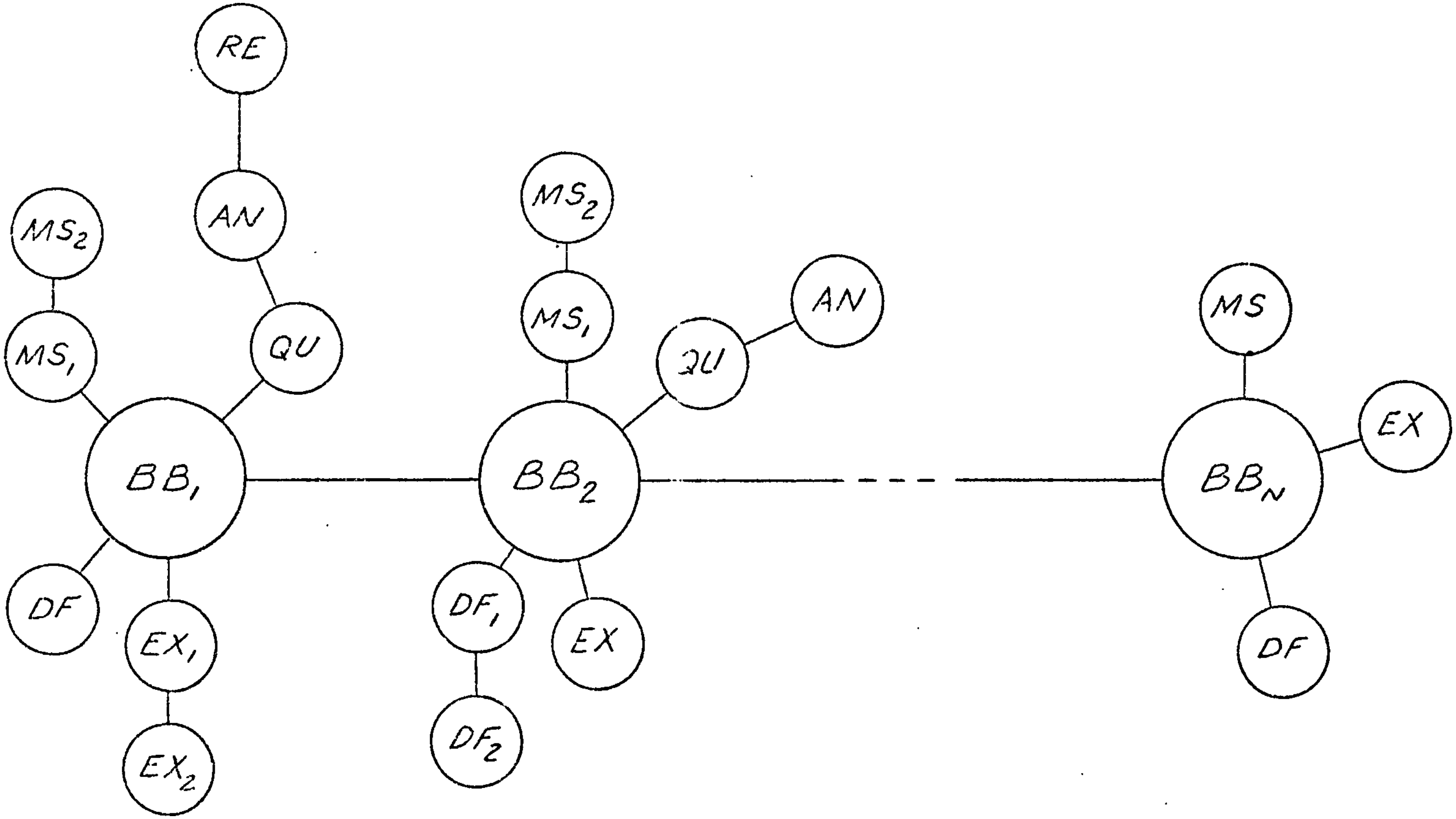


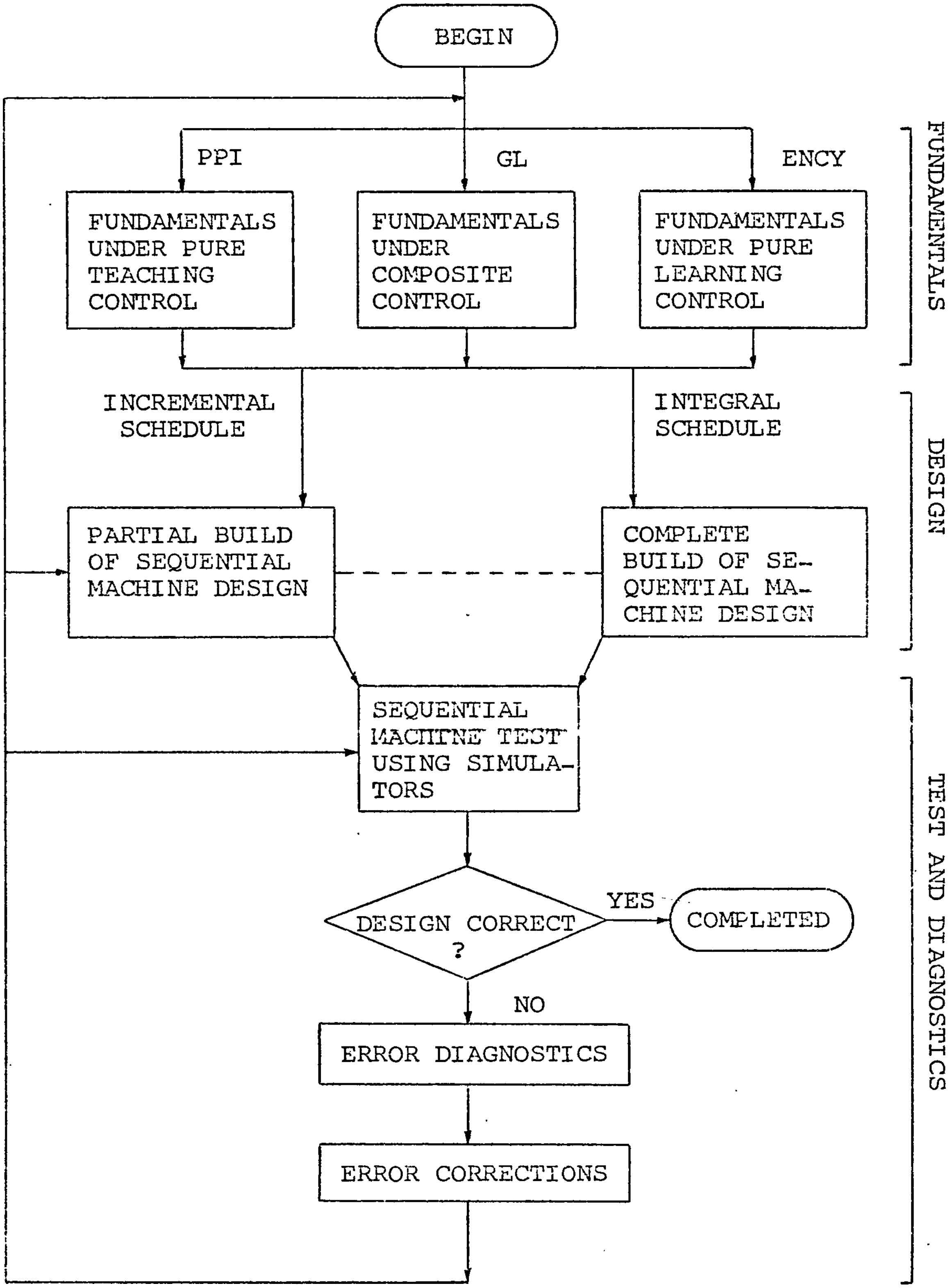
Figure 2-4. Subject Matter Organization

basic bite, nor could one access some particular one in a set of one type of peripheral without chaining through the sequence of peripheral bites in the set of that type. For example, if a student wished to see Definition 4 associated with Basic Bite 5, he had to first be exposed to Definitions 1-3.

In the Instruction Control Encyclopedia, the student had absolute control over what and how material was accessed. The student, using a directory could select not only any basic bite at any time, but also any peripheral bite at any time. The sequence of presentation was entirely the learner's choice.

2.4 COURSE CONTENT AND ORGANIZATION

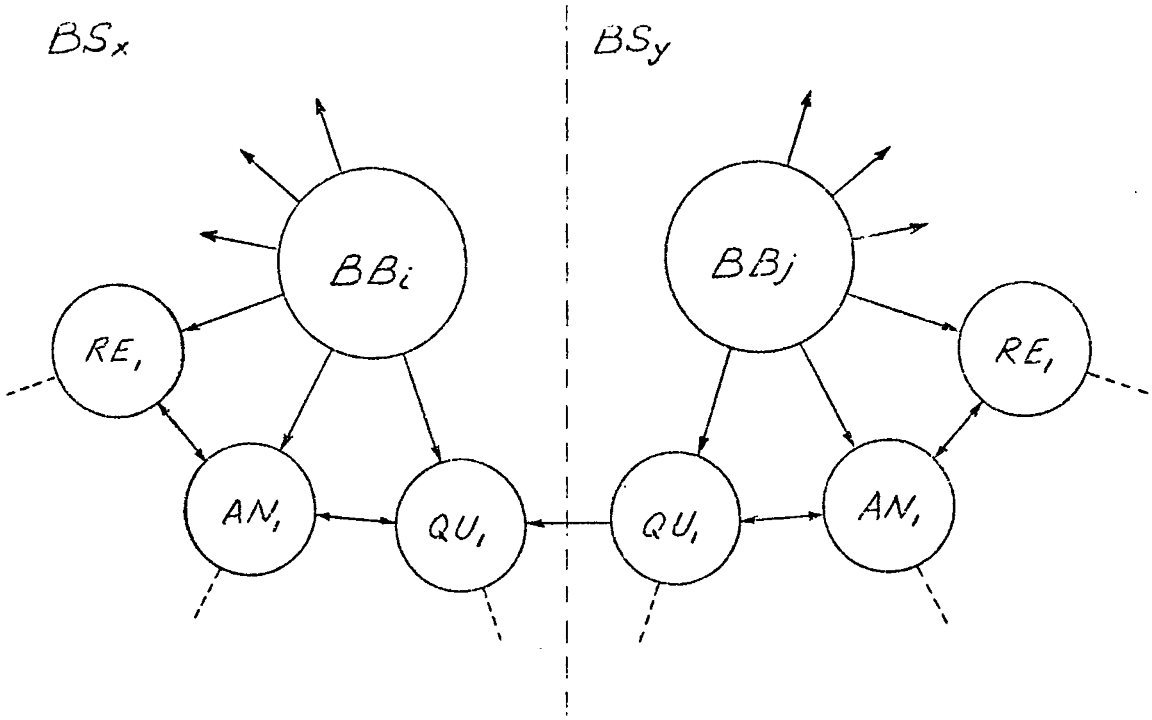
The subject matter presented by the Interactive Human-Machine System was Sequential Logic Circuit Theory. The students were to learn sufficient sequential machine fundamentals to interpret design specifications and to translate them into a design procedure. Then, given the word specification of the problem, they were to create a sequential machine state diagram design, to build and test the design on the interactive machine, and to modify the design until it met all the initial specifications. To facilitate this, the course (data base) was divided into three major sections: Fundamentals, Design, and test and diagnosis (Figure 2-5). The first section consisted of basic concepts and definitions, state diagram types based on the criteria of



2-5. Learning-Design Schedule

fixed input history and identifying states. A method of classifying state diagrams was needed since it was necessary to quantify the step of translating a word statement of the design to a state diagram without considerable intuition. The second section was a design problem, and included a word specification of the design requirements and the execution of the design steps. In the third section the student engaged the use of three special Design Simulators to test his sequential machine design for possible errors. If any errors existed, the student had available to him a diagnostic portion to assist him in discovering and correcting these errors. During the use of the BUILD, TEST, and LOOK simulators in Design, the time taken by the student was not included as part of the student's total time in the Bite Structure. After he returned from the simulations into the Bite Structure again, the accounting of his intercommunications with the interactive system resumed. Thus, the accounting considered only the activity with the Bite Structure during Design and Fundamentals. The totality of these two stages of activity was called the Composite course.

These three sections were organized by dividing each section into sets of fundamental concepts and/or procedural concepts (steps) which were interrelated but unredundant. These steps, called Basic Bites, were organized into a linear sequence. Usually this Basic Bite sequence would not be sufficient, in itself, to provide a student with a complete [illegible] ere was, in addition, the information related to the Basic Bites that was classified according to the nature of the information and called Peripheral Bites. These classifications were Reason, Example, More Specific, Quiz, Answer, and Definition. Each Basic Bite had a number of these Peripheral Bites associated with it (see Figure 2-4, page 24). Varying amounts of information was available to the six Interaction Strategies (Tables I, II). The much larger number of Peripheral Bites available to the Guided Learning students is not to be interpreted as unique information from that of the other Instruction Controls. It was a matter of cross-referencing that inter-linked certain peripherals for the purpose of re-inforcing related concepts if the student chose (Figure 2-6).



[illegible] Learning Interlinkages to Peripherals

TABLE I

NUMBER OF BITE UNITS IN THE BITE SETS

Strategy	BS1	BS2	BS4	BS5	BS6
ENCY-INC	17	10	9	35	28
PPI -INC	18	12	9	29	25
GL -INC	20	12	9	35	31
ENCY-INT	17	10	9	28	24
PPI -INT	18	12	9	26	20
GL -INT	20	12	9	32	27

TABLE II

NUMBER OF PERIPHERAL BITES IN THE BITE SETS

Strategy	BS1	BS2	BS4	BS5	BS6
ENCY-INC	79	53	32	51	42
PPI -INC	76	52	34	75	49
GL -INC	137	93	69	203	88
ENCY-INT	79	53	32	50	45
PPI -INT	76	52	34	59	44
GL -INT	137	93	69	212	101

2.5 EXPERIMENTAL SEQUENCE AND DATA GATHERING

There were a series of five experiments using the interactive system at the University of Wisconsin. This thesis is concerned with Experiments #2, #3, and #4. Experiment #2 was conducted in the fall of 1968 with 113 sophomore engineering students as subjects randomly assigned to one of the six possible combinations of the Interaction Strategy. Experiments #3 and #4 were undertaken in the spring and fall semesters of the following year with 64 students from Madison Vocational Technical College. Experiment #3 students were randomly assigned to one of the three possible Incremental Design Schedules while the Experiment #4 students were similarly assigned to one of the three possible Integral Design Schedules (see Table III).

All intercommunications (transactions) between a student and the machine in the interactive system were automatically recorded and retained for later analysis. Each transaction had its time of commencement and classification recorded. All the transactions from each student's sessions were combined into one complete interactive protocol for that student and formed the basis for the analysis of each student's performance. Any student whose transactions were complete was considered a "valid" subject whose parameter values could be included in the analyses. This raw data as received from the Synnoetics Laboratory totalled some 50,000 80-column IBM key-punch cards. From this raw data, all the parameters of time,

TABLE III

EXPERIMENTAL SUBJECTS AND FREQUENCIES

Exp. No.	Interaction Strategy*	College	Valid Bite Structure Parameters	ACT Scores	POST Scores	RET1 Scores	RET2 Scores
2	ENCY-INC	U. of Wisconsin	9	0	9	2	6
2	PPI -INC	U. of Wisconsin	17	0	17	3	13
2	GL -INC	U. of Wisconsin	17	0	17	4	14
2	ENCY-INT	U. of Wisconsin	12	0	13	1	12
2	PPI -INT	U. of Wisconsin	13	0	13	5	10
2	GL -INT	U. of Wisconsin	18	0	18	7	17
3	ENCY-INC	Madison Voc.	7[a]	7	7	7	7
3	PPI -INC	Madison Voc.	12[b]	0	12	12	11
3	GL -INC	Madison Voc.	8[c]	8	8	8	7
4	ENCY-INT	Madison Voc.	5	5	4	4	4
4	PPI -INT	Madison Voc.	5	5	5	5	5
4	GL -INT	Madison Voc.	6	6	4	4	4

* See Figure 1-3, page 15.
[a] 20% interrupted by 8-day Easter vacation
[b] 17% interrupted by 8-day Easter vacation
[c] 45% interrupted by 8-day Easter vacation

utilization, and access (see Appendix A) were calculated and a file containing each student's set of parameters was prepared at the University of Houston as part of the antecedent Friere thesis.

As part of the experiments students were given three tests: a post test at the conclusion of their last terminal session provided they had successfully completed the sequential logic circuit they were to design; an unannounced retention test some two weeks later given during a regular class lecture session; and a second retention test given the following month by appointment in the laboratory. Each of these tests were prepared and graded so that there were sub-totals of the score that could be compared with the student's performance in the Bite Structure. i.e., Each test had a "fundamentals" section testing the material covered in Bite Sets 1, 2, and 4 of the Bite Structure. Each test had a "familiar" section which included questions of the same nature as the student experienced during his designing stage. The post test had a transfer section of problems intended to evaluate the student's understanding of the principles in an unfamiliar or untaught situation. The value of unattempted or unanswered questions was also accumulated into a subtotal.

Unfortunately the actual test papers of the students of Experiment #2 did not arrive with the data from the University of Wisconsin. The Experiment #2 test scores were thus secured from a single unsubstantiated source, a computer print-out. Other data on the dump, such as the matching [illegible] student identification numbers with the assigned courses, were confirmed so that the subsequent columns of post total, post fundamental, post familiar, post transfer, post unanswered, retention 1 total, fundamental, familiar, and unanswered were accepted as valid data. The retention 2 subtotals, however, did not appear to be good data in that their sums did not match the stated totals. A decision was made to accept only the retention 2 totals. Understandably, this lack of retention 2 sub-totals in Experiment #2 was an unfortunate handicap to the completeness of this thesis. Additional student data that had been collected at the University of Wisconsin included certain standardized scores, i.e., the American College Testing Service scores and the Programmer's Aptitude Test scores. Very few of these particular data collections arrived in Houston and in spite of hope, phone calls, and letters all of these standardized scores for Experiment #2 students and the Experiment #3 PPI students remained missing.

2.6 PROCEDURE

Initially all students were given a 15-20 minute period of terminal acclimation. This acclimation was constructed along instruction control strategy lines so that a student who was assigned to a PPI mode received his acclimation in this mode.

The acclimation explained and illustrated how the student could interact with the machine to receive information and how he would use simulators to build and test the machine he would eventually design and construct.

Students were given tests upon completion of the course and on selected intervals thereafter. The purpose of the latter was to determine the student's retention of the subject matter.

The Experimental Procedures were completely documented and the staff directed to follow them rigorously for each student. Except for the procedures denoted "Student Instructions" and "Recovery Procedures", a condensation of these procedures may be found in Appendix B.

Chapter 3

EXPERIMENT #2 DATA ANALYSIS

3.1 METHODOLOGY

There were two general statistical interests to be pursued in the data of Experiment #2. One was the search for correlations with a probability level of 5 percent or less between student test scores and student Bite Structure performance as it was measured by a variety of parameters. Another was the search for differences in the Instruction Control treatment (the columns effect) or differences in the problem-solving or Design Schedule (the row effect) that would be significant at an alpha level of 5 percent or less.

The first interest was met by examining a series of correlation matrices with their corresponding significance matrices. If the data consist of N specific observations on p variables denoted as x_{ij} for $i = 1,2,\ldots,N$ and $j = 1,2,\ldots,p$, then the sample mean for variable j is defined as

$$\bar{x}_j = \frac{1}{N}\sum_{i=1}^{N} x_{ij}$$

The sample variance for each variable j is defined as

$$s_j^2 = s_{jj} = \frac{1}{N-1}\sum_{i=1}^{N}(x_{ij} - \bar{x}_j)^2$$

The sample covariance between two variables j and k is denoted by s_{jk} and defined as

$$s_{jk} = \frac{1}{N-1} \sum_{i=1}^{N} (x_{ij} - \bar{x}_j)\ (x_{ik} - \bar{x}_k)$$

The sample standard deviation of variable j is defined as

$$s_j = \sqrt{s_j^{\,2}}$$

The Pearson product-moment correlation coefficient between two variables j and k is denoted by r_{jk} and is defined as

$$r_{jk} = s_{jk} \,/\, (s_j s_k)$$

Fisher's Z-transformation of a correlation coefficient r_{jk} is defined as

$$Z_{jk} = \frac{1}{2} \sqrt{N - 3}\ \log \frac{1+r_{jk}}{1-r_{jk}}$$

The significance level for a particular value of Z_{jk} is the probability that a unit normal variate is greater than or equal to Z_{jk} in absolute value (a two-tailed test).

The second interest involved the selection of an analysis of variance technique for the factorially designed fixed-effect model the experiment intended. A principle decisive factor in the choice of the statistical method to be used was that all the valid raw data be included in the analyses. The experiment was designed as a factorial 2-way classification, with three columns for Instruction Control and 2 rows for the Design Schedule (Figure 3-1).

		ENCY	PPI	GL
		INSTRUCTION CONTROL		
DESIGN SCHEDULE	INC	1	2	3
	INT	4	5	6

Figure 3-1. Experiment in Interaction Strategy as a Fixed-Effects Model

It was immediately apparent that the six cells most assuredly would not contain equal or proportional frequencies for each set of parameters to be examined. To avoid equalizing the cell frequencies of each dependent variable under consideration by some manner of dispensing with observations, a method of obtaining ANOVA summaries with the unequal frequencies was sought to conserve valuable data.

The ultimate selection was the method of constructing the standard 2-way ANOVA table through a multiple linear regression analysis using dummy variable coding (Suits, 1957; Draper-Smith, 1967; Cohen, 1968). The tests for significance produce identical values for the F ratio with identically the same degrees of freedom because:

$$F = R_Y^2/df \Big/ (1-R_Y^2) \,/\, (n-df-1) = \frac{\text{Between Groups Mean Square}}{\text{Within Groups Mean Square}}$$

In this method the nominal scales (Schedule and Control) are used as the independent variables, x_i, of the linear multiple regression. The ANOVA variable being analyzed (the test scores or bite structure parameters) or the linear multiple regression criterion variable are referred to as the dependent variable, y. In order for y to be studied as a function of the variables x_i, i = 1,6 (the six possible Interaction Strategies), the expression of group membership as independent variables in the linear multiple regression is accomplished by the dummy variable coding in which each group is distinguished from the remainder by a patterning of 0,+1 and -1.

The linear regression model in matrix form is $Y = XB + e$. Expanded,

$y_i = B_i x_{i1} + B_2 x_{i2} + \cdots + \cdots + B_p x_{ip} + e_i$, $i = 1,2,\ldots,n$

If $x_{i1} = 1$ for all i, then the more usual form in which B_1 is the constant term results. The model involves the following assumptions:

(1) x_{ij} s are fixed known values

(2) y_i s are observed values

(3) e_i s are random variables, normally distributed, with the estimate of $e_i = 0$ and the variance of $e_i = \sigma^2$

(4) the B_j s are unknown parameters to be estimated.

In the given factorial design with i = 2 and j = 3 (Figure 3-2), one might begin by thinking of some y_{ij} as having some relation to $u + a_1x_{1ij} + a_2x_{2ij} + b_1x_{3ij} + b_2x_{4ij} + b_3x_{5ij} + e_{ij}$ where the a's represent row coefficients, the b's represent column coefficients, and u's represent the mean of the y_{ij}'s.

FACTOR 'b'

FACTOR 'a'

	ENCY	PPI	GL
INC			
INT			

Figure 3-2. Factorial Design of Learning Experiment

Now if the fixed known values of the x's are dummy-coded as in the matrix, we obtain the following set of equations.

$$\begin{bmatrix} y_{11} \\ y_{12} \\ y_{13} \\ y_{21} \\ y_{22} \\ y_{23} \end{bmatrix} = \begin{bmatrix} 1 & 1 & -1 & 1 & 0 & -1 \\ 1 & 1 & -1 & 0 & 1 & -1 \\ 1 & 1 & -1 & -1 & -1 & 2 \\ 1 & -1 & 1 & 1 & 0 & -1 \\ 1 & -1 & 1 & 0 & 1 & -1 \\ 1 & -1 & 1 & -1 & -1 & 2 \end{bmatrix} \begin{bmatrix} u \\ a_1 \\ a_2 \\ b_1 \\ b_2 \\ b_3 \end{bmatrix} + \begin{bmatrix} e_{11} \\ e_{12} \\ e_{13} \\ e_{21} \\ e_{22} \\ e_{23} \end{bmatrix}$$

Since this matrix is singular (rank $\neq 6$), we cannot estimate the model parameters as such (because the equations are either inconsistent or indeterminant) but we can obtain the best linear unbiased estimates of certain linear combinations of the model parameters. Thus the reformulated model becomes:

$$\begin{bmatrix} y_{11} \\ y_{12} \\ y_{13} \\ y_{21} \\ y_{22} \\ y_{23} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 0 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & 1 & 0 \\ 1 & -1 & 0 & 1 \\ 1 & -1 & -1 & -1 \end{bmatrix} \begin{bmatrix} u \\ a_1 \\ b_1 \\ b_2 \end{bmatrix} + \begin{bmatrix} e_{11} \\ e_{12} \\ e_{13} \\ e_{21} \\ e_{22} \\ e_{23} \end{bmatrix}$$

and the normal equations

$X'X\hat{B} = X'Y$

$$\begin{bmatrix} 6 & 0 & 0 & 0 \\ 0 & 6 & 0 & 0 \\ 0 & 0 & 4 & 2 \\ 0 & 0 & 2 & 4 \end{bmatrix} \begin{bmatrix} \hat{u} \\ \hat{a} \\ \hat{b}_1 \\ \hat{b}_2 \end{bmatrix} = \begin{bmatrix} \sum_i \sum_j \; y_{ij} \\ \sum_j (y_{1j} - y_{2j}) \\ \sum_i (y_{i1} - y_{i3}) \\ \sum_i (y_{i2} - y_{i3}) \end{bmatrix}$$

Since, in reality, the experimental design was factorial, we also need to include parameters for the possible interaction effects. This finally leads to the fully developed model:

$$y_{ij} = u + a_1x_{1ij} + b_1x_{2ij} + b_2x_{3ij} + a_1b_1x_{4ij} + a_1b_2x_{5ij} + e_{ij}$$

$$\begin{bmatrix} y_{11} \\ y_{12} \\ y_{13} \\ y_{21} \\ y_{22} \\ y_{23} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 0 & 1 & 0 \\ 1 & 1 & 0 & 1 & 0 & 1 \\ 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & -1 & 1 & 0 & -1 & 0 \\ 1 & -1 & 0 & 1 & 0 & -1 \\ 1 & -1 & -1 & -1 & 1 & 1 \end{bmatrix} \begin{bmatrix} u \\ a_1 \\ b_1 \\ b_2 \\ a_1b_1 \\ a_1b_2 \end{bmatrix} + \begin{bmatrix} e_{11} \\ e_{12} \\ e_{13} \\ e_{21} \\ e_{22} \\ e_{23} \end{bmatrix}$$

To obtain the total sum of squares due to linear regressions, the full model,

$$y = u + a_1x_1 + b_1x_2 + b_2x_3 + a_1b_1x_4 + a_1b_2x_5 + e,$$

is run in the regression computer program, STEPREG1 of STATJOB, from the University of Wisconsin. This results in the computations summarized in Figure 3-3.

A Linear Regression	B Error
C Correction for Mean	

Figure 3-3. Total Sum of Squares of the Raw Dependent Variable y

A second model, $y = u + a_1x_1 + b_1x_2 + b_2x_3 + e$, is then run to obtain the computations shown graphically in Figure 3-4.

A

D SS Due to Rows or Columns	E SS Due to Interaction

Figure 3-4. Sum of Squares Due to Linear Regression Part A of Figure 3-3.

A third model, $y = u + a_1x_1 + e$, is then run to obtain the computations shown in Figure 3-5.

D

E SS Due to Columns	F SS Due to Rows

Figure 3-5. Sum of Squares Due to Linear Regression Rows or Columns

Thus all of the sources of the sums of squares may be examined independently of any unequal cell frequency considerations.

Another way to view this approach to the sources of the Sums of Squares and of their significance is via Figure 3-6.

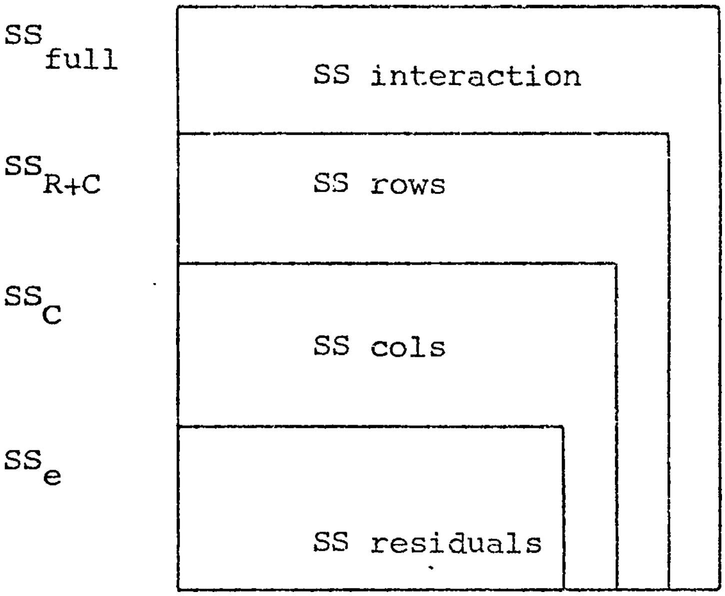


Figure 3-6. Sums of Squares Distribution (adjusted for the Sums of Squares for the Means)

To determine if there is anything significant in the full model the overall F with degrees of freedom 5 and n - 5 - 1 is computed:

$$F^{5}_{n-6} = (SSR_{full}/5) \bigg/ (SSE_{full} \,/\, (n-6))$$

To determine if the interaction sums of squares due to regression is significant compute:

$$F^{2}_{n-6} = (SSR_{interaction}/2) \bigg/ (SSE_{full} \,/\, (n-6))$$

To determine if the sums of squares due to row regression is significant compute:

$$F^{1}_{n-6} = (SSR_{rows}/1) \bigg/ (SSE_{full} \,/\, (n-6))$$

To determine if the sums of squares due to column regression is significant compute:

$$F^{2}_{n-6} = (SSR_{columns}/2) \bigg/ (SSE_{full} \,/\, (n-6))$$

However, the F test of these mean squares is an omnibus test and by itself, if significant, provides no information about possible differences between a given pair of the treatment means. With six treatment means we have 15 possible tests that might be made if every treatment mean is compared with every other treatment mean. The method selected to determine any significant differences was that of Scheffe (1953). This method also allows group comparisons. Thus the S-method permits what Scheffe has called "data snooping". One may examine the data and test any or all comparisons that appear to be of interest. If the F of the $(SSR_{full} / 5)/(SSE_{full} / n-6)$ is significant in our case, then at least one of the possible comparisons on the treatment means will be significant. The S-method F is denoted by

$$F = \frac{(\bar{x}_1 - \bar{x}_2)^2}{\frac{MS_w}{N_1} - \frac{MS_w}{N_2}} \quad \text{with } 1/df_w$$

where MS_w is the mean square error within of the ANOVA summary table and df_w is the associated degrees of freedom. Homogeneity of variance between the groups being compared is assumed or can be tested by Hartley's F_{max} test if in doubt. However, there is abundant evidence that these comparative tests on means are remarkably insensitive to general non-normality of the parent population (Box, 1953).

3.2 DATA PREPARATION

In November 1971, the author began work with Mr. Friere in an effort to catalog precisely the Bite Structure: some 900 bites each by its type, bite unit, bite set and availability to any or all of the six Interaction Strategies. This information formed part of the data base Mr. Friere used in his thesis (Friere, 1972).

The students' standardized scores and experiment test scores were to be organized by Interaction Strategy groups and missing data codes established. However, the standardized scores for the Experiment #2 students were all missing as described in Section 2.5. The three sets of test scores--Post, Retention 1, and Retention 2--with all the available subtotals were grouped according to their Interaction Strategy. Then particular combinations of test scores were calculated (see Appendix A, Table 5). Short-Term Forgetting was defined as the difference between the Post Test score and the first Retention Test score. Long-Term Forgetting was defined as the difference between the Post Test score and the second Retention test score. Consolidation was defined as the difference between the second Retention test score and the first Retention test score. Whenever the subtotals were available, the related subtotals of the calculated test score parameters were determined, e.g., the short-term forgetting fundamentals score was calculated from the difference between the post fundamentals subtotal and the retention 1 fundamentals subtotal.

A data file was to be prepared from the reformatted data of Experiments #2, #3, and #4. It was to be organized by student and each student's performance was to be recorded in terms of the parameters in Appendix A, Table 4. This data file is hereafter referred to as the Master Student File. Since the size and format of the Master Student File were not well-suited to the intent of this thesis, and since no test scores or standardized scores were included in its contents, another data file was planned for the specific purposes of this thesis. This file became known as the Group Summary File and consisted of a selected subset of the Appendix A Table 4 parameters which are therein denoted by an asterix. However, the preparation of the Group Summary File waited on the completion of the Master Student File.

In the meantime, it was expedient to build Univac Fastran files from punched cards of the grouped test scores in order to begin with the analysis. A decision had to be made as to which students' scores could be included in the analysis. Over a period of time, three different assumptions on student validity were made. Initially, the decision was to analyze all of the test scores available for all of the students in the experiment. The second decision was to analyze only those students who completed the Composite course, i.e., all of the Fundamentals accomplished before having gone to the design and then all of the problem-solving or design area accomplished including a correct solution to the required machine design. As this depleted the [illegible] of certain cells in certain tests, this stipulation was revised. Only total scores required students defined as "Composite"; the Fundamentals portion of the tests would include the "Composite" students and those others who performed satisfactorily in the Fundamentals areas of the Bite Structure but were defined invalid in the Design portion; the Design (familiar and transfer subtotals) portion of the tests would include students defined previously as "Composite" and those whose were valid only in the Design portion of the Bite Structure. Some of the students who had to be classified as invalid were so only because a machine error in the automatic recording process resulted in the partial loss of students' transaction records. These definitions of a Composite, a Fundamentals-only, or a Design-only student continued to be used later with the Bite Structure parameters. About forty STEPREG1 runs of three models each were thus obtained for Experiment #2 of which only sixteen were eventually considered acceptable.

Decisions were made as to the subset of the Master Student File with which this thesis would be concerned and the format of the Group Summary File to contain them was established. A program for the preparation of the table of contents with each student's address pointer and flags with settings for valid or missing data was written and tested. Another program prepared the student's record of test scores. These were then incorporated into the program by which Mr. Friere addressed the Student Master File to select the particular bite structure parameter values that were required for this thesis and the Student Group Summary File was prepared. A program was written to test the validity of the file on several critical points.

The statistics package to be used was STATJB from the University of Wisconsin. The STATJB STEPREG1, the linear multiple regression program, and DSTAT2, the correlation program, each required particular and different format styles for the data set. Programs were written to prepare the required organization for each of these STATJB programs. The files thus created (Table IV) were also checked for validity before preceding.

TABLE IV

DATA FILES CREATED

Data File	Author
Test Scores Fastran File	Erb
Master Student File	Friere
Group Summary Files –Composite values –Fundamentals values –Design values	Friere-Erb
ANOVA Group Files –Composite values –Fundamentals values –Design values	Erb
Correlation Matrix Files –Composite values –Fundamentals values –Design values	Erb

All these files were prepared on the IBM 360/44 because of the convenient hands-on operation possible for the graduate student. However, the statistics package, STATJB, was available only on the UNIVAC 1108. This required that a program be written to read a "360" tape, to convert the 4 byte words to 6 byte words, and to write the conversion onto an "1108" tape. PL/1 was used to do this on a character by character basis using a translation between the hex and octal codes.

Because the number of runs would require repeated mounts of the tape on which the files were stored, it was more economical and less time-consuming (in turn-around time) to build Fastran files from the tapes and then to access these data files from programs on keypunch cards. This required a program with two purposes: the program would read the converted "1108" tape to create a data file, and then would process the data file so that it would be a Standard Format file, a requirement of STATJB.

The STEPREG1 program was one of two canned statistics programs tested against the data and results of a published problem (Draper and Smith, 1967, p. 258) involving the use of linear multiple regression to produce analysis of variance summaries. Differences in the two programs appeared in the results of the reduced models. STEPREG1 produced tables consistent with the published results and appeared superior in the availability of other related statistics.

When the Group Summary Files were complete, the following parameters (see Appendix A) were analyzed by the linear multiple regression program:

Time in the Universe (TU)

Accesses to the Universe (AU)

5 Utilization of Bite Sets (UBS)

5 Normalized Utilization of Bite Sets (NUBS)

5 Relative Accesses to the Bite Sets (RABS)

5 Normalized Relative Accesses to the Bite Sets (NRABS)

5 Relative Time in the Bite Sets (RTBS)

5 Normalized Relative Time in the Bite Sets (NRTBS)

5 Distinctly Accessed Bite Units in the Bite Set (DABU)

41 Normalized Utilization of Bite Sets (covering Bite Sets 1 and 2) (NUBU)

41 Normalized Relative Access to the Bite Units (NRABU)

41 Normalized Relative Time in the Bite Units (NRTBU)

Five correlation matrices were run of the nearly 80 variables maximum possible per run. Each run's output included a general statistics package plus matrices of means, standard deviations, covariances, correlation, Z-transformation values, and their probability levels.

At this juncture, these parameters were viewed as not telling the whole story as they were using only "complete" students, "complete" time in the universe, and so forth. So four more tapes were prepared from the newly created Group

Summary Tape-Fundamentals parameters, and Group Summary Tape-Design parameters. Then, after the usual intermediate steps, most of the same set of parameters were re-run against the four new files.

Based on the excessive positive deviations seen in the time parameter analyses, a set of students was checked against the sign-in sheets which noted the time-in and the time-out of the laboratory sessions. A number of the students obviously had faulty clock times set during some session that resulted in interactive student-machine times in excess of the physical time spent in the laboratory. Rather than omit this data, these errors were found and corrected in the Master File by Mr. Friere. Six new tapes were thus required to be built and their corresponding Fastran files established in order to re-run all the time-related parameters.

After these were all re-run, another problem appeared in the method of the calculations of the Master Tape. These calculations affected all the parameters of the Guided Learning students. Jointly, checking was done by hand to determine the validity of the newly calculated figures compared with the old. The differences, ranging from 25 percent to 300 percent, meant that all the tapes, files and runs were currently invalid. Thus the entire procedure was repeated using the new calculations on the Guided Learning students. However, only those parameters producing non-duplicate results were included. This reduced set consisted of TU, AU, UBS, RABS, RTBS, DABU, and NUBU.

After viewing the test score means and bite structure parameter means, certain compound parameters were suggested. These included Processing Rate (PR), Performance Rate (PfR), Effective Learning (EL), Effective Learning Capacity (ELC), and Effective Learning Rate (ELR). Processing Rate was defined as the ratio of the number of bites accessed in the universe and the amount of time spent,

$$PRU = AU/TU$$

$$PR_i = ABS_i/TBS_i \quad , \text{ or}$$

$$PR_i = DABU_i/TBS_i$$

Performance Rate was defined as the ratio of the test score achieved and the amount of time spent in the Bite Structure.

$$PfR_{PTOT} = PTOT/TUC$$

$$PfR_{R1TOT} = R1TOT/TUC$$

$$PfR_{R2TOT} = R2TOT/TUC$$

Effective Learning was defined as the ratio of the test score achieved and the number of bites accessed in the universe of the Bite Structure.

$$EL_{PTOT} = PTOT/AUC$$

$$EL_{R1TOT} = R1TOT/AUC$$

$$EL_{R2TOT} = R2TOT/AUC$$

Effective Learning Capacity was defined as the ratio of the test score and the processing rate.

$$ELC_{PTOT} = PTOT/(AUC/TUC)$$

$$ELC_{R1TOT} = R1TOT/(AUC/TUC)$$

$$ELC_{R2TOT} = R2TOT/(AUC/TUC)$$

Effective Learning Rate was defined as the ratio of Effective Learning and the time spent in the Bite Structure.

$$ELR_{PTOT} = EL_{PTOT}/TUC$$

$$ELR_{R1TOT} = EL_{R1TOT}/TUC$$

$$ELR_{R2TOT} = EL_{R2TOT}/TUC$$

A selected group of these compound parameters were then run for its ANOVA summaries.

Scheffe tests, to compare means--both individually and grouped means--, were run on all parameters whose alpha levels were ≤ 0.05. This amounted to over 1100 comparisons in the five bite sets alone. The Scheffe and the homogeneity of variance tests that were run were from programs written by the author.

Two Chi-Squared tests were calculated to determine whether the Relative Accesses to the five Bite Sets were different from:

(1) an expected frequency distribution based on the number of Bite Units available in each Bite Set,

(2) an expected frequency distribution based on an assumption that the student accesses uniformly among the Bite Sets regardless of the differences in the Bite Set sizes.

The Chi-Squares were then done on the Relative Times under analagous assumptions.

3.3 RESULTS OF EXPERIMENT #2

The factorial design of the experiment and the mnemonics used for the various strategies are repeated in Figure 3-7 for convenient reference.

		INSTRUCTION CONTROL		
		ENCY	PPI	GL
DESIGN SCHEDULE	INC	11	12	13
	INT	21	22	23

Figure 3-7. Factorial Design of Experiment's Interaction Strategies

Legend:
ENCY - Encyclopedia
PPI - Pre-Programmed Instruction
GL - Guided Learning
INC - Incremental
INT - Integral

The calculations were of five types and are charted by type with separations into the categories to be examined: Universe parameters, Relative Accesses and Times in Bite Sets, Bite Unit Parameters, Test Scores, and several sets of Compound Parameters. The F ratios of the Analysis of Variance whose values would indicate significance if compared at the 5 percent significance level are shown along with the degrees of freedom. The means of the cells are shown using a matrix notation of 11,12,13,21,22,23, to denote ENCY Incremental, PPI Incremental, GL Incremental, ENCY Integral, PPI Integral, and GL Integral, respectively. The mneumonics used for the parameters are those defined in Appendix A. Parameters from the Composite, Fundamentals and Design portions of the experiment are designated by "C", "F", and "D" respectively. The probabilities of Pearson's coefficients of correlation whose values would indicate significance if compared at the 5 percent significance level are shown. Those probabilities which represent negative correlations are marked with a superscript minus sign.

The clearest result of the experiment was that ENCY, complete learner control of the interactive system, consistently indicated low utilization of the Bites in the Bite Sets, the selection of the fewest distinct Bite Units in each Bite Set, the lowest rate of processing the Bites, and the highest Effective Learning Rate. To substantiate this and other results, the analyses of the parameters are presented in sets of:

Universe Parameters
Relative Accesses and Times Parameters
Bite Unit Parameters
Test Scores
Processing Rates
Performance Rates
Effective Learning
Effective Learning Capacities
Effective Learning Rates

The ANOVA Sums of Squares on each of the selected parameters were calculated and if the Fs were larger than that required for an alpha level of 0.05, the Scheffe test was made to compare the means. If differences between the means were found to exist, also assuming a significance level of 0.05, these differences were noted in summary form [illegible] a lowest, medium, and high trichotomy which was abbreviated to LO, MED, and HI in the figures. Whenever the six strategy means dichotomized, according to the Scheffe, only the mean(s) which fell on the extreme lowest or highest position was labelled, i.e., the six cells were divided into LO and the unlabelled remainder, or HI and the unlabelled remainder.

3.3.1 The Universe Parameters

The ANOVA and correlation tables, Tables V and VI, for the parameters are found on pages 56 and 57 and are immediately followed by graphs of the means of the parameters (Figures 3-9 and 3-10).

There was an apparent difference in the number of accesses made among the six instructional strategies as shown by Figure 3-8.

	ENCY	PPI	GL
INC	LO		
INT	LO		

Figure 3-8. Comparison of Means
AU - C,F,D
Experiment #2

ENCY accesses were lower than those of PPI or GL which could not be distinguished from one another. This was the picture in the Composite course, the Design portion, and also in the Fundamentals. In the Fundamentals portion, the incremental cell of the ENCY control was conspicuously different by its low value. The total time a student spent in the course,

TABLE V

ANALYSIS OF VARIANCE EXPERIMENT #2
UNIVERSE PARAMETERS

Parameter	$\overline{X}$	s	$\overline{X}_{11}$	$\overline{X}_{12}$	$\overline{X}_{13}$	$\overline{X}_{21}$	$\overline{X}_{22}$	$\overline{X}_{23}$	RxC F	ROWS F	COLS F
TJ C	3.57	0.66	3.12	3.66	3.43	3.84	3.48	3.75			
TJ F	2.06	0.48	1.89	2.14	1.88	2.34	2.10	1.99			
TJ D	0.59	0.51	1.33	1.53	1.53	1.48	1.40	1.68			
AJ C	249.8	57.9	188.2	284.4	251.7	222.8	259.9	256.6			9.94^{2}_{80}
AJ F	135.8	36.9	106.5	146.2	129.6	132.6	150.9	141.9			4.75^{2}_{92}
AJ D	113.3	39.0	83.7	140.2	122.9	92.0	113.3	110.4		4.14^{1}_{88}	8.74^{2}_{88}

Legend for all ANOVA Tables:

Parameter mneumonics as per Appendix A

$\overline{\overline{X}}$ - Grand Mean

s - Standard Deviation

$\overline{X}_{xy}$ - Mean of cell in row x and column y

RxC - An interaction effect F with alpha level of ≤ 0.05

ROWS - Row effect F with alpha level of ≤ 0.05

COLS - Column effect F with alpha level of ≤ 0.05

TABLE VI

PROBABILITY OF PEARSON'S COEFFICIENT OF CORRELATION ≤ 0.05
EXPERIMENT #2 UNIVERSE - TEST SCORES

Parameter	PTOT	PFD	PFM	PTRS	PUN	R1TOT	R1FD	R1FM	R2TOT	STFT	STFD	STFM	LTFT	CONSOL
TU C	.007$^-$	.005$^-$				.027$^-$	.003$^-$					.014		.034
TU F								.002$^-$			.033$^-$	.005$^-$		
TU D	.002$^-$	.004$^-$		.019$^-$										
AU C			.036$^-$											
AU F														
AU D	.030$^-$													

$^-$ represents a negative correlation

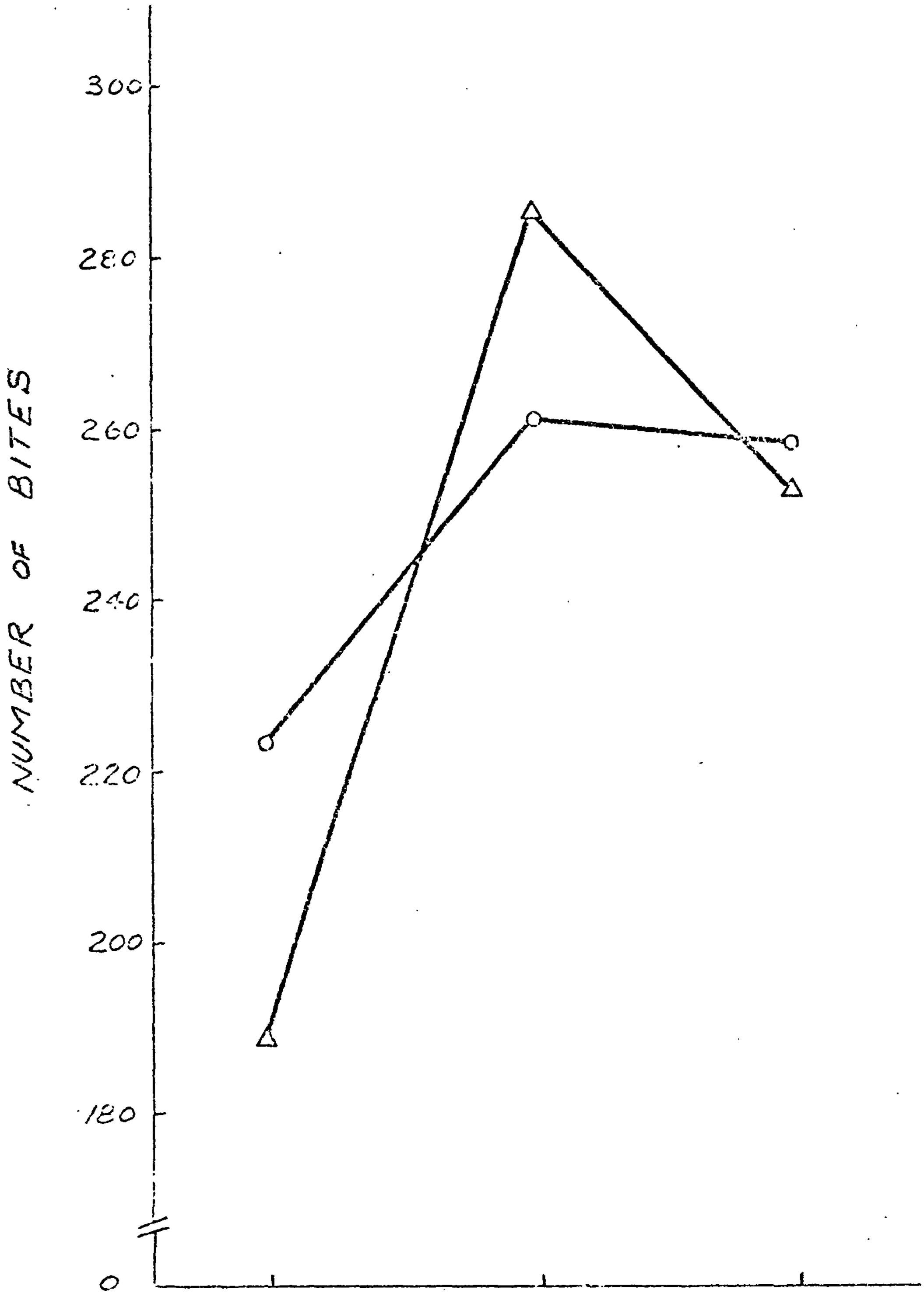


Figure 3-9. Means of AU-C
Experiment #2

INC △
INT ○
C
D
F

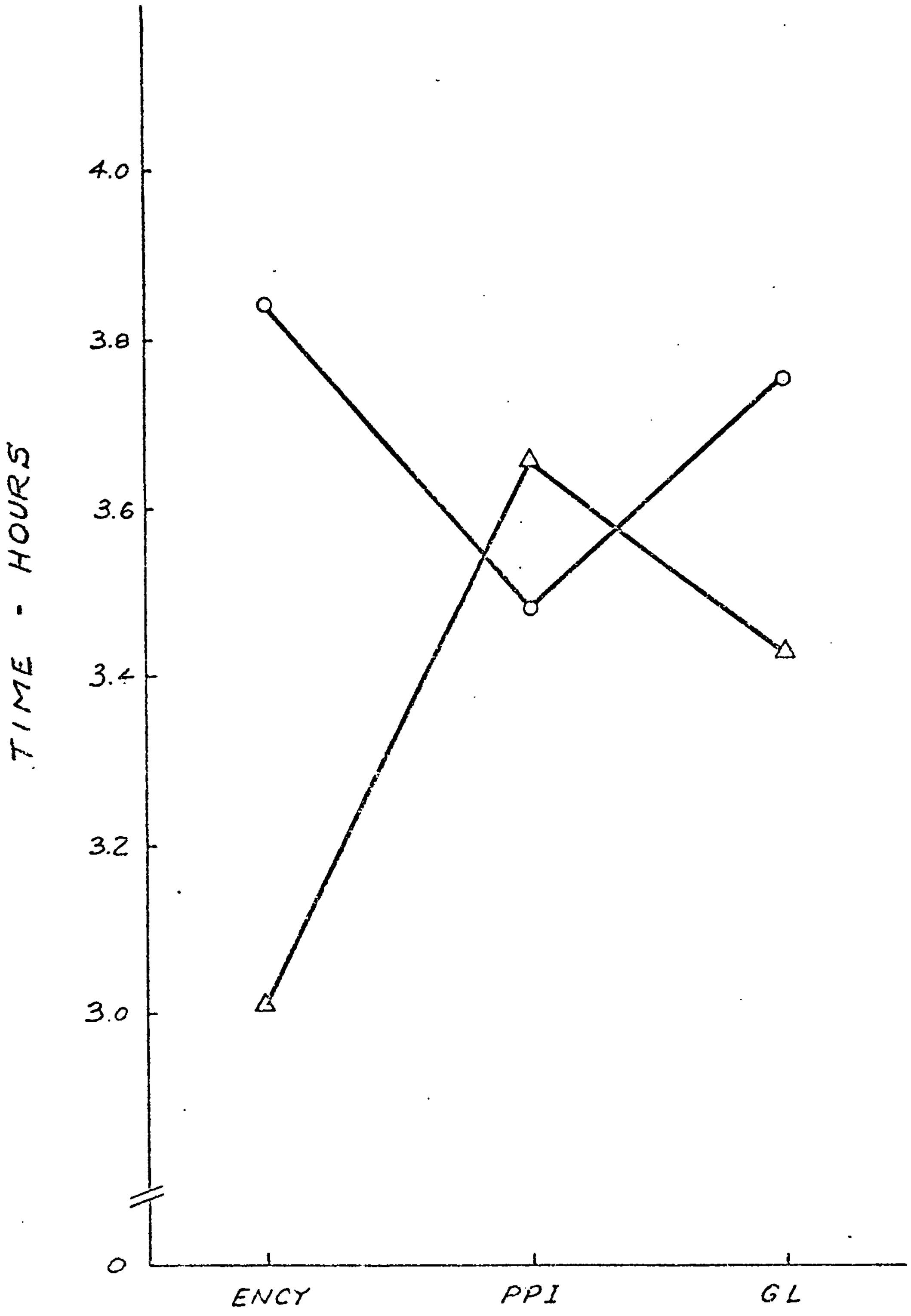
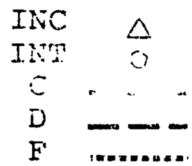


Figure 3-10. Means of TU-C
Experiment #2



whether in the Fundamental, Design or the Composite, does not vary on the basis of any particular interaction strategy (see Table V). However, there is a correlation between the total amount of time any student spent on his course and certain test scores (see Table VI). A student's composite TU correlates negatively with his Post Total test score, his Post Fundamentals test score, his Retention 1 Total test score, and his Retention 1 Fundamentals test score, but correlates positively with his Consolidation Total (Retention 2 - Retention 1) test score.

3.3.2 The Relative Access and Time in Bite Set Parameters

The χ^2, ANOVA and correlation tables for the parameters, Tables VII, VIII, IX and X, are found on pages 61-64. They are immediately followed by graphs of the means of selected parameters (Figures 3-11 through 3-20). These relativized parameters did not provide a source of distinguishing information in the analyses. Recalling that the Relative Access to a Bite Set is the ratio of the number of accesses to Basic and Peripheral Bites in that Bite Set to the total number of Bites accessed in all the Bite Sets, one is merely examining a ranking of Bite Set attention. In general, the students ranked the Bite Sets equivalently with their attention in terms of time and accesses. There were no single outstanding contenders for the highest value or the lowest value in any bite set with the possible exception of Bite Set 4 during Design. Here, GL integral clearly had the

TABLE VII

RELATIVE ACCESSES TO BITE SETS
IN EXPERIMENT #2 - COMPOSITE

Strategy (BS)	1	2	4	5	6	"Expected" Mean
ENCY INC	0.26	0.18	0.11	0.19	0.27	0.20
PPI INC	0.23	0.18	0.11	0.24	0.23	0.20
GL INC	0.25	0.15	0.11	0.21	0.27	0.20
ENCY INT	0.31	0.19	0.12	0.17	0.20	0.20
PPI INT	0.29	0.19	0.13	0.27	0.19	0.20
GL INT	0.27	0.18	0.12	0.17	0.24	0.20

$\chi^2 = 0.33$ with 4df representing a probability level of 0.95

TABLE VIII

RELATIVE TIMES IN BITE SETS IN
EXPERIMENT #2 - COMPOSITE

Strategy (BS)	1	2	4	5	6	"Expected" Mean
ENCY INC	0.30	0.14	0.12	0.17	0.26	0.20
PPI INC	0.30	0.15	0.15	0.20	0.20	0.20
GL INC	0.28	0.12	0.15	0.18	0.25	0.20
ENCY INT	0.37	0.14	0.14	0.16	0.20	0.20
PPI INT	0.35	0.14	0.16	0.18	0.16	0.20
GL INT	0.32	0.12	0.14	0.16	0.26	0.20

$\chi^2 = 0.79$ with 4df representing a probability level of 0.85

TABLE IX

ANALYSIS OF VARIANCE EXPERIMENT #2
RELATIVE TIMES AND ACCESSES
IN THE BITE SETS

Parameter	$\overline{X}$	s	$\overline{X}_{11}$	$\overline{X}_{12}$	$\overline{X}_{13}$	$\overline{X}_{21}$	$\overline{X}_{22}$	$\overline{X}_{23}$	RxC F	ROWS F	COLS F
RTBS1 C	.318	.065	.302	.297	.284	.366	.351	.322		15.1^{1}_{80}	
RTBS1 F	.550	.120	.538	.494	.526	.571	.565	.598		6.60^{1}_{92}	
RTBS1 D	.018	.041	.008	.013	.019	.030	.034	.007			
RTBS2 C	.134	.043	.138	.150	.124	.140	.142	.117			3.27^{2}_{80}
RTBS2 F	.216	.074	.246	.257	.184	.218	.214	.192			4.83^{2}_{92}
RTBS2 D	.016	.038	.005	.000	.037	.023	.014	.017			
RTBS4 C	.143	.048	.122	.145	.153	.135	.158	.139			
RTBS4 F	.217	.083	.214	.245	.247	.208	.214	.181		5.75^{1}_{92}	
RTBS4 D	.019	.060	.003	.004	.010	.015	.028	.050		4.63^{1}_{88}	
RTBS5 D	.437	.139	.413	.483	.448	.438	.453	.376			
RTBS6 D	.507	.132	.570	.497	.483	.490	.468	.548			

TABLE IX (Continued)

Parameter	$\overline{X}$	s	$\overline{X}_{11}$	$\overline{X}_{12}$	$\overline{X}_{13}$	$\overline{X}_{21}$	$\overline{X}_{22}$	$\overline{X}_{23}$	RxC F	ROWS F	COLS F
RABS1 C	.270	.065	.261	.227	.252	.307	.292	.290		15.2^{1}_{80}	
RABS1 F	.490	.130	.496	.419	.500	.497	.509	.527			
RABS1 D	.015	.025	.005	.016	.014	.025	.024	.008			
RABS2 C	.176	.049	.175	.179	.154	.192	.185	.180			
RABS2 F	.297	.093	.318	.353	.245	.297	.300	.280			4.68^{2}_{92}
RABS2 D	.021	.044	.009	.000	.045	.029	.015	.026			3.75^{2}_{88}
RABS4 C	.116	.030	.107	.115	.110	.123	.125	.117			
RABS4 F	.190	.064	.183	.224	.203	.203	.187	.162			
RABS4 D	.014	.043	.005	.001	.008	.012	.017	.036		4.45^{1}_{88}	
RABS5 D	.459	.133	.431	.502	.470	.455	.469	.413			
RABS6 D	.489	.126	.549	.477	.461	.476	.472	.515			

TABLE X

PROBABILITY OF PEARSON'S COEFFICIENT OF CORRELATION ≤ 0.05
EXPERIMENT #2 RELATIVE TIMES AND ACCESSES

Parameter	PTOT	PFD	PFM	PTRS	PUN	R1TOT	R1FD	R1FM	R2TOT	STFT	STFD	STFM	LTFT	CONSOL
RABS1 F				.032^{-}			.019^{-}							
RABS2 C	.021	.008	.047											
RABS4 C							.046							
RABS5 D				.005	.009^{-}									
RABS6 D	.009^{-}	.035^{-}		.013^{-}										
RTBS1 F				.024^{-}										
RTBS2 C		.042												
RTBS4 C	.017	.005					.012							
RTBS4 F				.022										.039
RTBS5 D				.009	.046^{-}									
RTBS6 D				.020^{-}	.007		.044^{-}							

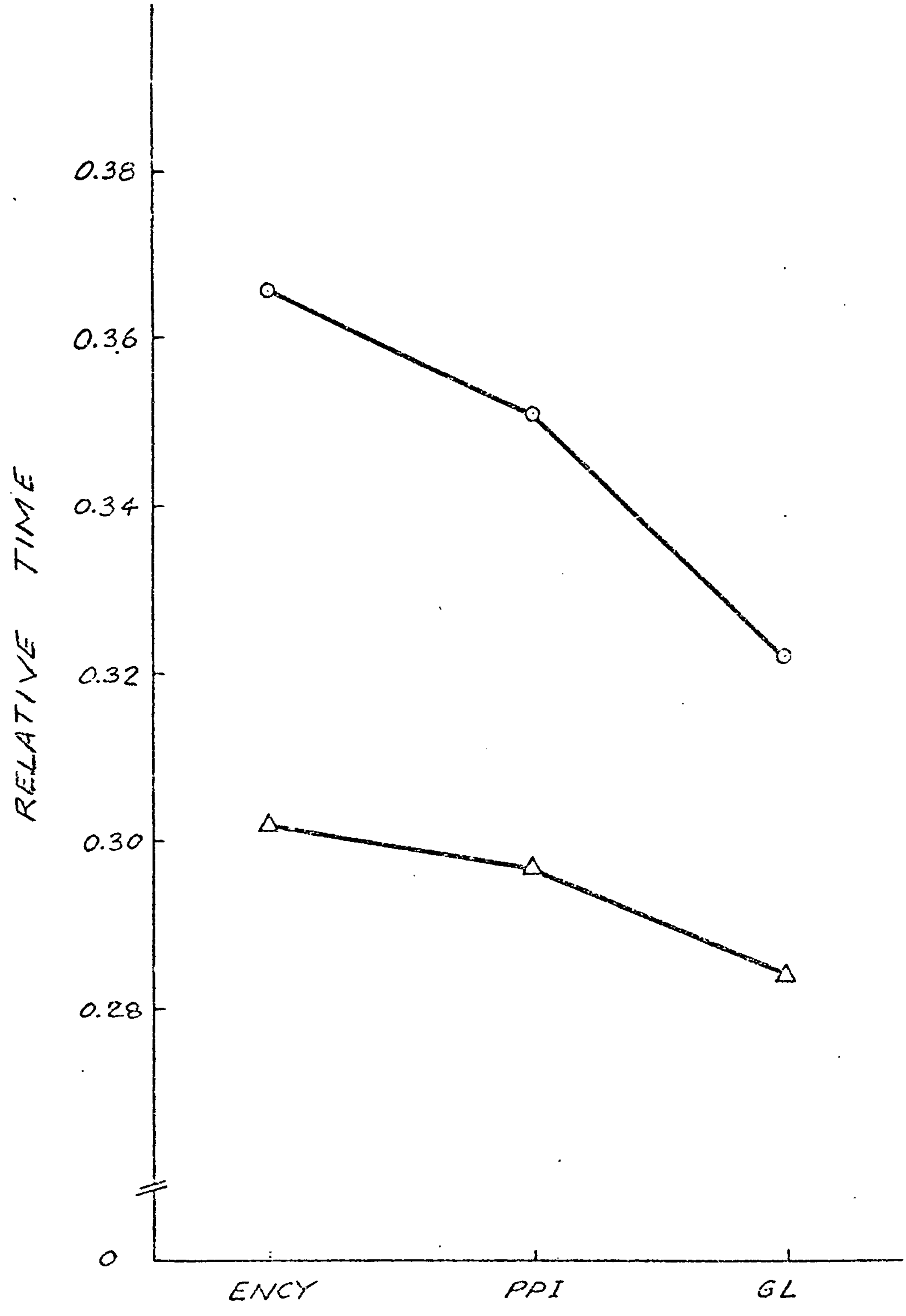


Figure 3-11. Means of RTBS1-C
Experiment #2

INC
INT
C
D
F

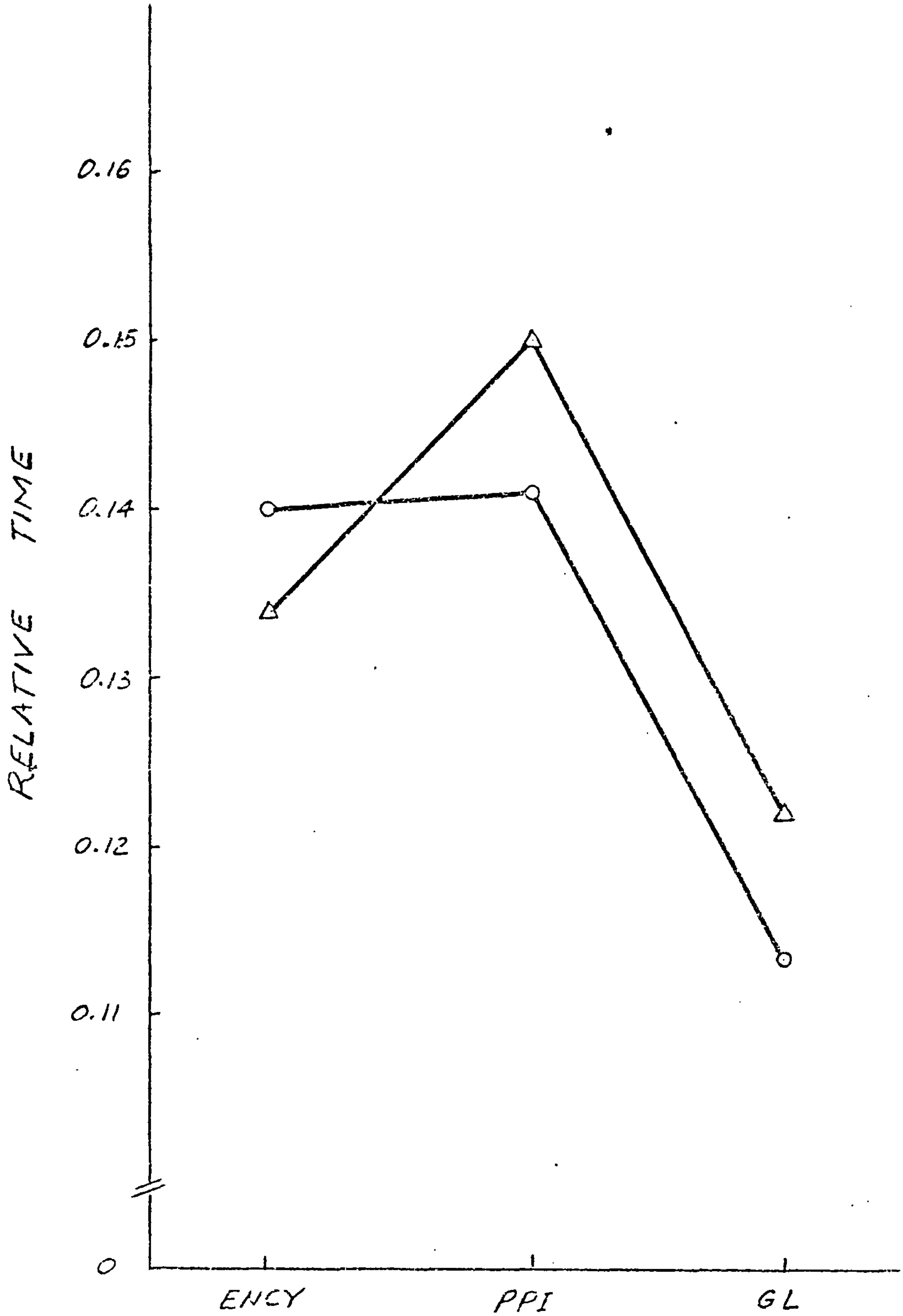


Figure 3-12. Means of RTBS2-C
Experiment #2

INC △
INT ○
C ———
D — — —
F ....

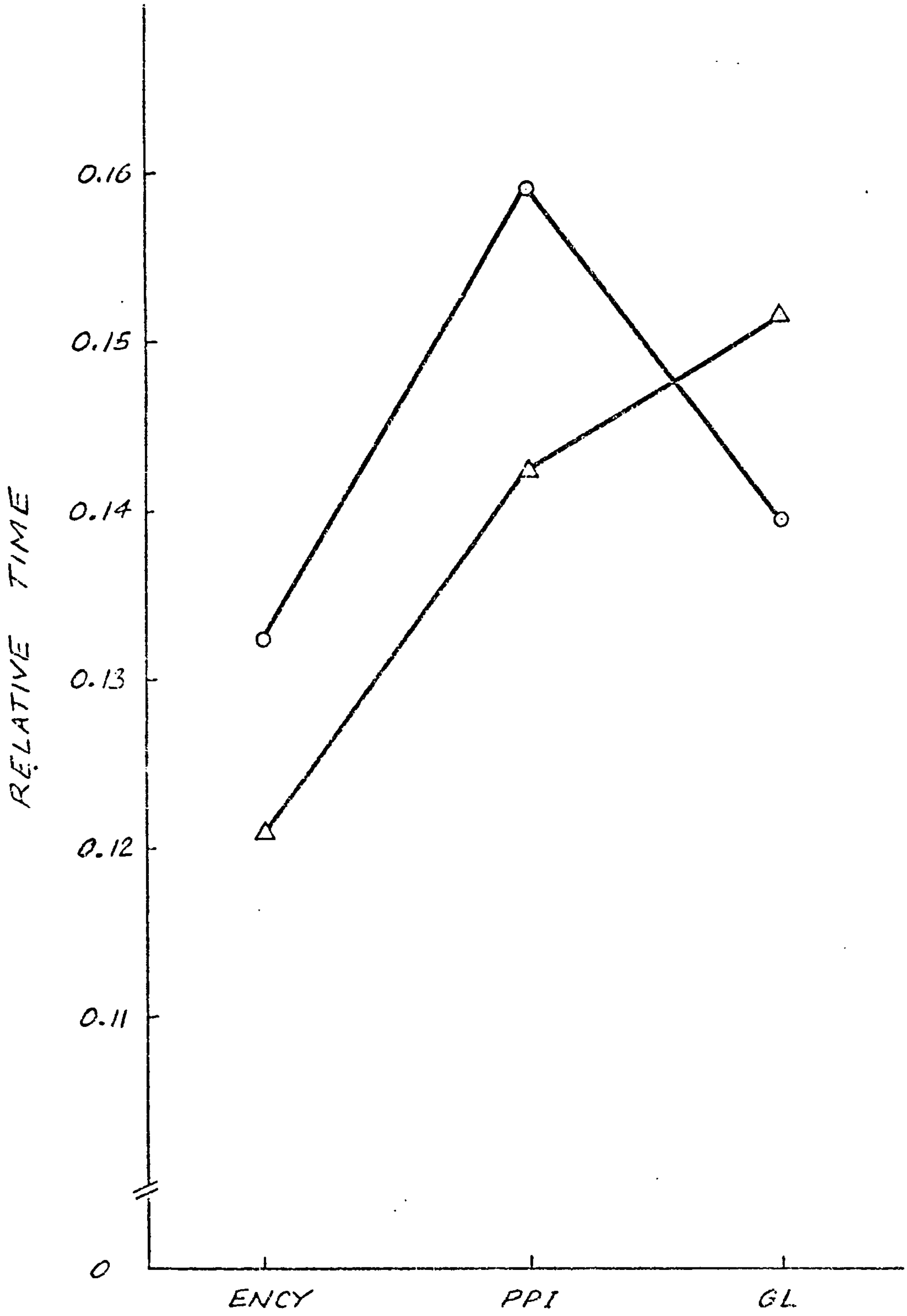


Figure 3-13. Means of RTBS4-C
Experiment #2

INC △
INT ○
C
D
F

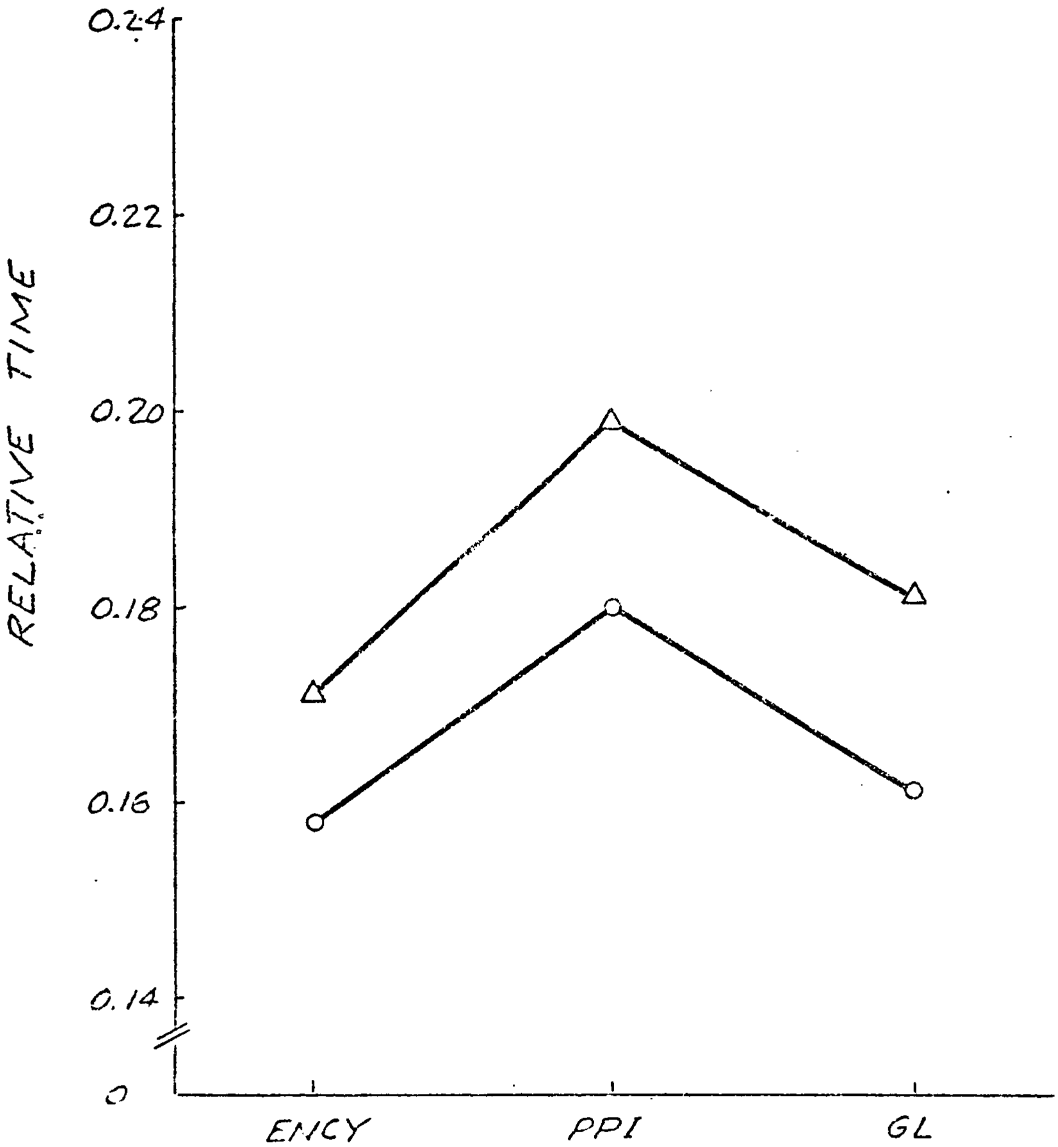
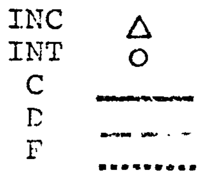


Figure 3-14. Means of RTBS5-C
Experiment #2



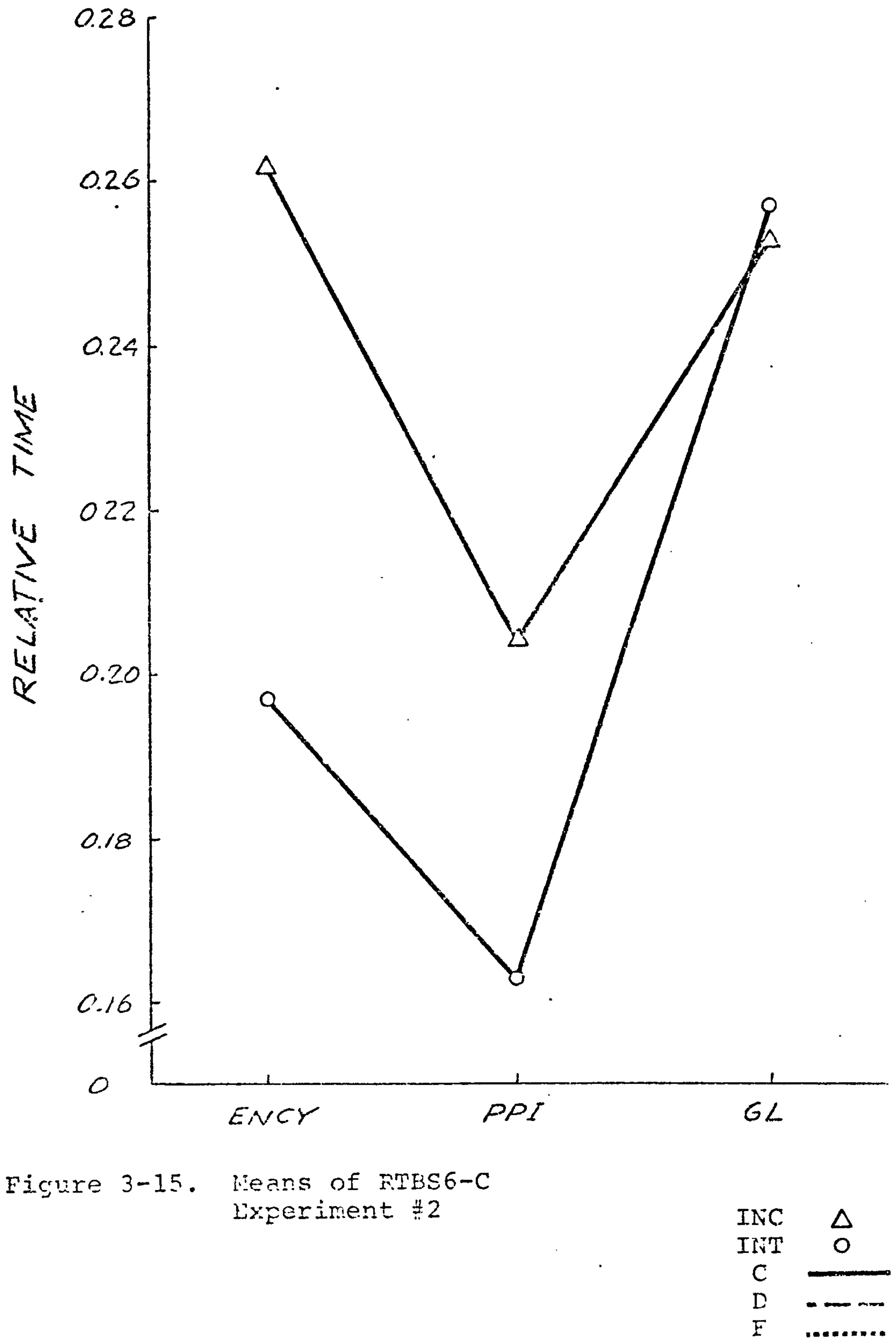


Figure 3-15. Means of RTBS6-C
Experiment #2

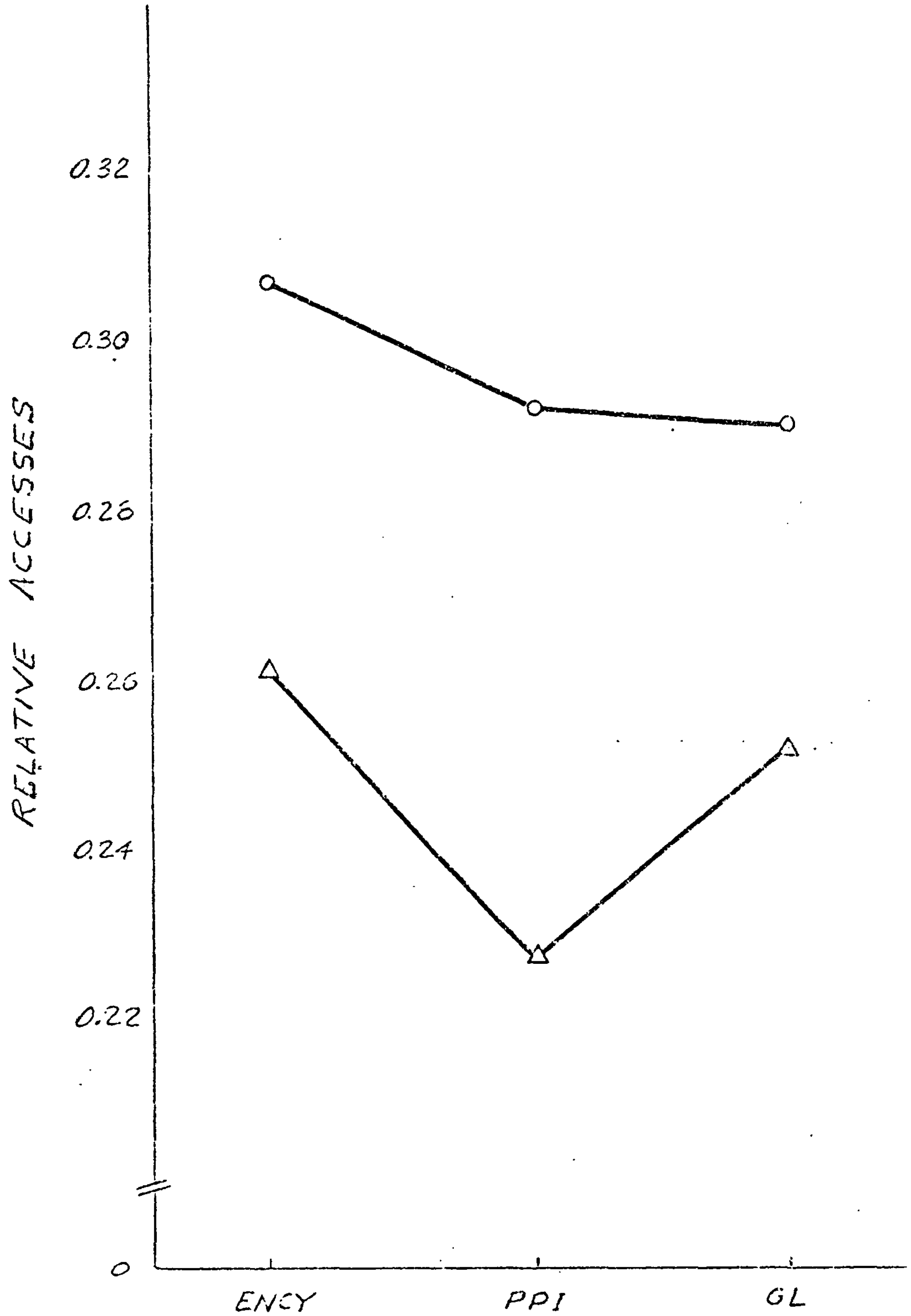


Figure 3-16. Means of RABS1-C
Experiment #2

INC △
INT ○
C
D
F

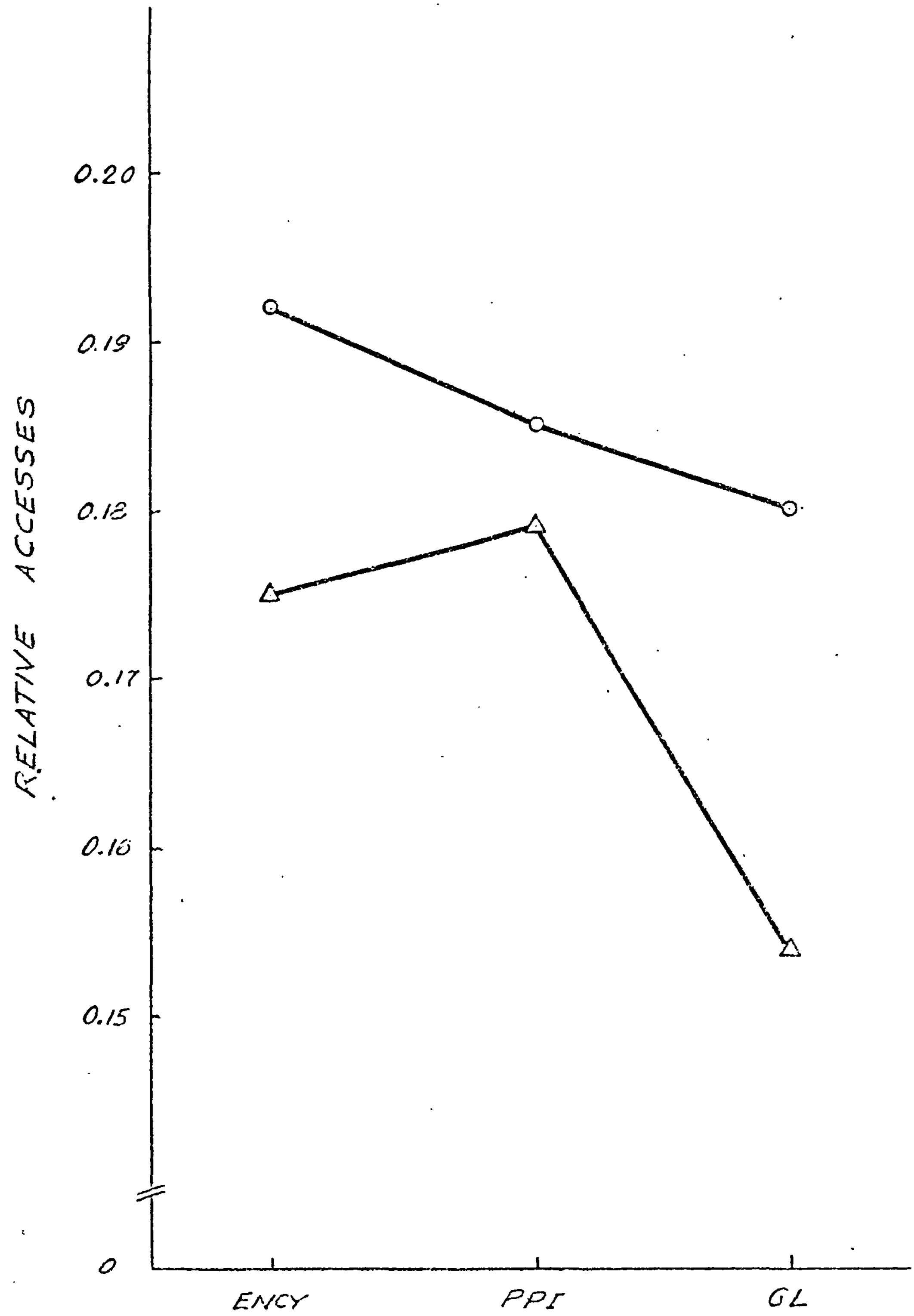


Figure 3-17. Means of RABS2-C
Experiment #2

INC △
INT ○
D
F

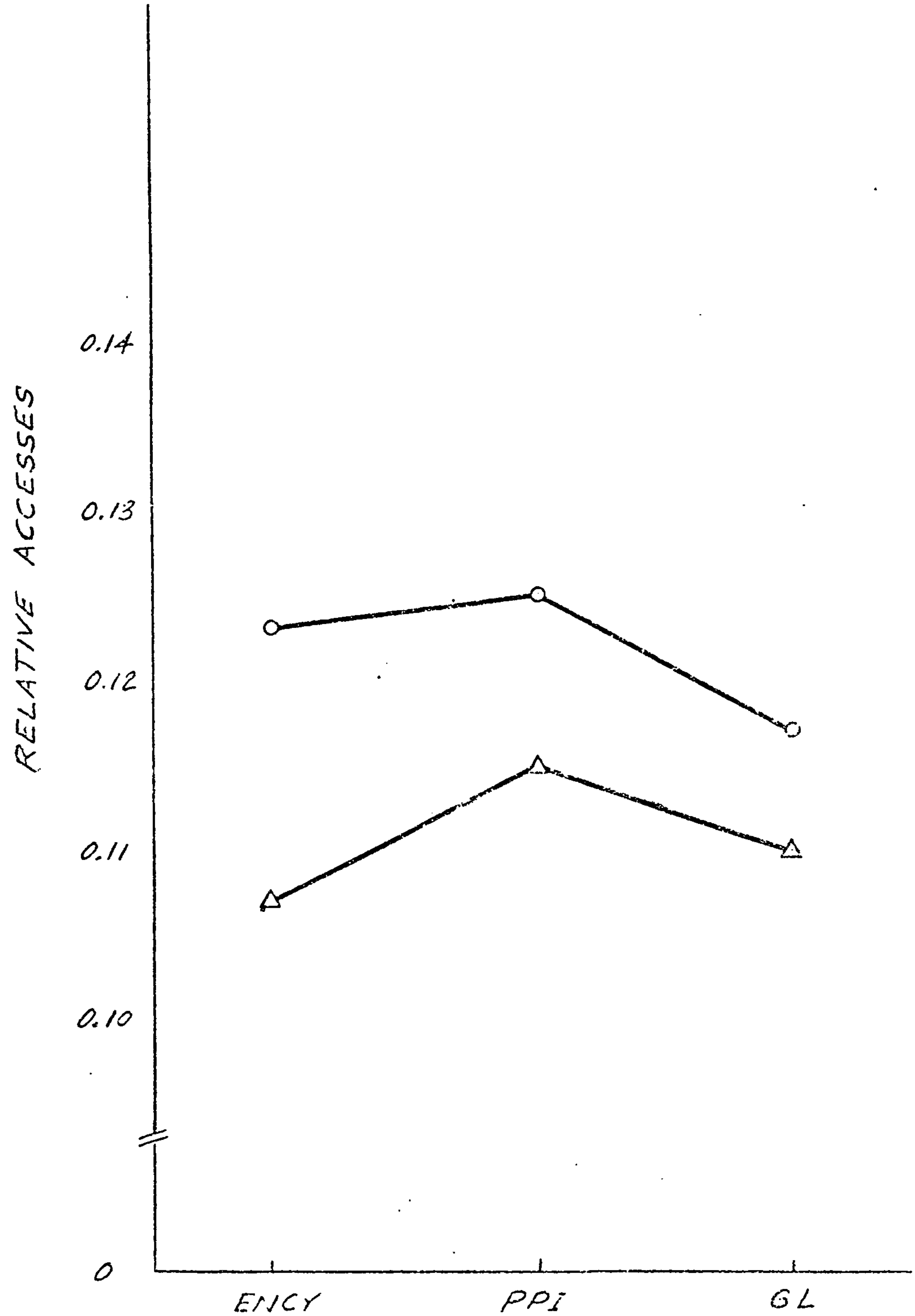
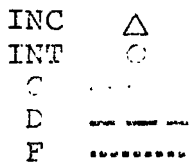


Figure 3-18. Means of RABS4-C
Experiment #2



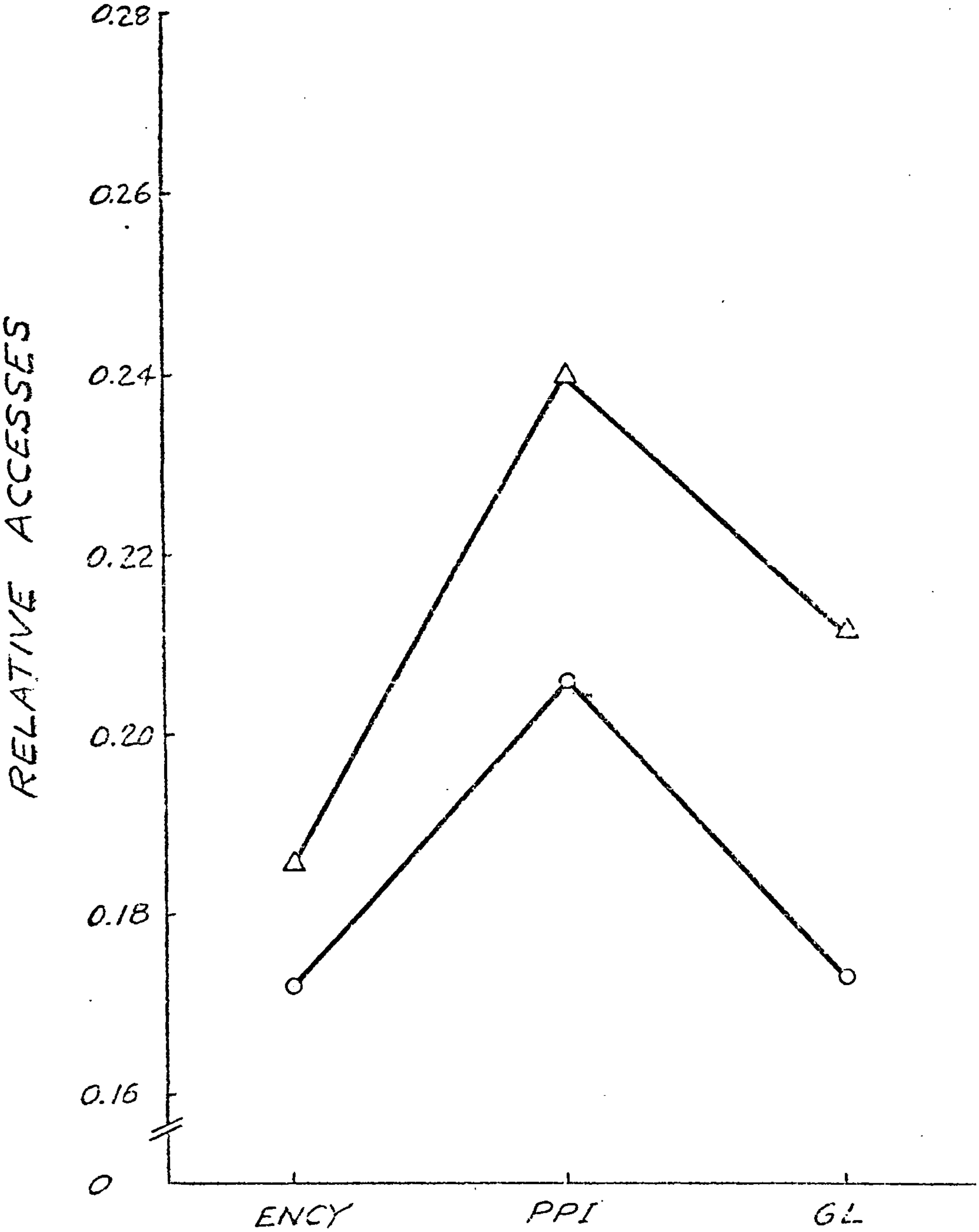


Figure 3-19. Means of RABS5-C
Experiment #2

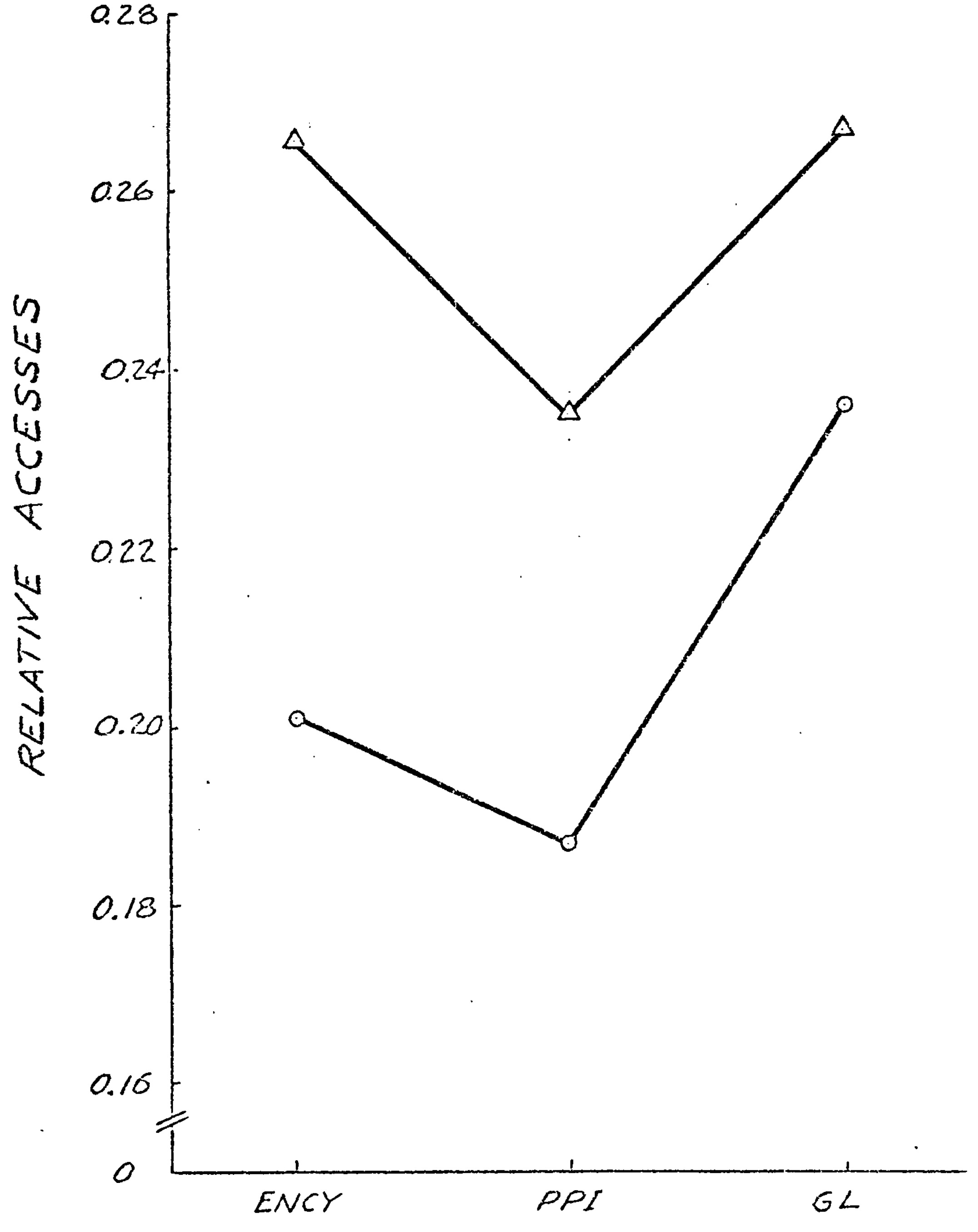


Figure 3-20. Means of RABS6-C
Experiment #2

highest Relative Accesses and Relative Time while PPI incremental has the lowest (Figure 3-21).

	ENCY	PPI	GL
INC		LO	
INT			HI

Figure 3-21. Comparison of Means
RABS4, RTBS4 - D
Experiment #2

The Chi-Squared test, examining the Relative Accesses and Relative Times spent during the composite course, would indicate that there was no difference between the observed means from cell to cell and an expected value of equal relative accesses or time (0.2). Thus, most of the cell means within any one of these parameters tended to be equivalent (see Tables VII, VIII and IX, pages 61-63).

While the Relative Accesses to Bite Set 1 were not different among the cells during the Fundamentals or Design portions of the Course, their Composite does combine into an implied row effect from the Design Schedule where the incremental cells of the PPI and GL controls were both relatively lower. The Relative Time in Bite Set 1, both in Fundamentals and the Composite, shows a Design Schedule effect that again is a factor of the low Relative Time of PPI incremental with the added factor that ENCY integral spent a higher Relative Time. However, taken separately, in a Scheffe test, the cell means were really not different. These "row effects" should therefore be considered with caution.

In Bite Set 2, the Composite means of the Relative Accesses were equivalent because the Design portion showed a relatively high access rate by the GL strategy, while on the other hand, the Fundamentals portion showed a relatively low access rate by the GL strategy. In particular, the relative accesses of the incremental group of GL were low. The Relative Time in Bite Set 2, both Composite and Fundamental, showed the same phenomenon (Figures 3-22 and 3-23).

	ENCY	PPI	GL
INC			LO
INT			LO

Figure 3-22. Comparison of Means
RABS2 F
Experiment #2

	ENCY	PPI	GL
INC.			HI
INT			HI

Figure 3-23. Comparison of Means
RABS2 - D
Experiment #2

There was a positive correlation between the Composite Relative Accesses to Bite Set 2 and three of the Post test scores. But Composite Relative Time in Bite Set 2 correlated only with the Post Fundamentals (Table X, page 64). There were no correlations with an alpha level of 0.05 for Bite Set 2 during Fundamentals or Design.

Relative Accesses to Bite Set 4 were different only at the Design stage where again there was a relatively high access rate by the GL integral cell and a low PPI incremental access rate. A similar imbalance appeared in the Relative Time during Design (Figure 3-21, page 75). Very nearly the reverse order of the cells' ranking in Relative Times was found during the Fundamentals portion of the course. The GL integral cell was conspicuously low (Figure 3-24).

	ENCY	PPI	GL
INC			
INT			LO

Figure 3-24. Comparison of Means
RTBS4 - F
Experiment #2

Relative Time in Bite Set 4, although not Relative Accesses to Bite Set 4, correlated positively with POST TOTAL and POST FUNDAMENTAL test scores in the composite course. During the Fundamentals portion, RTBS4 correlated positively with the subtotal POST TRANSFER (Table X, page 64).

The Relative Accesses and Relative Time spent in Bite Sets 5 and 6 (available to the student only during the Design state) were equivalent across the six groups. However, there are some correlations between the student's Relative Access and Relative Time in these two Bite Sets. RABS5 and RTBS5 show a positive correlation with POST TRANSFER test score. RABS6 and RTBS6 show a negative correlation with the POST test scores (Table X, page 64).

3.3.3 The Bite Unit Parameters

The ANOVA and correlation tables, XI, XII, XIII, and XIV, are found on pages 79 through 83 and are immediately followed by graphs of the means of selected parameters (Figures 3-26 through 3-30). The Utilization of the Bite Units in Bite Set 1 and the number of Distinctly Accessed Bite Units in Bite Set 1 showed a similar pattern during Fundamentals that remains unchanged in the Composite (Tables XI, XII). The cell means group roughly into three groups from high to medium to low values--the PPI integral and GL, the ENCY integral and PPI incremental, and the lone lowest--ENCY incremental (Figure 3-25).

	ENCY	PPI	GL
INC	LO	MED	HI
INT	MED	HI	HI

Figure 3-25. Comparison of Means
UBS1, DABU1 - C,F
Experiment #2

Neither UBS1 nor DABU1 showed differences in the cell means during the reviewing of the Bite Set in the Design stage.

The Utilization of individual Bite Units in Bite Set 1 showed no row effects in Bite Units 1 through 17 inclusive (Table XIII). Bite Units 18-20 were available only to GL students. Therefore, any row effects in Bite Set 1 must be the result either of:

TABLE XI

ANALYSIS OF VARIANCE EXPERIMENT #2
UTILIZATION OF BITE SETS

Parameter	$\overline{X}$	s	$\overline{X}_{11}$	$\overline{X}_{12}$	$\overline{X}_{13}$	$\overline{X}_{21}$	$\overline{X}_{22}$	$\overline{X}_{23}$	RxC F	ROWS F	COLS F
UBS1 C	.88	.12	.727	.826	.935	.858	.942	.927	4.18^{2}_{80}	8.80^{1}_{80}	11.6^{2}_{80}
UBS1 F	.88	.12	.749	.826	.936	.834	.939	.929	3.49^{2}_{92}	6.87^{2}_{92}	15.1^{2}_{92}
UBS1 D	.05	.09	.018	.049	.062	.096	.056	.039			
UBS2 C	.87	.14	.731	.966	.891	.701	.981	.883			40.6^{2}_{80}
UBS2 F	.84	.21	.708	.966	.842	.713	.911	.844			10.6^{2}_{92}
UBS2 D	.09	.20	.045	.000	.205	.124	.067	.092			3.12^{2}_{88}
UBS4 C	.86	.14	.728	.980	.842	.795	.957	.820			23.7^{2}_{80}
UBS4 F	.82	.20	.740	.980	.796	.784	.889	.740			8.65^{2}_{92}
UBS4 D	.07	.22	.047	.030	.006	.065	.071	.074		3.47^{1}_{88}	
UBS5 D	.57	.14	.475	.672	.702	.466	.537	.515	4.71^{2}_{88}	32.2^{1}_{88}	12.4^{2}_{88}
UBS6 D	.54	.13	.478	.595	.603	.473	.489	.544		7.15^{1}_{88}	4.82^{2}_{88}

TABLE XII

ANALYSIS OF VARIANCE EXPERIMENT #2
DISTINCTLY ACCESSED BITE UNITS

Parameter	$\overline{X}$	s	$\overline{X}_{11}$	$\overline{X}_{12}$	$\overline{X}_{13}$	$\overline{X}_{21}$	$\overline{X}_{22}$	$\overline{X}_{23}$	RxC F	ROWS F	COLS F
DABU1 C	17.6	2.4	14.6	16.5	18.7	17.2	18.9	18.6	4.18^{2}_{80}	8.47^{1}_{80}	11.2^{2}_{80}
DABU1 F	17.5	2.4	15.0	16.5	18.7	16.7	18.8	18.6	3.39^{2}_{92}	6.72^{1}_{92}	14.7^{2}_{92}
DABU1 D	1.1	1.9	0.4	1.0	1.2	1.9	1.1	0.8			
DABU2 C	10.5	1.7	8.8	11.6	10.7	8.4	11.8	10.6			40.4^{2}_{80}
DABU2 F	10.0	2.5	8.5	11.6	10.1	8.6	10.9	10.1			15.3^{2}_{92}
DABU2 D	1.1	2.4	0.5	0.0	2.5	1.5	0.8	1.1			3.14^{2}_{88}
DABU4 C	7.8	1.2	6.6	8.8	7.6	7.2	8.6	7.4			22.9^{2}_{80}
DABU4 F	7.4	1.8	6.7	8.8	7.2	7.1	8.0	6.7			8.67^{2}_{92}
DABU4 D	0.7	2.0	0.3	0.1	0.6	0.6	0.7	1.7		3.46^{1}_{88}	
DABU5 D	24.6	6.1	20.5	28.9	30.2	20.1	23.1	22.2	4.80^{2}_{88}	32.1^{1}_{88}	12.6^{2}_{88}
DABU6 D	20.5	4.8	18.2	22.6	22.9	18.0	18.6	20.7		7.17^{1}_{88}	4.84^{2}_{88}

TABLE XIII

ANALYSIS OF VARIANCE EXPERIMENT #2
NORMALIZED UTILIZATION OF
BITE UNITS 1-17 IN
BITE SET 1

Parameter	$\bar{X}$	s	$\bar{X}_{11}$	$\bar{X}_{12}$	$\bar{X}_{13}$	$\bar{X}_{21}$	$\bar{X}_{22}$	$\bar{X}_{23}$	RxC F	ROWS F	COLS F
NUBU1 C	0.98	0.15	1.00	0.94	1.00	1.00	1.00	1.00			
NUBU2 C	0.01	0.01	0.01	0.01	0.01	0.01	0.10	0.01			
NUBU3 C	0.31	0.18	0.22	0.46	0.22	0.29	0.50	0.19			35.5^{2}_{80}
NUBU4 C	0.21	0.15	0.22	0.28	0.08	0.31	0.33	0.09			35.2^{2}_{80}
NUBU5 C	0.09	0.05	0.08	0.12	0.06	0.76	0.14	0.06			31.6^{2}_{80}
NUBU6 C	0.03	0.02	0.04	0.03	0.01	0.04	0.36	0.02			22.8^{2}_{80}
NUBU7 C	0.19	0.17	0.25	0.29	0.02	0.29	0.33	0.05			57.1^{2}_{80}
NUBU8 C	0.03	0.02	0.03	0.03	0.02	0.03	0.04	0.02			8.23^{2}_{80}
NUBU9 C	0.39	0.44	0.22	0.82	0.04	0.27	1.00	0.04			139.0^{2}_{80}
NUBU10C	0.08	0.07	0.04	0.13	0.03	0.09	0.17	0.03			61.6^{2}_{80}

TABLE XIII (Continued)

Parameter	$\overline{X}$	s	$\overline{X}_{11}$	$\overline{X}_{12}$	$\overline{X}_{13}$	$\overline{X}_{21}$	$\overline{X}_{22}$	$\overline{X}_{23}$	RxC F	ROWS F	COLS F
NUBU11 C	0.12	0.07	0.13	0.12	0.10	0.15	0.15	0.09			3.41^{2}_{80}
NUBU12 C	0.07	0.05	0.07	0.10	0.03	0.09	0.11	0.03			29.5^{2}_{80}
NUBU13 C	0.09	0.06	0.06	0.12	0.06	0.10	0.13	0.07			9.23^{2}_{80}
NUBU14 C	0.46	0.45	0.39	0.94	0.05	0.40	1.00	0.07			148.0^{2}_{80}
NUBU15 C	0.07	0.06	0.05	0.14	0.03	0.06	0.11	0.03			47.6^{2}_{80}
NUBU16 C	0.08	0.06	0.06	0.09	0.06	0.07	0.15	0.07			14.3^{2}_{80}
NUBU17 C	0.04	0.03	0.04	0.05	0.02	0.05	0.06	0.02			23.0^{2}_{80}

TABLE XIV

PROBABILITY OF PEARSON'S COEFFICIENT OF CORRELATION ≤ 0.05
EXPERIMENT #2 UTILIZATION BITE SETS*

Parameter	PTOT	PFD	PFM	PTRS	PUN	R1TOT	R1FD	R1FM	R2TOT	STFT	STFD	STFM	LTFT	CONSOL
UBS2 C		.022												
UBS2 F				.046										
UBS4 F		.016												
UBS4 D				.025										
UBS6 D					.018	$.013^{-}$	$.012^{-}$							

* or equivalently, Distinctly Accessed Bite Units in the Bite Sets

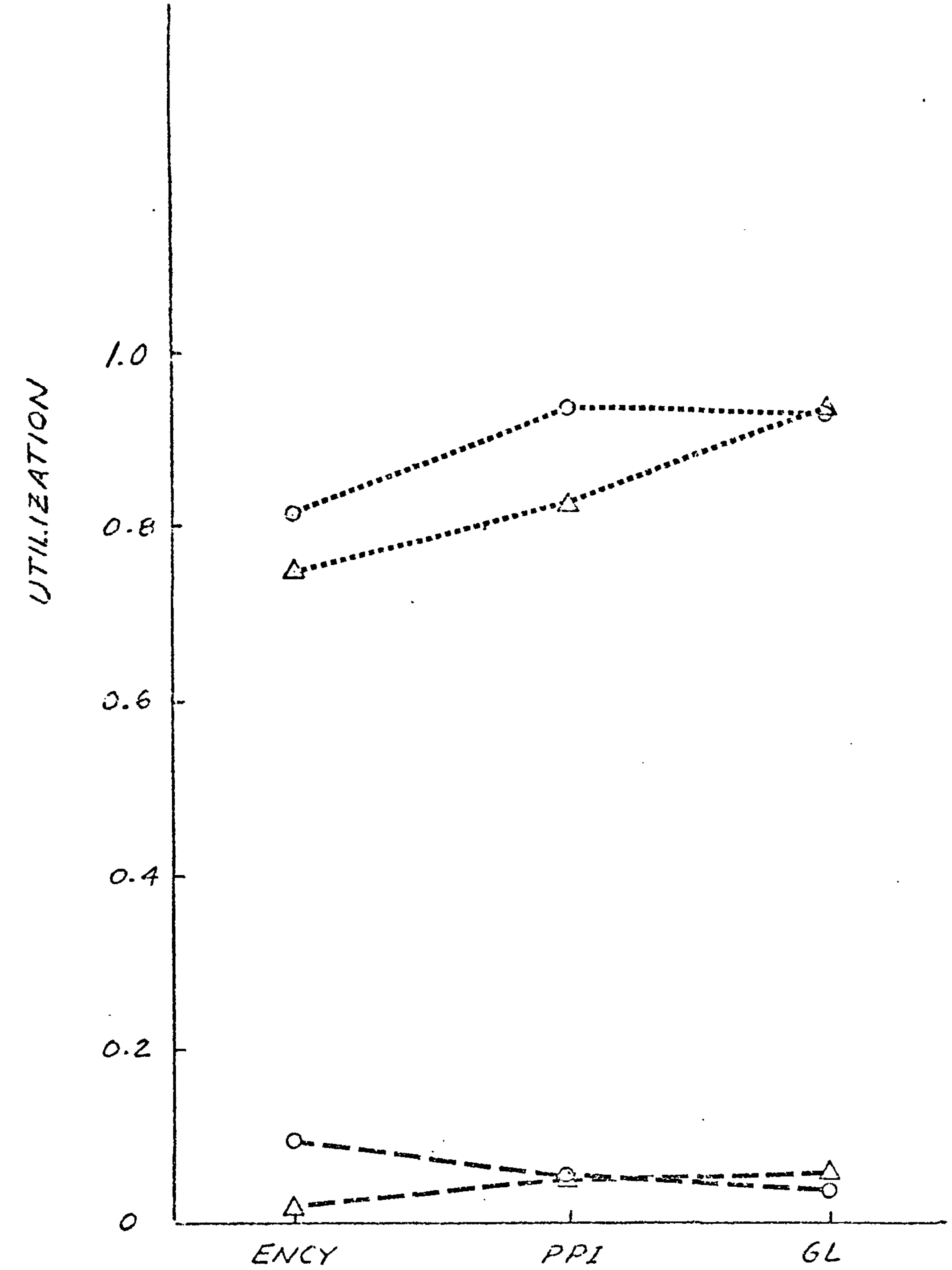
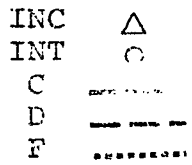


Figure 3-26. Means of UBS1-F,D
Experiment #2



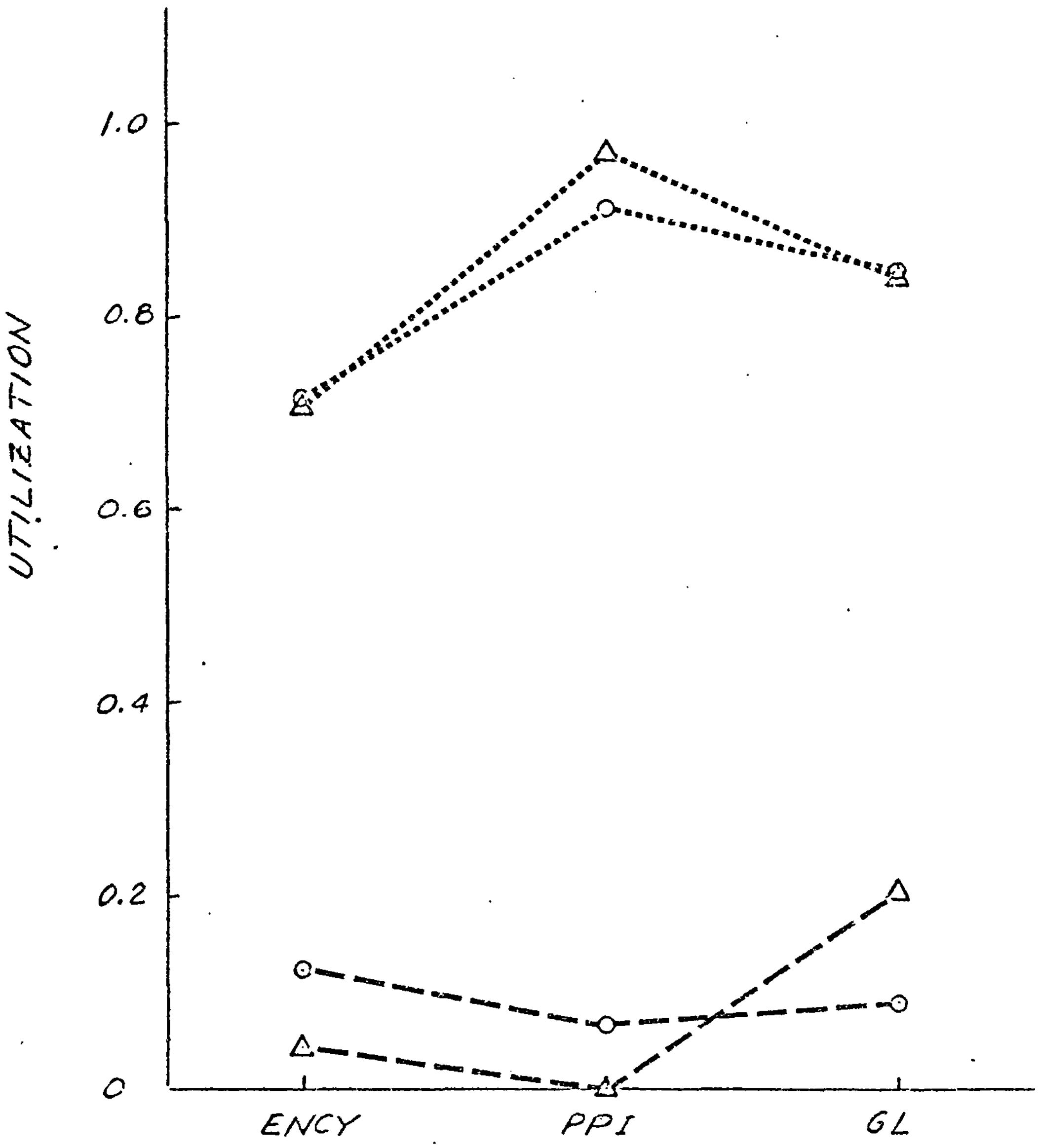


Figure 3-27. Means of UBS2-F,D
Experiment #2

INC
INT
C
D
F

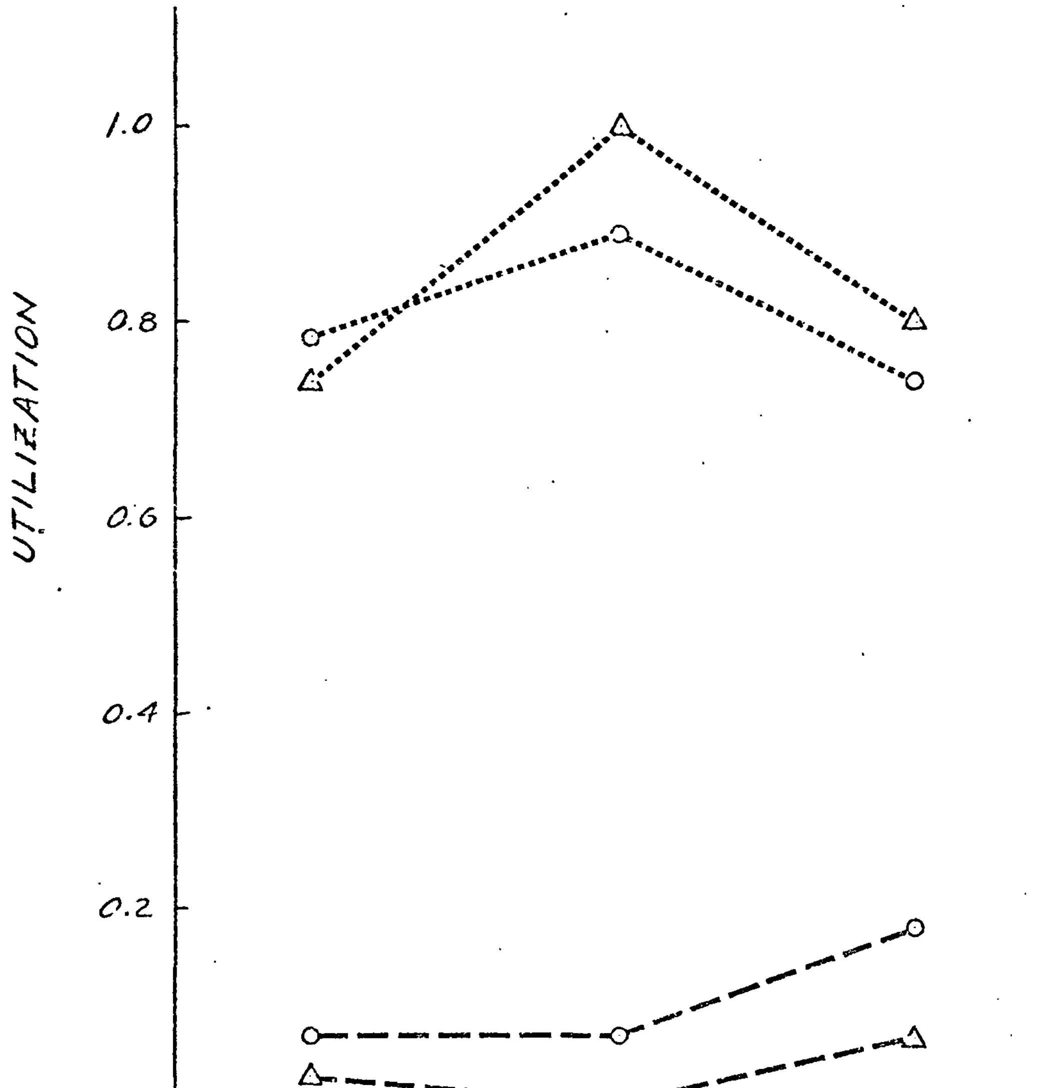


Figure 3-28. Means of UBS4-F,D
Experiment #2

INC △
INT ○
C
D
F

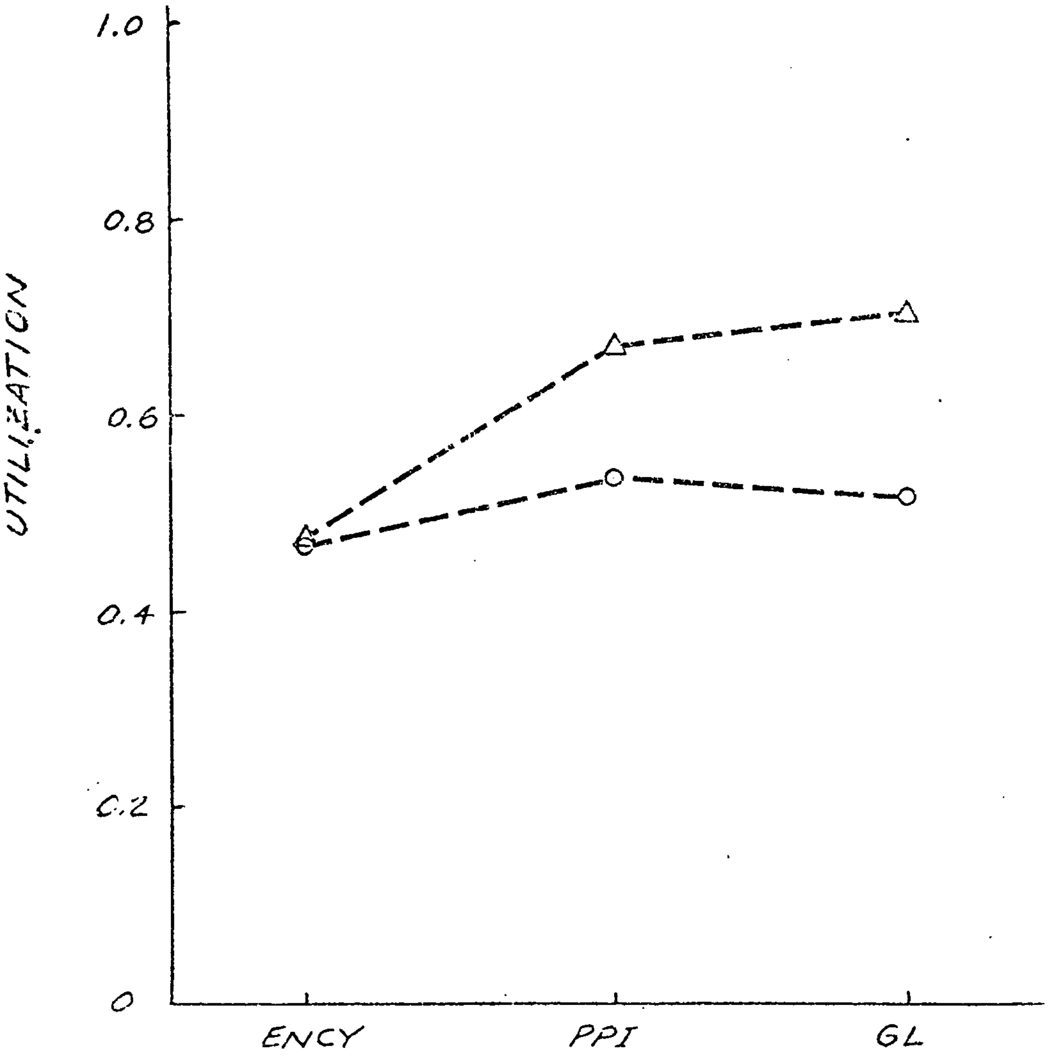


Figure 3-29. Means of UBS5-D
Experiment #2

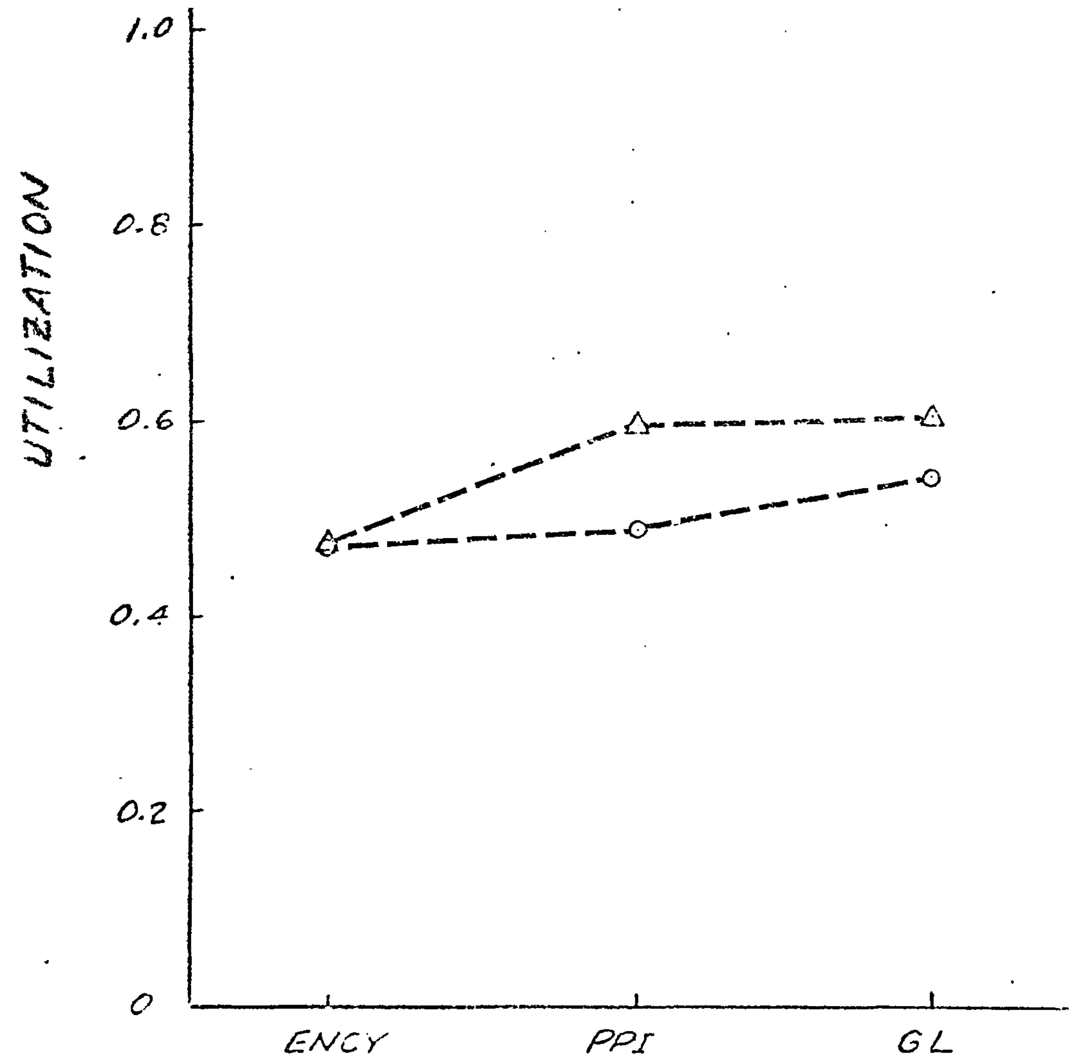
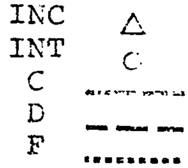


Figure 3-30. Means of UBS6-D
Experiment #2



(1) a peculiar total compounding of Design Schedule differences in the Bite Units that did not appear separately, or

(2) a difference in the accessations to Bite Units 18-20 by the two GL groups that accounted for the apparent Design Schedule effect where it had no cause to occur.

The parameters, Utilization of Bite Set 2 and the Distinctly Accessed Bite Units in Bite Set 2, were cleaner in the differences to be seen among the instruction control effects during the Fundamentals stage. These effects are strong enough to re-appear in the Composite in spite of very different column effects that appear during the Design portion (Figures 3-31 and 3-32).

	ENCY	PPI	GL
INC	LO	HI	MED
INT	LO	HI	MED

Figure 3-31. Comparison of Means
UBS2, DABU2 - F
Experiment #2

	ENCY	PPI	GL
INC		LO	HI
INT		LO	HI

Figure 3-32. Comparison of Means
UBS2 and DABU2 - D
Experiment #2

Clear column effects of the same pattern as BS2 are seen in Bite Set 4 for Fundamentals and Composite. The Design portion shows essentially no difference between the Design Schedule effects of UBS4 and DABU4. However, the same general pattern existed that was seen in the Relative Accesses and the Relative Time of Bite Set 4 during the Design portion. The GL integral accessed a higher number of Bite Units compared with the other cells, and in particular compared with PPI incremental.

Both Bite Sets 2 and 4 showed the Utilization parameter and the Distinctly Accessed Bite Units parameter correlating with the test scores in the same manner; a positive correlation with the POST TRANSFER test subtotal during Fundamentals, and with the POST FUNDAMENTALS test subtotal in the Composite. There were no correlations of the Fundamental Bite Structure parameters with the FUNDAMENTALS test scores that were found. All the Bite Set 2 and 4 parameters--UBS, RABS, RTBS, and DABU--correlate positively with POST TRANSFER scores while the Bite Set 1 relative parameters correlate negatively with these same test scores (Tables XIV, page 83, and X, page 64).

The Utilization of the Bite Units and the Distinctly Accessed Bite Units of Bite Sets 5 and 6 both had the same pattern. The most important item to observe is that the two ENCY groups were conspicuously low while the PPI incremental and GL incremental were high. In general, there is a division in all four cases that looks like Figure 3-33.

	ENCY	PPI	GL
INC		HI	HI
INT			

Figure 3-33. Comparison of Means
UBS5, UBS6, DABU5, DABU6 - D
Experiment #2

A row effect was seen in the Design Schedule, the Utilization and Distinct Accesses of the Incremental students being greater than that of the Integral students.

The column effect is such that ENCY was considered different from the others but GL and PPI were essentially equivalent. Also the instruction control (column) effect of ENCY was sufficient to dampen the Design Schedule (row) effect within itself. There was no difference between the means of ENCY incremental and ENCY integral.

There was a negative correlation between the UBS6 and the RETENTION 1 TOTALS test score that was repeated by the DABU6 parameter. All of the correlations between tests (except for the "unanswered" subtotal of the tests) and Bite Set 6 were negative (Table XIV, page 83).

3.3.4 Test Scores

The ANOVA table, Table XV, for the parameters is found on page 92. The three major tests, Post, Retention 1, and Retention 2, numbering 16 with their subtotals and combinations, are most to be noted for the consistent lack of [illegible] of any test.

TABLE XV

ANALYSIS OF VARIANCE EXPERIMENT #2
TEST SCORES IN PERCENT

Parameter	$\overline{X}$	s	$\overline{X}_{11}$	$\overline{X}_{12}$	$\overline{X}_{13}$	$\overline{X}_{21}$	$\overline{X}_{22}$	$\overline{X}_{23}$	RxC F	ROWS F	COLS F
PTOT	59	15	57	59	60	61	62	56			
PFD	46	10	45	46	46	50	48	43			
PFM	8	5	10	8	7	9	8	7			
PTRS	4	5	1	5	5	5	6	2			
PUN	15	12	16	19	14	14	16	12			
R1TOT	18	6	67	41	53	30	61	47			
R1FD	10	3	36	30	26	28	37	25			
R1FM	7	4	31	11	25	2	25	22			
R2TOT	80	16	79	83	74	88	82	78			
STFT	71	19	- 8	18	13	25	1	5			
STFD	18	11	12	14	21	24	13	21			
STFM	-15	14	-20	- 2	-14	1	-20	-17			
LTFT	-21	20	-20	-22	-13	-30	-18	-22			
CONTOT	34	25	-20	53	45	56	26	32	4.35^{2}_{12}		

The Post test scores are variable as seen in Table XIV, page 83. The general appearance of Post tests is shown in Figure 3-34.

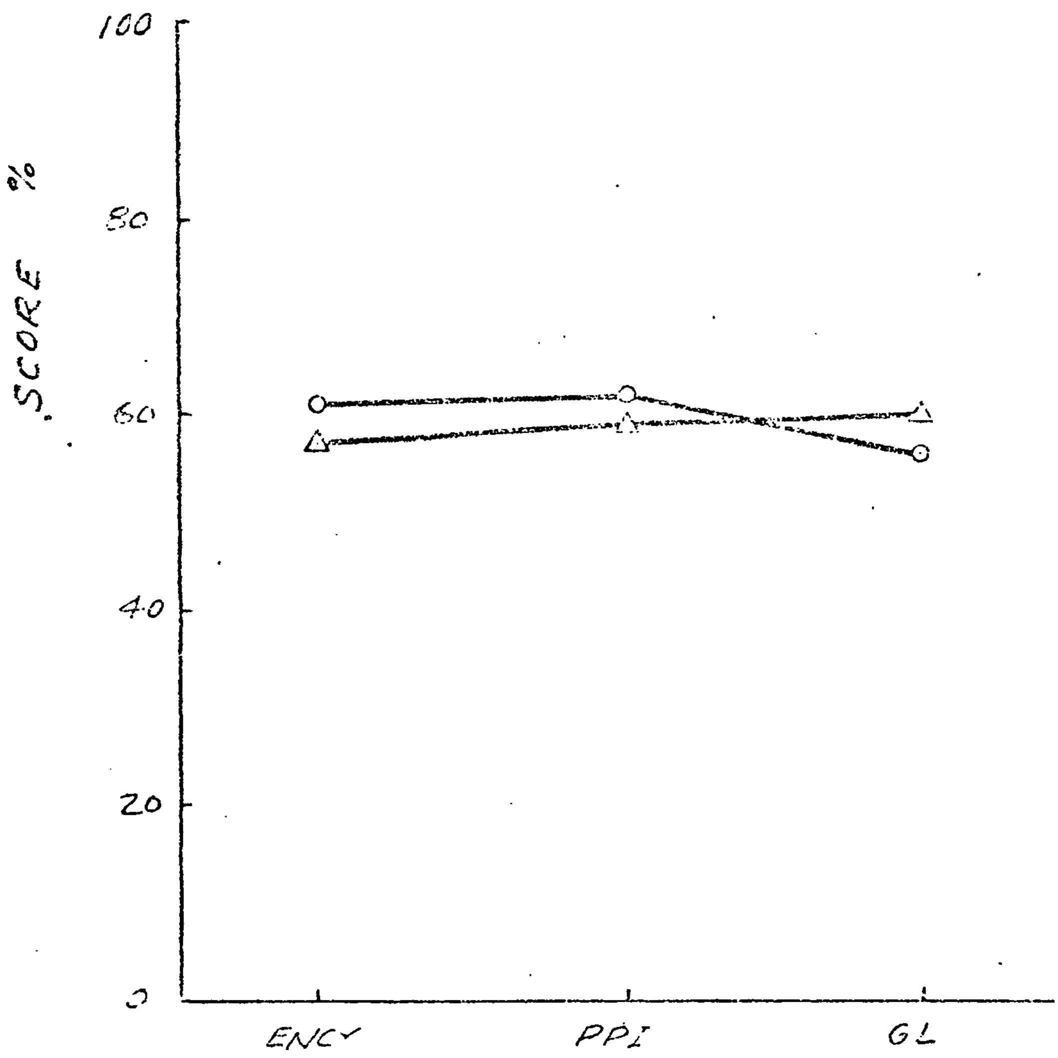


Figure 3-34. Means of Post Test Totals
Experiment #2

TABLE XVI

VARIATION IN POST TEST SCORE OBSERVATIONS

Statistic \ Test	PTOT	PFD	PFM	PTRS	PUN
$\overline{X}$	59	46	8	4	15
s	15	10	5	5	12
Range of X_{ij}'s	6	7	3	5	7

A serious difficulty in the analyses of the Retention 1 test scores was that the total number of observations, 22, provided very low frequencies in the cells. The total set of observations in both cells of ENCY control was three (Figure 3-35). Therefore, the results of the analyses on this test and those connected with it, such as Short-term Forgetting and Consolidation, needed to be considered cautiously.

	ENCY	PPI	GL
INC	2	3	4
INT	1	5	7

Figure 3-35. Cell Frequencies
Retention 1 Test

A graph of the means of the Retention 1 test totals is found in Figure 3-36, page 96.

The Retention 2 test had no reliable sub-totals to analyze but the 70 observations formed reasonably-sized cell frequencies, and the results are of some interest. There was a grand mean of 80, noticeably higher than the test means of Post and Retention 1. Unfortunately, an overall standard deviation of 16 dominated the maximum difference between the means which was 14 (Table XV, page 92). The means of the Retention 2 test score totals are graphed in Figure 3-37, page 97.

The Short-term Forgetting, Post - Retention 1, was very much affected by the low frequencies of Retention 1.

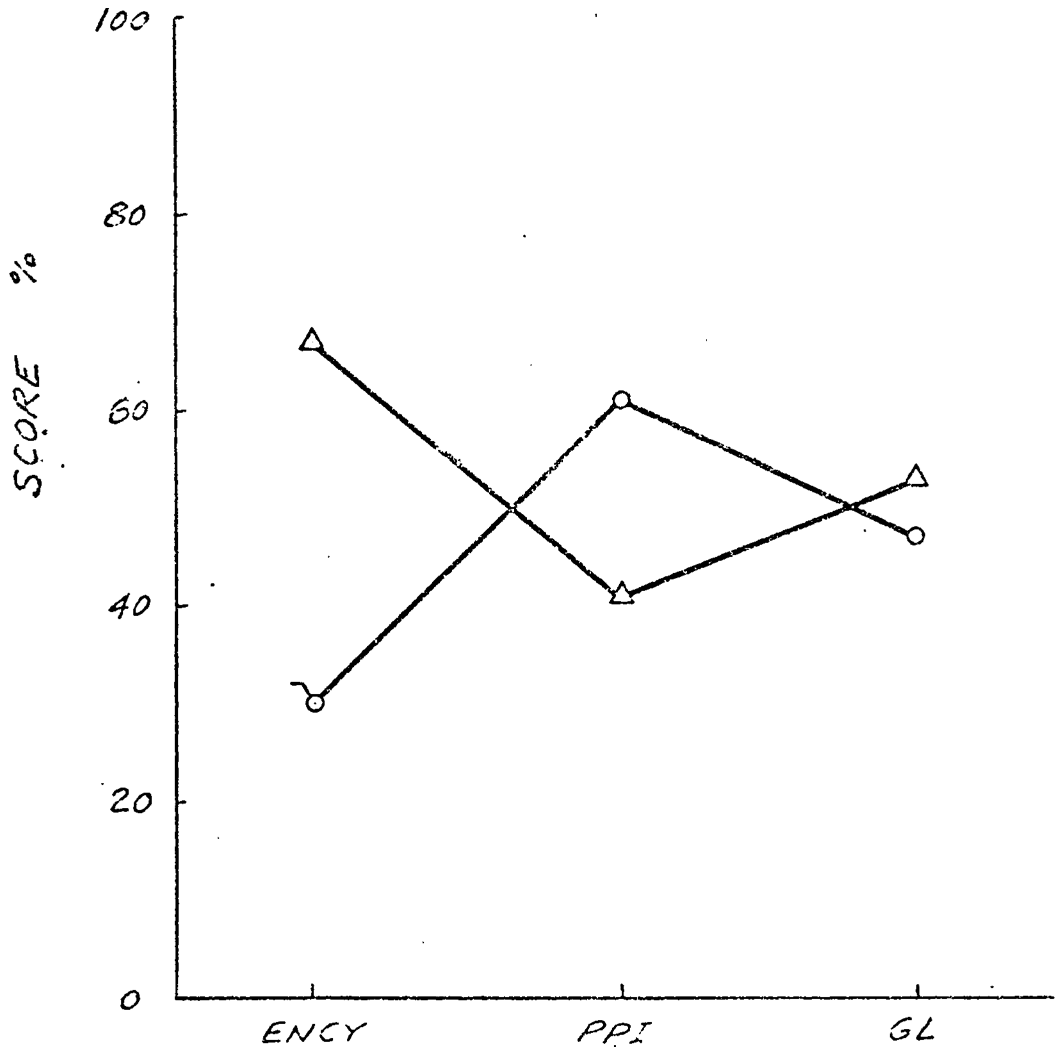


Figure 3-36. Means of Retention 1 Totals
Experiment #2
⌐ denotes low cell frequency

INC △
INT ○
C
D
F

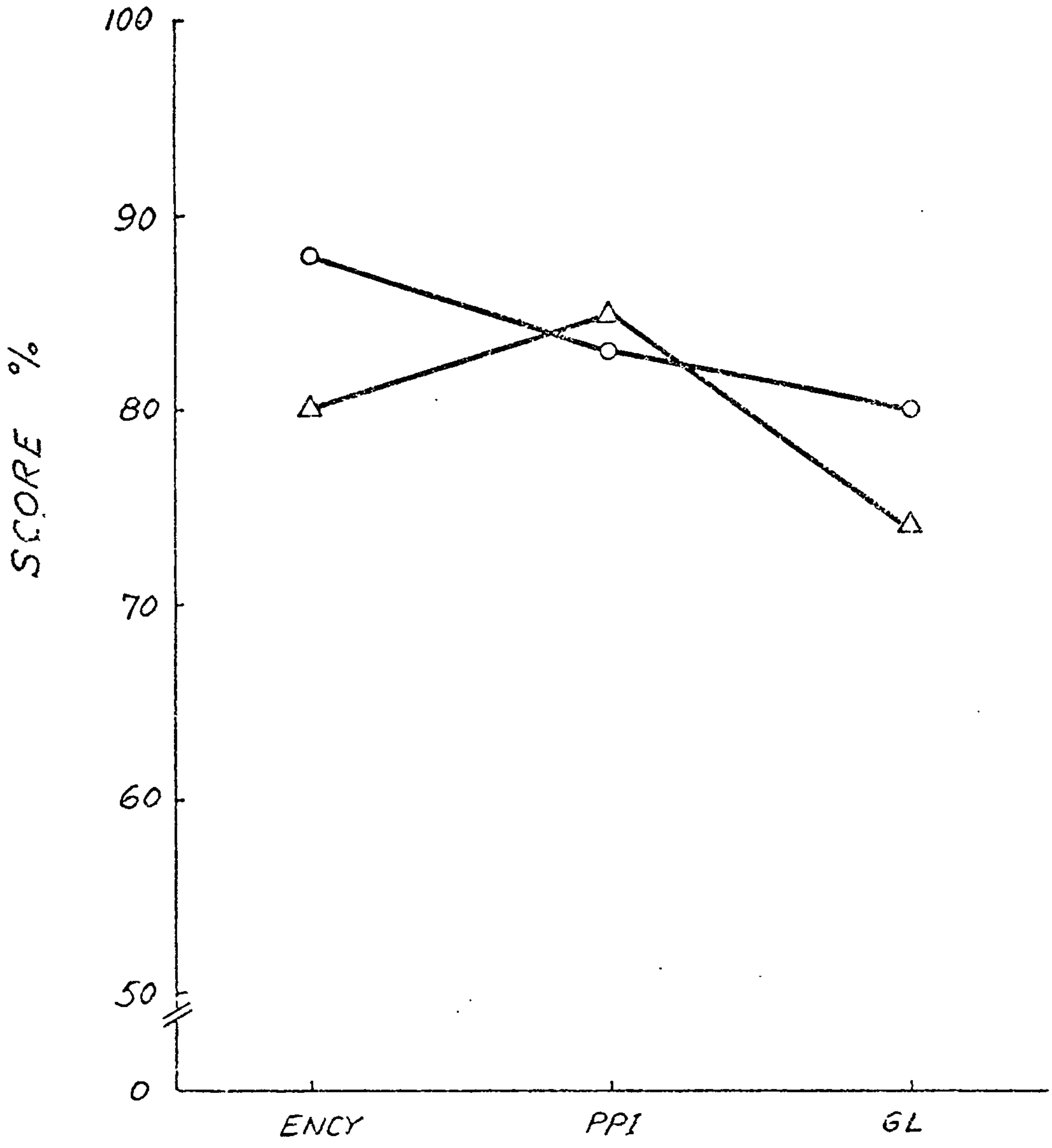


Figure 3-37. Means of Retention 2 Totals
Experiment #2

INC △
INT ○
C
D
F

Somewhat of a simple row reversal of Retention 1 was apparent (Figure 3-39, page 99).

The Long-term Forgetting, Post - Retention 2, were not really forgetting scores at all. All the cell means were negative, implying consolidation occurred in the five weeks between the Post and the Retention 2 tests (Figure 3-40, page 100).

The Consolidation scores, Retention 2 - Retention 1, showed an interaction effect that must be considered cautiously, if at all, because of the low cell frequencies (Figures 3-41, page 101). All that can be claimed is that the score of the one student in ENCY incremental is different from the others (Figure 3-38).

	ENCY	PPI	GL
INC	1	3	2
INT	1	4	7

Figure 3-38. Cell Frequencies
Consolidation Test Scores

3.3.5 The Processing Rates

The ANOVA tables, Tables XVII and XVIII, for the parameters are found on pages 102 and 103 and are immediately followed by graphs of the means of selected parameters (Figures 3-42 through 3-47).

These compound parameters tend to amplify the differences in the six interaction strategies by dividing out the spurious conditions. The smallest bite set, [illegible]

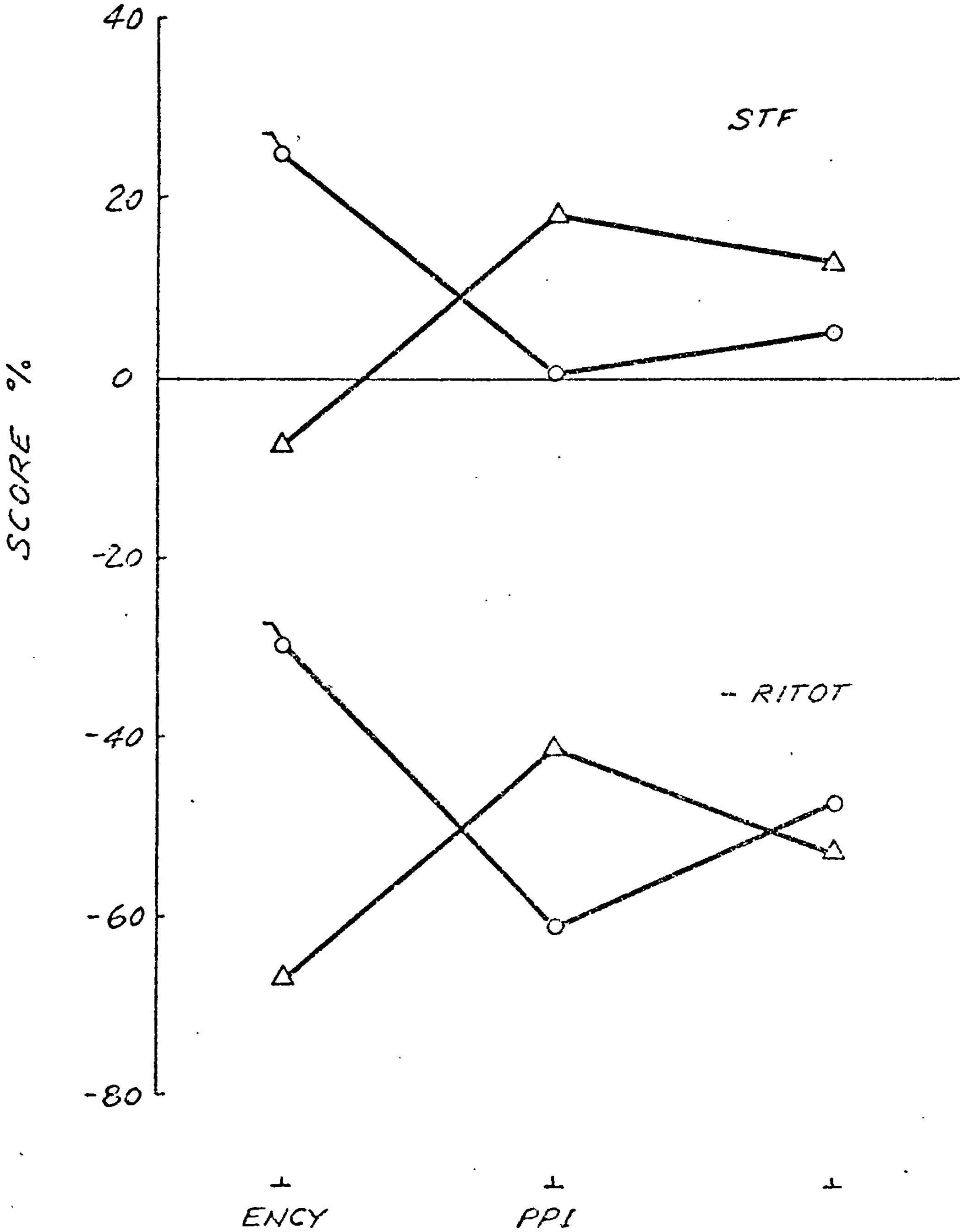


Figure 3-39. Means of STFT and -R1TOT
Experiment #2

INC △
INT ○
C
D
F

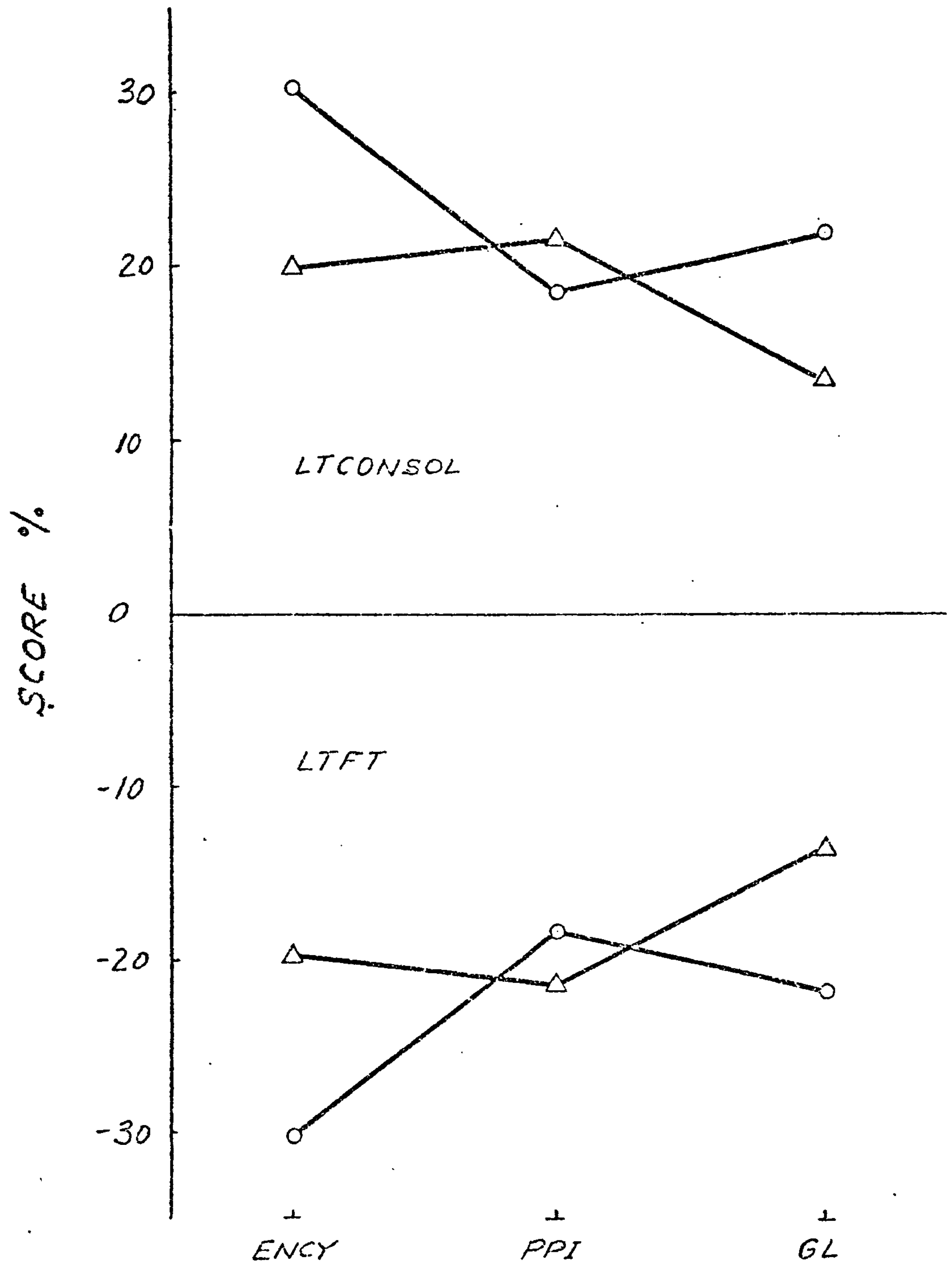


Figure 3-40. Means of LTFT and LTCONSOL Experiment #2

INC △
INT ○
C
D
F

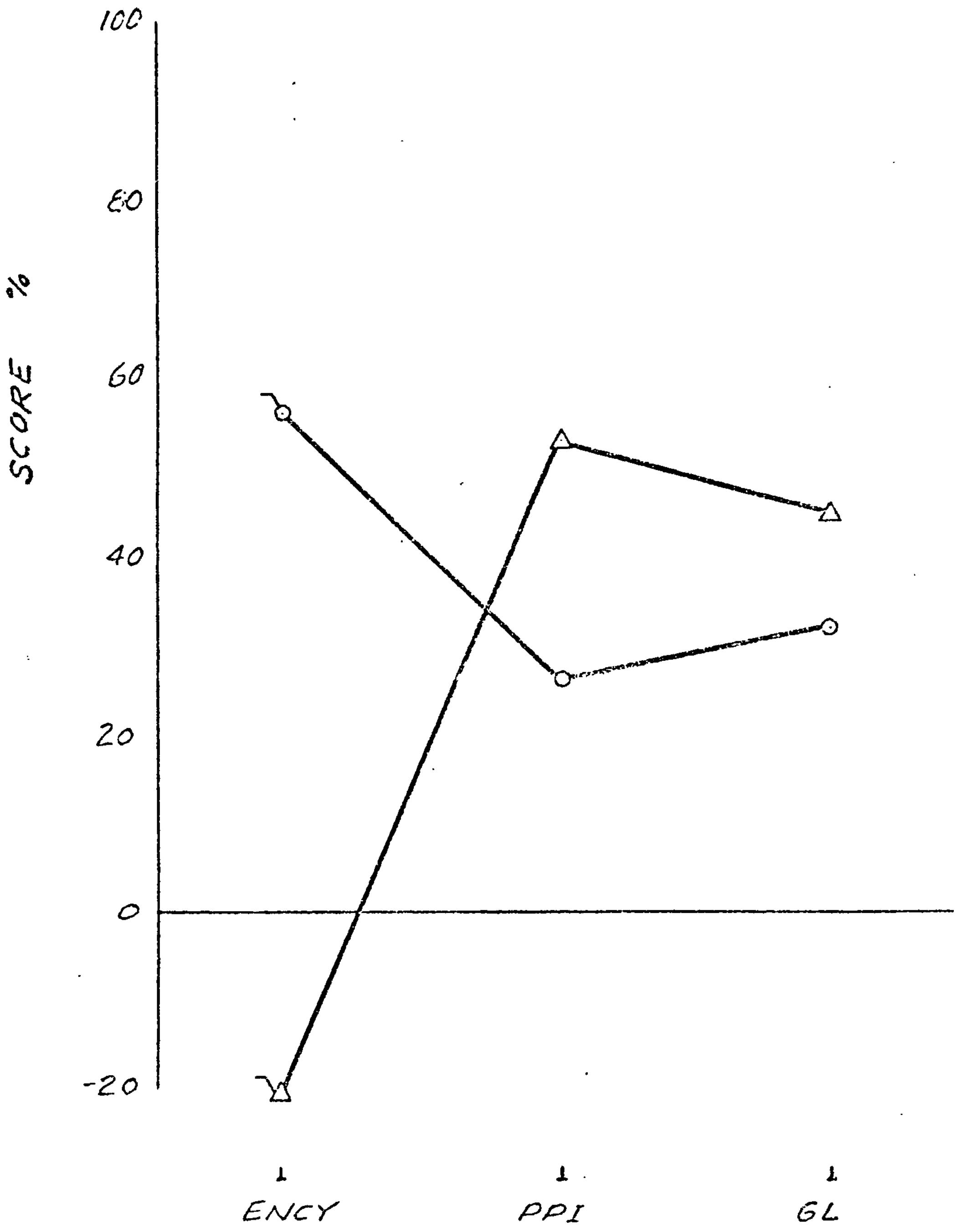


Figure 3-41. Means of Consolidation Test
Experiment #2
⌝ denotes low cell frequency

INC △
INT ○
C
D
F

TABLE XVII

ANALYSIS OF VARIANCE EXPERIMENT #2
PROCESSING RATES IN ACCESSED BITES/HOUR

Parameter	$\overline{X}$	s	$\overline{X}_{11}$	$\overline{X}_{12}$	$\overline{X}_{13}$	$\overline{X}_{21}$	$\overline{X}_{22}$	$\overline{X}_{23}$	RxC F	ROWS F	COLS F
PRU C	70.9	15.6	60.1	80.1	73.6	59.7	76.5	68.6			10.0^{2}_{80}
PRU F	67.3	17.8	56.6	70.3	69.2	58.1	72.9	72.9			6.81^{2}_{92}
PRU D	77.2	19.6	62.5	95.5	81.4	64.3	84.2	66.9		11.6^{1}_{88}	
PR1 C	60.3	17.4	51.8	60.4	66.0	50.0	63.7	63.6			4.63^{2}_{80}
PR1 F	60.3	18.1	52.5	59.0	66.2	50.4	65.7	64.8			5.60^{2}_{92}
PR1 D	78.5	101.7	9.0	174.9	23.7	32.6	170.5	30.1			43.5^{2}_{88}
PR2 C	94.9	22.6	80.1	97.1	91.8	81.9	100.1	108.2			6.43^{2}_{80}
PR2 F	91.5	28.9	75.3	97.1	89.4	79.9	98.8	101.8			4.85^{2}_{92}
PR2 D	32.7	54.0	46.0	0.0	58.9	52.4	4.1	42.8			10.3^{2}_{88}
PR4 C	60.6	18.4	59.5	65.8	55.8	55.5	64.4	61.3			
PR4 F	62.3	26.6	53.6	66.1	56.5	57.6	65.0	70.8			
PR4 D	8.4	21.7	8.4	2.0	6.9	14.4	5.3	14.6			
PR5 D	81.9	22.1	66.1	99.4	85.7	66.3	89.2	75.7		5.81^{1}_{88}	15.4^{2}_{88}
PR6 D	73.8	24.6	59.8	92.9	72.4	59.3	86.0	64.7		3.15^{1}_{88}	15.3^{2}_{88}

TABLE XVIII

ANALYSIS OF VARIANCE EXPERIMENT #2
PROCESSING RATES IN DISTINCT
ACCESSES/HOUR

Parameter	$\bar{X}$	s	$\bar{X}_{11}$	$\bar{X}_{12}$	$\bar{X}_{13}$	$\bar{X}_{21}$	$\bar{X}_{22}$	$\bar{X}_{23}$	RxC F	ROWS F	COLS F
PR1 C	16.6	5.0	15.8	16.2	20.8	12.9	16.0	16.4		7.39^{1}_{80}	6.64^{2}_{80}
PR1 F	16.9	5.0	15.4	16.5	21.3	13.2	16.8	17.1		6.33^{1}_{92}	9.70^{2}_{92}
PR1 D	57.1	96.1	9.2	112.5	17.4	33.0	127.8	25.0			14.3^{2}_{88}
PR2 C	24.7	9.0	23.7	22.7	27.7	18.1	25.0	28.7			5.68^{2}_{80}
PR2 F	24.4	10.2	21.8	22.6	29.2	18.8	23.4	28.0			6.63^{2}_{92}
PR2 D	17.2	32.4	29.3	0.0	27.8	38.9	1.3	14.4			9.94^{2}_{88}
PR4 C	17.5	6.9	21.7	18.3	16.4	15.5	17.6	16.7			
PR4 F	18.8	11.3	21.1	18.4	15.9	16.1	18.3	22.8			
PR4 D	3.9	11.7	5.1	0.5	3.8	8.8	1.3	5.3			
PR5 D	41.6	12.8	39.1	42.5	51.2	35.0	40.6	39.1		6.76^{1}_{88}	3.10^{2}_{88}
PR6 D	28.8	10.7	25.0	32.8	30.0	24.3	32.4	26.4			4.10^{2}_{88}

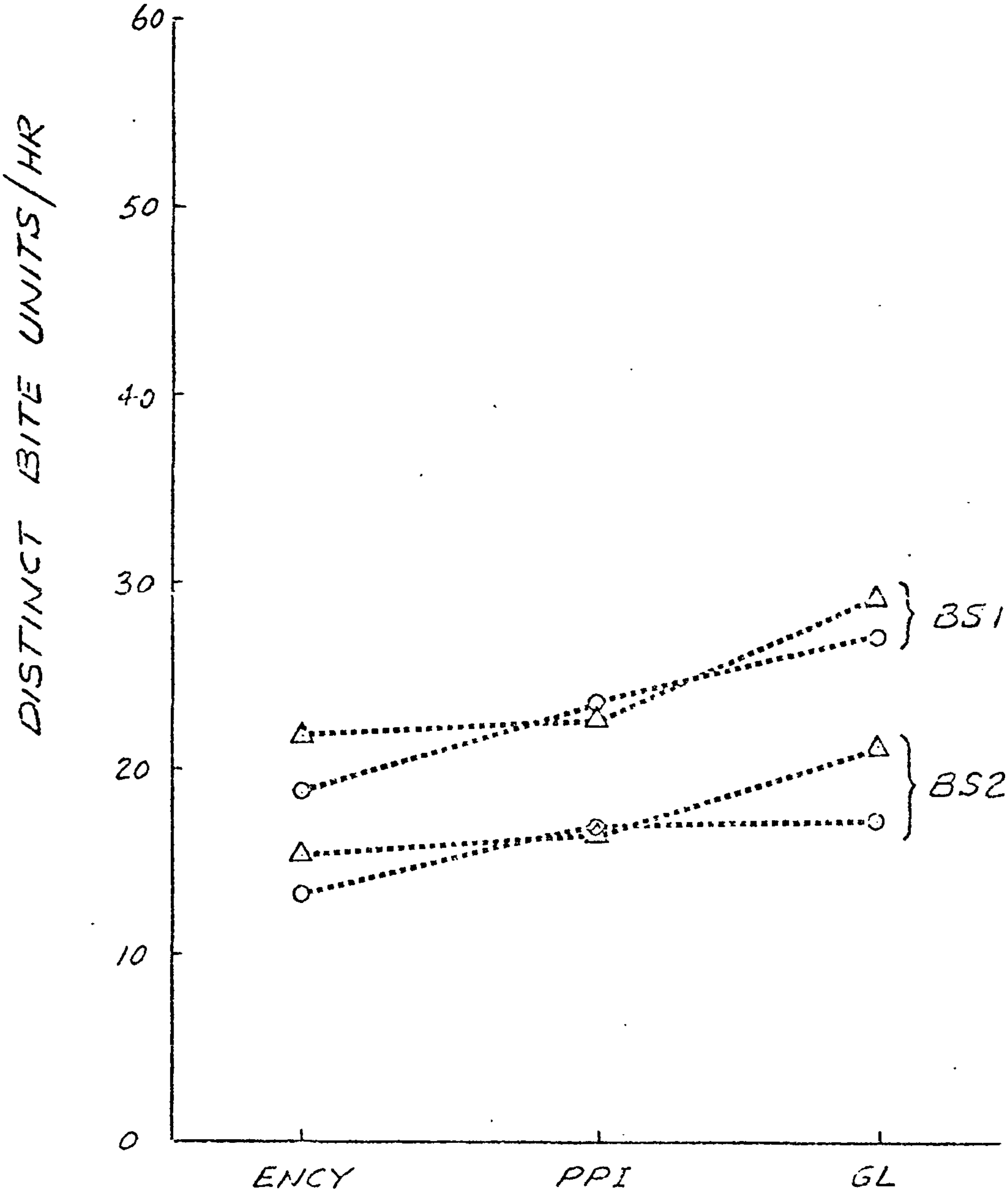


Figure 3-42. Means of PR1, PR2-F (DABU)
Experiment #2

INC △
INT ○
C
D
F

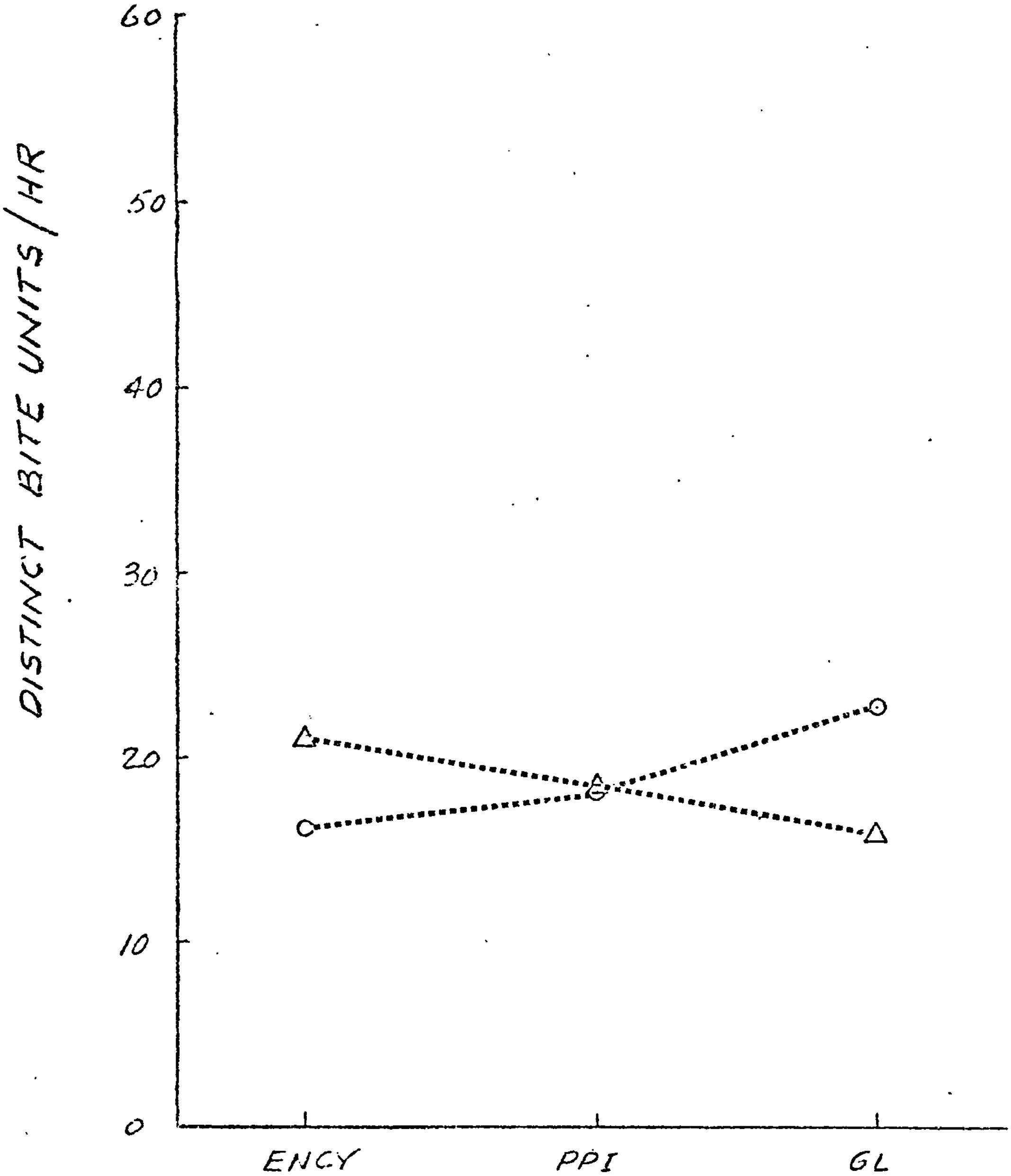
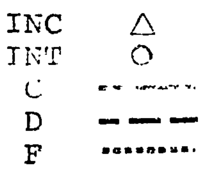


Figure 3-43. Means of PR4-F (DABU)
Experiment #2



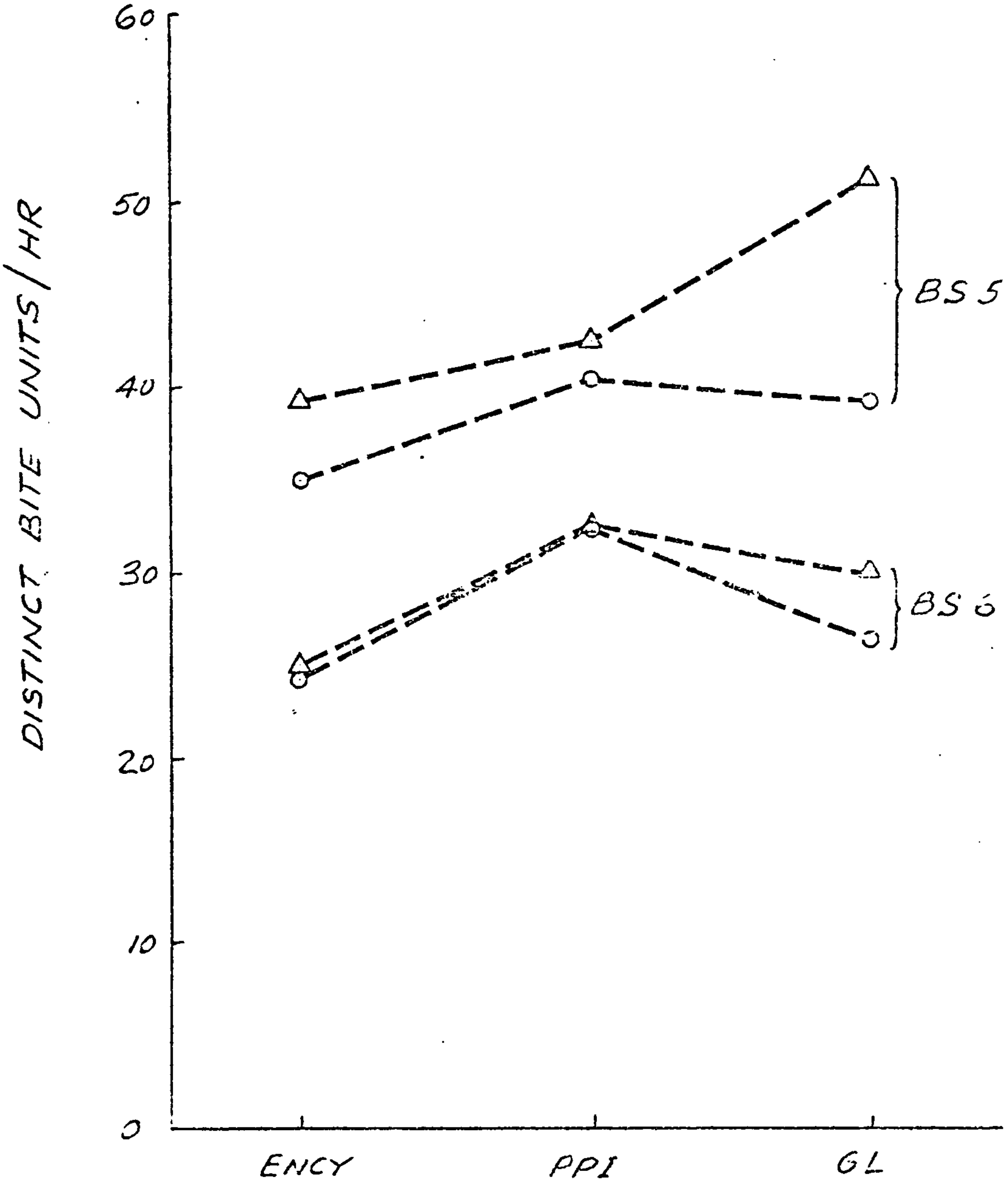


Figure 3-44. Means of PR5, PR6-D (DABU)
Experiment #2

INC △
INT ○
C
D
F

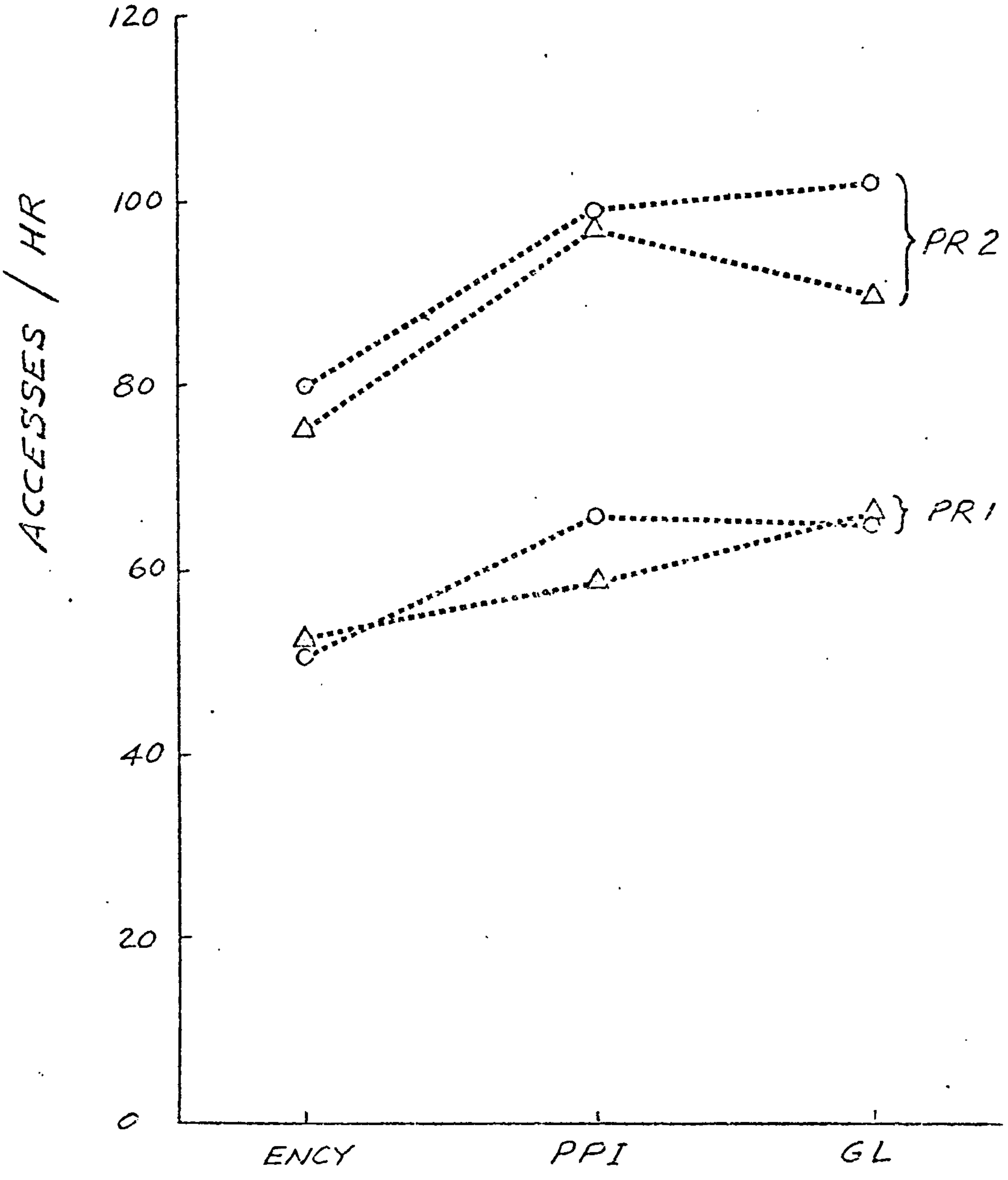


Figure 3-45. Means of PR1, PR2-F (ABS)
Experiment #2

INC △
INT ○
C
D
F

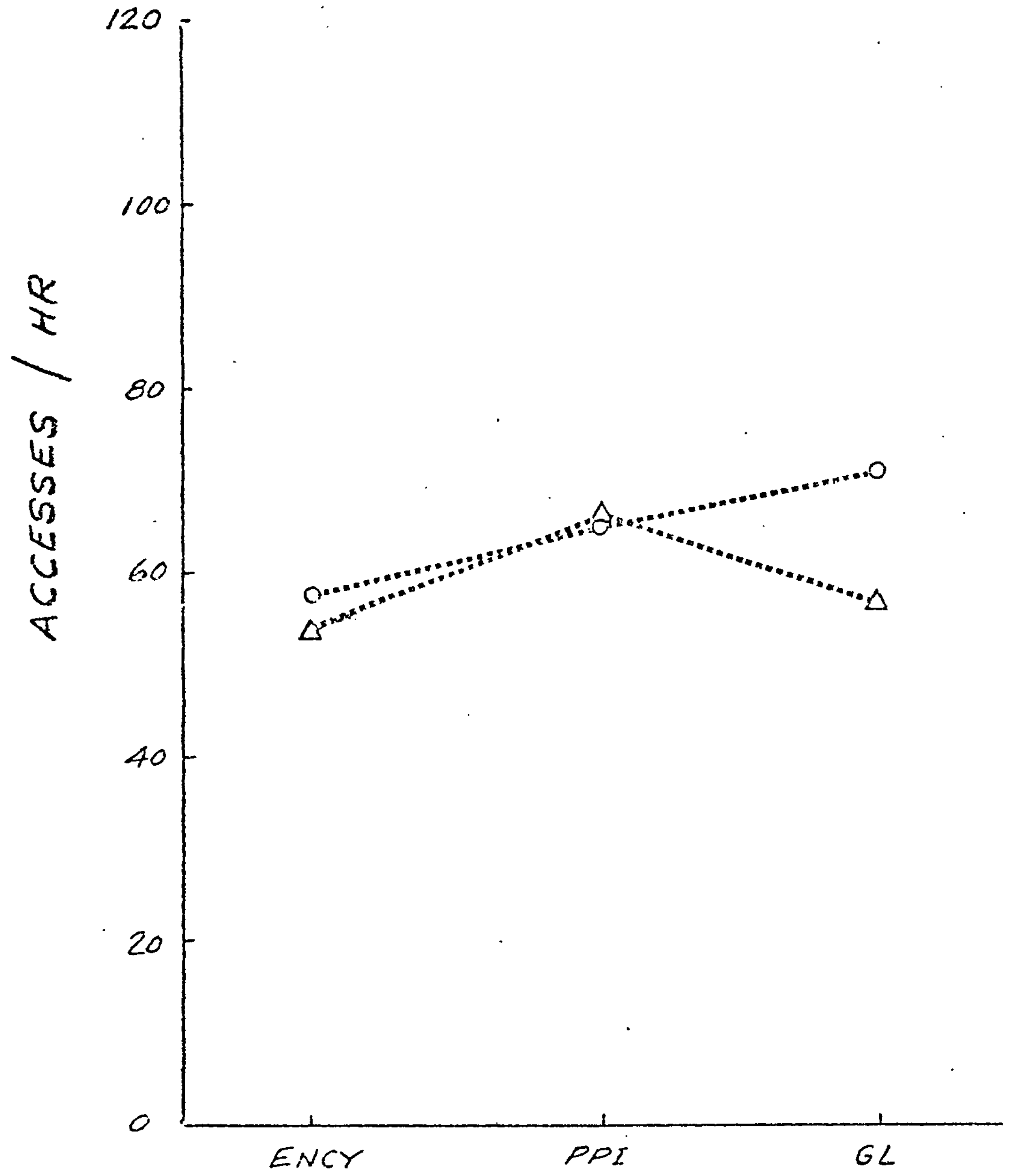


Figure 3-46. Means of PR4-F (ABS)
Experiment #2

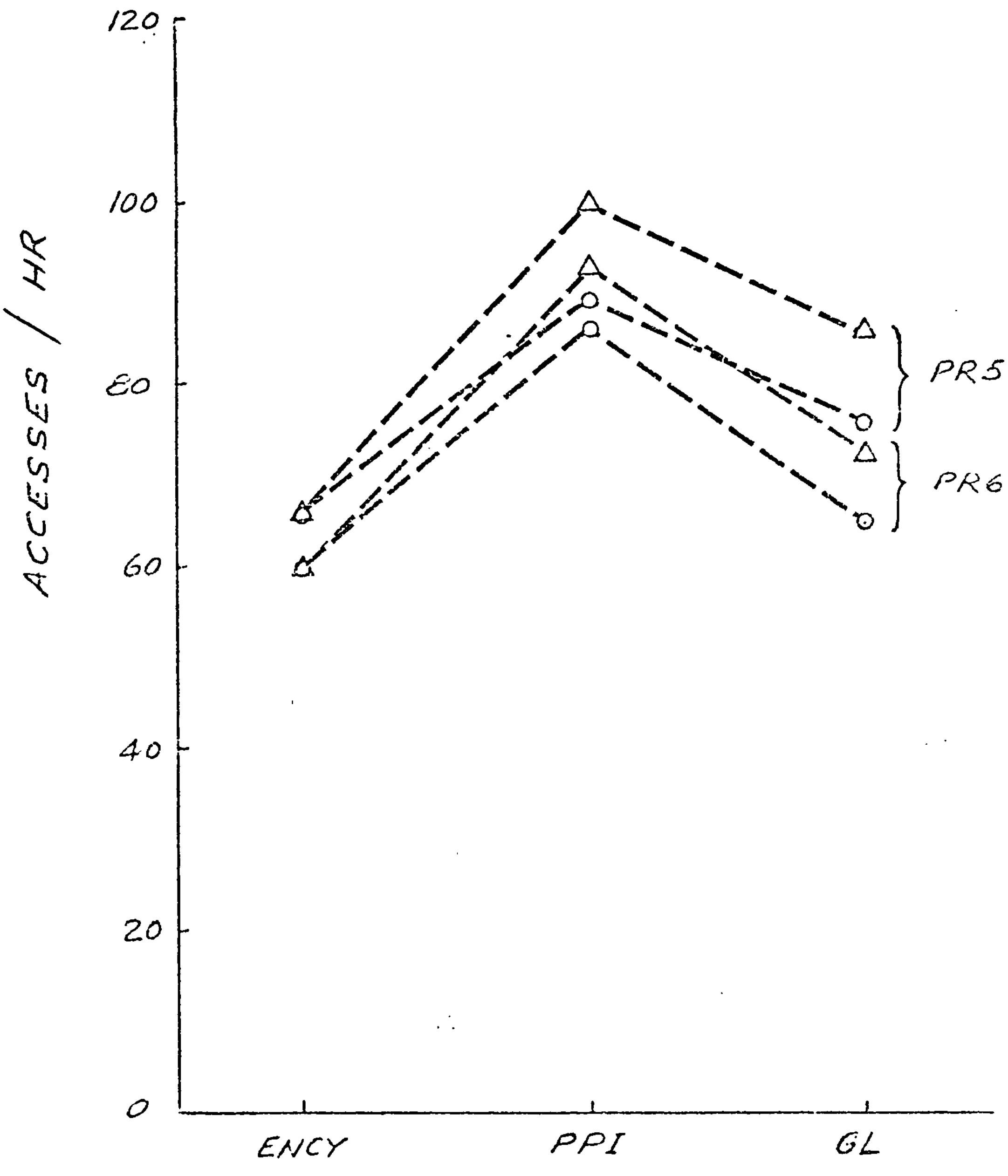


Figure 3-47. Means of PR5, PR6-D (ABS)
Experiment #2

INC
INT
C
D
F

lost its impact altogether. In neither the Fundamentals nor the Design portions of the experiment can any difference in processing rate be determined among the cells of Bite Set 4. Otherwise, differences in the Processing Rates of the strategies were found.

The Processing Rates were assessed by two methods: by the number of Bite accesses per time, and by the number of Distinctly Accessed Bite Units per time. In Accesses to the Bites per Time in the Universe and Bite Sets 1 and 2 of the Fundamentals (Figure 3-48), the ENCY cells were decidedly lower than the roughly equivalent PPI and GL cells. With Distinct Accesses to Bite Units per Time during Fundamentals (Figure 3-49) in Bite Sets 1 and 2, the GL cells were decidedly higher than the other cells which were roughly equivalent to each other.

	ENCY	PPI	GL
INC	LO		
INT	LO		

Figure 3-48. Comparison of Means of AU/TU, ABS1/TBS1, ABS2/TBS2 - F Experiment #2

	ENCY	PPI	GL
INC			HI
INT			HI

Figure 3-49. Comparison of Means of DABU1/TBS1, DABU2/TBS2 - F Experiment #2

But during the Design stage, PPI control tended to produce the highest processing rates except for the reversals between Fundamentals and Design so consistently seen in Bite Set 2 (Figures 3-50 through 3-52). Here, PPI exhibited the lowest of the processing rates during Design. Bite Set 2 was the only place and time where the ENCY control did not produce the lowest processing rates. The Design Schedule (row) effect showed up as expected in Bite Sets 5 and 6 with the Incremental cells processing at a higher rate than the Integral cells.

	ENCY	PPI	GL
INC		HI	
INT		HI	

Figure 3-50. Comparison of Means
ABS_i/TBS_i - D and
$DABU_i/TBS_i$ - D, $i = 1,5,6$
Experiment #2

	ENCY	PPI	GL
INC		LO	
INT		LO	

Figure 3-51. Comparison of Means
DABU2/TBS2 - D
Experiment #2

	ENCY	PPI	GL
INC	LO	HI	MED
INT	LO	MED	LO

Figure 3-52. Comparison of Means
AU/TU - D, Experiment #2

In the Composite, the well-defined position of the lowest processing rate went to the ENCY cells. The highest processing rates tended to be from the PPI control for the Accesses per Time (Figure 3-53), but from the GL control for the Distinctly Accessed Bite Units per Time (Figure 3-54).

	ENCY	PPI	GL
INC	LO	HI	MED
INT	LO	HI	MED

Figure 3-53. Comparison of Means
ABS_i/TBS_i - C, i = 1,2,5,6;
DABU6/TBS6 - C
Experiment #2

	ENCY	PPI	GL
INC	LO	MED	HI
INT	LO	MED	HI

Figure 3-54. Comparison of Means
$DABU_i/TBS_i$ - C, i = 1,2,5
Experiment #2

3.3.6 Performance Rates

The ANOVA table, Table XIX, for the Performance Rates and Effective Learning parameters is found on page 113. Immediately following are the graphs of the three Performance Rates and the graphs of the three measures of Effective Learning (Figures 3-55 through 3-60). The six groups of students interacted differently with the machine, but nevertheless, as far as could be determined, they did equivalently well

TABLE XIX

ANALYSIS OF VARIANCE EXPERIMENT #2
PERFORMANCE RATE AND
EFFECTIVE LEARNING

Parameter	$\bar{X}$	s	$\bar{X}_{11}$	$\bar{X}_{12}$	$\bar{X}_{13}$	$\bar{X}_{21}$	$\bar{X}_{22}$	$\bar{X}_{23}$	RxC F	ROWS F	COLS F
						PfR					
PTOT/TU C	17.2	6.05	18.26	17.11	18.53	16.03	18.28	15.54			
R1TOT/TU C	16.3	7.80	27.64	16.59	18.19	8.41	18.53	12.95			
R2TOT/TU C	23.3	5.89	26.10	25.25	21.79	23.53	24.53	21.18			
						EL					
PTOT/AU C	0.250	0.095	0.301	0.212	0.259	0.276	0.245	0.235			
R1TOT/AU C	0.225	0.117	0.463	0.191	0.240	0.122	0.254	0.185			
R2TOT/AU C	0.336	0.101	0.430	0.302	0.294	0.409	0.322	0.324			7.56^{2}_{64}

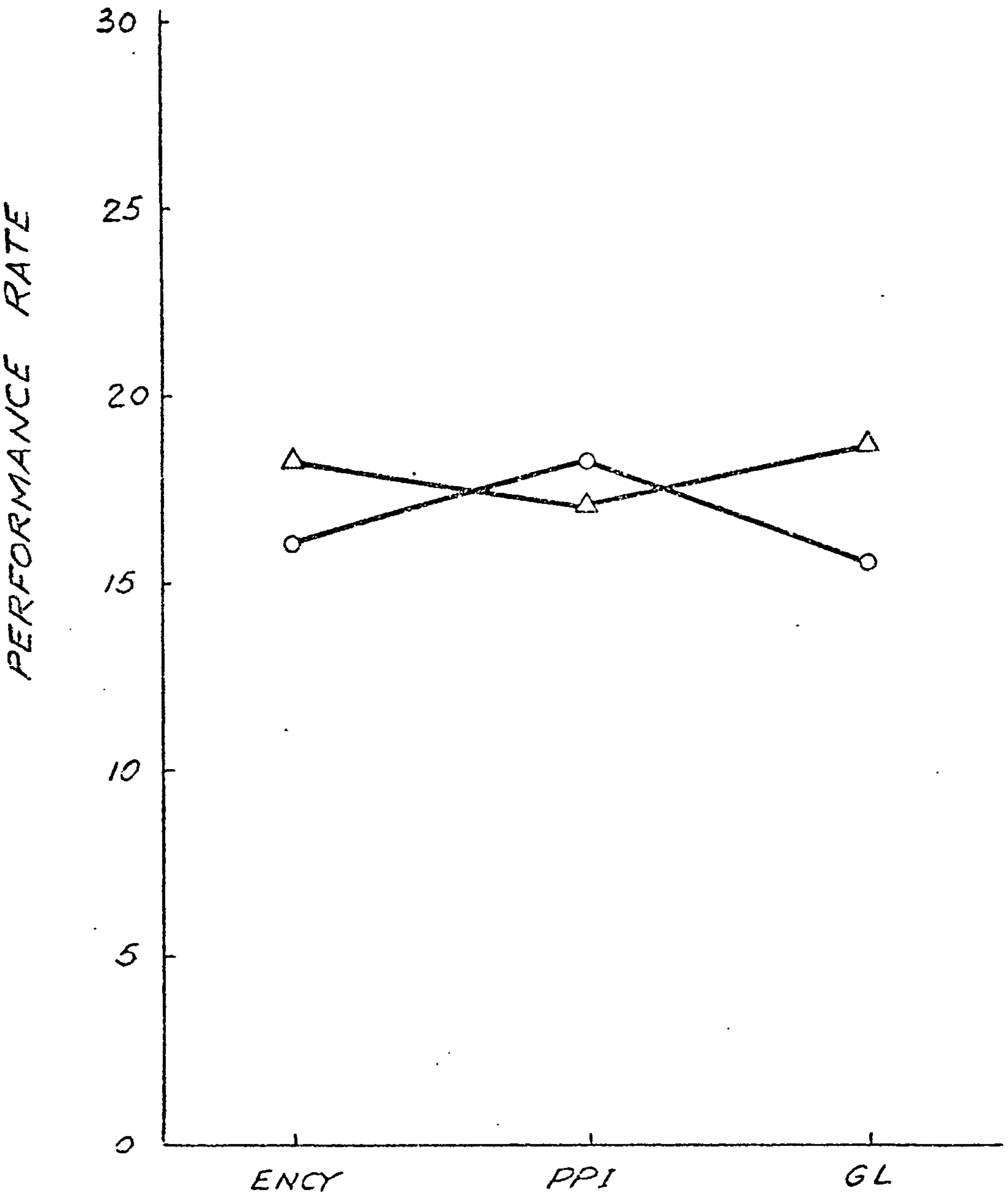


Figure 3-55. Means of PfR (PTOT)
Experiment #2

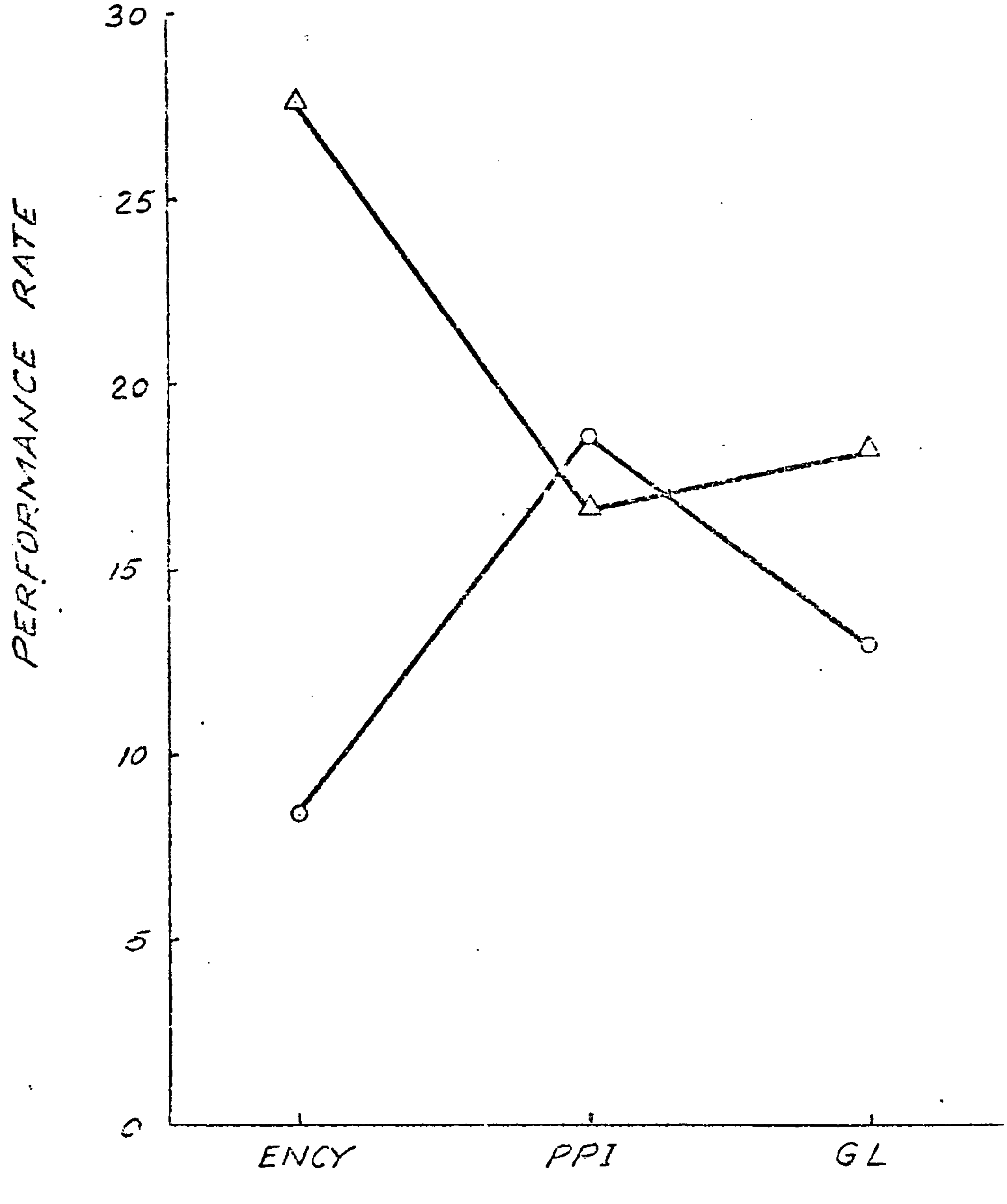


Figure 3-56. Means of PfR (R1TOT)
Experiment #2

INC
INT
F

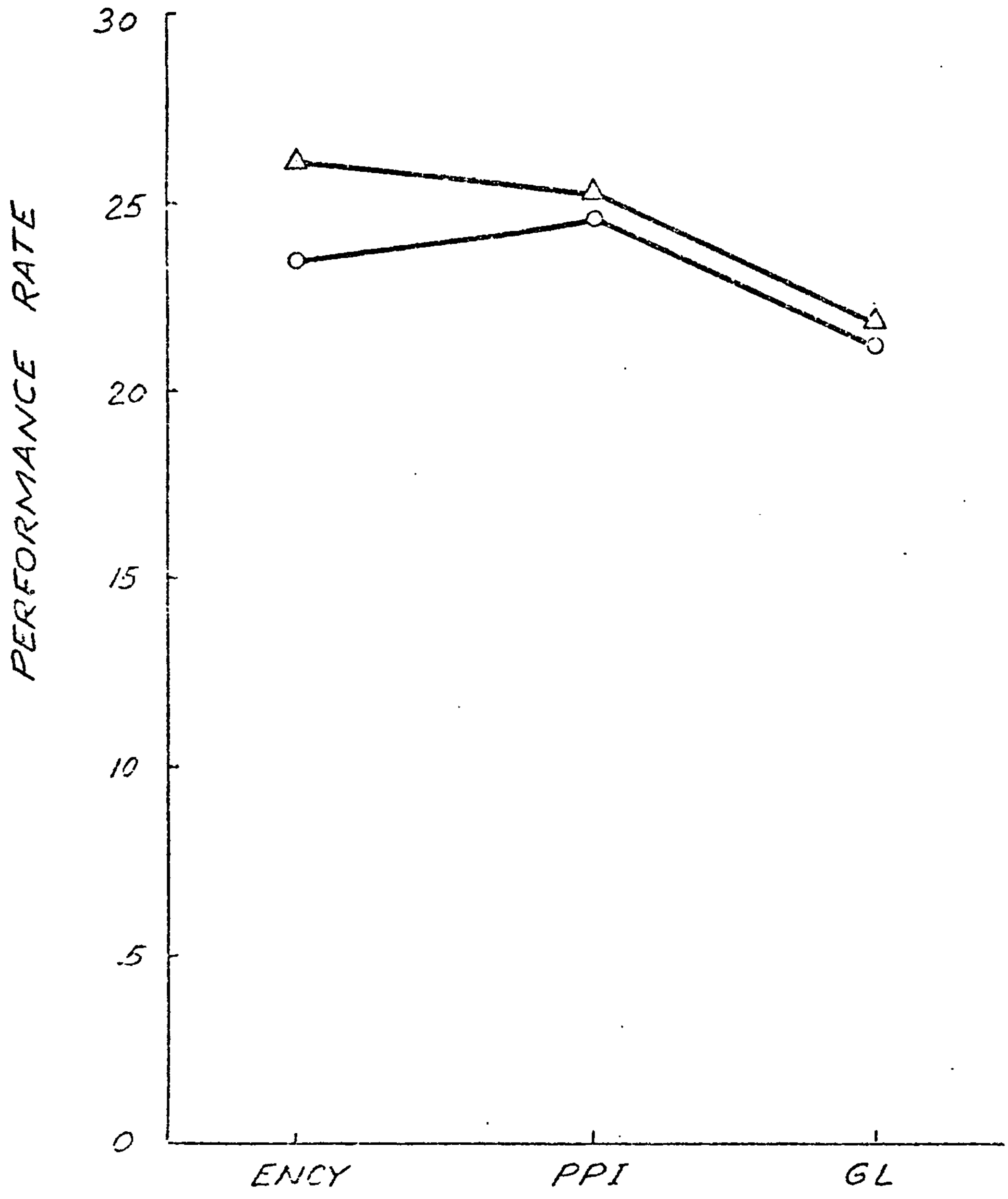


Figure 3-57. Means of PfR (R2TOT)
Experiment #2

INC △
INT ○
C
D
F

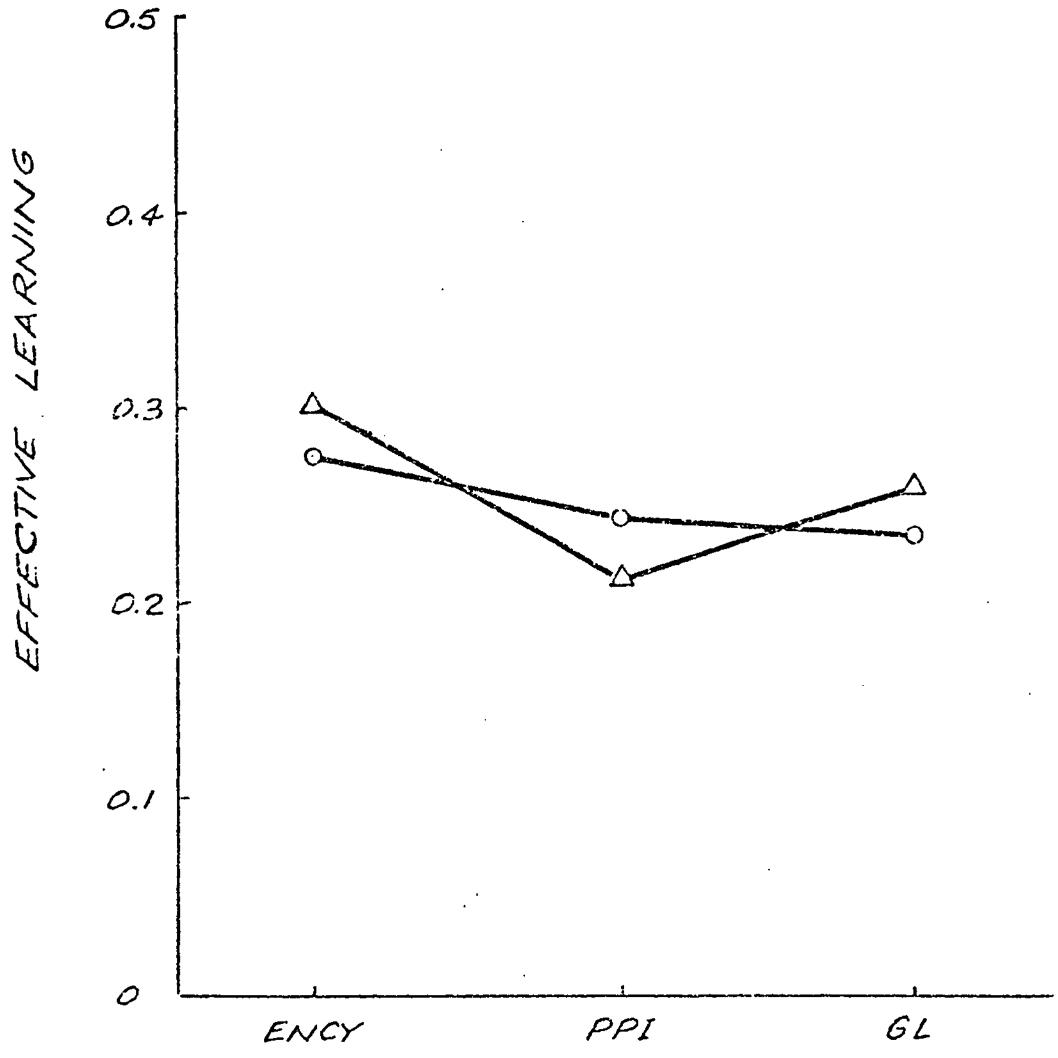


Figure 3-58. Means of EL (PTOT)
Experiment #2

INC △
INT ○
C
D
F

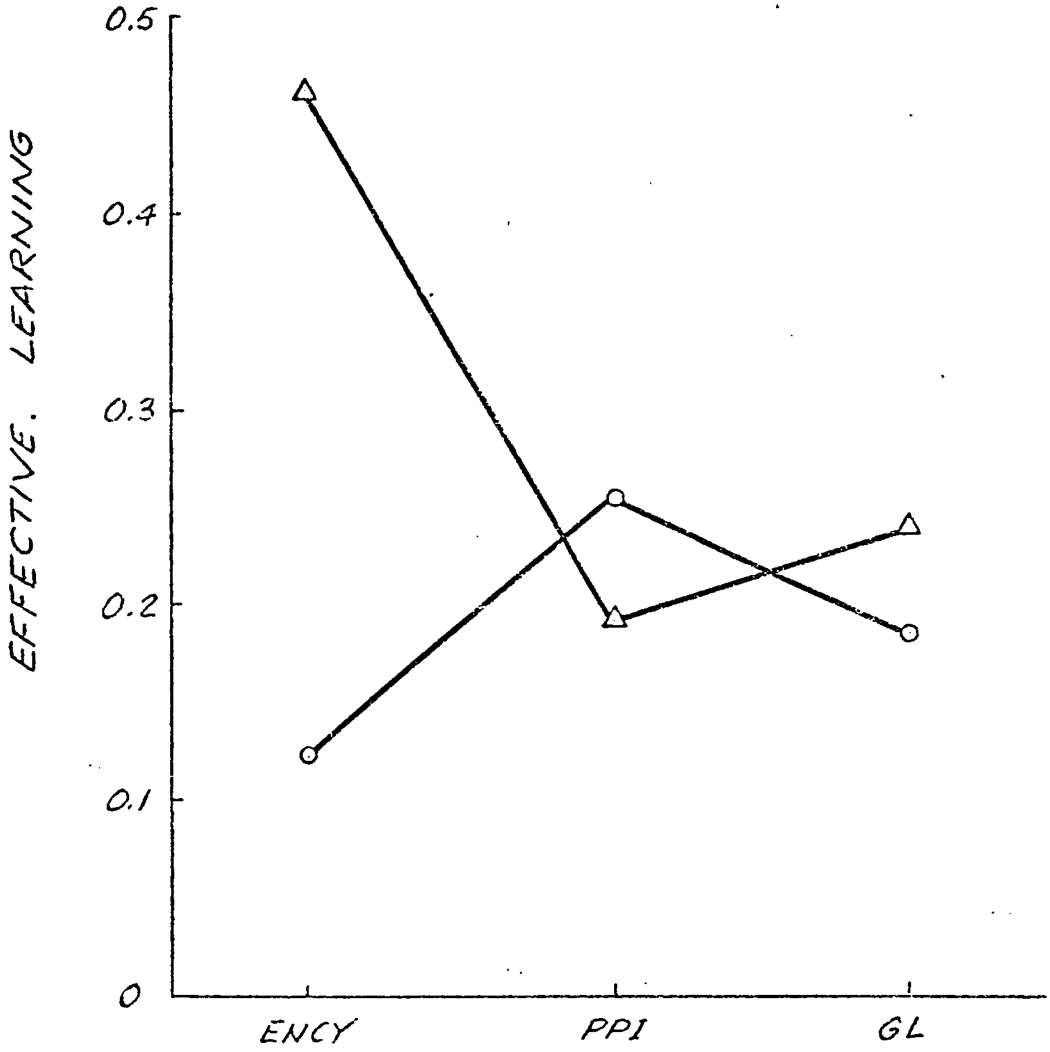


Figure 3-59. Means of EL (R1TOT)
Experiment #2

INC △
INT ○
C
D
F

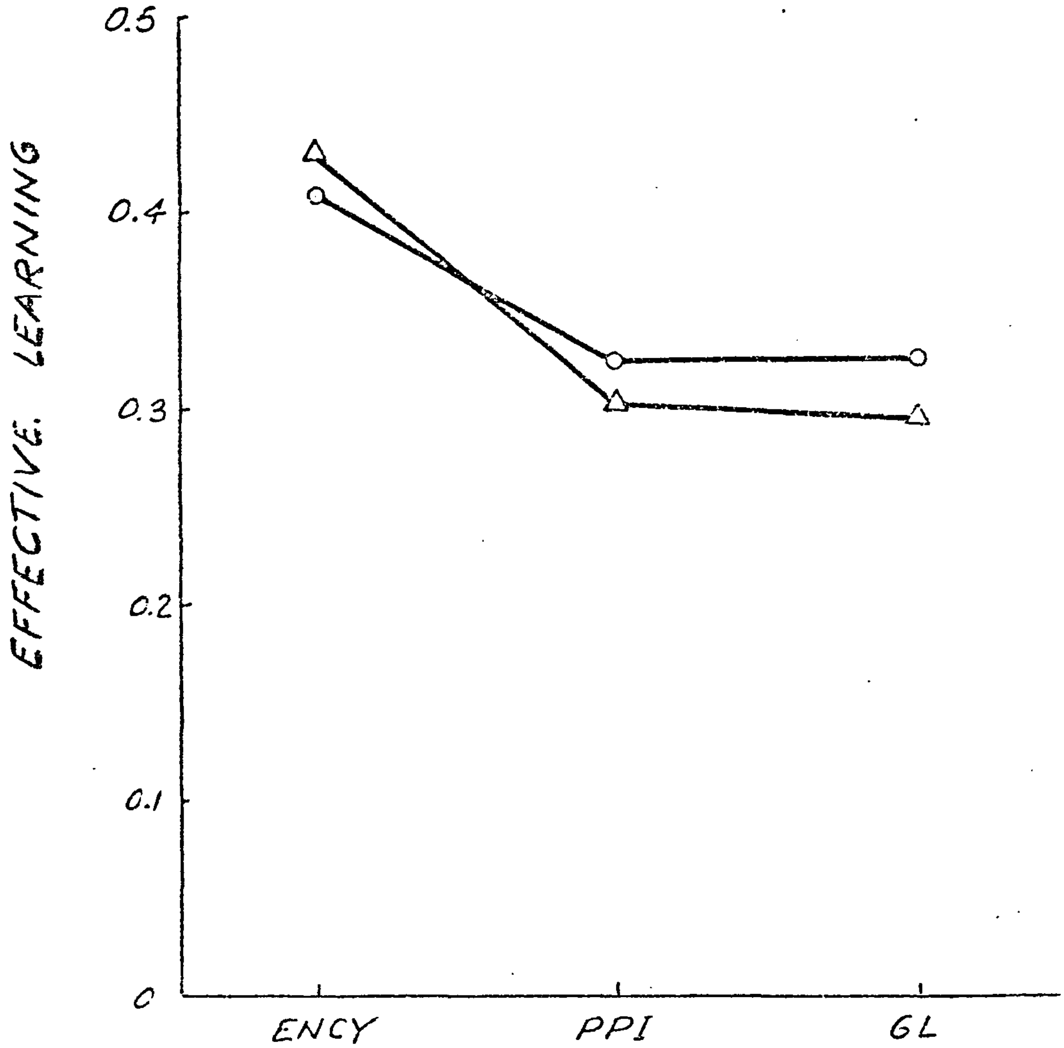


Figure 3-60. Means of EL (R2TOT)
Experiment #2

INC △
INT ○
C
D
F

on the sixteen test measures applied to determine how well they had learned. The question became--were there particular interaction strategies that could be said to be more efficient of the student's time and/or his access of the information towards obtaining the test score he achieved?

The objective of the next set of compound parameters was to answer that question. The Performance Rates were defined as the ratio of the test score total and the time required by the student to complete the Sequential Logic course. There were no differences between the six means for Time in the Universe or for the Test Scores. Further, individual relationships between the three tests scores (Post, Retention 1, Retention 2) did not combine into differences among the means of the groups either (Table XIX, page 113).

3.3.7 Effective Learning

Effective Learning was defined as the ratio of the test score achieved to the number of accesses made into the Bite Structure during the complete course. The ratios of the Post test and the Retention 1 test to accesses did not produce differences between their respective means (Table XIX, page 113, and Figures 3-59 through 3-60, pages 117-119). In fact, the Effective Learning for the Post test was very similar to that of the Retention 1 test. The overall mean Effective Learning for Retention 2 was 50 percent higher than EL_{Post} or EL_{Ret1}. There are differences between the means with the students under the ENCY control having distinguishably higher Effective Learning (Figure 3-61).

	ENCY	PPI	GL
INC	HI		
INT	HI		

Figure 3-61. Effective Learning - Ret2

3.3.8 Effective Learning Capacities

The ANOVA table, Table XX, for the parameters is found on page 122 and is immediately followed by graphs of the means of the three parameters (Figure 3-63 through 3-65). Each of the three test score totals--Post, Retention 1, and Retention 2--were rated against the number of accesses taken to achieve those scores as a measure of Effective Learning. To obtain the respective Effective Learning Capacities, the product of a specific Effective Learning and Time in the Universe was calculated. ELC_{Post} showed no significant differences among the rows, columns, or strategy means. Because of the low cell frequencies in the ELC_{Ret1}, the ANOVA result of an interaction effect in this data must be viewed cautiously (Figure 3-62).

	ENCY	PPI	GL
INC	HI		
INT			

Figure 3-62. Comparison of Means
Effective Learning Capacity
(Retention 1)

TABLE XX

ANALYSIS OF VARIANCE EXPERIMENT #2
EFFECTIVE LEARNING CAPACITIES
AND EFFECTIVE LEARNING RATES

[illegible]meter	$\overline{X}$	s	$\overline{X}_{11}$	$\overline{X}_{12}$	$\overline{X}_{13}$	$\overline{X}_{21}$	$\overline{X}_{22}$	$\overline{X}_{23}$	RxC F	ROWS F	COLS F
						ELC					
[illegible]T/PRU	0.87	0.30	0.93	0.75	0.84	1.06	0.86	0.84			
[illegible]OT/PRU	0.73	0.29	1.37	0.59	0.69	0.44	0.86	0.66	4.24^{2}_{14}		
R[illegible]OT/PRU	1.18	0.41	1.31	1.01	1.00	1.58	1.11	1.20		5.45^{1}_{64}	
						ELR					
EL_{PTOT}/TU	0.07	0.04	0.10	0.06	0.08	0.07	0.07	0.07			
EL_{R1TOT}/TU	0.07	0.05	0.16	0.06	0.09	0.03	0.08	0.05			
EL_{R2TOT}/TU	0.10	0.04	0.14	0.09	0.09	0.11	0.10	0.09			4.86^{2}_{64}

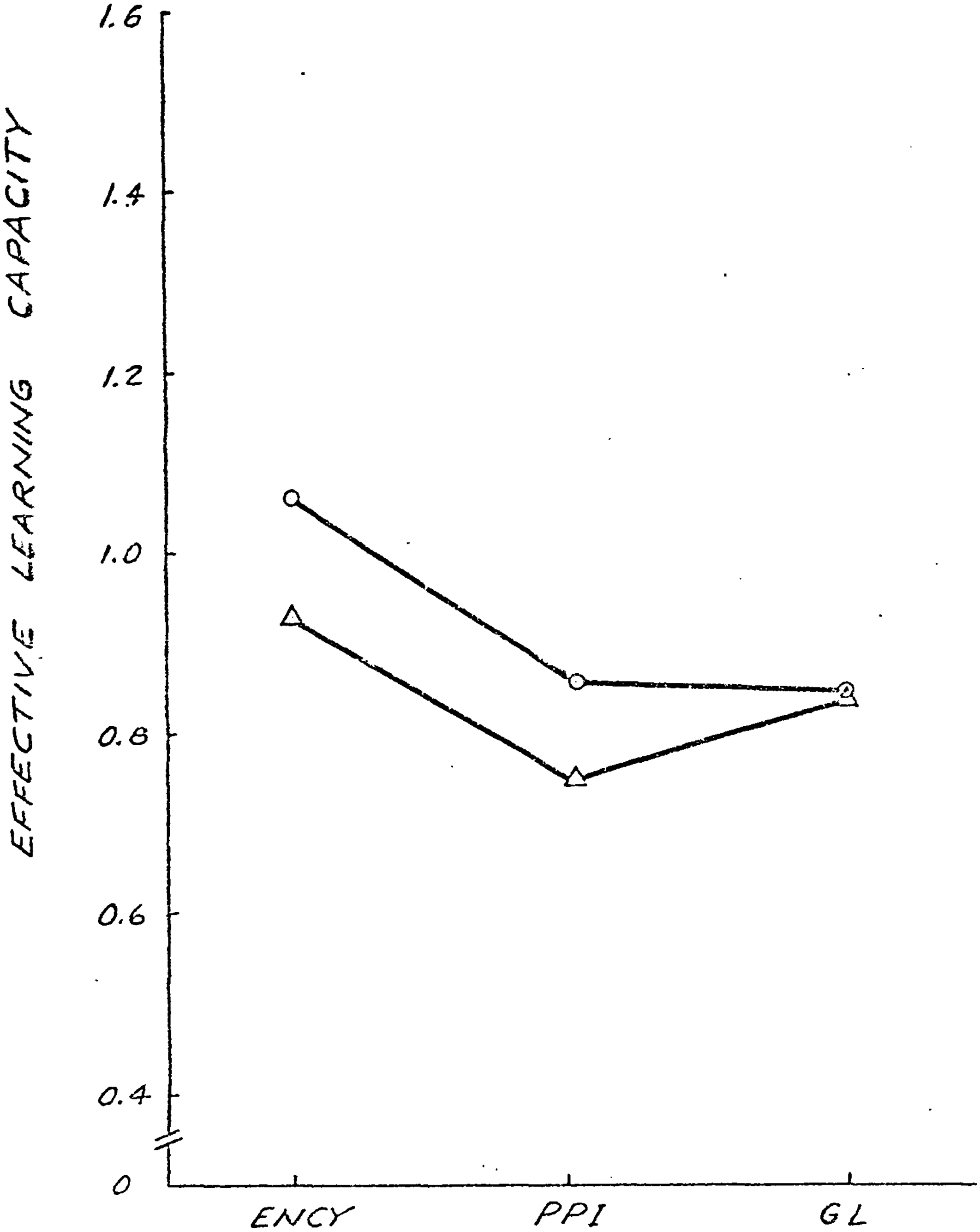


Figure 3-63. Means of ELC (PTOT)
Experiment #2

INC △
INT ○
C
D
F

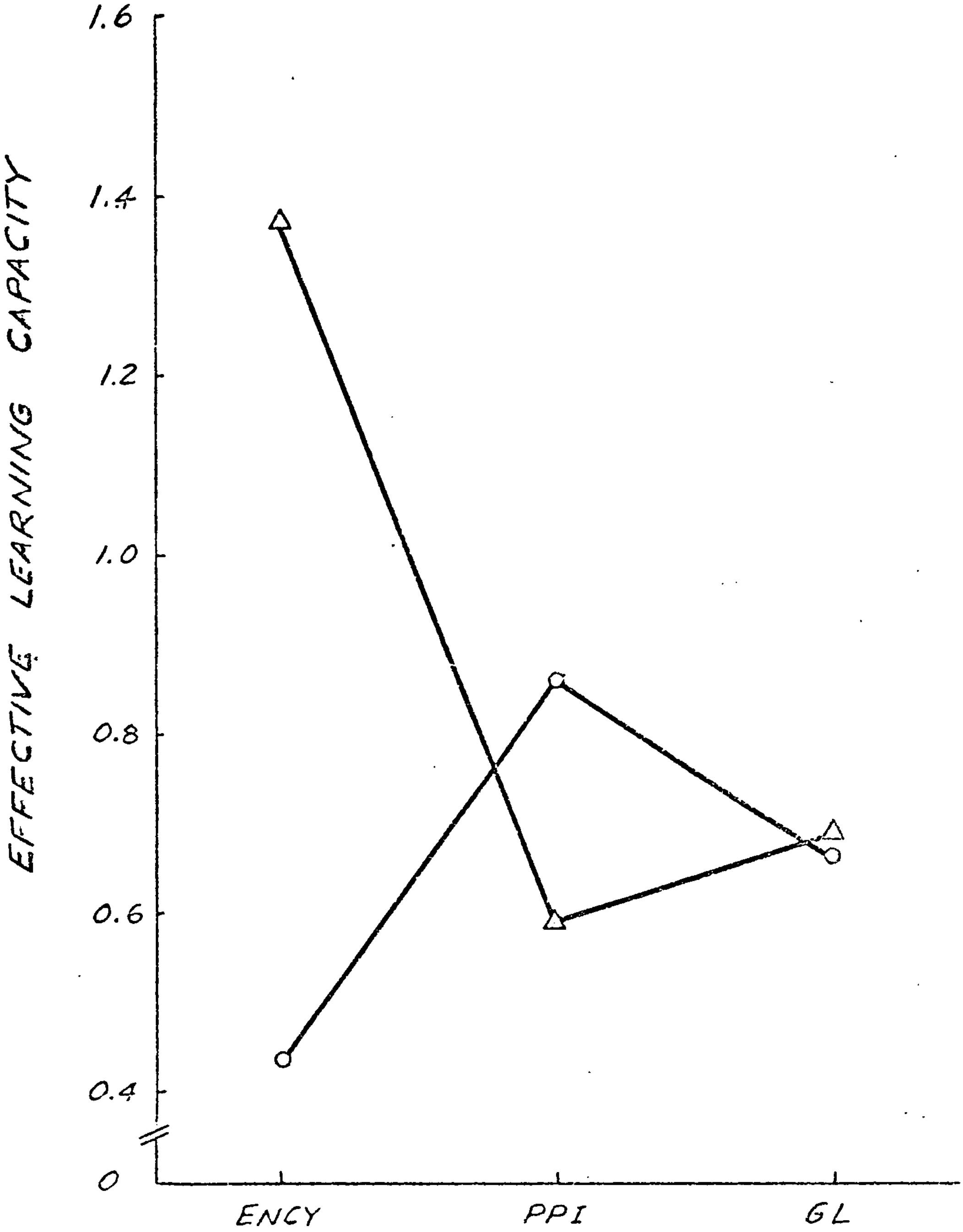


Figure 3-64. Means of ELC (R1TOT)
Experiment #2

INC △
INT ○
C
D
F

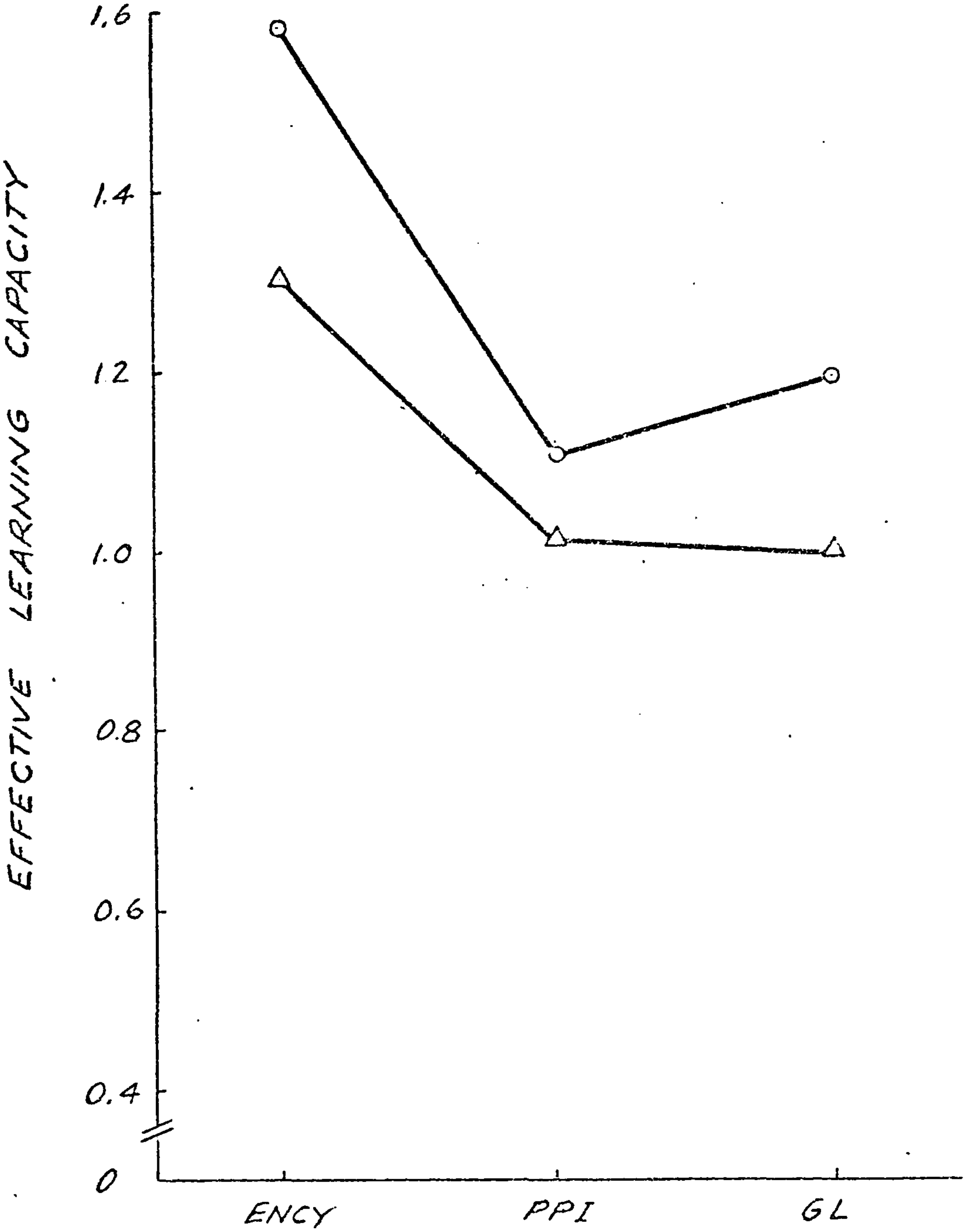


Figure 3-65. Means of ELC (R2TOT)
Experiment #2

INC △
INT ○
C
D
F

Differences in cell means appeared again in the Retention 2 data (Figure 3-66). The Scheffe found that the Design Schedules were different as well as that the Instruction Control, ENCY, was different from the other controls. The ANOVA models found only a column (Instruction Control) effect (Table XX, page 122).

	ENCY	PPI	GL
INC			
INT	HI		

Figure 3-66. Comparison of Means Effective Learning Capacity (Retention 2)

3.3.9 Effective Learning Rates

The ANOVA table, Table XX, for the parameters is found on page 122. The graphs of the means of the three parameters (Figures 3-67 through 3-69) are on pages 127 through 129. Effective Learning Rate was defined as the ratio of the Effective Learning, Test Score/Accesses, to the time taken during the accessing, i.e.:

$$ELR = TEST\ SCORE / AU / TU$$

None of the Instruction Controls can be said to be superior to the others based on the Effective Learning Rate as a function of the immediate or Post test of the experiment (Figure 3-67). The Effective Learning Rate of the six strategies as a function of the Retention 1 test had a grand mean of [illegible] with a standard deviation of 0.054 and the low

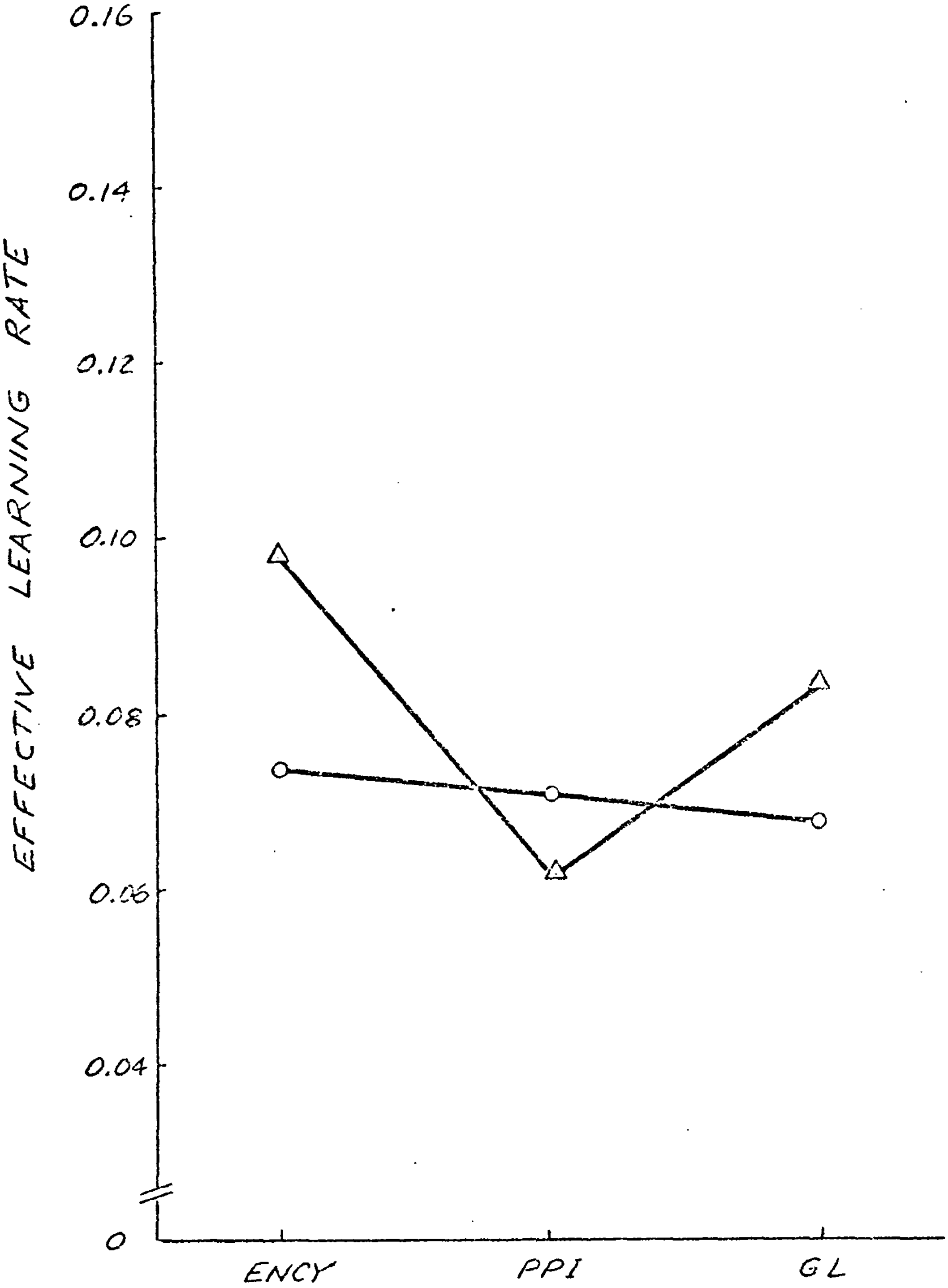
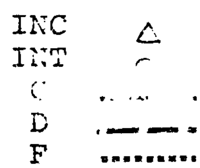


Figure 3-67. Means of ELR (PTOT)
Experiment #2



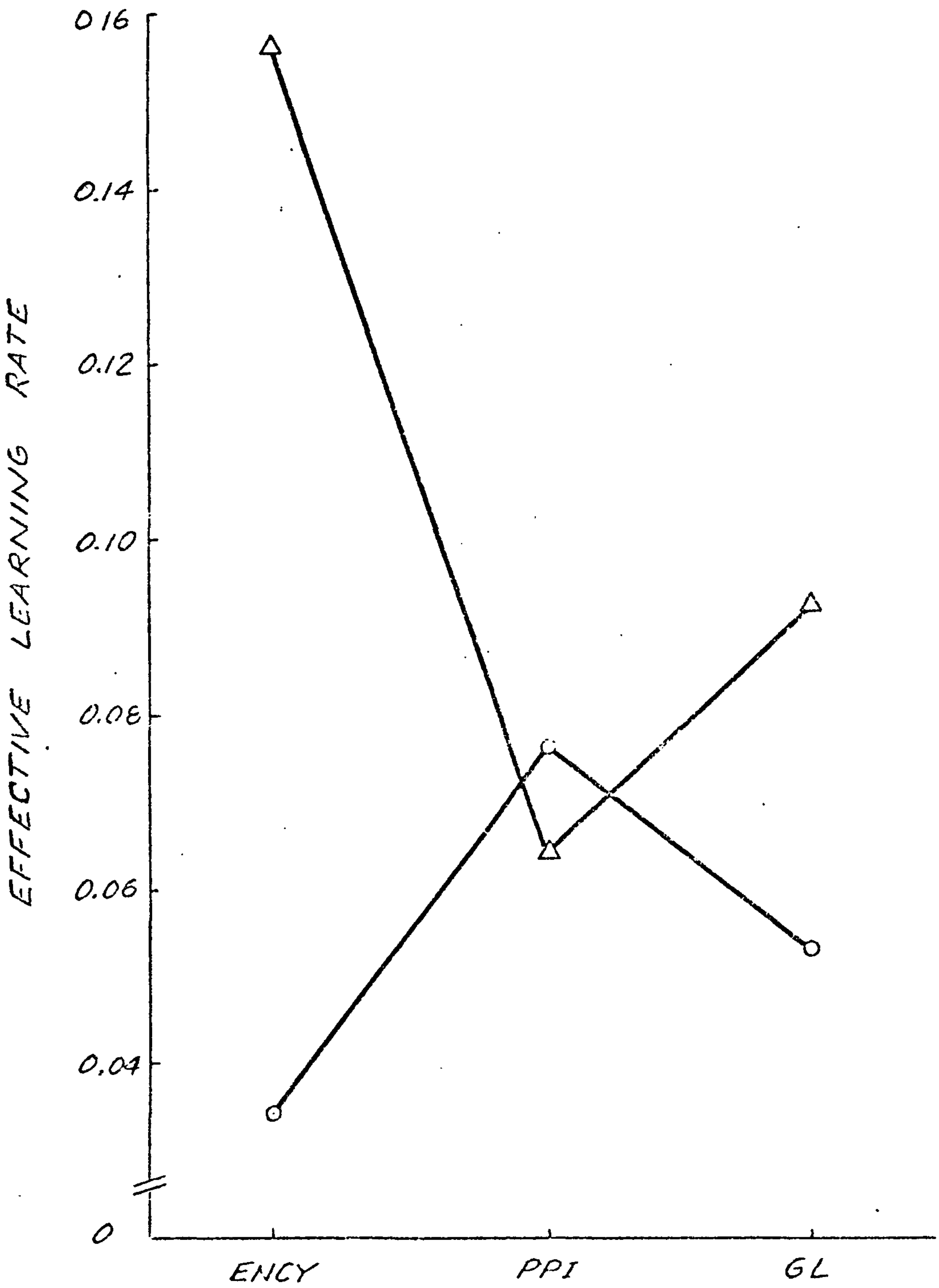


Figure 3-68. Means of ELR (R1TOT)
Experiment #2

INC
INT
C
D
F

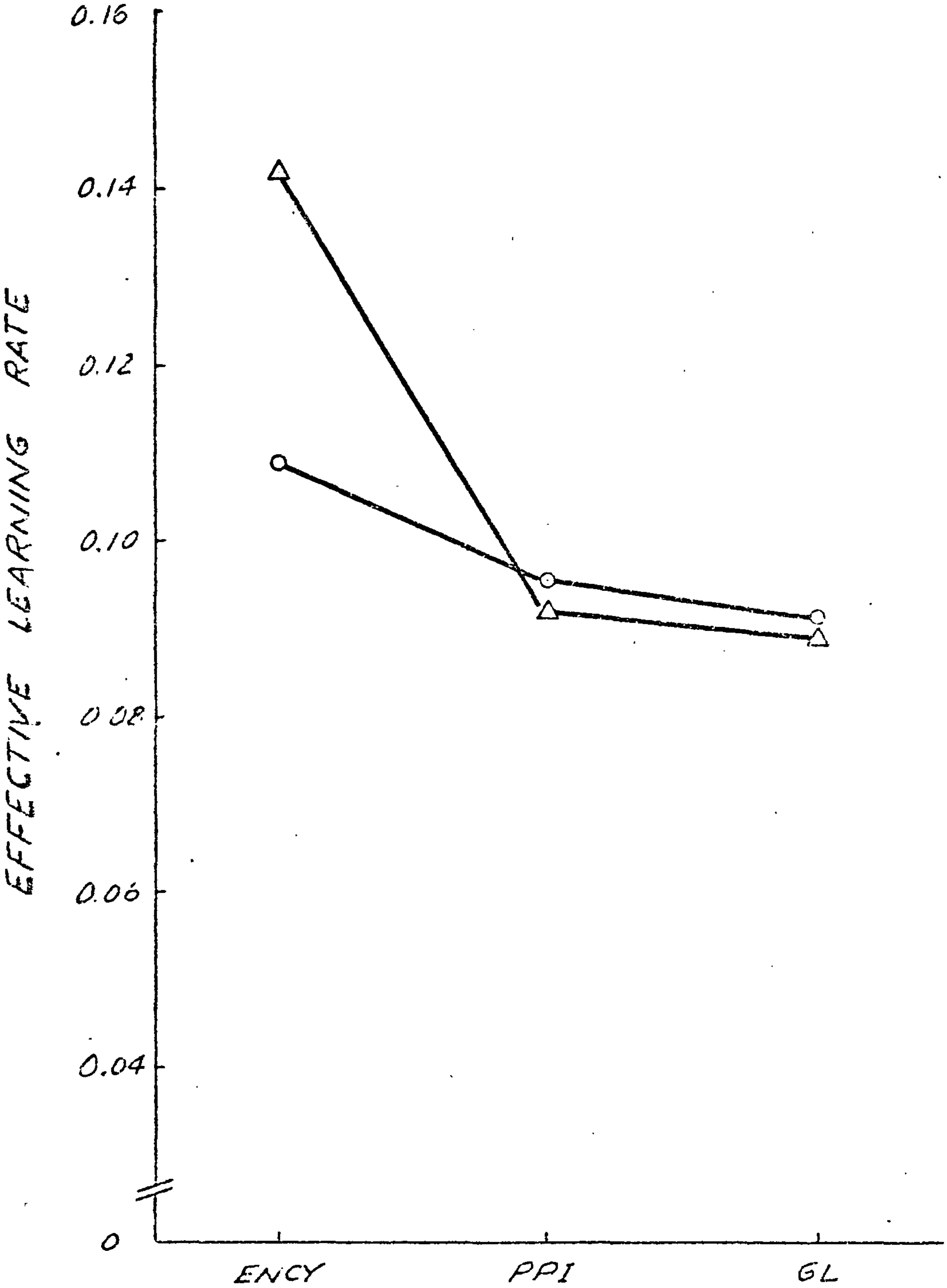


Figure 3-69. Means of ELR (R2TOT)

INC △
INT ○
C
D
F

frequencies problem. The Effective Learning Rate of each of the six strategies cannot be said to be different for the short-term retention in this study (Figure 3-68).

The Effective Learning Rate as a function of the second retention test showed differences among the instruction controls. The ENCY control had a different ELR from the other two controls. Within ENCY, the Incremental cell was equivalent to the Integral cell. Under either Design Schedule then, the ENCY control had a higher ELR than any other of the interaction strategies (Figures 3-69, 3-70).

	ENCY	PPI	GL
INC	HI		
INT	HI		

Figure 3-70. Comparison of Means of ELR (RET2)

3.4 DISCUSSION OF EXPERIMENT #2 RESULTS

In no other Computer-Assisted Instruction experiment report, aside from those relating to the Synnoetics Laboratory at the University of Wisconsin, did the author find the possibility of the counting, timing, and general record-keeping that this Interactive Human-Machine System provided. Another difference in the series of experiments at Wisconsin was the inclusion of a second retention test to ascertain longer-term effects of the Interaction Strategies. Without a record of the time and accesses throughout the acquisition and application stages of the learning process, the results of these analyses would be based largely on the Post and Retention 1 test scores where no differences were found. This finding would have collaborated the results of many CAI vs. non-CAI experiments as well as the CAI strategy experiments to date. Students will learn under all manner of conditions and short-term differences in achievement are not readily found.

3.4.1 The Universe Parameters

The first hint of the learner-directed control being different occurred in its having the fewest accesses to the Universe. Each of these accesses had to be a conscious selection within the Bite Structure, as distinct from either the accesses of a PPI or a GL student who could mindlessly press a NEXT (BASIC) BITE key. The ENCY control thus demanded a higher level of alertness and involvement in the learning process. If it is a mistake to assume that learning is the passive consequence of being exposed to an instruction environment, and if it is a mistake to assume that a specific input to the student produces a logical output, then the ENCY control should bear watching.

The negative correlations of the TU with the Post scores could have been a manifestation of fatigue and possibly annoyance combined with an urgency to finish the Post Test and be able to leave. Also, slower students achieving lower grades would contribute to this correlation. The Post Test was given immediately following the student's last session.

3.4.2 The Relative Access and Time in Bite Set Parameters

The Interaction Strategies do not differentially influence the time a student spends within the Bite Structure. The distribution of the student's time taking this Sequential Logic course was more likely a habit-dominated phenomenon. There were five bite sets and the students averaged five sessions in the laboratory taking the course. The mean interactive time spent by a student was 3.57 hours. This implies about a three-quarter hour "class". This does not consider the time spent by the student preparing to interact with the machine nor the time he spent on the BUILD, TEST, and LOOK Simulators (Chapter 2.4, page 20). Lacking figures to substantiate any further comment, the author suggests only that a student's attention span was already conditioned to about an hour per session and his motivation inclined him, in general, to complete a Bite Set per session regardless of the differences in the Bite Set size which was unknown to him in any case. This result is a curiosity in the light that the number of Bites (Basic and Peripheral) available from one Bite Set to another vary by as much as a factor of three (Table II, page 29). At any rate, an even distribution of time and accesses per Bite Set occurred.

The Design Schedule row treatments were not in force during the Fundamentals portion of the course. There were the same number of Bites available for each schedule--Incremental and Integral--through Bite Sets 1, 2 and 4 during the Fundamentals. Technically, Design Schedule differences could therefore appear only during the Design phase and these, in turn, could re-appear in the Composite of the Fundamentals and Design since Composite was calculated from the sum of the times and accesses in Fundamentals and Design. Therefore, it is reasonable to state that any apparent row effect could not be due to the Design Schedule in Bites 1, 2, and 4 of the Fundamentals. And further, any apparent row effects in Fundamentals, not visible in the Design portion, can be assumed to be responsible for any apparent row effects seen in the Composite of a parameter in Bite Sets 1, 2, and 4. A likely source of this apparent row effect is discussed under the Bite Unit parameters.

In Bite Set 2, the Instruction Control effects in the Fundamentals portion were the reverse of those of the Design portion as a result of the differing needs to review that Bite Set while in the Design state. The PPI students were constrained to access large amounts of Bite Set 2 by virtue of the author-imposed Bite Sequence during their Fundamentals but either did not return to it at all (the PPI Incremental students), or only very lightly (the PPI Integral students) during the Design stage. The Guided Learning students appeared to have skimmed the surface originally, electing to return to it for needed information during the Design stage. Probably, the GL style of superficial accessing in the Bite Structure led these students to a premature decision as to when they had learned the fundamentals of the course and could proceed to problem solve. These differences among the means in Bite Set 2 were a matter of the Instruction Control within the subject matter and not typical of the behavior throughout the Bite Sets.

The Design Schedule was always in effect when the student was in Bite Sets 5 and 6. This meant that an Incremental student could be expected to spend more time and accesses as part of the machine's incremental checking of his design. However, the differences expected from the imposition of the Design Schedule were not significant as measured by the Relative Time and Access parameters. In part, this might have been caused by the difference in the number of Peripheral Bites available to the Incremental and Integral students. But the Relative Access of one Interaction Strategy compared with another was more likely to be numerically larger when the number of Peripheral Bites available was smaller. A more probable cause could have been the repetitive use of the Bites by the Integral students.

Bite Set 6 contained the first design problem for the students to do. It was a sequential machine similar to ones which had been discussed earlier in the Bite Structure. But it was the first time the students were required to perform on the basis of their overall comprehension of the Fundamentals they had studied earlier. A student who spent a long time in this Bite Set may have discovered that he was not prepared to proceed with his design and that he needed to review the Fundamentals. Based on the sign-up sheets, it seems that at least some of Bite Set 6 was likely to have been included in the student's last session. Bite Set 5 followed Bite Set 6 and required the student to design an unfamiliar sequential machine. It appears likely that students who spent above average time and who accessed more than average may have felt pushed to complete Bite Set 5 and may have concluded the course more fatigued and ready to leave (having spent more time than their allotted mental block of time to this activity). This state of mind and body would naturally have a detrimental effect on test scores obtained at that time, i.e., the Post Test scores.

3.4.3 The Bite Unit Parameters

A Bite Unit contained one Basic Bite and one or more Peripheral Bites. Its purpose was to develop one concept as fully as a student might require. By taking measures of the Distinctly Accessed Bite Units in a Bite Set or of the Utilization of Bite Units in the Bite Set one takes a measure of the number of separate concepts the student was exposed to--if only by the unadorned statement of the concept in a Basic Bite. These two measures are related, of course:

$$UBS_i = DABU_i \;/\; \text{Total Available Bite Units in } BS_i$$

Comparing the rate of access of bites in Bite Set 1 to the utilization of Bite Units therein, it is apparent that GL students "tasted" most of the Bite Units available by using the NEXT BASIC BITE key but did not especially reinforce a Basic Bite by an examination of its peripheral information such as its examples, definitions, and so forth. There were not the same number of each Peripheral Bite type with each Basic Bite so that a student could not be certain whether or not he had exhausted the supply of a given PB type. According to the GL students' comments, requests for PBs generally tended to decline with the increased frequency of "none available" responses received to requests for Peripheral Bites in a given Bite Unit. Another factor in the high utilization rate of the GL students and the use of the NEXT BASIC BITE key was that the GL Instruction Control had available a few more Bite Units than did either ENCY or PPI controls (Table I, page 29). On the other hand, while PPI students were exposed to 5-10 percent fewer Bite Units than the GL students, they obviously pursued other bites than the Basic Bite within these Bite Units as their Relative Accesses to Bites in Bite Set 1 are equivalent to those of the GL students. And the ENCY Incremental students chose this style even more so; they accessed 20 percent fewer Bite Units while maintaining an equivalent number of Relative Accesses. The ENCY students used a selective focussing process. It was this combination of the low mean for the Incremental ENCY students with the high means for the Integral GL and PPI students that implied a Design Schedule effect in the ANOVA for the time (Fundamentals) when no Design Schedule was imposed.

The Instruction Controls also differed in the manner in which a student was directed once he was in the Peripheral [illegible] it. Specifically, suppose a student had obtained a quiz Peripheral bite. If he were a PPI student he must have answered the question before he could have gone on. If he were a GL student, he was strongly encouraged to answer but he could have requested another item in lieu of answering. If the student were an ENCY student, he could have responded to the machine, to himself, or not at all before continuing in the Bite Structure. So that the Instruction Control contributed to the cause of the accesses among the Peripherals being greatest for the PPI students and least for the ENCY students.

The author feels there are several behavioral factors involved in the utilization differences. Information received by the senses is available beyond the duration of the event for a short while in the sensory projection areas of the brain as well as at the receptor level (Fitts and Posner, 1969). While Fitts and Posner are speaking in terms of fractions of a second, there is some indication that when differing concepts are presented rapid-fire, masking of the early stimuli by subsequent stimuli can occur. The PPI Instruction Control group spent 40 percent less time per Bite than the ENCY student and did so in 35 percent more Bite Units. However, if masking did occur, it did not become apparent until the long-term Retention test. Or if masking was not involved, the utilization of the greater amount of information was merely superfluous exposure yielding inefficient learning, or excessive proactive and retroactive interference [illegible] ive learning. In any case, "the smaller amount of material presented to the subject, the more likely it is to reach the long term storage system. In addition, the longer the subject is free to rehearse the information, the more likely he is to store it permanently." (Fitts and Posner, 1969, p. 69)

Another statistical event that was probably a result of the interaction of human neuro-physiology and the experimental method was the negative correlations of the Utilization of Bite Set 6 (and DABU6) with the test scores. Loss of alertness and fatigue are always assumed to be associated with poor performance. It has been noted that many students began the last session at some point within Bite Set 6. Extraordinary use of this Bite Set in the last session could have left the student in precisely these conditions at the time of the Post Test.

But other factors in the high use of Bite Set 6 were involved to affect negative correlations with the Retention 1 tests--two weeks later. The low number of observations available for this test, 22, could mean that the negative correlation with the Retention 1 test was certain behavior exhibited by only the PPI and/or GL control groups since they represented 86 percent of that population. This postulate is strengthened by the fact that the strategies having the highest mean Utilization of Bite Set 6 (or highest mean DABU6) are the Incremental PPI and GL. Since BS6 was the first design experience for the students, students who utilized the Bite Set the most were presumably those who were least [illegible] the problem-solving experience, and consequently needed the most assistance. These slower students would also be expected to do more poorly than others on the tests.

The row effect seen in the UBS5, UBS6, DABU5 and DABU6 was probably the result of the imposition of the Design Schedule. The feedback for the Incremental students was a step-by-step check as the student progressed with his design problem, whereas the Integral students had no feedback until the completion of their design. Therefore, the Incremental students could have utilized more Bites than the Integral students during these two Bite Sets. Alternatively, a similar phenomenon to that discussed on page 136 with regard to the UBS1, UBS2, and UBS4 during Fundamentals could have occurred. Only in this case, the Integral PPI and GL students having had the high means during Fundamentals may have been better able to move ahead in Bite Sets 5 and 6 and it is the Incremental PPI and GL students whose high means combined with the relatively low ENCY-INT means that gave an only apparent Design Schedule effect.

3.4.4 Test Scores

There are two features of the test score analyses to note. One is that there are no great differences to be seen among the cell means of any test; the other is that in the tests of greatest interest to judgments on the viability of that which was learned--the Retention tests, either the frequencies were too small or the variations among the observations obscured the differences that might have been otherwise quite stark.

The number of observations for the Post test was equivalent to that of the valid students for the Composite scores of the Bite Structure parameters because this test was a part of the last session each student had with the machine. The students were probably tired, maybe even bored, but certainly must have sensed the usual "let-down" one has on the completion of any major project. But the understandings and abilities tested, even to that of an unfamiliar (transfer) problem type, were equivalently achieved by each of the Interaction Strategies.

The Retention 1 test was a "pop" test given to a class in an 8:30 a.m. lecture period from which the experimental population was drawn. The decision was disastrous to the statistics because 75 percent of the experimental group was absent. The attendance of the ENCY control was 14 percent, of the PPI--26 percent, and of the GL--31 percent of the experimental group. The author sorely regrets the lack of Standardized scores on these students at this juncture as this difference in attendance provided another curious event to analyze. What kind of student cuts class?

No differences in the short-term retention of those present could be ascertained with any certainty because of the low frequencies. The PPI and GL cell means seem to be stretching into the difference pattern that is seen later in

The Retention 2 test was given by individual appointment and in the Synnoetics Laboratory. The students were told that the test was important and would "count." The students had nothing to study from, and the Sequential Logic Circuit Theory was unrelated to other subjects which they were taking. It was therefore assumed that long-term retention was not being re-inforced except possibly by conversations with colleagues about the experiment. Nonetheless, at this juncture, differences in the test results are such that when Retention 2 is combined (i.e., Consolidation test score) or compounded (Effective Learning Rate), the ENCY control separates from the other Instruction Control groups.

The differences in the test score means in Experiment #2 were not precisely those found from the Experiment #1 data (Lenahan and Clatur, 1969). There the PPI-INC students performed best on the immediate Post test. This has also been the case in those CAI experiments in which differences were found between programmed instruction and other forms of instruction. But the Retention tests must be considered more appropriate measures of whether learning has consolidated into and is retrievable from the student's Long-term Memory. And here the PPI results began to appear least promising. Only the trends of this expectation can be seen in the graphs of the Experiment #2 tests. In both Experiments #1 and #2, the relative positions of the test scores for PPI and GL students remained the same. It was in ENCY controlled strategies where the Design Schedule showed signs of difference over the long term (Figures 3-71 and 3-72).

Further, the rate of forgetting is said to be limited to a number of factors that include time and meaningfulness (Slamecks, 1967). The Retention 2 test was the same time lapse for all students, but there is good reason to believe that the students in ENCY-INT strategy had a more organized set of information to remember and that it may well have been more meaningful to them. Consolidation test score results re-inforce this position.

3.4.5 The Processing Rates

Both methods of determining student Processing Rate, either the number of Accesses/hour or the number of Distinctly Accessed Bite Units/hour, resulted in the Instruction Control effect appearing in the ANOVA throughout the Universe and Bite Sets (excepting in Bite Set 4 where there were no significant effects). There was only one occasion, during Design in Bite Set 2, when the processing rates did not show ENCY control in the lowest position of the three controls, or in the lowest position of two divisions where equivalence of two or more groups was indicated. This uniformly low Processing Rate for ENCY reflects the relative difference in absolute accesses to Bites or distinct Bite Units since the time spent by the six interaction strategies was basically equivalent. The Distinctly Accessed Bite Units parameter provided a different order for the PPI and GL Processing Rates. The main

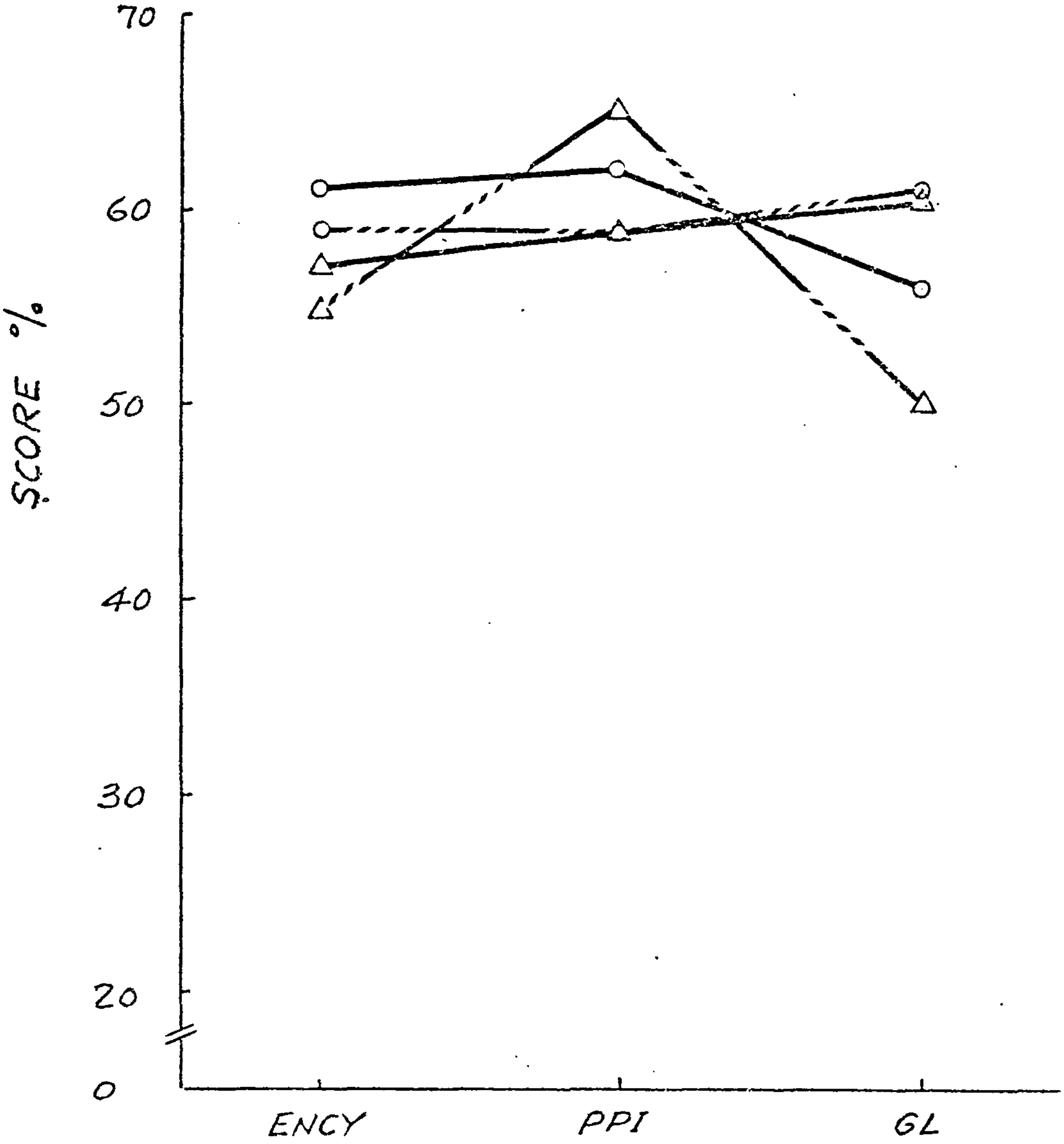


Figure 3-71. Means of PTOT
Experiments #1, #2

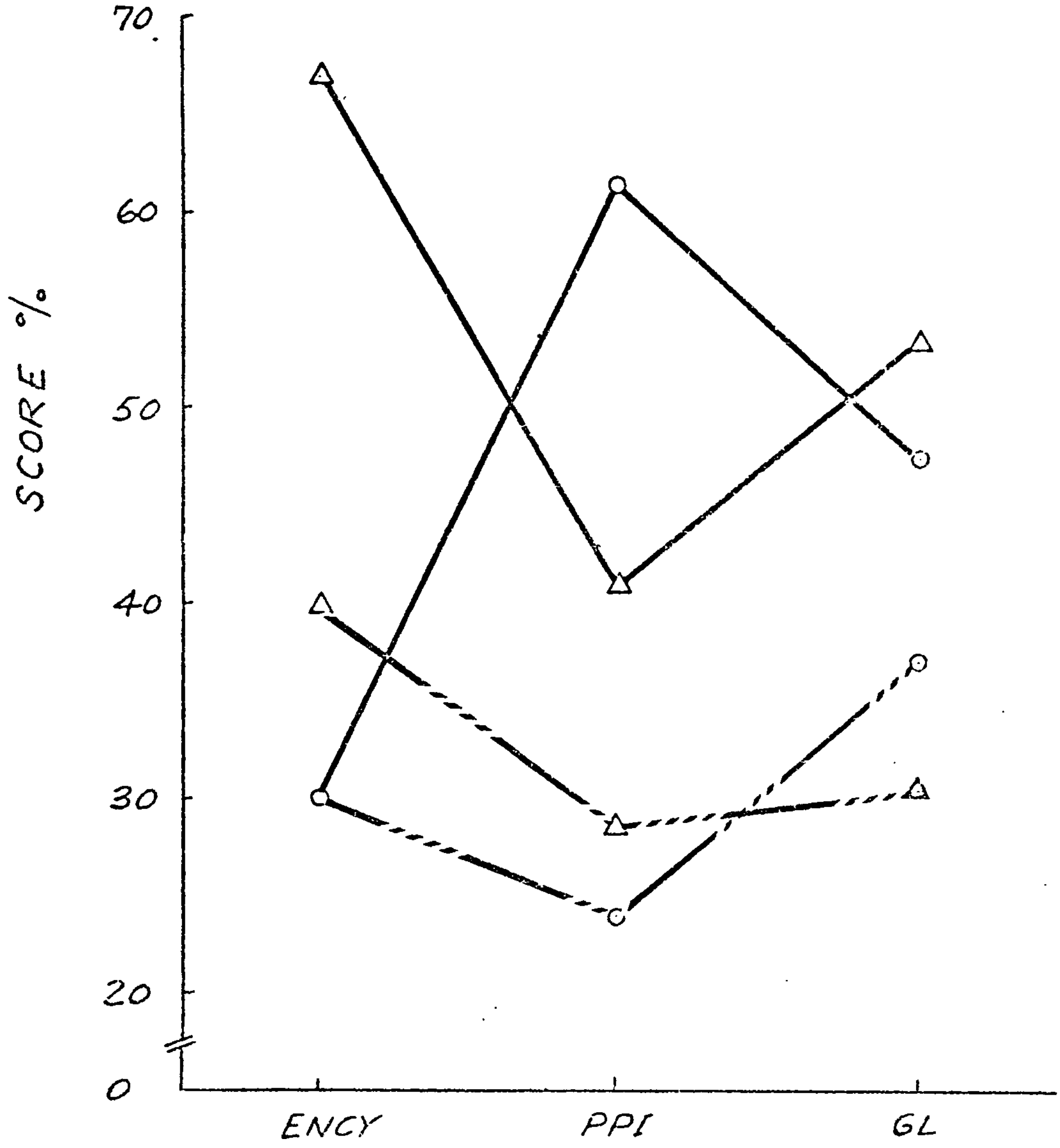


Figure 3-72. Means of R1TOT
Experiments #1, #2

INC △
INT ○
EXP.#1

reason was that the GL had more Bite Units to access than the other controls in most Bite Sets (Table I, page 29). The GL students would also be insured of having a higher processing rate of Distinctly Accessed Bite Units if they used the superficial, exploratory method of pushing the NEXT BASIC BITE key and largely ignored the peripherals.

The overall means of the Processing Rates (Accesses/hour) were about the same during the Fundamentals of Bite Sets 1 and 4, i.e., about 60 Bites/hour. However, the Processing Rate in Bite Set 2 during Fundamentals is 50 percent higher than this which indicates that the subject matter was considered relatively trivial or repetitious. During Design the higher Processing Rates (about 70-80 Bites/hour) in Bite Sets 1, 5, and 6 probably imply a random search for particular sets of information required for the solution of the design problem. The Processing Rates of Bite Sets 2 and 4 during Design ought to be disregarded because only a very few members in the cells re-accessed these Bite Sets.

3.4.6 Performance Rates

Performance Rate, defined as the number of test score points per hour in the Bite Structure, was equivalent among the students in the six groups. This was undoubtedly due to the lack of differences found among the time the students spent in the Universe and the test scores. The time the average student took in the Bite Structure was 3.57 hours and there were [illegible] differences to be found among the strategies in this regard. Thus Performance Rate became directly proportional to the test scores. This reduced the analysis of Performance Rates to that of the three test scores which showed no differences, not necessarily because there were none, but perhaps because the high variation among the observations with the groups and/or the low cell frequencies obscured them. Therefore, the Performance Rates of Experiment #2 students must also be considered as indicating no differences either because there were, in fact, none to be found among the six strategies, or because of the same reasons that may have obscured the differences among the test scores.

3.4.7 Effective Learning

Effective Learning, defined as the number of test score points per the number of accesses to the Bite Structure, was equivalent across the means for Short-term Learning (Post) and Retention 1 comparison, respectively. The Composite number of accesses made to the Universe was a parameter with a difference among the Instruction Controls. The ENCY control had a lower number of accesses. The low accesses of the ENCY control students was the key to the higher Effective Learning of that same group. For the Retention 2 test, the forgetting of the ENCY students had been less than that of the other students. This combination of effects was sufficient to produce the differences among the means seen in Effective Learning (Ret2).

3.4.8 Effective Learning Capacities

Effective Learning Capacities, defined as the product of time and the Effective Learning ratio, was affected most by the variations among the test score observations. The Sum of Squares Error term reduced from the ANOVA of the Post to Retention 1, to Retention 2. The discernible differences among the strategy means of the ELC increased in the same direction. Thus, the ELC (Post) showed no differences while the means of ENCY control separated out with high scores for the ELC (Ret1) and ELC (Ret2). Recall that in the Retention 1 test scores, the Incremental students of ENCY control had the leading mean score, while in the Retention 2 test scores, the ENCY Integral students had the highest mean numerically. This pattern is repeated in the ELC for Retention 1 and 2. And this shift to higher values for the Integral students of ENCY over the long-term is a consistent result throughout the analysis of Experiment #2.

The fact that significant differences appeared only in the retention scores could relate to a neurophysiological interpretation of the Effective Learning Capacity parameter. Since ELC = (Test Score / Accesses) * Time, for any given test score, the fewer the accesses and/or the longer the time spent, the greater the Effective Learning Capacity. And permanent (long-term) storage in the human memory is more probable as smaller amounts of material are presented to a student with longer periods of time to rehearse the informa-

ould be considered a

ratio of the retrievable storage (the test score) and the potential long-term storage (time/accesses).

3.4.9 Effective Learning Rates

In this compound parameter, as in the others involving the test scores, the effect of the variability among the test score observations had a dominating effect. Also, recall that the cell means of both the Time of the Universe and any test score were respectively equivalent. This implies that, among this set of students in Experiment #2 on a group or cell basis, the Effective Learning Rate as a function of some test score was approximately some constant divided by the Accesses, i.e., the ELR of any average student was inversely proportional to the number of accesses he required. The constant would take on different values with each different test because any one test was not equivalent to the others. In the general case, however, the ELR increases as either the student scored higher, accessed fewer bites, and/or spent less time in the Bite Structure.

Only in ELR(Ret2) did the relatively low access rate of the ENCY students overcome the non-differences in the means of the three tests (Post, Retention 1, and Retention 2). The ENCY control produced the most Effective Learning Rate for long-term retention.

Another study of the effectiveness of different instructional strategies concluded that what is termed a "precisely-tailored instruction" yielded the largest gains and holds the promise of improvement in the effectiveness of teaching. It was difficult to determine the nature of this tailoring process beyond the idea that a student was tested for his state of knowledge p and provided an instructional sequence S(p) (Shuford and Massengill, 1967). It may be fair to say that the ENCY Instruction Control herein was a "most precisely-tailored instruction" and that it does indeed show promise of being an improvement in the effectiveness of teaching.

3.5 CONCLUSIONS

Instruction Control and Design Schedule were observed to affect the performance of students in learning the Sequential Logic Circuit Theory. Their performance was affected during the acquisition of the fundamentals of the course and during the application and/or re-acquisition of these fundamentals to the problems, both familiar and unfamiliar, in Sequential Logic Circuit designing. Instruction Control and Design Schedule were observed to affect the long-term retention of the fundamentals and designing skills. In particular, those students who directed their own learning were observed to have utilized the least amount of information available in the course, to have had the lowest rate of processing information in the course, to have had the highest Effective Long-term Learning, and to have had the highest Effective Learning Rate for long-term retention. The students

[illegible] who solved their design

problems as unified, integral tasks, had the highest Effective Learning Capacity for long-term storage. The students whose learning was machine controlled were observed to have the highest rate of processing information in the course. The Guided Learning students were observed to have the highest processing rate of distinct statements of concept. No Interaction Strategy was found to be clearly different from the others based on the immediate or retention test scores alone.

The performance of all students in the course was observed to be such that the longer the time taken in the course, the more likely the student was to obtain lower test scores; the more time and accesses spent in his first problem-solving set, the more likely he was to obtain lower test scores; and the more accesses the student took during his last problem-solving set, the more likely he was to perform well on the questions relating to unfamiliar problems on the post test.

In this experiment, a high utilization of the course material was observed to imply superficiality or undirected purpose. The learner-control group, ENCY, selectively focussed on those concepts not well understood by them and spent their time and accesses perusing the peripherals of these concepts. The other groups were observed to rely on the machine to present them with the top-level statements of more concepts but without the accompanying depth searches. In the short-term, the differences in involvement, self-organizing, and integration of the subject matter had no observable effect on the learning achieved. After a number of weeks, however, the more meaningful, better integrated, more rehearsed smaller amounts of information of the learner-control group were observed to be more effectively learned than that of the machine control group (PPI) or the collaboratively controlled group (GL).

Overall then, the most effective instruction system for long-term learning was observed to be that in which the student directed his own learning.

Chapter 4

EXPERIMENTS #3 AND #4 ANALYSES

4.1 METHODOLOGY

The general statistical interest in the results of Experiments #3-#4 combined was to determine to what extent the vocational students would corroborate the results found in Experiment #2.

Therefore, the same analysis procedure and statistical techniques were used in this set of experiments as were documented in Chapter 3.1, with the exception of the Chi-Square tests on the Relative Access and Times to the Bite Sets. These were not calculated for this set of analyses because the data did not justify the null hypothesis of equality among the cell means across the Bite Sets.

4.2 DATA PREPARATION

With the exception of the availability of most of the standardized scores for Experiments #3 and #4, the preparation of the data of this set of experiments parallels that of Experiment #2. Experiment #3 students represented the three Instruction Controls of the Incremental Schedule and Experiment #4 students represented the three Instruction Controls under the Integral Schedule.

From the one Master Student File a set of files, i.e., the Group Summary Files, ANOVA data Files, and the Correlation Matrix Data Files, were also built for the students in Experiments #3 and #4. (Refer to Table IV, Section 3.2, page 47.) The standardized scores available were those five of the American College Testing Service--the ACT Composite, the ACT English, the ACT Mathematics, the ACT Natural Science, and the ACT Social Science, as well as the Programmer's Aptitude Test. There being no comparable scores available for the Experiment #2 students, these scores were analyzed in their raw form. This avoided the decision of which percentile scale to equate them to, i.e., to a comparison of students who subsequently entered college, or to a comparison of mixed college-bound and non-college-bound high school students. This decision did not affect the use of the scores in the correlations, of course.

The one cell, PPI-INC, of student standardized scores all being missing precluded doing the two-way ANOVAS for the six standardized scores. However, a standard set of descriptive statistics was run for these scores and a correlation matrix of the test scores and standardized scores was also prepared. Correlation coefficients with alpha levels ≤ 0.05 were noted.

4.3 RESULTS OF EXPERIMENTS #3 AND #4

As in Chapter 3, the calculations are charted by type with separations into the categories to be examined:

Universe parameters
Relative Accesses and Times parameters
Bite Unit parameters
Standardized Test Scores
Experiment Test Scores
Processing Rates
Performance Rates
Effective Learning
Effective Learning Capacities
Effective Learning Rates

In the ANOVA tables, only those Fs which indicated significance at the 5 percent alpha level are shown. In the table of Significant Correlation Coefficients, a negative sign indicates a negative Pearson's r correlation coefficient.

The overall result was that students under ENCY Instruction Control, complete learner-control, generally utilized the Bite Structure the least. ENCY students under the Integral Design Schedule took the most time, generally had the lowest rate of processing the Bites, the lowest Performance Rate, and the Lowest Effective Learning Rate. On the other hand, the ENCY and PPI students under the Incremental Design Schedule generally had the highest Performance Rate and the highest Effective Learning Rate. The GL students had the poorest test score performance.

4.3.1 The Universe Parameters

The ANOVA and correlation Tables XXI and XXII and the related graphs in Figures 4-1, 4-2 refer to the Universe

TABLE XXI

ANALYSIS OF VARIANCE EXPERIMENTS #3-#4
UNIVERSE PARAMETERS

Parameter	$\bar{X}$	s	$\bar{X}_{11}$	$\bar{X}_{12}$	$\bar{X}_{13}$	$\bar{X}_{21}$	$\bar{X}_{22}$	$\bar{X}_{23}$	RxC F	ROWS F	COLS F
TU C	5.62	1.80	4.98	4.79	5.04	8.55	5.94	6.08		17.0^{1}_{37}	
TU F	3.29	1.10	3.31	2.94	2.92	4.95	3.00	3.21		4.93^{1}_{44}	5.59^{2}_{44}
TU D	2.36	1.24	1.90	1.85	2.13	2.79	2.88	3.18		8.55^{1}_{41}	
AU C	384.4	97.9	328.7	390.1	367.9	451.0	466.6	336.3			
AU F	214.8	55.2	205.7	206.8	212.0	265.7	222.8	187.3			
AU D	171.5	73.7	133.3	183.3	172.6	147.0	243.8	164.3			3.23^{2}_{41}

TABLE XXII

PROBABILITY OF PEARSON'S COEFFICIENT OF CORRELATION ≤ 0.05
EXPERIMENTS #3-#4 UNIVERSE - TEST SCORES

Parameter	PTOT	PFD	PFM	PTRS	PUN	R1TOT	R1FD	R1FM	R2TOT	STFT	STFD	STFM	LTFT	CONSOL
TU C			.020^{-}		.001	.034^{-}	.038^{-}							
TU F														
TU D	.017^{-}	.042^{-}	.020^{-}		.000	.021^{-}								
AU C														
AU F														.040
AU D		.038^{-}												

$^{-}$ negative correlation of coefficient

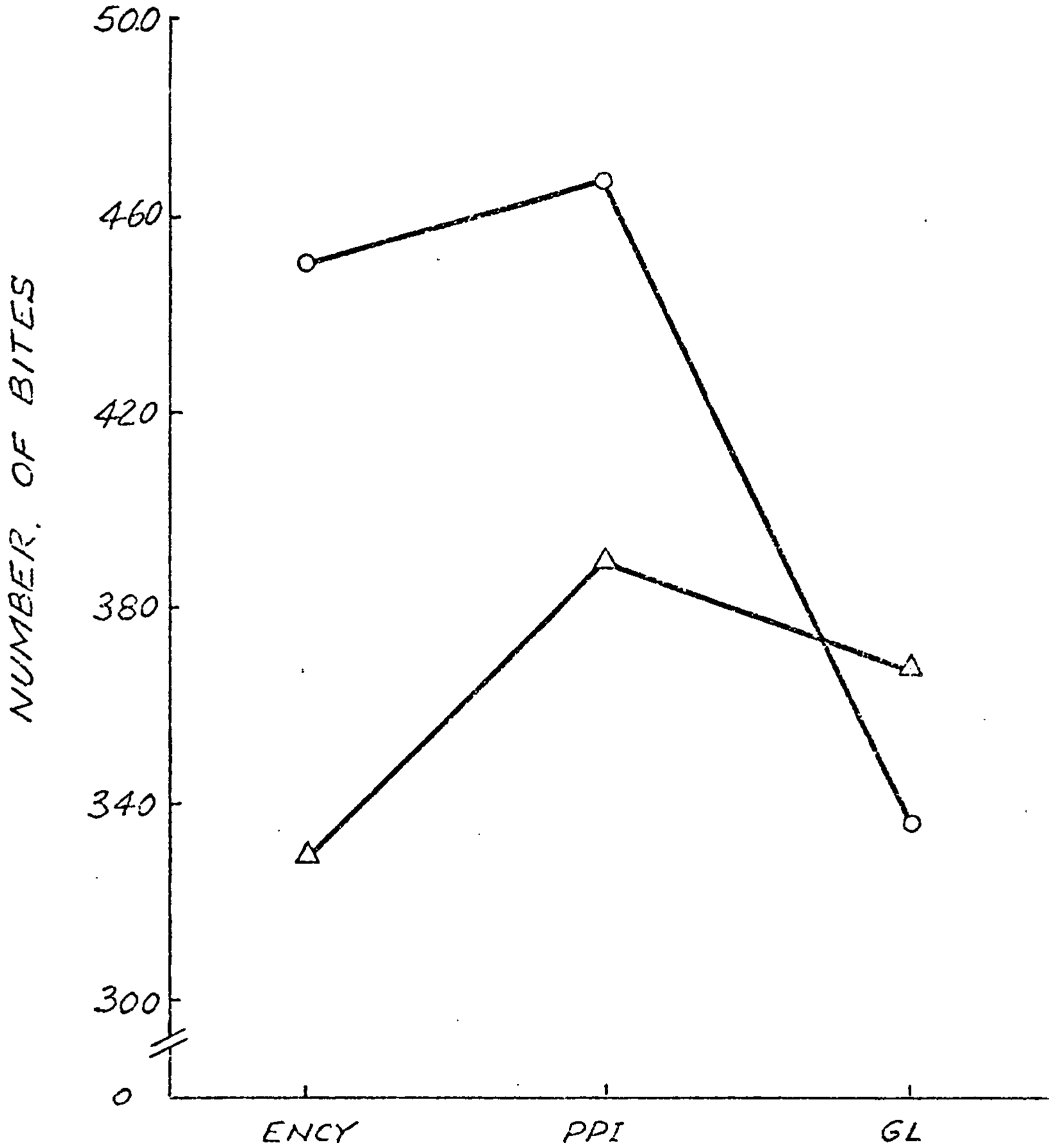


Figure 4-1. Means of AU-C
Experiments #3-#4

INC
INT
C
D
F

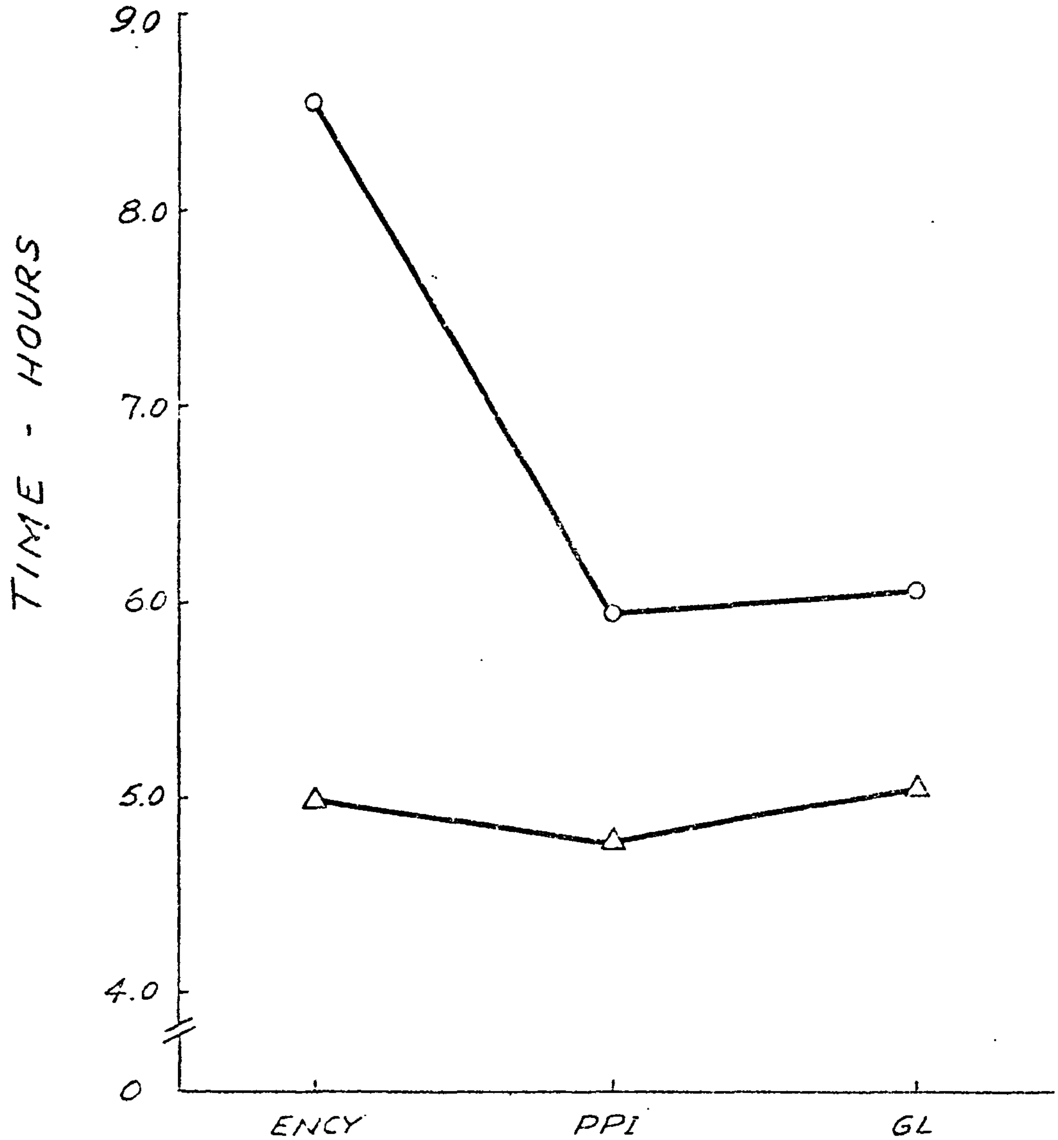
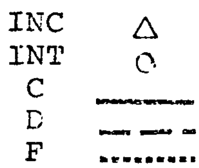


Figure 4-2. Means of TU-C
Experiments #3-#4



parameters. There was a difference in the number of accesses to the Universe made among the six interaction strategies, but only during the Design portion of the course (Figure 4-3). During Design, the students under ENCY control accessed the least number of Bites in the Bite Structure. During the Fundamentals, the groups accessed the Bite Structure equivalently (Table XXI).

Further, the correlations indicated that high accesses during Design had an adverse effect on the Post Fundamentals test score subtotal (Table XXII).

	ENCY	PPI	GL
INC	LO		
INT	LO		

Figure 4-3. Comparison of Means
AU - D
Experiments #3-#4

There were differences in the times the students spent in the acquisition and application stages of the course (Table XXI). During Fundamentals and carrying into the Composite, the students in the ENCY-INT strategy took more time in the Universe than any of the other groups (Figure 4-4). During Design, the Experiment #4 or Integral Schedule students took more time than the Experiment #3 or Incremental Schedule students (Figure 4-5).

	ENCY	PPI	GL
INC			
INT	HI		

Figure 4-4. Comparison of Means
TU - C,F
Experiments #3-#4

	ENCY	PPI	GL
INC			
INT	HI	HI	HI

Figure 4-5. Comparison of Means
TU - D
Experiments #3-#4

Even more than with the accesses during Design, the time spent during Design correlated negatively with student results on the Post test scores (Table XXII).

4.3.2 The Relative Access and Time in Bite Set Parameters

The ANOVA and correlation Tables XXIII and XXIV and the related graphs in Figures 4-6 to 4-15 are found on pages 161-174. There were differences in the Relative Times and/or Accesses made to every Bite Set in the six groups (Table XXIII). In Bite Set 1, the Relative Time spent was the highest among the PPI students during Design, lowest among the GL students during the Fundamentals, while the Composite picture was one in which the ENCY control students and PPI-INC strategy students spent the greatest Relative Time (Figures 4-16, 4-17, 4-18). There were positive correlations

TABLE XXIII

ANALYSIS OF VARIANCE EXPERIMENTS #3–#4
RELATIVE TIMES AND ACCESSES
IN THE BITE SETS

Parameter	$\overline{X}$	s	$\overline{X}_{11}$	$\overline{X}_{12}$	$\overline{X}_{13}$	$\overline{X}_{21}$	$\overline{X}_{22}$	$\overline{X}_{23}$	RxC F	ROWS F	COLS F
RTBS1 C	0.319	0.083	0.392	0.353	0.272	0.349	0.257	0.254		6.41^{1}_{37}	8.46^{2}_{37}
RTBS1 F	0.527	0.124	0.609	0.538	0.499	0.581	0.514	0.386			6.30^{2}_{44}
RTBS1 D	0.027	0.038	0.031	0.053	0.000	0.004	0.040	0.023			5.00^{2}_{41}
RTBS2 C	0.130	0.046	0.126	0.154	0.110	0.163	0.125	0.113			
RTBS2 F	0.217	0.072	0.205	0.248	0.191	0.212	0.216	0.219			
RTBS2 D	0.009	0.016	0.012	0.002	0.011	0.009	0.016	0.008			
RTBS4 C	0.149	0.066	0.112	0.127	0.180	0.154	0.166	0.180			
RTBS4 F	0.244	0.098	0.182	0.211	0.293	0.204	0.268	0.335			7.05^{2}_{44}
RTBS4 D	0.006	0.035	0.001	0.000	0.000	0.000	0.012	0.029			
RTBS5 D	0.390	0.150	0.418	0.401	0.486	0.370	0.404	0.274		4.33^{1}_{41}	
RTBS6 D	0.560	0.160	0.534	0.541	0.501	0.615	0.525	0.663			

TABLE XXIII (Continued)

Parameter	$\overline{X}$	s	$\overline{X}_{11}$	$\overline{X}_{12}$	$\overline{X}_{13}$	$\overline{X}_{21}$	$\overline{X}_{22}$	$\overline{X}_{23}$	RxC F	ROWS F	COLS F
RABS1 C	0.280	0.070	0.351	0.282	0.263	0.316	0.231	0.262			5.81^{2}_{37}
RABS1 F	0.486	0.115	0.557	0.477	0.495	0.522	0.470	0.377			
RABS1 D	0.029	0.041	0.029	0.059	0.000	0.017	0.041	0.026			5.88^{2}_{41}
RABS2 C	0.167	0.052	0.167	0.177	0.135	0.226	0.157	0.152			3.71^{2}_{37}
RABS2 F	0.286	0.083	0.267	0.331	0.239	0.294	0.290	0.283			
RABS2 D	0.014	0.027	0.016	0.003	0.020	0.011	0.017	0.020			
RABS4 C	0.121	0.047	0.099	0.101	0.141	0.124	0.133	0.149			
RABS4 F	0.215	0.083	0.172	0.190	0.181	0.238	0.279	0.233			4.84^{2}_{44}
RABS4 D	0.006	0.035	0.002	0.000	0.000	0.000	0.010	0.030			
RABS5 D	0.410	0.160	0.444	0.447	0.525	0.378	0.412	0.244	3.43^{2}_{41}	10.8^{1}_{41}	
RABS6 D	0.536	0.169	0.506	0.488	0.452	0.608	0.516	0.679		7.72^{1}_{41}	

TABLE XXIV

PROBABILITY OF PEARSON'S COEFFICIENT OF CORRELATION $\leq$ 0.05
EXPERIMENTS #3-#4 RELATIVE TIMES AND ACCESSES

Parameter	PTOT	PFD	PFM	PTRS	PUN	R1TOT	R1FD	R1FM	R2TOT	STFT	STFD	STFM	LTFT	CONSOL
RABS1 C	.016	.025												
RABS1 F	.018	.029			$.009^{-}$									
RABS1 D					.004									
RABS2 C														
RABS2 F					.028									
RABS2 D														
RABS4 C	$.049^{-}$			$.022^{-}$										
RABS4 F	$.004^{-}$	$.039^{-}$		$.034^{-}$										
RABS4 D														
RABS5 D			.013											
RABS6 D			$.040^{-}$											

TABLE XXIV (Continued)

Parameter	PTOT	PFD	PFM	PTRS	PUN	R1TOT	R1FD	R1FM	R2TOT	STFT	STFD	STFM	LTFT	CONSOL
RTBS1 C	.012	.025				.027			.012					
RTBS1 F	.018	.048												
RTBS1 D					.005									
RTBS2 C														
RTBS2 F					.033									
RTBS2 D														
RTBS4 C														
RTBS4 F														
RTBS4 D														
RTBS5 D														
RTBS6 D														

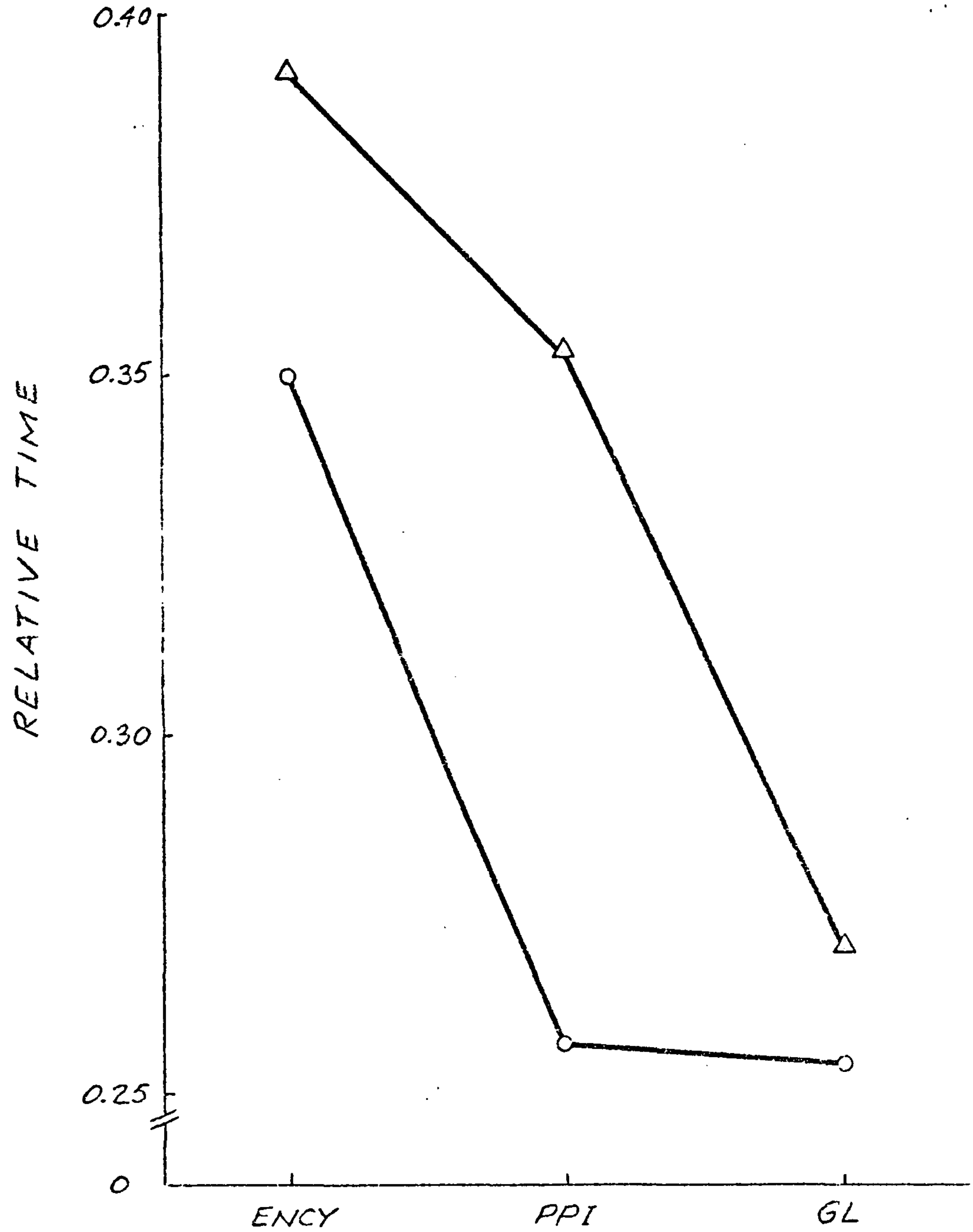


Figure 4-6. Means of RTBS1-C
Experiments #3-#4

INC
INT
C
D
F

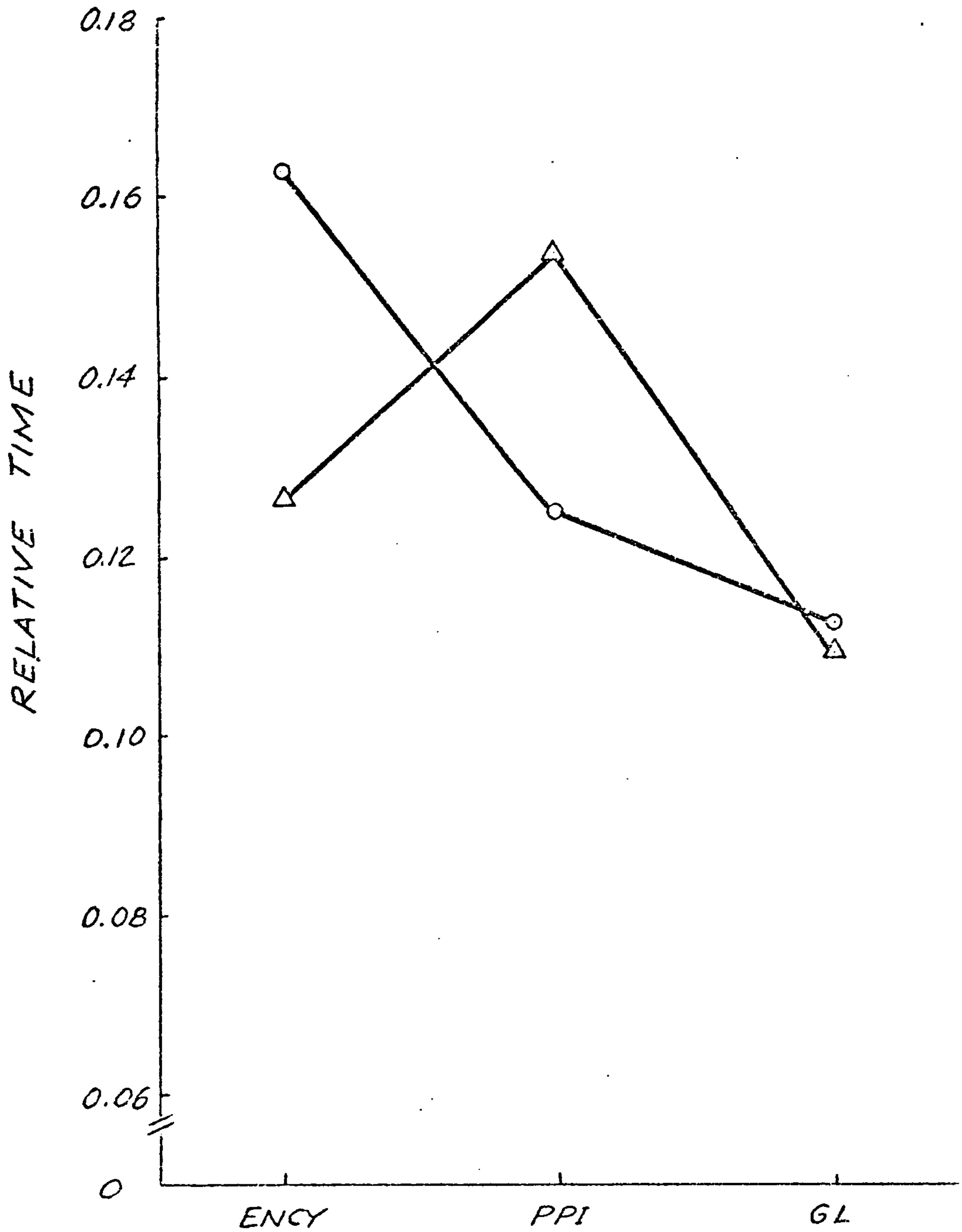


Figure 4-7. Means of RTBS2-C
Experiments #3-#4

INC
INT
C
D
F

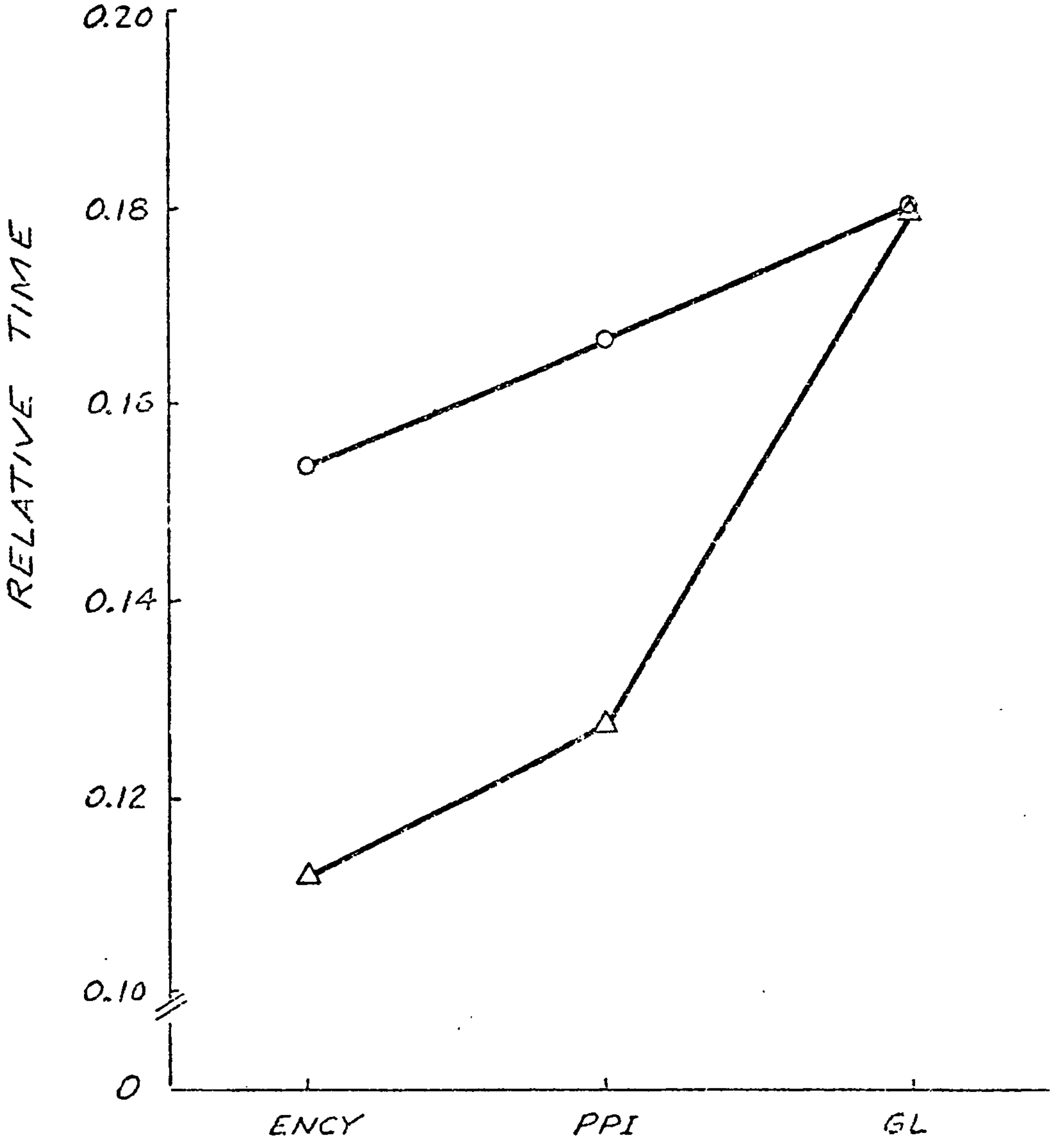


Figure 4-8. Means of RTBS4-C
Experiments #3-#4

INC △
INT ○
C
D
F

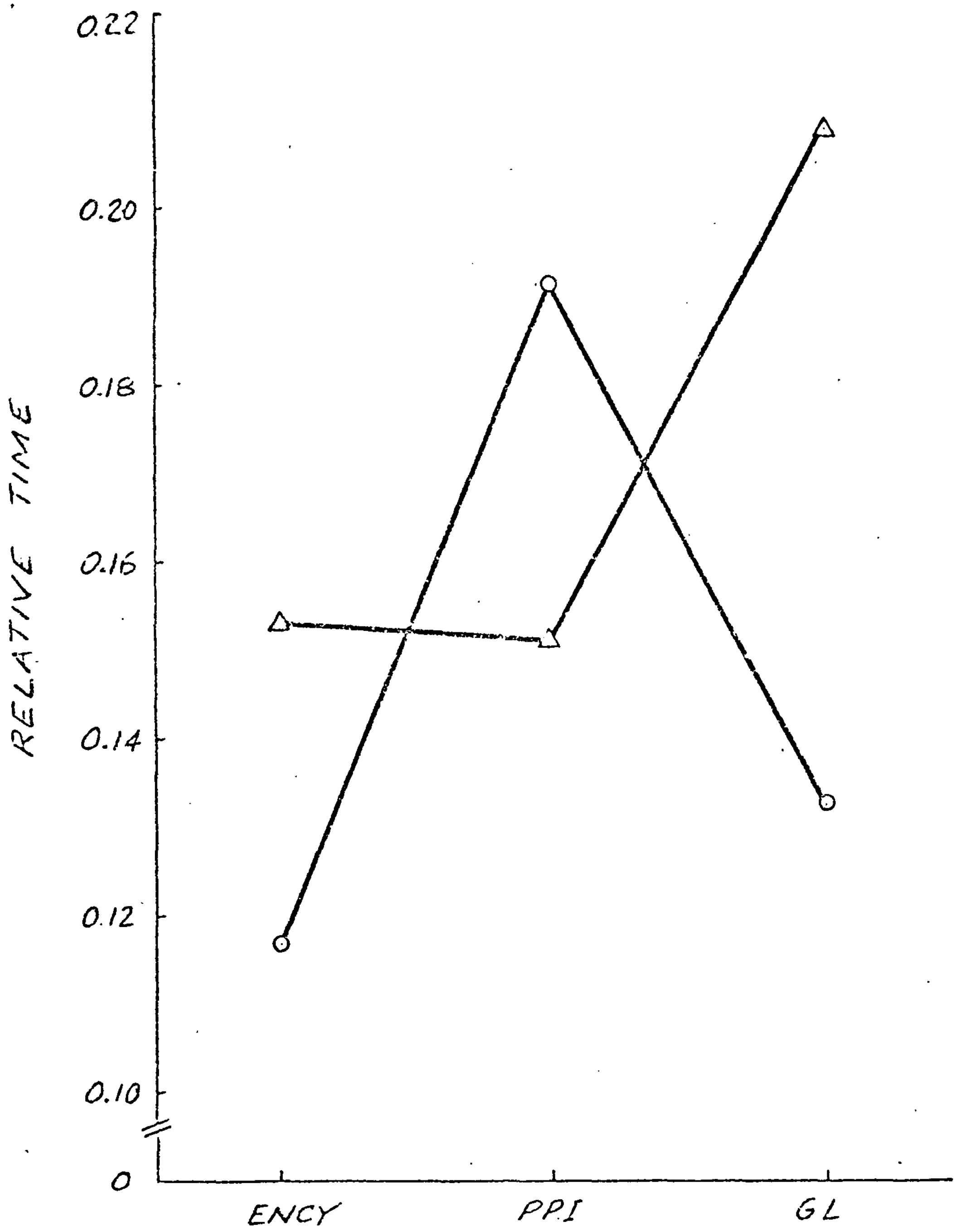


Figure 4-9. Means of RTBS5-C
Experiments #3-#4

INC △
INT ○
C
D
F

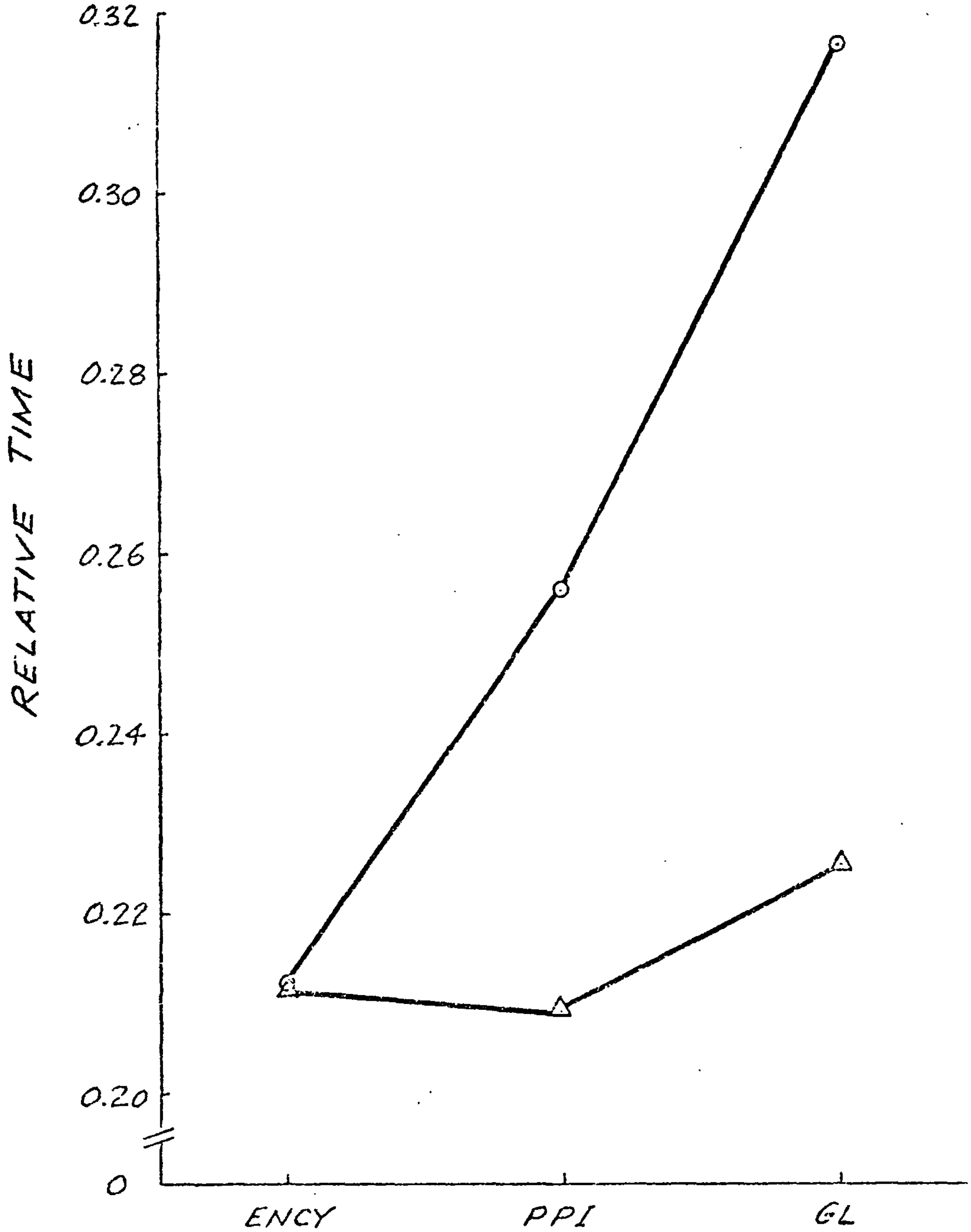


Figure 4-10. Means of RTBS6-C
Experiments #3-#4

INC △
INT ○
C
D
F

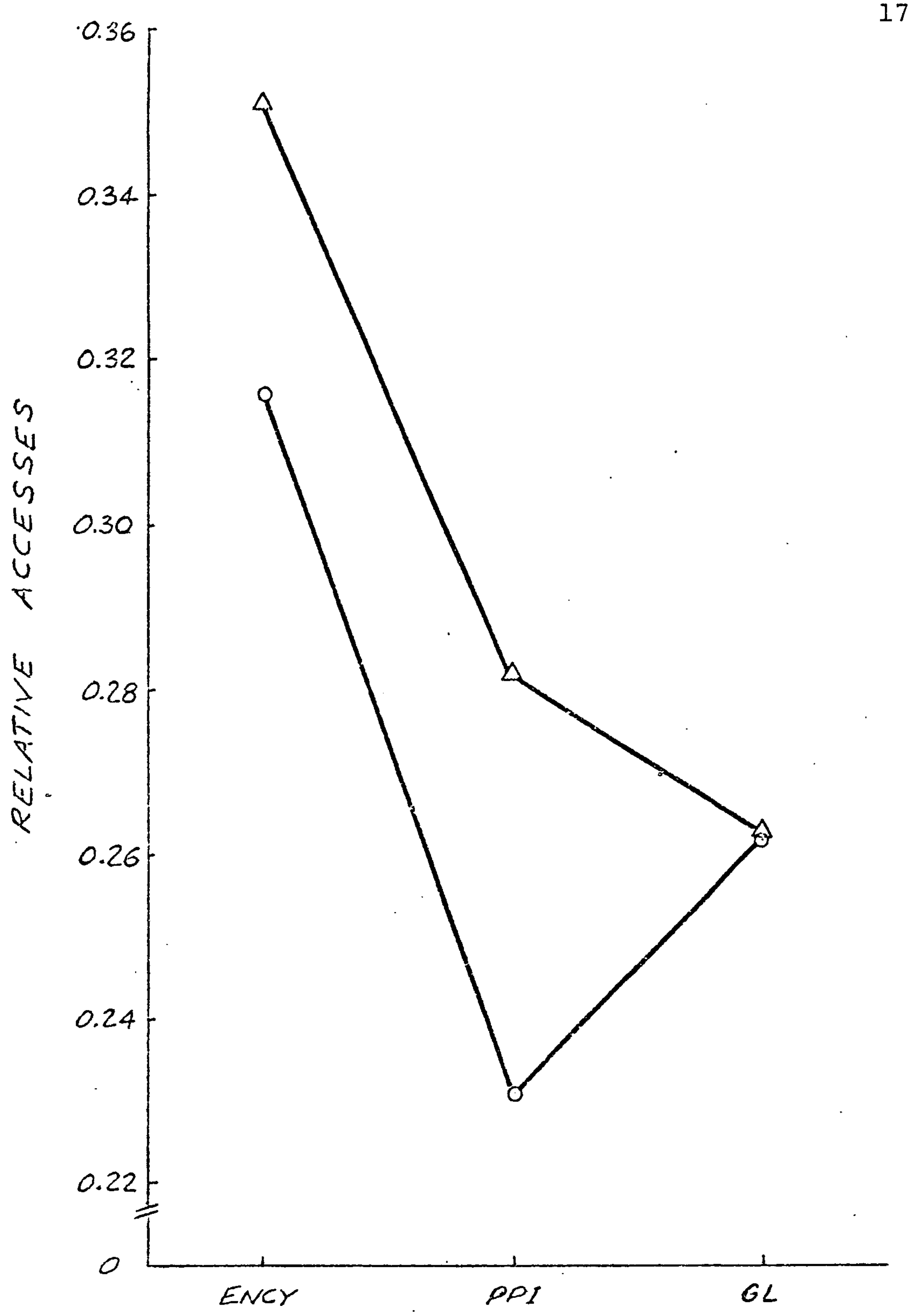


Figure 4-11. Means of RABS1-C
Experiments #3-#4

INC △
INT ○
C
D
F

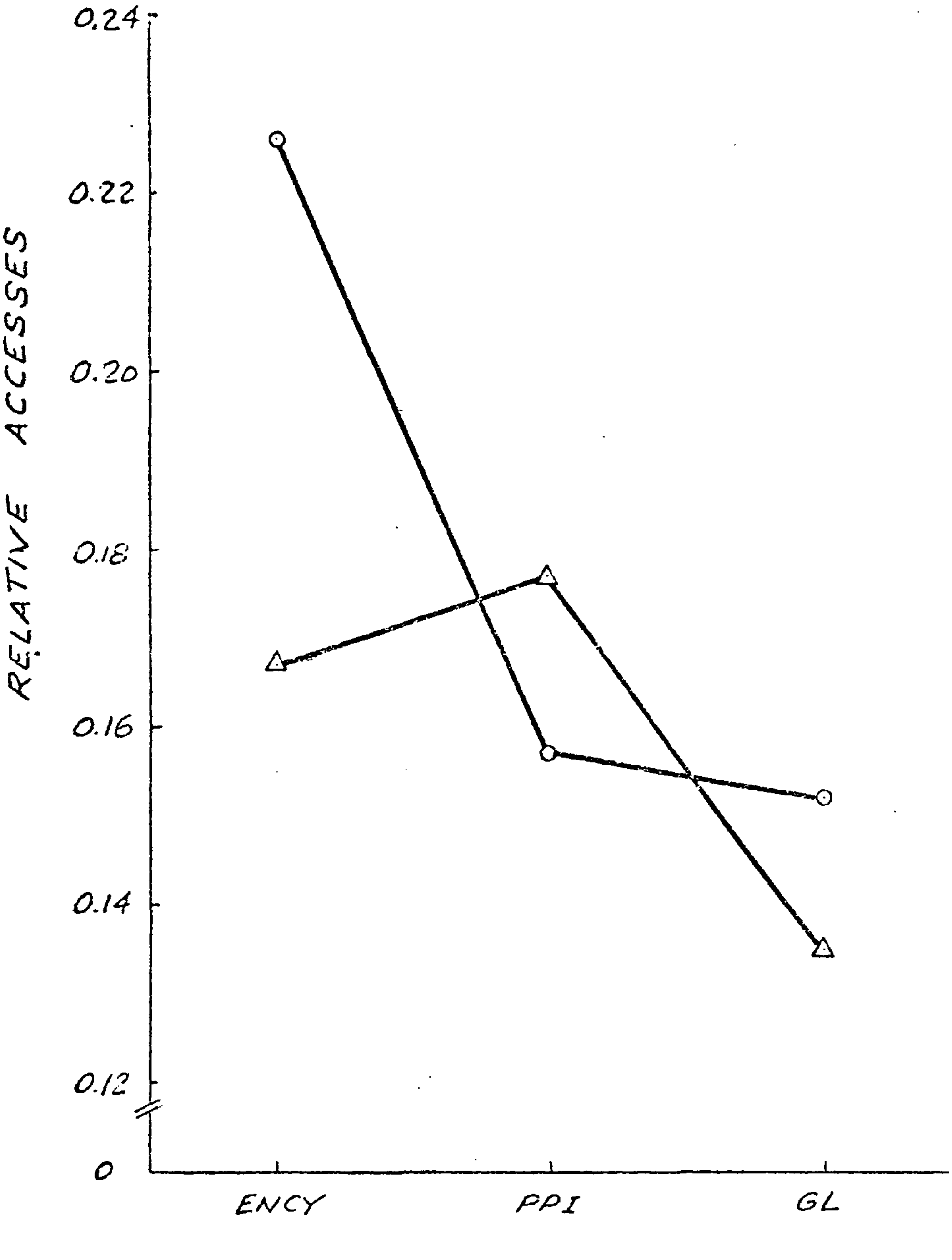
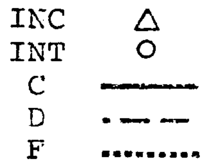


Figure 4-12. Means of RABS2-C
Experiments #3-#4



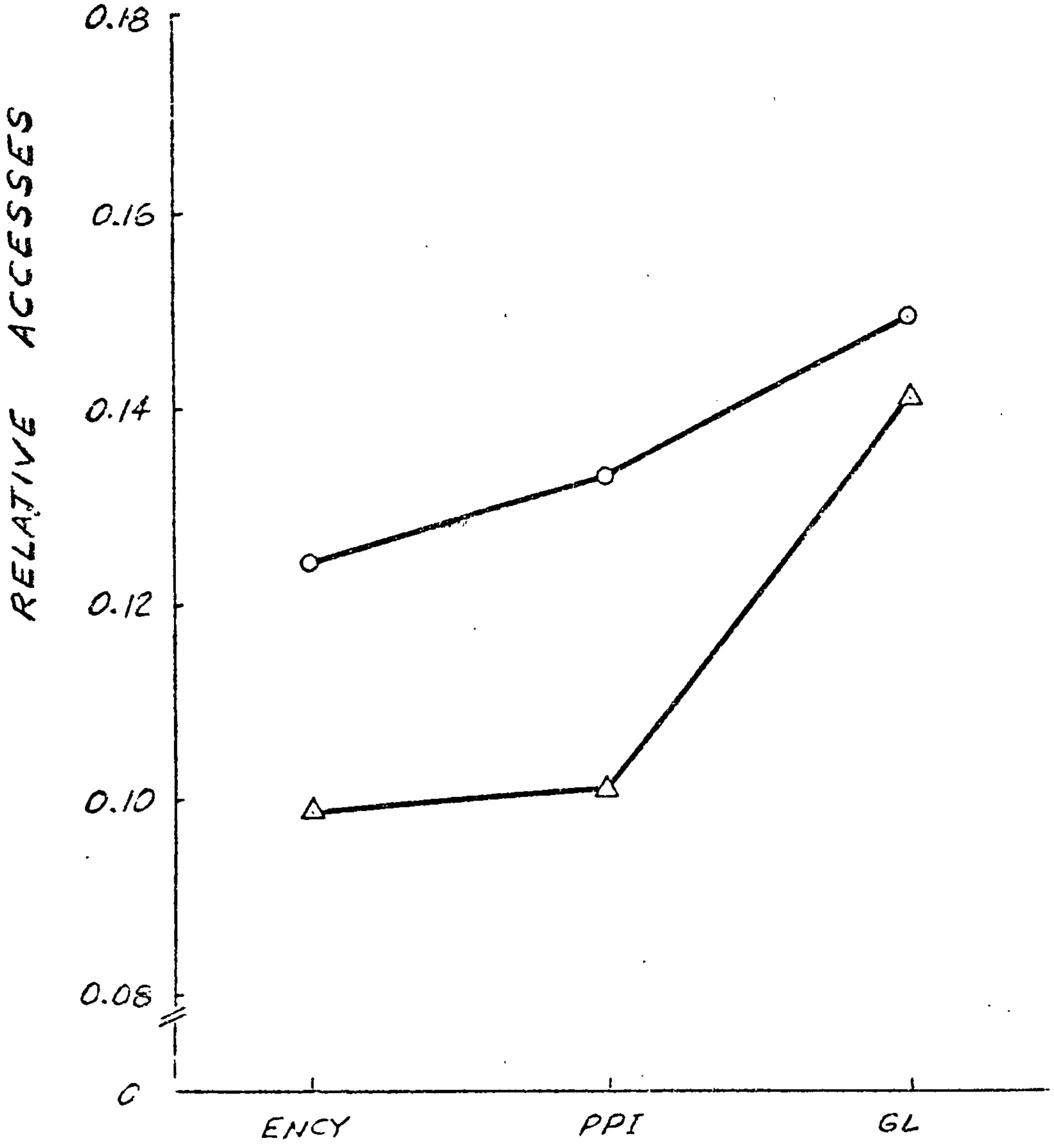


Figure 4-13. Means of RABS4-C
Experiments #3-#4

INC △
INT ○
C
D
F

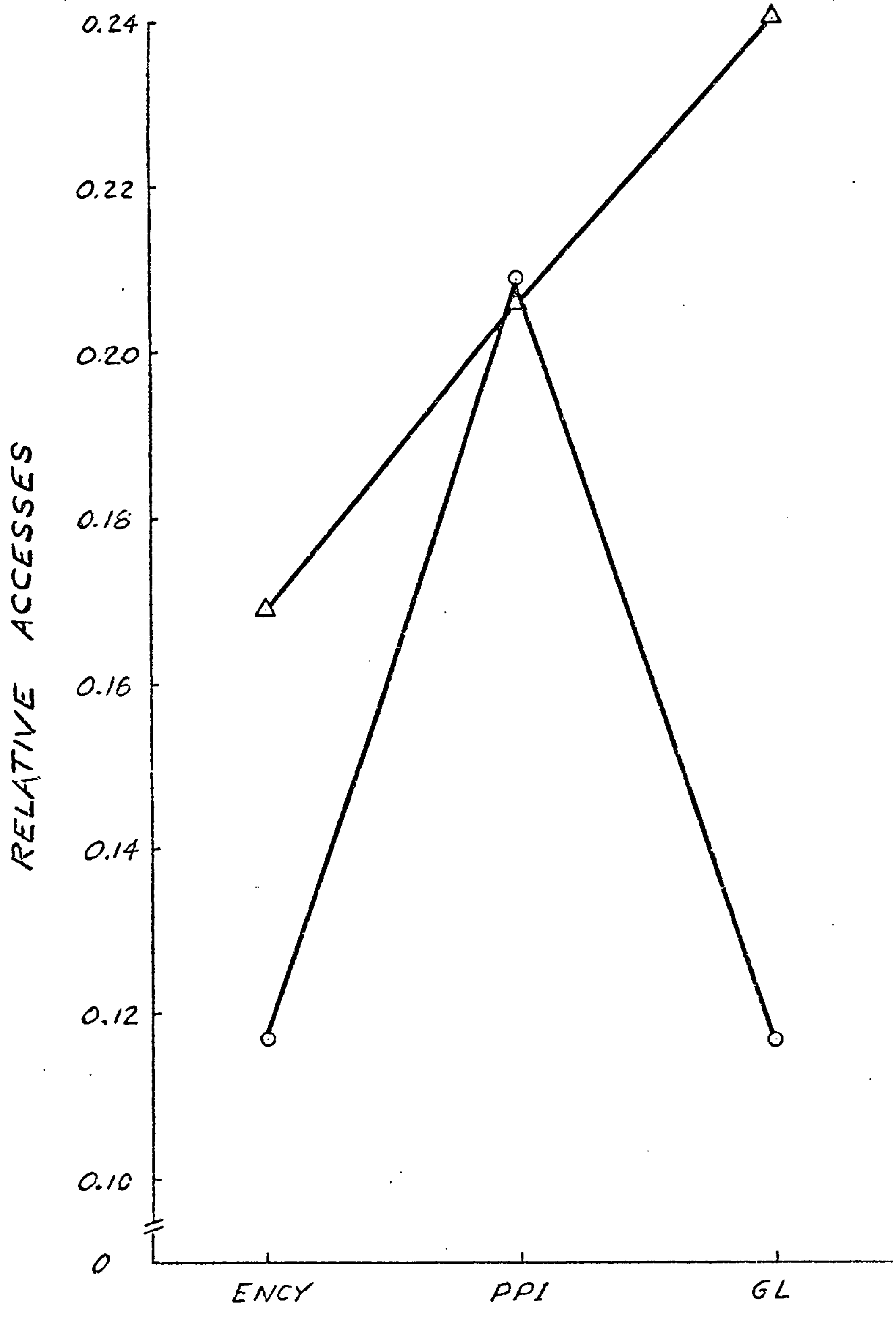
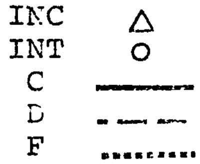


Figure 4-14. Means of RABS5-C
Experiments #3-#4



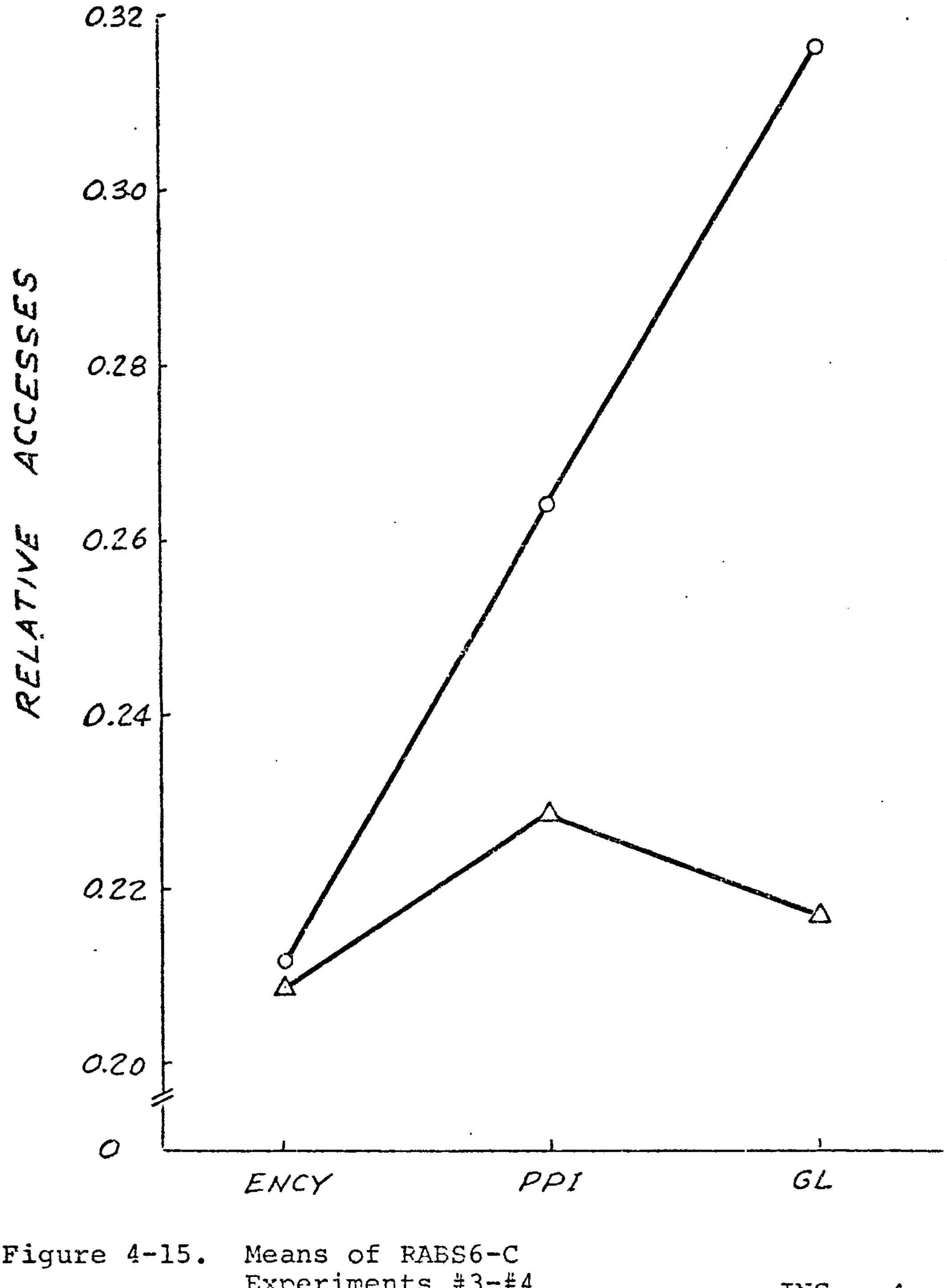


Figure 4-15. Means of RABS6-C
Experiments #3-#4

between the Relative Time in Bite Set 1 and the totals of all three tests--Post, Retention 1 and Retention 2. The higher the Relative Time spent in this Bite Set the higher was the test total (Table XXIII).

	ENCY	PPI	GL
INC		HI	
INT		HI	

Figure 4-16. Comparison of Means
RTBS1 - D

	ENCY	PPI	GL
INC			LO
INT			LO

Figure 4-17. Comparison of Means
RTBS1 - F

	ENCY	PPI	GL
INC	HI	HI	
INT	HI		

Figure 4-18. Comparison of Means
RTBS1 - C

The differences in the Relative Accesses to Bite Set 1 were limited to the Design portion of the course and the Composite. The differences in the Design portion were not sufficient to be the same ones as appeared for the Composite. During Design, the highest Relative Accesses (as well as the highest Relative Time) were made by the PPI control students.

In the Composite, the ENCY control had the highest Relative Accesses to the Bite Set (Figures 4-19, 4-20).

	ENCY	PPI	GL
INC	H1		
INT	H1		

Figure 4-19. Comparison of Means
RABS1 - C
Experiments #3-#4

	ENCY	PPI	GL
INC		H1	
INT		H1	

Figure 4-20. Comparison of Means
RABS1 - D
Experiments #3-#4

The correlations between the Relative Accesses to Bite Set 1 and the test scores are similar, although more limited, to those of Relative Time. Both the RABS1 - C and RABS1 - F correlated positively with the Post test Totals and Fundamentals. The more Relative Accesses to BS1 during Fundamentals, the fewer unanswered questions on the Post test. However, the more Relative Accesses (and Relative Time) during Design, the more unanswered questions on the Post test (Table XXIV).

The Relative Time spent in Bite Set 2 was equivalent from group to group. There is a column effect, however, for the Composite of the Relative Accesses to Bite Set 2 (Table XXIII). The Scheffe test acknowledged that the mean of the

ENCY control was different from the mean of the GL control but that the most different (highest) cell mean was that of ENCY-INT (Figure 4-21). The only significant correlation of the RTBS2 and RABS2 to the test scores was that which positively correlated them to the Post Unanswered subtotal. The more Relative Time and Accesses in Bite Set 2, the more unanswered questions on the Post test.

	ENCY	PPI	GL
INC			
INT	HI		

Figure 4-21. Comparison of Means
RABS2 - C
Experiments #3-#4

Only during Fundamentals were there apparent differences among the means of the Relative Time in Bite Set 4 and of the Relative Accesses to Bite Set 4 (Table XXIII). In both cases the GL control students had significantly higher means than either the ENCY or PPI controls' students, which were considered equivalent (Figure 4-22). Only the RABS4 showed significant correlations. This parameter correlated negatively during the Fundamentals portion and in the Composite course with the Post test Totals and the Post Transfer subtotals. The higher the relative number of accesses to Bite Set 4 the lower the achievement in the Post test.

	ENCY	PPI	GL
INC			HI
INT			HI

Figure 4-22. Comparison of Means
RABS4 - F and RTBS4 - F
Experiments #3-#4

Bite Sets 5 and 6, accessed only during Design, showed Design Schedule differences in the means of the Relative Times in Bite Set 5 and for both Relative Times and Relative Accesses in Bite Set 6 (Table XXIII). The Scheffes indicated a low Relative Access in Bite Set 5 for the GL-INT students to contrast with a high Relative Access in Bite Set 6. In Bite Set 5 the Incremental students took more time and access. In Bite Set 6 the ANOVA row effect would initially indicate that the Integral students took more accesses than the Incremental students, an unexpected result. However, the Scheffe results were such that all the cell means were equivalent excepting for GL-INT (Figures 4-23 through 4-25).

An interesting comparison of correlations was found for RABS5 and RABS6. While they both correlated with the Post Familiar test subtotal, the RABS5 correlation was positive and the RABS6 was negative (Table XXIV).

	ENCY	PPI	GL
INC	HI	HI	HI
INT			

Figure 4-23. Comparison of Means
RTBS5 - D, Experiment #3-#4

	ENCY	PPI	GL
INC	HI	HI	HI
INT			LO

Figure 4-24. Comparison of Means
RABS5 - D
Experiments #3-#4

	ENCY	PPI	GL
INC			
INT			HI

Figure 4-25. Comparison of Means
RABS6 - D
Experiments #3-#4

4.3.3 The Bite Unit Parameters

The ANOVA and correlation tables, Tables XXV, XXVI, and XXVII, are related graphs, Figures 4-26 through 4-30 are found on pages 180 through 187. Neither the Distinctly Accessed Bite Units in Bite Set 1 nor the Utilization of Bite Set 1 showed any significant ANOVA effects during Design or in the Composite. There was an ANOVA row effect registered for Fundamentals but the Scheffe test on the means did not recognize a row effect or any differences among the means (Tables XXV, XXVI).

The correlations are positive between the Utilization of Bite Set 1, Fundamentals and the Post Totals and Post Fundamentals. There is another positive correlation between the Utilization of Bite Set 1, Design and the Post Unanswered subtotals (Table XXVII).

TABLE XXV

ANALYSIS OF VARIANCE EXPERIMENTS #3–#4
UTILIZATION OF BITE SETS

P[illegible]eter	$\bar{X}$	s	$\bar{X}_{11}$	$\bar{X}_{12}$	$\bar{X}_{13}$	$\bar{X}_{21}$	$\bar{X}_{22}$	$\bar{X}_{23}$	RxC F	ROWS F	COLS F
[illegible] C	0.857	0.090	0.849	0.895	0.874	0.849	0.749	0.866			
[illegible] F	0.840	0.140	0.843	0.895	0.877	0.841	0.805	0.733			
[illegible] D	0.079	0.137	0.131	0.095	0.000	0.008	0.109	0.118			
U[illegible]2 C	0.899	0.113	0.749	0.958	0.906	0.832	1.000	0.916			18.5^{2}_{37}
U[illegible]2 F	0.890	0.128	0.758	0.958	0.907	0.763	1.000	0.916			23.0^{2}_{44}
U[illegible]2 D	0.079	0.162	0.114	0.007	0.104	0.041	0.166	0.104			
UBS4 C	0.906	0.108	0.840	0.954	0.874	0.888	1.000	0.870			5.54^{2}_{37}
UBS4 F	0.908	0.105	0.839	0.954	0.876	0.888	1.000	0.870			7.90^{2}_{44}
UBS4 D	0.035	0.150	0.028	0.000	0.000	0.000	0.133	0.097			
UBS5 D	0.591	0.180	0.569	0.699	0.740	0.453	0.595	0.406	3.37^{2}_{41}	24.5^{1}_{41}	
UBS6 D	0.594	0.114	0.618	0.640	0.650	0.451	0.520	0.598		13.1^{1}_{41}	

TABLE XXVI

ANALYSIS OF VARIANCE EXPERIMENTS #3–#4
DISTINCTLY ACCESSED BITE UNITS
IN BITE SETS

P eter	$\bar{X}$	s	$\bar{X}_{11}$	$\bar{X}_{12}$	$\bar{X}_{13}$	$\bar{X}_{21}$	$\bar{X}_{22}$	$\bar{X}_{23}$	RxC F	ROWS F	COLS F
J1 C	17.16	1.80	17.00	17.92	17.50	17.00	15.00	17.33			
U1 F	16.86	2.85	16.89	17.92	17.56	16.83	16.13	14.67			
J1 D	1.60	2.74	2.63	1.92	0.00	0.17	2.20	2.38			
U2 C	10.79	1.36	9.00	11.50	10.98	10.00	12.00	11.00			18.1^{2}_{37}
U2 F	10.70	1.53	9.11	11.50	10.89	9.17	12.00	11.00			22.9^{2}_{44}
U2 D	0.96	1.94	1.38	0.08	1.25	0.50	2.00	1.25			
DABU4 C	8.16	0.97	7.57	8.58	7.88	8.00	9.00	7.83			5.39^{2}_{37}
DABU4 F	8.18	0.94	7.56	8.58	7.89	8.00	9.00	7.83			7.81^{2}_{44}
DABU4 D	0.32	1.35	0.25	0.00	0.00	0.00	1.20	0.88			
DABU5 D	25.47	7.75	24.50	30.08	31.83	19.50	25.60	17.50	3.34^{2}_{41}	24.4^{1}_{41}	
DABU6 D	22.59	4.34	23.50	24.33	24.75	17.17	19.80	22.75		13.1^{1}_{41}	

TABLE XXVII

PROBABILITY OF PEARSON'S COEFFICIENT OF CORRELATION ≤ 0.05
EXPERIMENTS #3-#4 UTILIZATION BITE SETS*

P eter	PTOT	PFD	PFM	PTRS	PUN	R1TOT	R1FD	R1FM	R2TOT	STFT	STFD	STFM	LTFT	CONSOL
1 C					$.047^{-}$									
1 F	.018	.037			$.000^{-}$									
1 D					.011					$.041^{-}$				
2 C														
2 F														
2 D														
UBS4 C														
UBS4 F														
UBS4 D														
UBS5 D		$.032^{-}$				$.026^{-}$		$.034^{-}$				.021		
UBS6 D														

* or equivalently Distinctly Accessed Bite Units

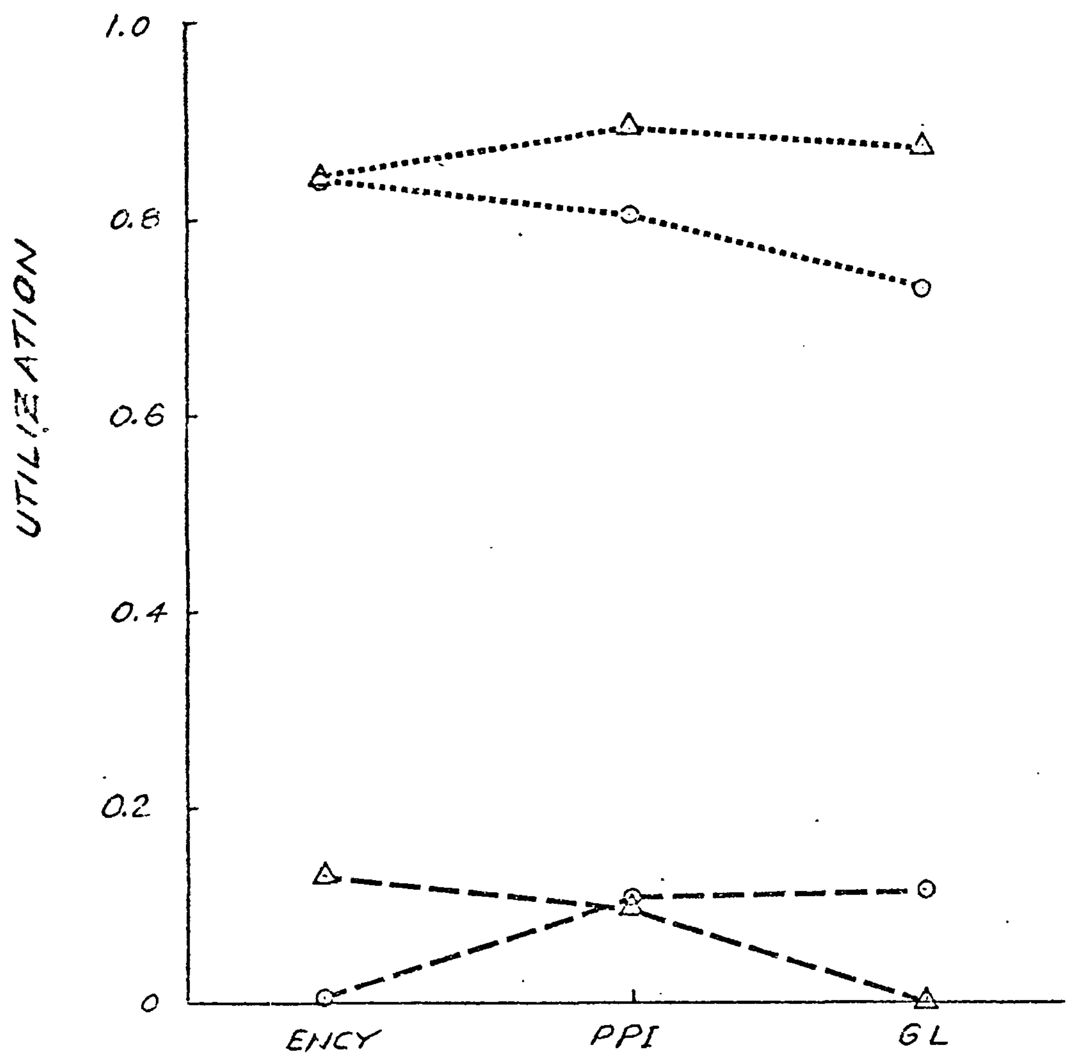


Figure 4-26. Means of UBS1-F,D
Experiments #3-#4

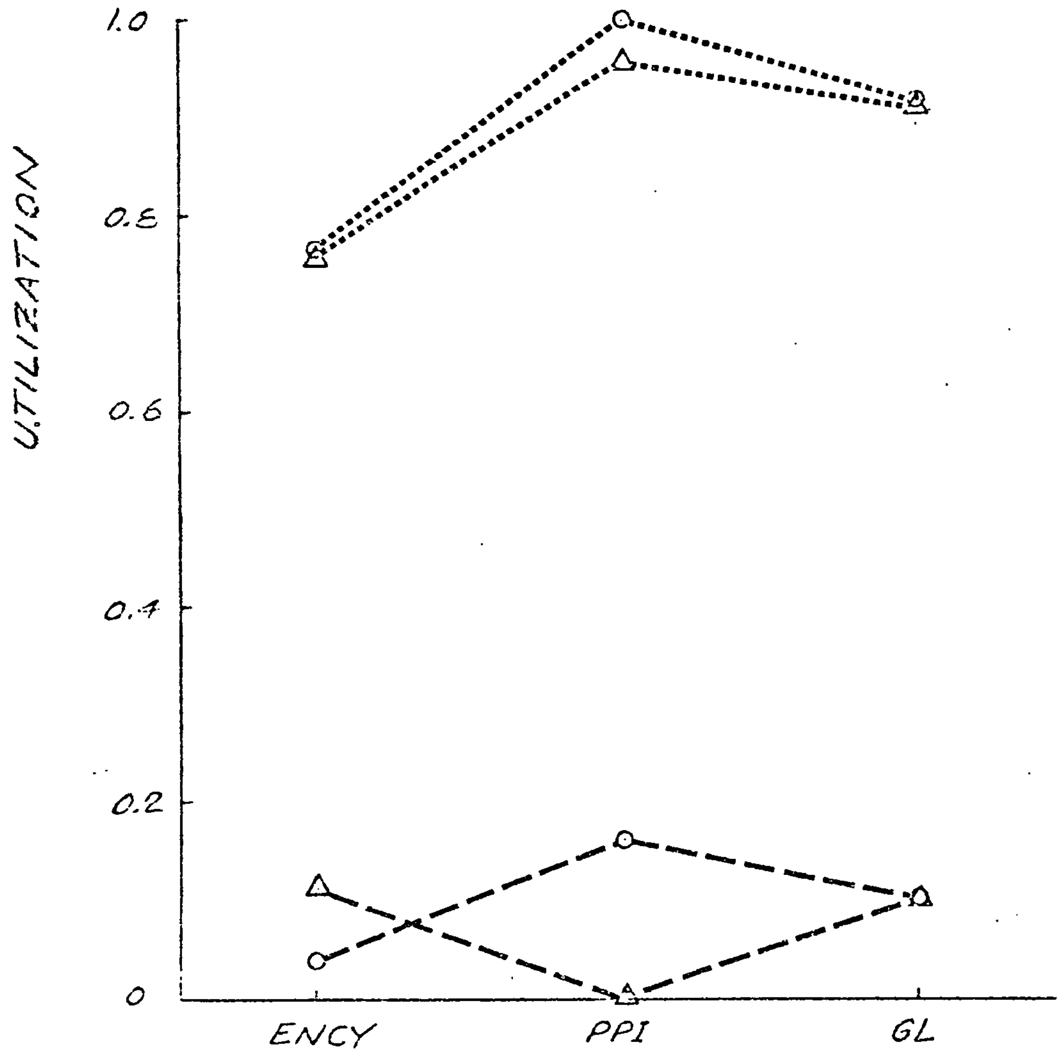


Figure 4-27. Means of UBS2-F,D
Experiments #3-#4

INC △
INT ○
C
D
F

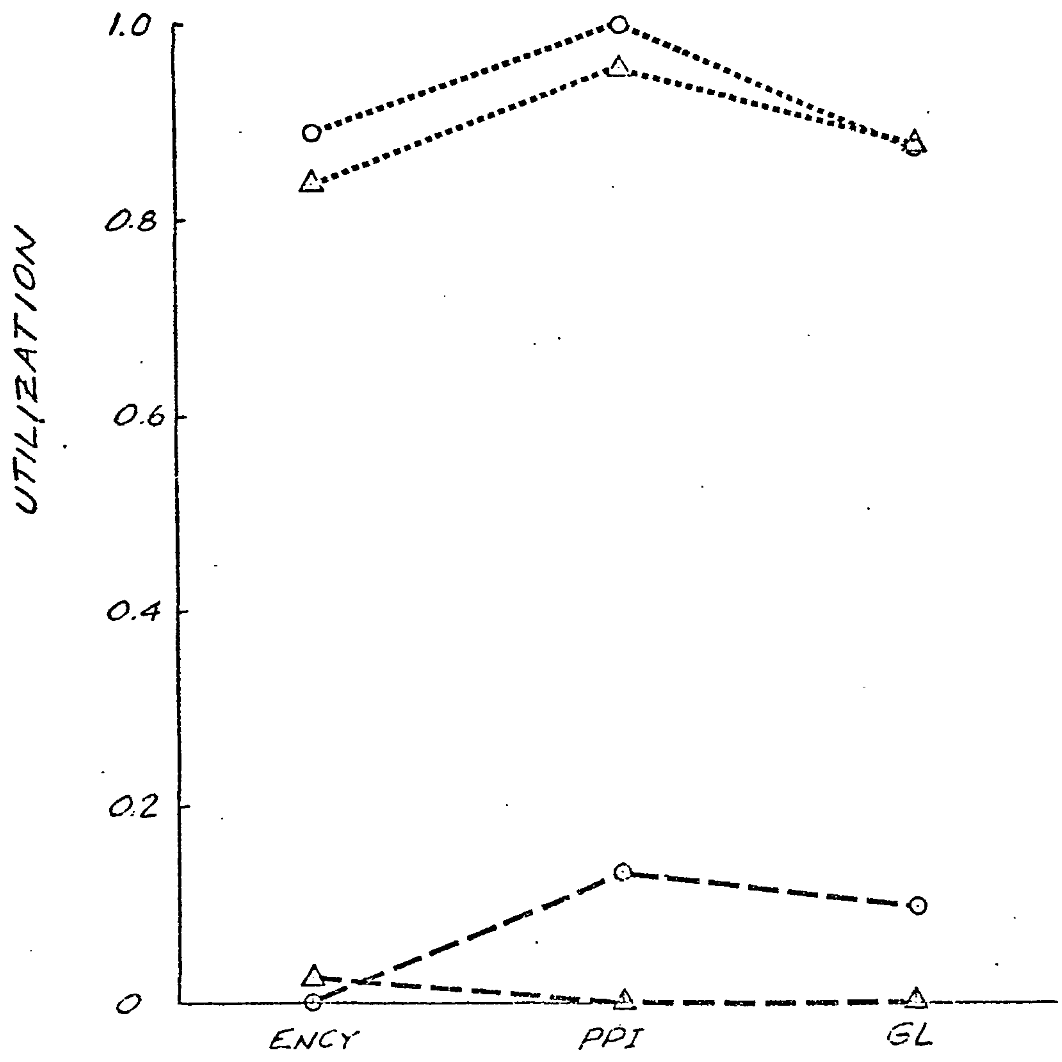


Figure 4-28. Means of UBS4-F,D
Experiments #3-#4

INC △
INT
C
D
F

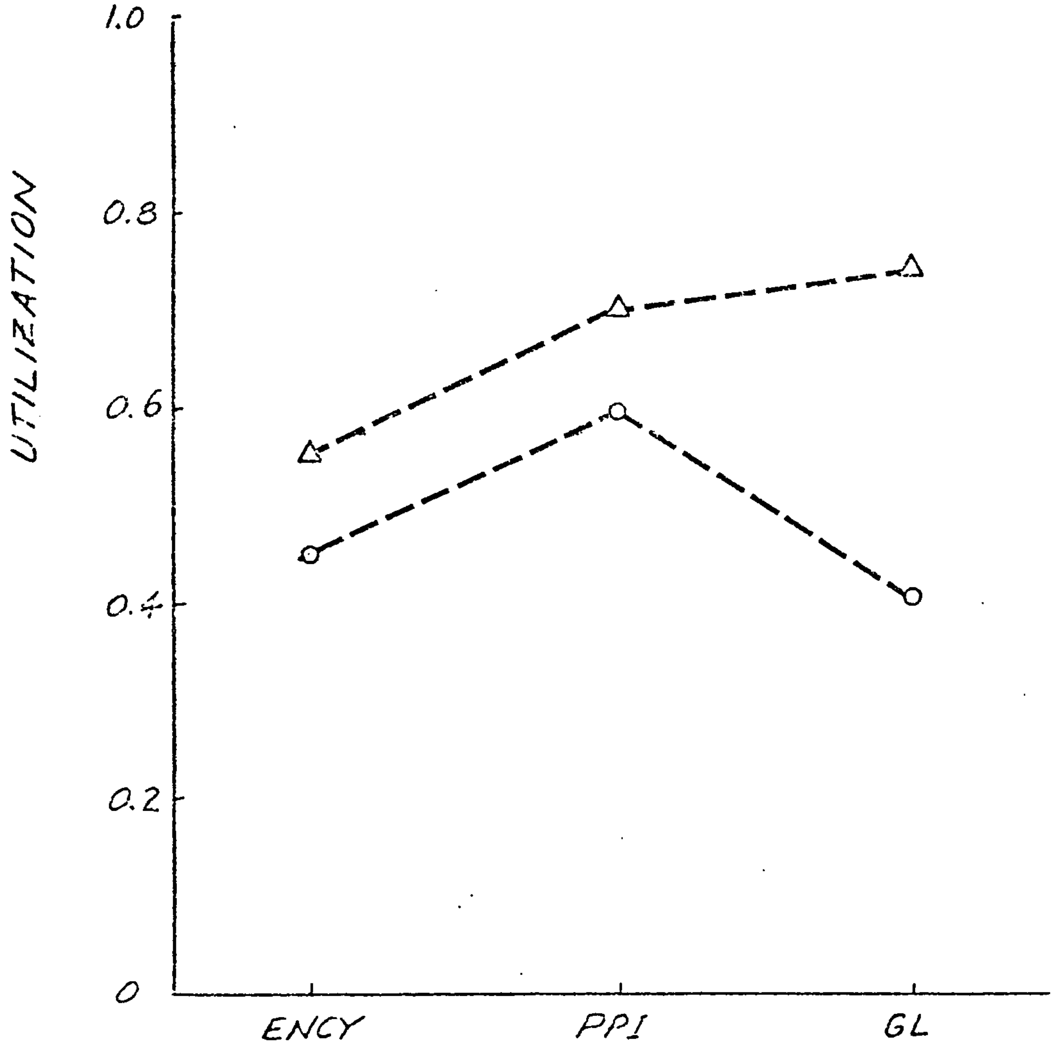


Figure 4-29. Means of UBS5-D
Experiments #3-#4

INC
INT
C
D
F

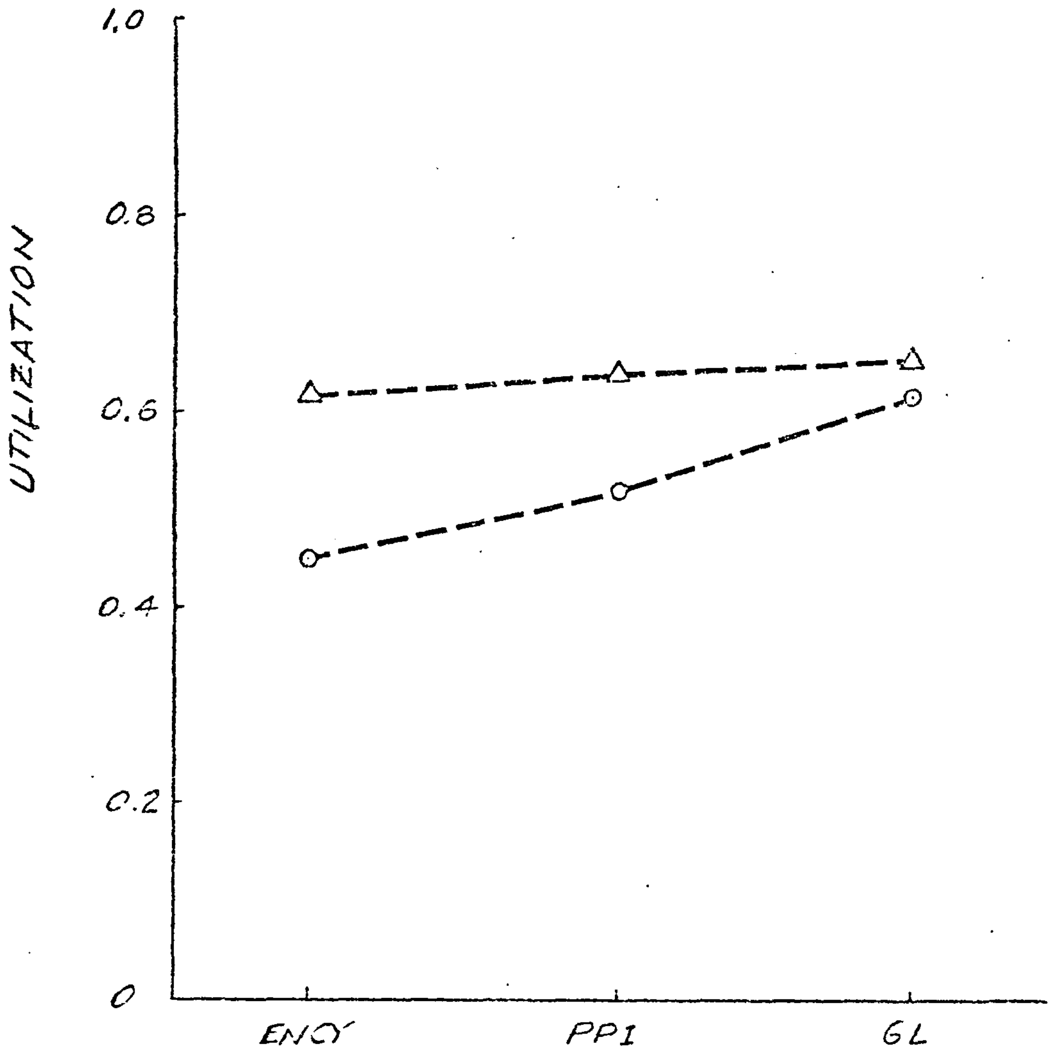
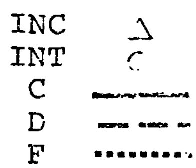


Figure 4-30. Means of UBS6-D
Experiments #3-#4



The use of Bite Units in Bite Set 2 produced clean instruction control effects in which the ENCY control students had the lowest mean during Fundamentals and the Composite (Figures 4-31 and 4-32).

	ENCY	PPI	GL
INC	LO	HI	MED
INT	LO	HI	MED

Figure 4-31. Comparison of Means
UBS2 - F
Experiments #3-#4

	ENCY	PPI	GL
INC	LO		
INT	LO		

Figure 4-32. Comparison of Means
UBS2 - C, DABU2 - C,F
Experiments #3-#4

The Utilization of Bite Set 4 and the Distinctly Accessed Bite Units in Bite Set 4 showed Instruction Control effects for the Fundamentals that carried into the Composite (Tables XXV, XXVI). The Scheffe tests showed the PPI control students had higher means than either of the ENCY or the GL students' means which were considered equivalent (Figure 4-33).

	ENCY	PPI	GL
INC		HI	
INT		HI	

Figure 4-33. Comparison of Means
UBS4 and DABU4 - C,F
Experiments #3-#4

The Utilization and Distinctly Accessed Bite Units in Bite Sets 5 and 6 showed the same ANOVA results as the Relative Accesses to Bite Sets 5 and 6 (Tables XXV, XXVI, and XXIII). However, the comparisons of the means formed differing sets of patterns in each case. For the Utilization of Bite Sets 5 and 6, the students under PPI instruction control had the highest mean with the lowest mean being that of the ENCY-INT students (Figure 4-34). The Distinctly Accessed Bite Units in Bite Set 5 had a low mean for the ENCY control students while Bite Set 6 was a clean Design Schedule effect with the Integral students using the lowest number of Bite Units (Figures 4-35, 4-36).

	ENCY	PPI	GL
INC		HI	
INT	LO	HI	

Figure 4-34. Comparison of Means
UBS5, UBS6 - D
Experiments #3-#4

	ENCY	PPI	GL
INC	LO	HI	HI
INT	LO		

Figure 4-35. Comparison of Means
DABU5 - D
Experiments #3-#4

	ENCY	PPI	GL
INC	HI	HI	HI
INT	LO	LO	LO

Figure 4-36. Comparison of Means
DABU6 - D
Experiments #3-#4

4.3.4 The Standardized Test Scores

Useful information was missing to the completeness of this study because of the lack of Standardized Scores that could be compared in the two-way ANOVA against the dummy variable codes representing the six interaction strategies. However, using the data for five of the groups, it did not appear by the "eyeball test" that there were any differences among the means of these scores which were available for the students in Experiments #3 and #4. Actually, all of the means were available because a summary chart of the Standardized Scores was found. The means of the five that could be checked agreed reasonably well. The chart seemed to have been constructed from the raw scores of all the students, whereas the data of this thesis was that from only the "valid" students referred to in Section 3.2, page 45. Therefore, the

PPI-INC all-student means from this summary chart have been included in parentheses in the Table XXVIII for visual comparison.

There were a number of correlations to be found between the Standardized Scores and the Experimental Test Scores (Table XXIX). The ACT Composite and Natural Science scores both correlated positively with the three Test Scores --Post, Retention 1 and Retention 2. The Fundamentals subtotals correlated with the ACT Composite, English, and Natural Science. Familiar and Transfer subtotals of the tests, relating to the Design portion of the course, did not show correlations with any Standardized Score.

The Programmer's Aptitude Test did not show any significant correlations with the Test Scores.

4.3.5 The Test Scores

The ANOVA table, TABLE XXX, for these parameters and related graphs in Figures 4-37 through 4-42 are found on pages 192 through 201. There are differences in the level of achievement among the interaction strategies as measured by the Post and Retention 1 tests (Table XXX).

In the Totals of the Post Test, the students in the GL instruction control did the poorest. ENCY and PPI students performed equivalently (Figure 4-43, page 202). In the Familiar subtotal of the Post Test, the ANOVA showed a Design Schedule effect. The Incremental Schedule students [illegible] the [illegible] Schedule students

TABLE XXVIII

DESCRIPTIVE STATISTICS
STANDARDIZED TEST SCORES
PAPT AND ACT EXPERIMENTS
#3-#4

Parameter	$\overline{X}$	s	$\overline{X}_{11}$	$\overline{X}_{12}$*	$\overline{X}_{13}$	$\overline{X}_{21}$	$\overline{X}_{22}$	$\overline{X}_{23}$
PAPT	49.8	12.0	48.3	(50.5)	45.2	54.5	58.4	43.8
ACTC	20.2	4.3	21.6	(19.9)	19.4	18.5	20.8	20.0
ACTE	17.4	4.4	19.6	(16.7)	16.4	15.5	19.3	15.3
ACTM	21.6	5.5	22.9	(22.1)	20.0	22.3	21.8	21.5
ACTNS	21.3	6.9	21.9	(20.2)	21.1	18.8	21.0	23.3
ACTSS	20.1	5.1	21.6	(20.0)	20.4	17.0	20.5	19.8

* not determined from raw data but from a Synnoetics Laboratory summary chart

TABLE XXIX

PROBABILITY OF PEARSON'S COEFFICIENT OF CORRELATION $\leq$ 0.05
EXPERIMENTS #3-#4 STANDARDIZED SCORES - TEST SCORES

Parameter	PTOT	PRD	PRM	PTRS	PUN	R1TOT	R1FD	R1FM	R2TOT	R2RD	R2FM
PAPT											
ACTC	.015	.006			.021$^-$	.023	.028		.014	.032	
ACTE	.026	.016			.013$^-$		.041				
ACTM		.038							.044		
ACTNS	.025	.010			.012$^-$	.034			.006	.023	
ACTSS						.030	.023				

TABLE XXX

ANALYSIS OF VARIANCE EXPERIMENTS #3-#4
TEST SCORES (IN PERCENT)

Parameter	$\overline{X}$	s	$\overline{X}_{11}$	$\overline{X}_{12}$	$\overline{X}_{13}$	$\overline{X}_{21}$	$\overline{X}_{22}$	$\overline{X}_{23}$	RxC F	ROWS F	COLS F
PTOT	46	10	54	49	39	47	47	41			4.31^{2}_{35}
PFD	38	7	41	38	33	40	40	36			
PFM	3	4	5	4	4	2	0	0		6.76^{1}_{39}	
PTRS	4	4	3	6	0	5	4	4			
PUN	16	12	10	12	15	19	18	30		5.13^{1}_{35}	
R1TOT	52	16	62	56	38	45	54	56	4.09^{2}_{34}		
R1FD	34	9	20	36	28	29	34	32			
R1FM	19	13	25	20	9	20	19	22			
R2TOT	54	18	62	60	40	44	54	56			
R2FD	34	10	39	38	30	28	36	34			
R2FM	20	12	24	22	15	20	20	20			

TABLE XXX (Continued)

Parameter	$\bar{X}$	s	$\bar{X}_{11}$	$\bar{X}_{12}$	$\bar{X}_{13}$	$\bar{X}_{21}$	$\bar{X}_{22}$	$\bar{X}_{23}$	RxC F	ROWS F	COLS F
STFT	- 6.0	13.7	- 9.0	- 7.0	1.0	2.0	-10.0	-15.0			
STFD	5.0	8.4	2.5	2.8	5.8	11.1	5.1	5.1			
STFM	-15.6	12.7	-19.6	-15.5	- 5.2	-16.6	-17.8	-21.3			
LTFT	- 7.0	16.8	- 8.5	-10.9	- 0.8	2.8	- 9.6	-15.0			
LTFD	3.2	8.8	2.5	0.3	5.0	12.7	1.7	2.6			
LTFM	-15.7	13.3	-17.0	-17.0	- 8.0	-16.0	-17.0	-22.0			
CONTOT	0.8	14.5	- 0.9	1.1	4.0	- 0.5	- 0.4	0.0			
CONFD	1.3	8.5	0.0	1.6	1.3	- 1.5	3.4	2.5			
CONFM	0.9	13.7	- 1.0	0.2	4.3	0.8	- 0.4	2.0			

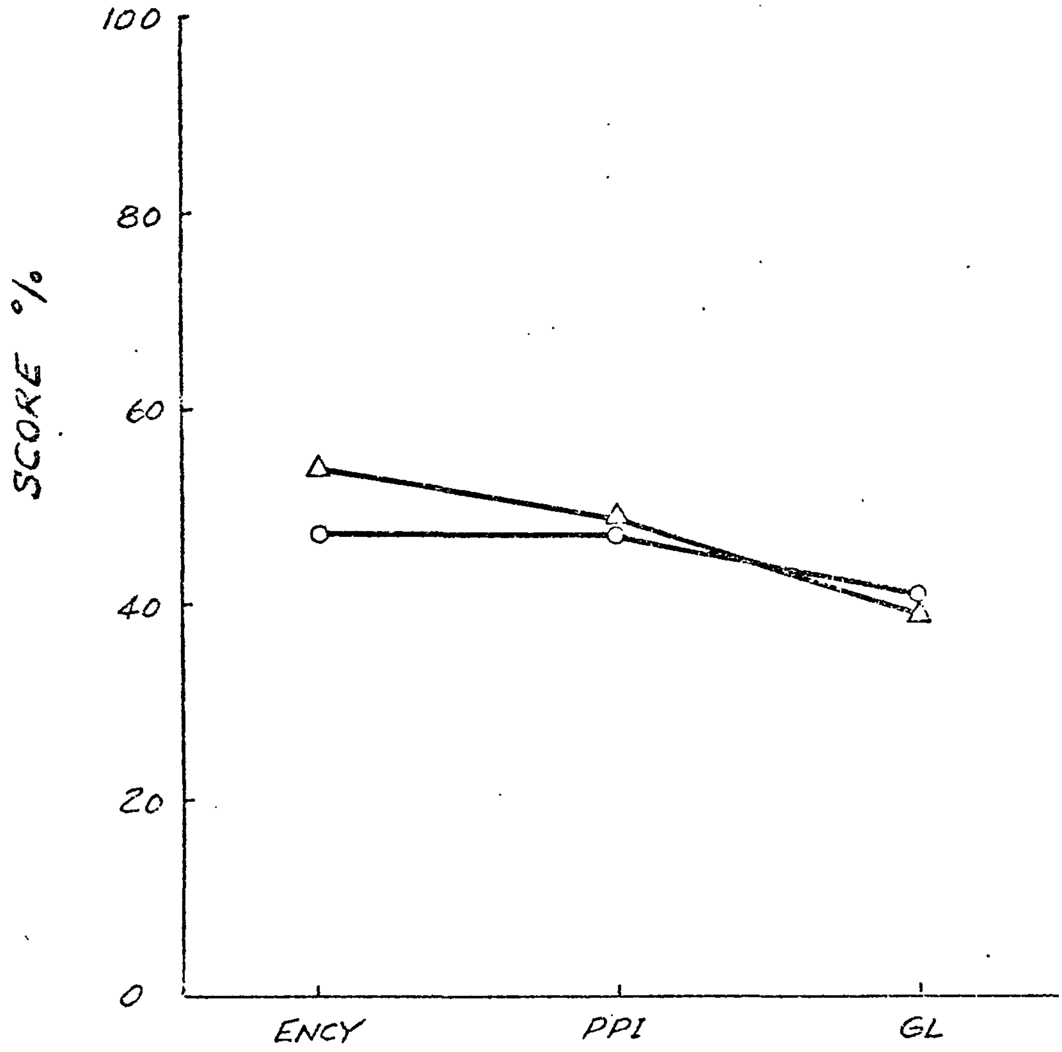


Figure 4-37. Means of Post Test Totals
Experiments #3-#4

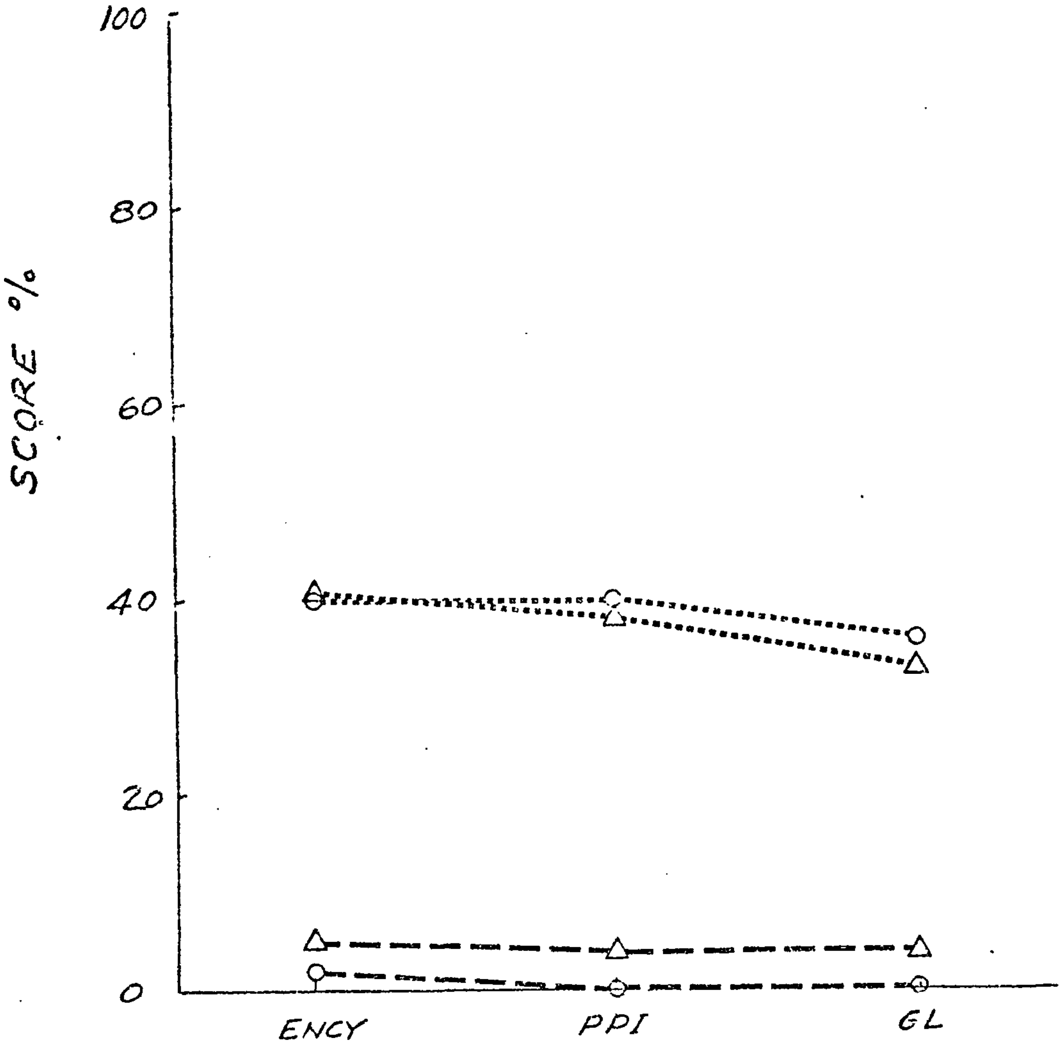


Figure 4-38. Means of Post Fundamentals, Familiar Experiments #3-#4

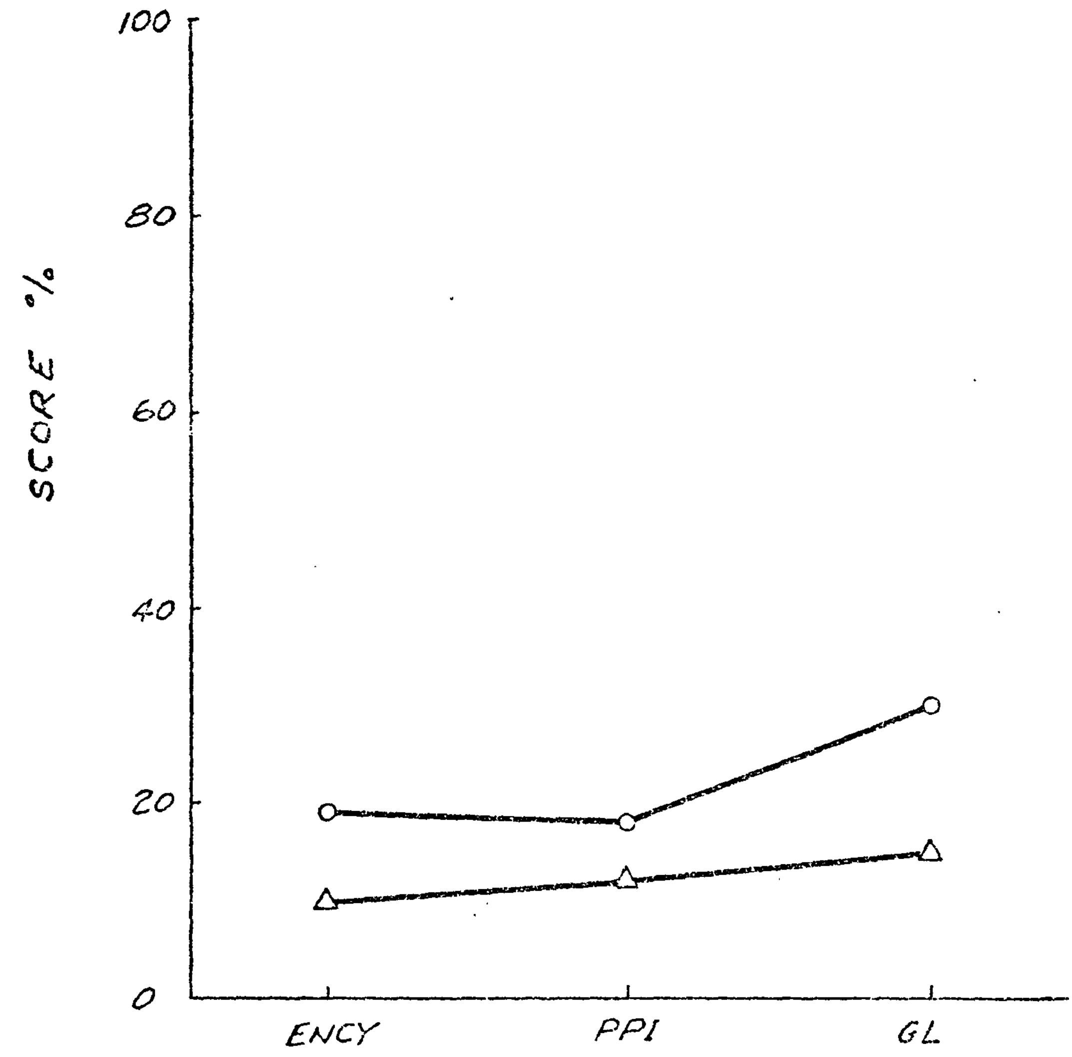


Figure 4-39. Means of Post Unanswered
Experiments #3-#4

INC △
INT ○
C
D
F

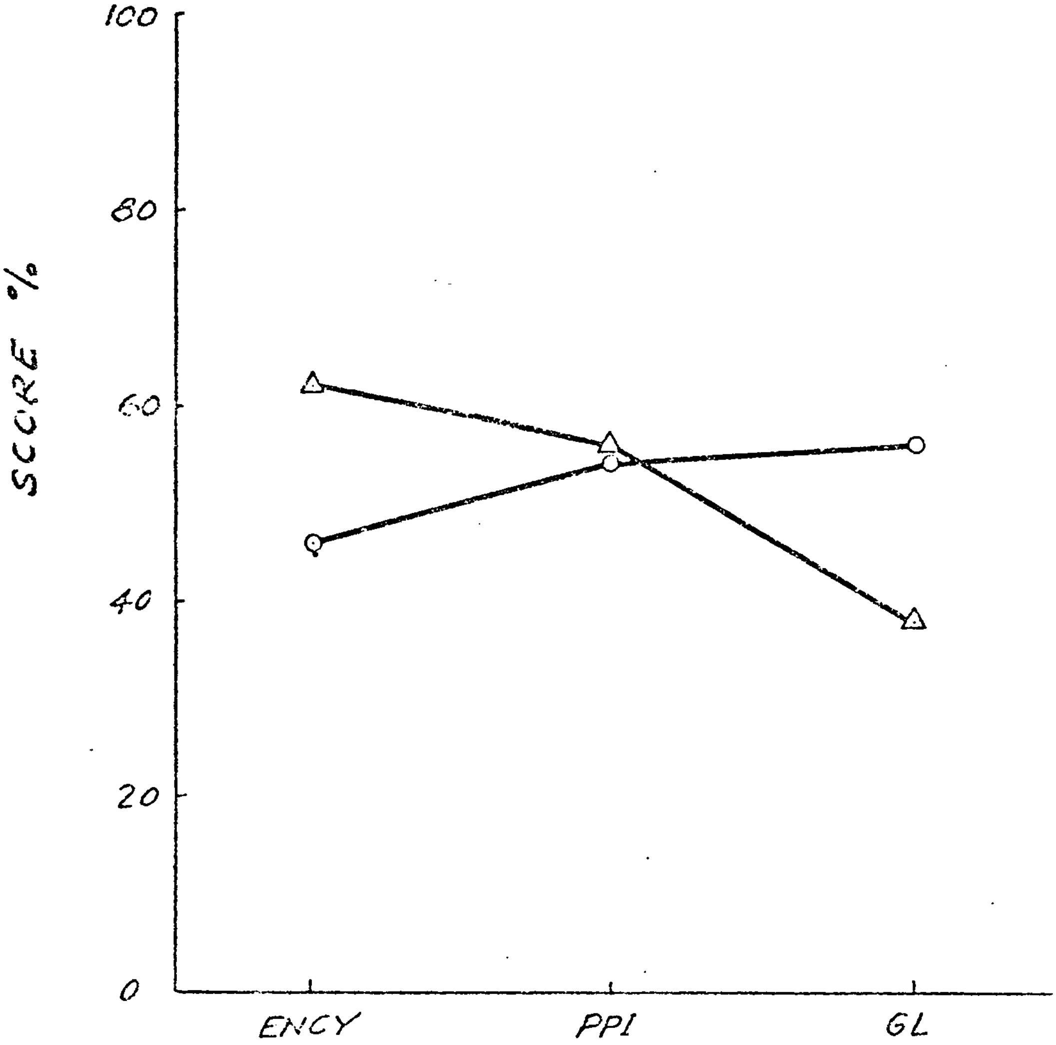


Figure 4-40. Means of Retention 1 Totals
Experiments #3-#4

INC △
INT ○
C
D
F

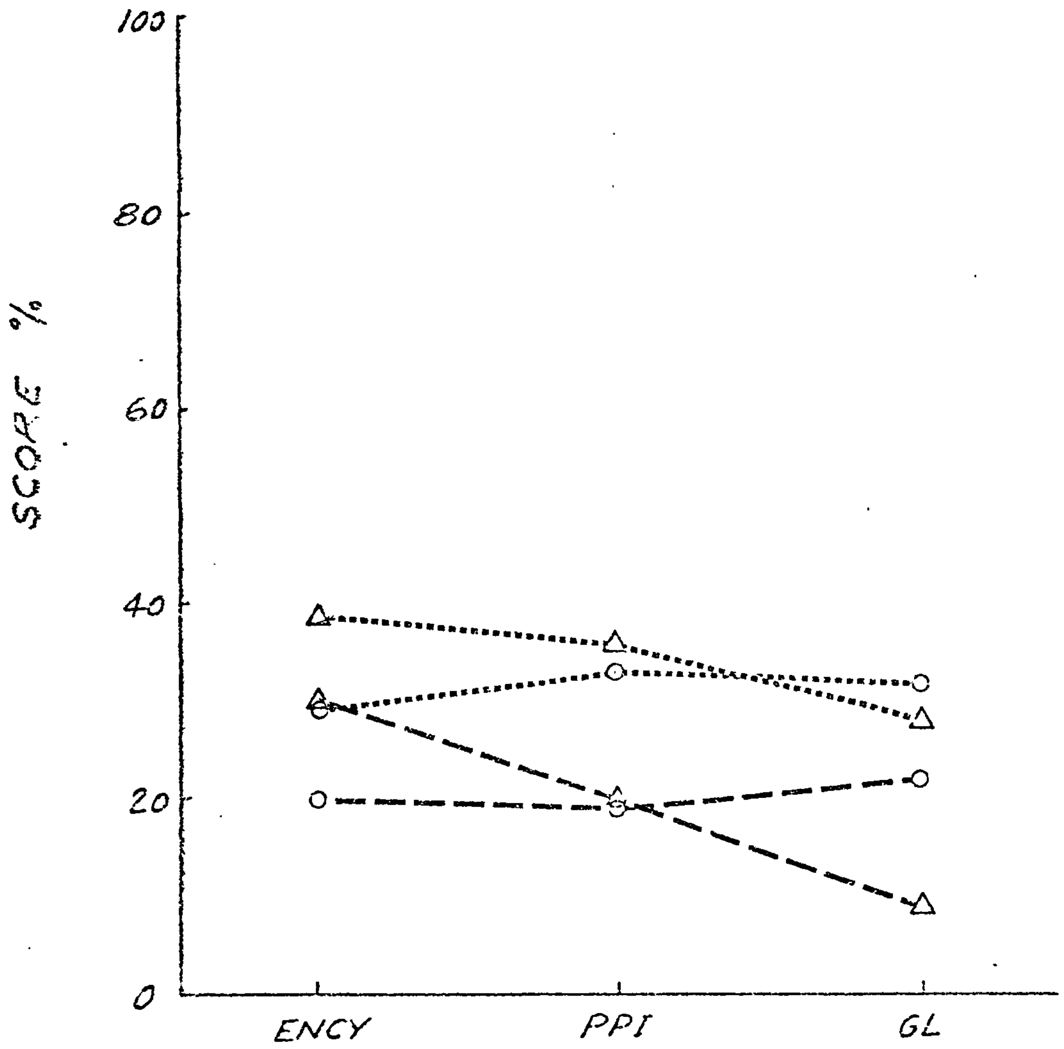


Figure 4-41. Means of Retention 1
Fundamentals, Familiar
Experiments #3-#4

INC △
INT ○
C
D
F

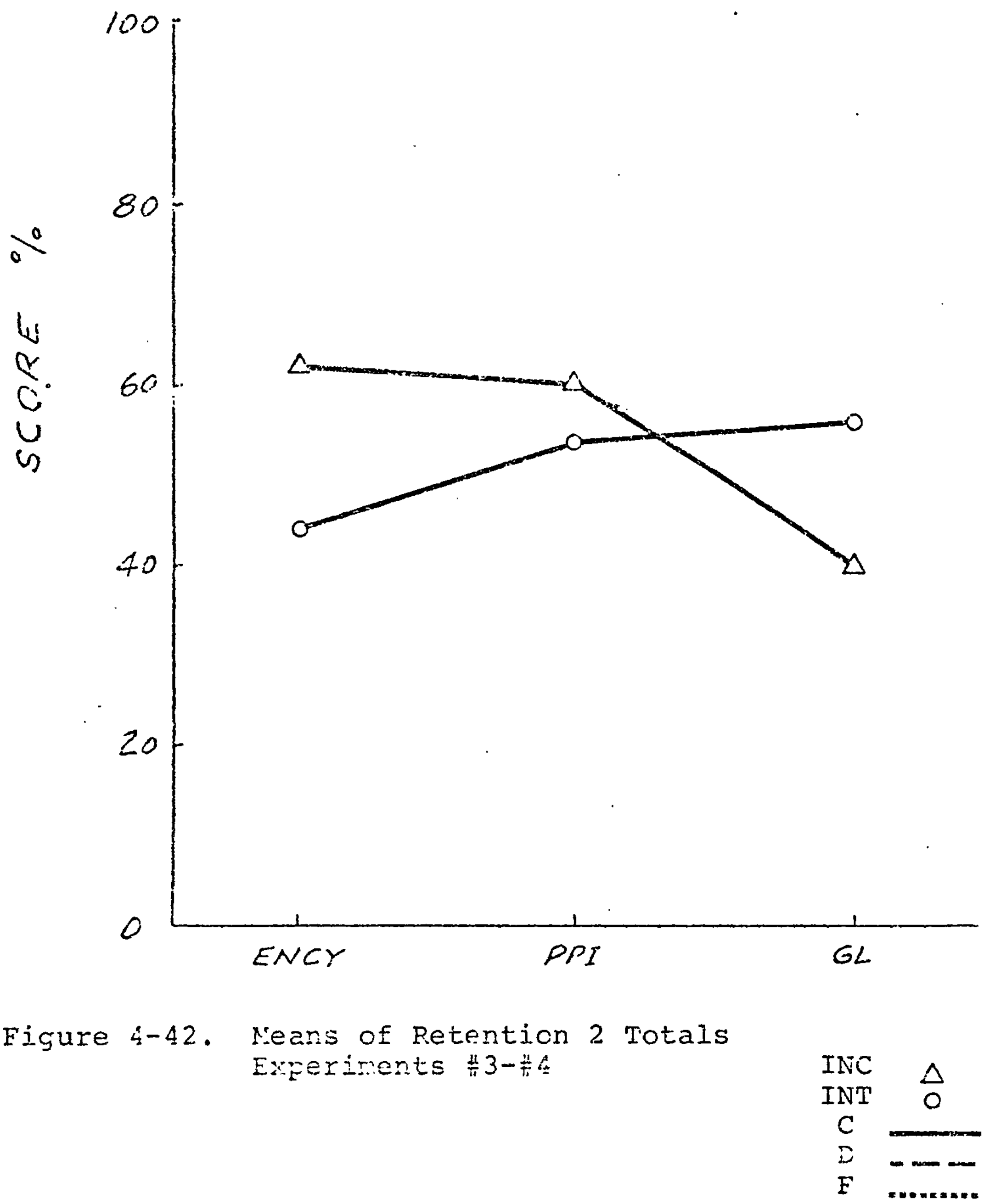


Figure 4-42. Means of Retention 2 Totals
Experiments #3-#4

(Figure 4-44). And the Unanswered questions of the Post Test were highest among the Integral Schedule students (Figure 4-45).

	ENCY	PPI	GL
INC			LO
INT			LO

Figure 4-43. Comparison of Means
PTOT
Experiments #3-#4

	ENCY	PPI	GL
INC	HI	HI	HI
INT	LO	LO	LO

Figure 4-44. Comparison of Means
PFM
Experiments #3-#4

	ENCY	PPI	GL
INC			
INT	HI	HI	HI

Figure 4-45. Comparison of Means
PUN
Experiments #3-#4

The Retention 1 Test showed an interaction effect in the ANOVA summary (Table XXX) which Scheffe separated out as the low mean of the GL-INC students. The means of the other groups were considered equivalent (Figure 4-46).

	ENCY	PPI	GL
INC			LO
INT			

Figure 4-46. Comparison of Means
R1TOT
Experiments #3-#4

The means of each of the other tests have no differences among the groups respective to a given test.

4.3.6 The Processing Rates

The ANOVA and correlations tables, Tables XXXI and XXXII, and related graphs in Figures 4-48 through 4-53 are found on pages 204 through 212. There were no differences among the means of the Processing Rates (AU/TU) of the Fundamentals Universe, but there were differences found in the Design and Composite (Table XXXI). Both an Instruction Control and Design Schedule effect were discernible in the Processing Rate of the Composite Universe with the PPI control students showing up with a high Processing Rate and the ENCY-INT students with a low Processing Rate. During Design the same difference pattern was noted (Figure 4-47).

	ENCY	PPI	GL
INC		HI	
INT	LO	HI	LO

Figure 4-47. Comparison of Means
AU/TU - C, D
Experiments #3-#4

TABLE XXXI

ANALYSIS OF VARIANCE EXPERIMENTS #3-#4
PROCESSING RATES IN ACCESSES PER HOUR

Parameter	$\overline{X}$	s	$\overline{X}_{11}$	$\overline{X}_{12}$	$\overline{X}_{13}$	$\overline{X}_{21}$	$\overline{X}_{22}$	$\overline{X}_{23}$	RxC F	ROWS F	COLS F
PRU C	71.4	18.2	67.00	82.55	74.31	53.36	78.78	59.30		6.22^{1}_{37}	5.17^{2}_{37}
PRU F	68.6	17.7	65.37	72.05	75.65	54.41	75.87	60.36			
PRU D	77.2	23.7	71.06	101.03	78.68	55.97	84.49	57.47			12.54^{2}_{41}
PR1 C	64.0	16.59	60.65	66.92	70.29	48.62	71.38	60.22			
PR1 F	63.4	17.9	59.83	64.11	74.39	49.47	69.68	56.49			
PR1 D	49.10	56.68	42.20	113.55	0.00	4.51	105.44	6.63		10.6^{1}_{41}	5.61^{2}_{41}
PR2 C	90.5	22.2	88.43	99.01	90.71	73.88	100.35	80.94			
PR2 F	91.8	23.1	85.50	98.80	94.80	76.60	105.10	80.40			3.44^{2}_{44}
PR2 D	35.8	52.9	62.46	10.16^{+}	60.11	20.92	55.06	23.39			

TABLE XXXI (Continued)

P... eter	$\overline{X}$	s	$\overline{X}_{11}$	$\overline{X}_{12}$	$\overline{X}_{13}$	$\overline{X}_{21}$	$\overline{X}_{22}$	$\overline{X}_{23}$	RxC F	ROWS F	COLS F
4 C	59.4	17.6	60.17	65.79	62.78	47.86	62.35	48.52			
R4 F	62.3	19.2	62.38	65.79	69.08	52.76	66.75	48.49			
4 D	5.7	24.2	16.80	0.00	0.00	0.00	18.77	5.10			
R5 D	78.9	34.9	76.38	113.08	85.17	46.81	88.43	42.24		29.0^{1}_{41}	11.2^{2}_{41}
R6 D	73.1	22.4	67.60	91.01	71.91	55.04	85.25	58.61		6.52^{1}_{41}	8.40^{2}_{41}

+ represents 1 observation of 121.93 and 11 zero observations

TABLE XXXII

ANALYSIS OF VARIANCE EXPERIMENTS #3-#4
PROCESSING RATES IN DISTINCT ACCESSES
PER HOUR

P. eter	$\bar{X}$	s	$\bar{X}_{11}$	$\bar{X}_{12}$	$\bar{X}_{13}$	$\bar{X}_{21}$	$\bar{X}_{22}$	$\bar{X}_{23}$	RxC F	ROWS F	COLS F
1 C	11.0	4.0	9.22	11.28	14.00	6.11	10.30	13.34			9.11^{2}_{37}
1 F	11.0	4.2	9.60	12.08	13.47	6.50	10.97	11.92			5.46^{2}_{44}
1 D	18.1	23.9	34.33	26.74	0.00	2.59	43.94	2.25	6.51^{2}_{41}		10.9^{2}_{41}
R2 C	17.5	7.9	16.62	16.81	23.07	8.17	17.20	20.83			5.49^{2}_{37}
R2 F	18.2	7.8	15.91	16.86	23.27	11.02	20.42	20.75			5.08^{2}_{44}
PR2 D	16.2	25.9	37.51	1.29	27.96	12.08	15.65	9.19			3.64^{2}_{41}
PR4 C	12.2	5.9	14.96	15.18	12.05	8.07	10.07	8.63		9.25^{1}_{37}	
PR4 F	12.9	6.1	14.95	15.11	12.45	10.42	12.61	8.58		4.20^{1}_{44}	
PR4 D	2.7	14.1	11.61	0.00	0.00	0.00	5.76	0.66			
PR5 D	30.3	14.9	32.88	43.73	35.12	18.42	25.06	14.66		37.0^{1}_{41}	3.90^{2}_{41}
PR6 D	21.4	8.9	24.71	26.75	24.27	15.79	14.99	15.45		18.8^{1}_{41}	

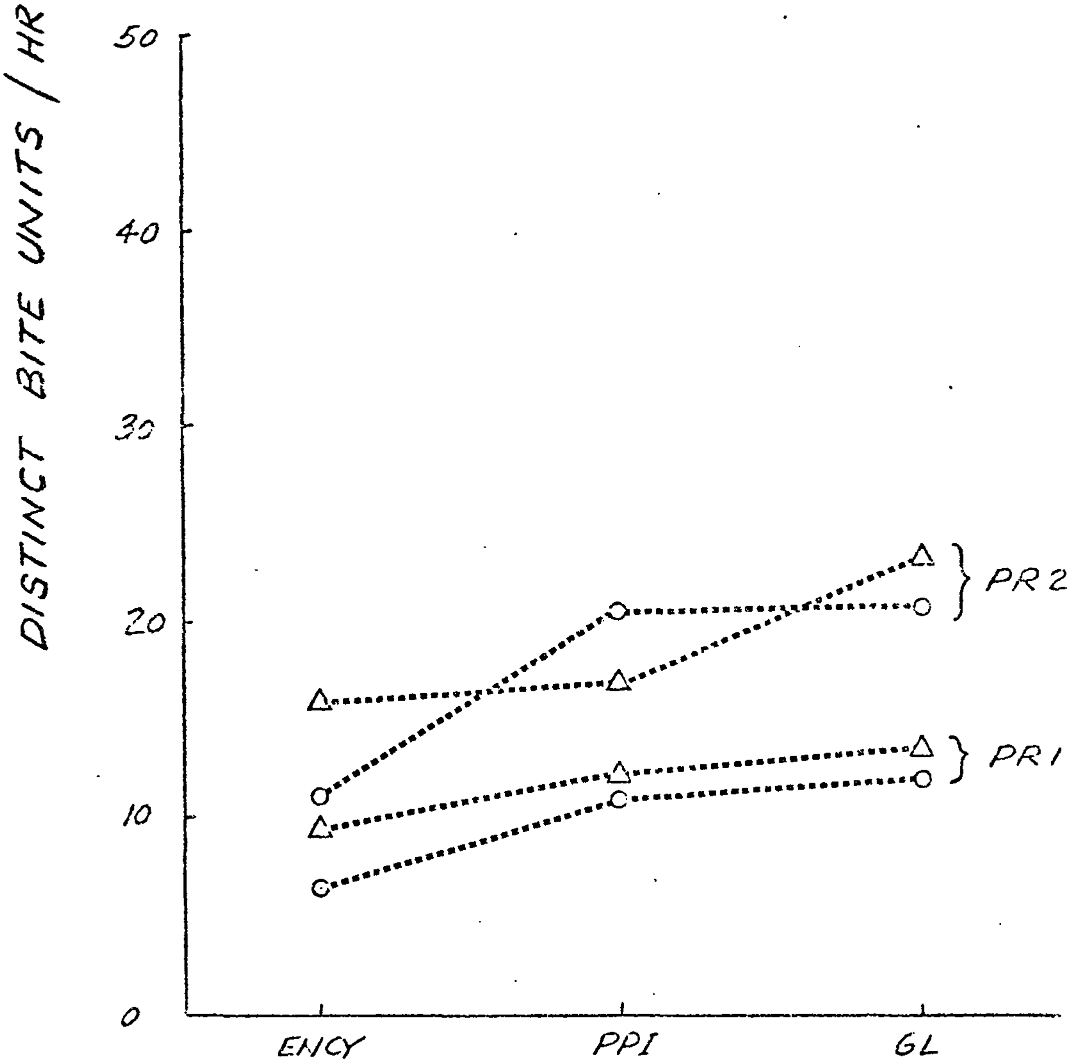


Figure 4-48. Means of PR1, PR2-F (DABU)
Experiments #3-#4

INC △
INT ○
C
D
F

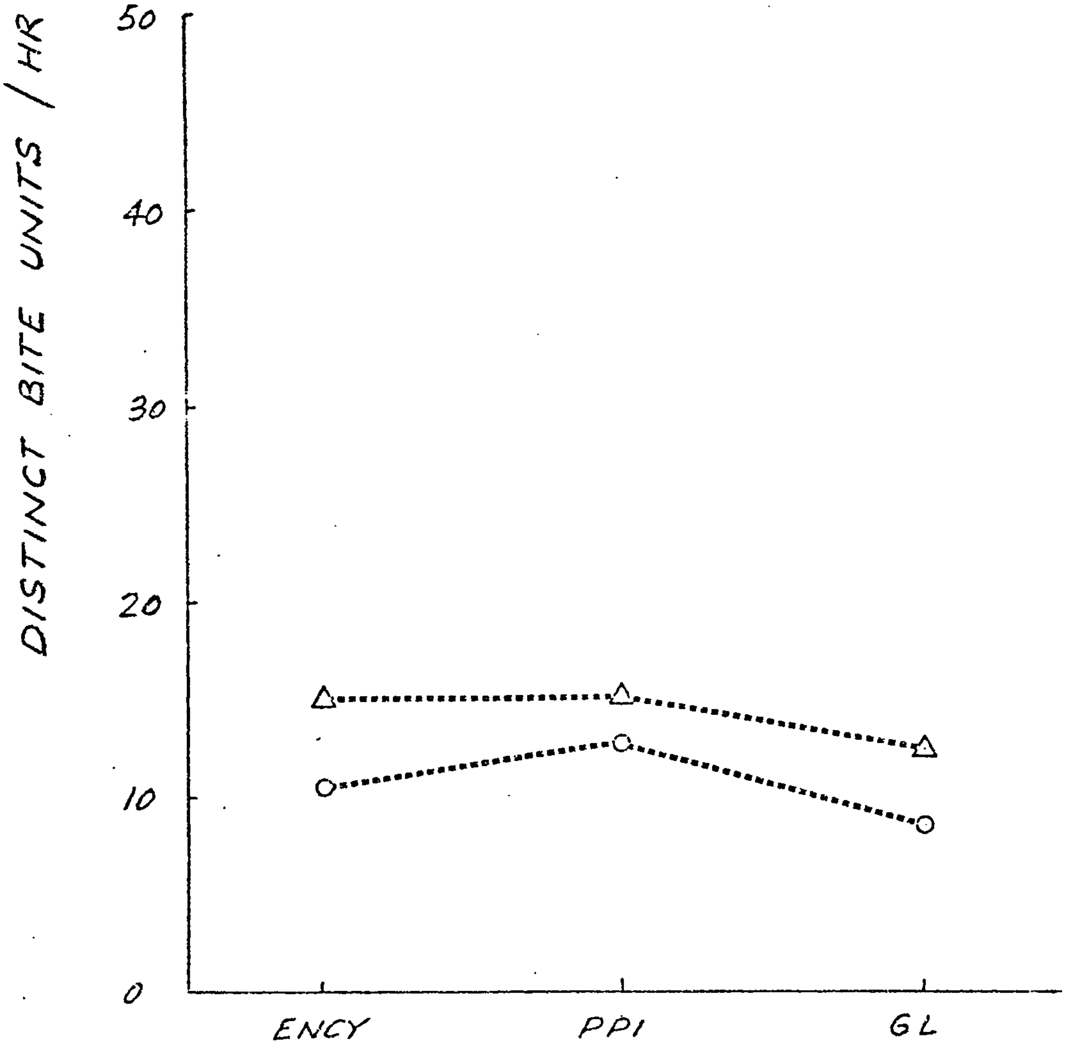
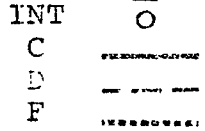


Figure 4-49. Means of PR4-F (DABU)
Experiments #3-#4



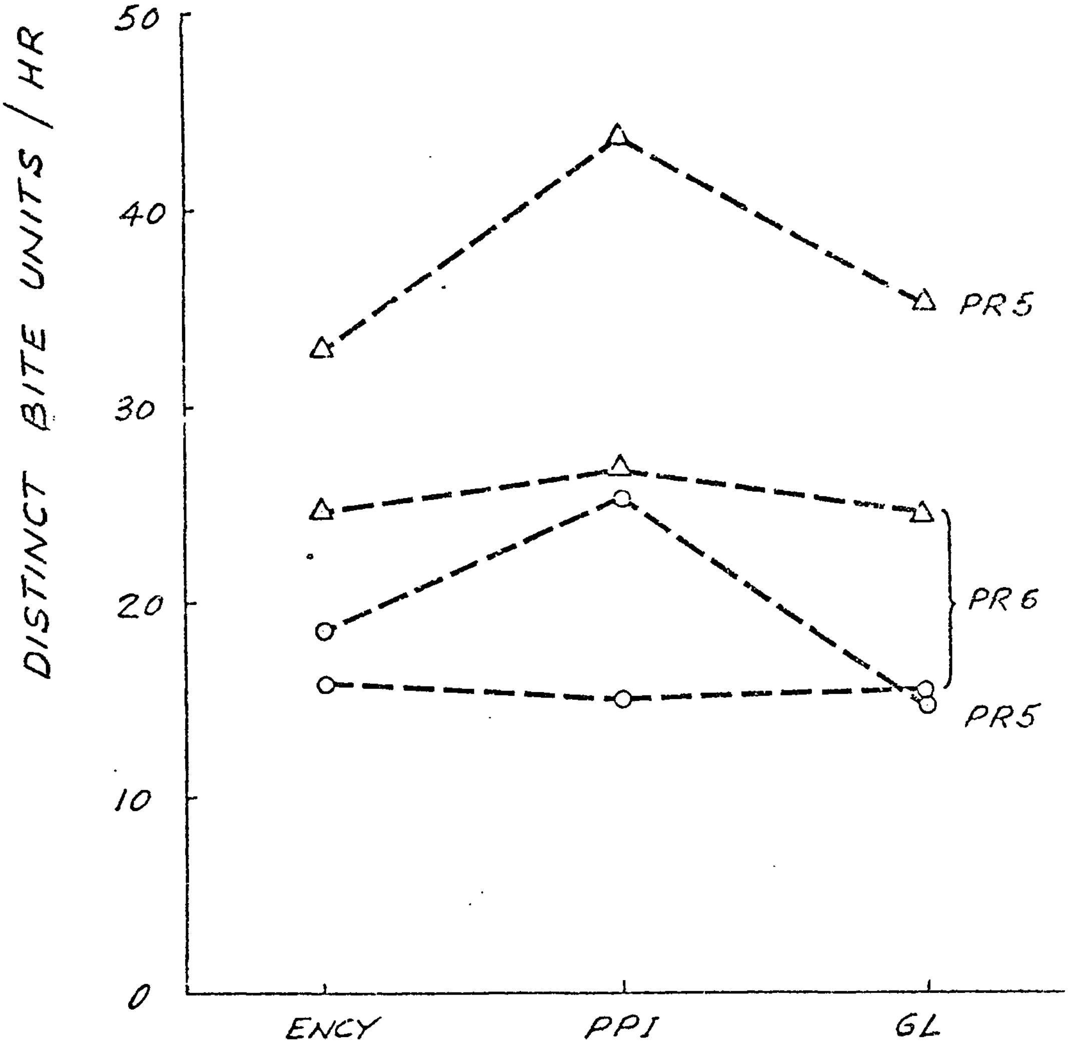
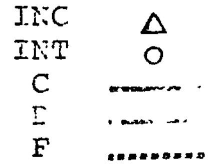


Figure 4-50. Means of PR5, PR6-D (DABU) Experiments #3-#4



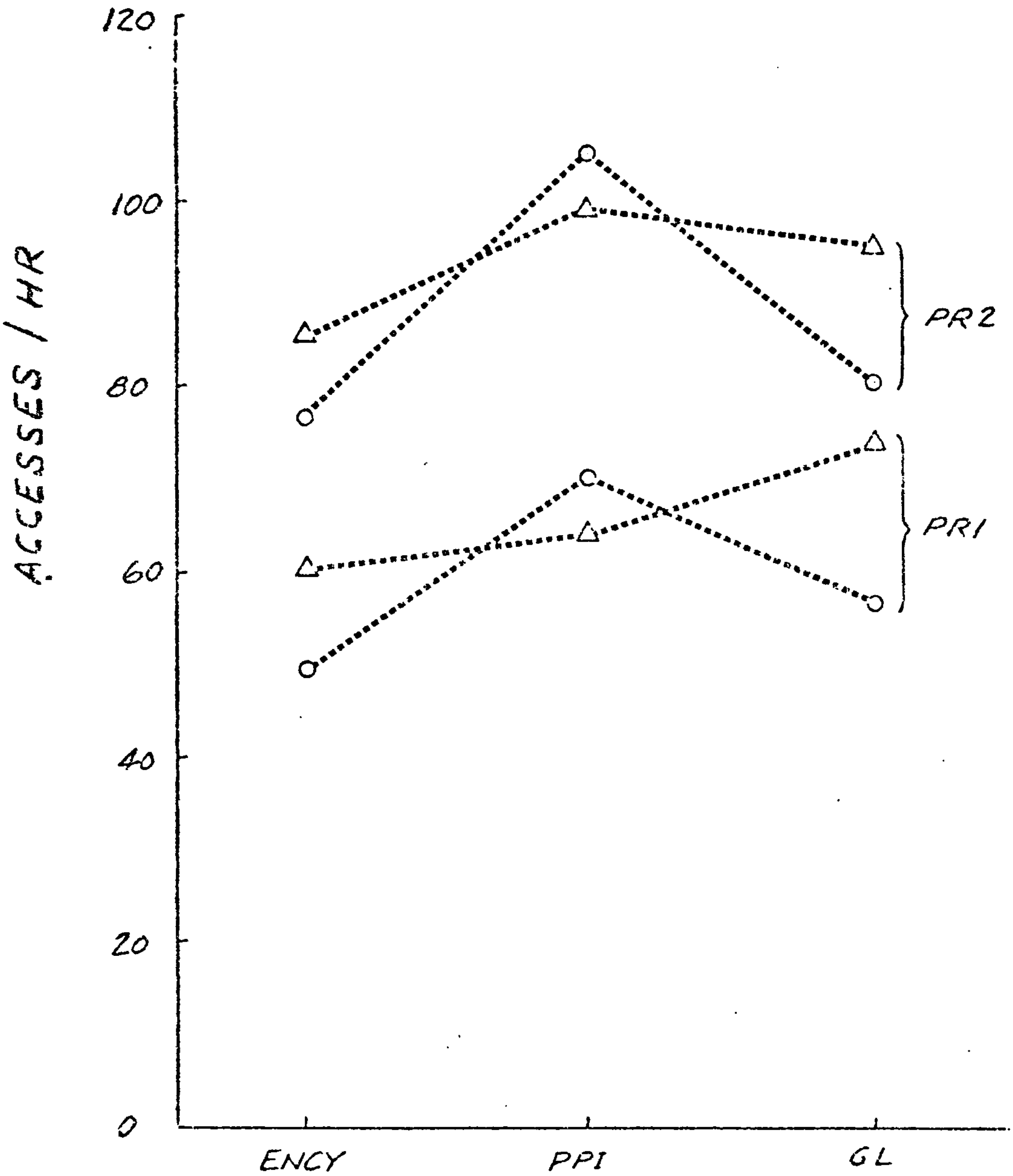


Figure 4-51. Means of PR1, PR2-F (ABS)
Experiments #3-#4

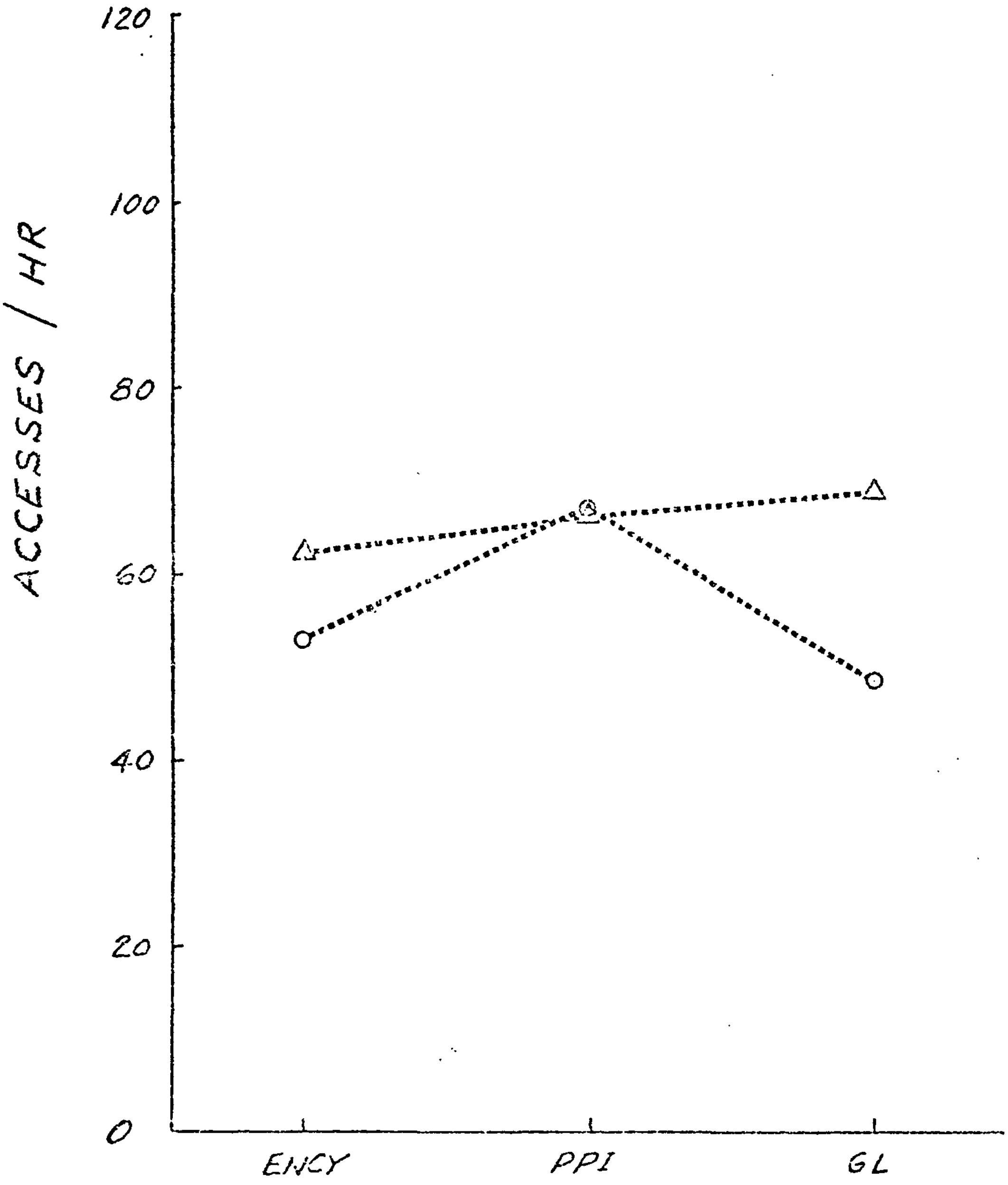
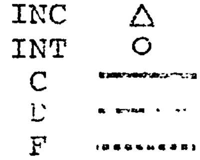


Figure 4-52. Means of PR4-F (ABS)
Experiments #3-#4



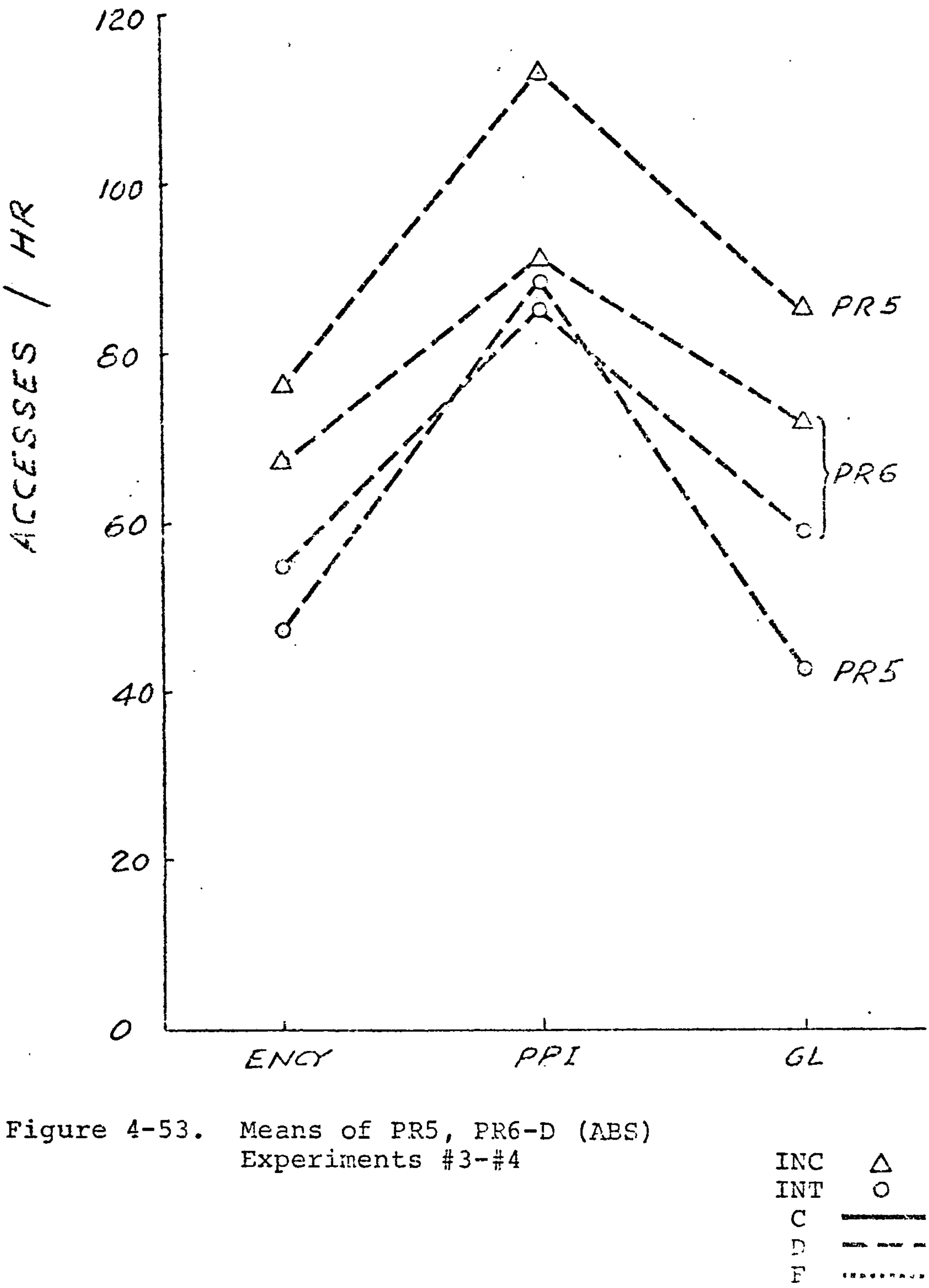


Figure 4-53. Means of PR5, PR6-D (ABS)
Experiments #3-#4

In the Bite Sets, two rates of processing were calculated. One was based on the total number of accesses made to the Bite Set. The other was based on the number of distinct Bite Units accessed in the Bite Set.

In Bite Set 1, significant ANOVA effects appeared only during Design for ABS1/TBS1, whereas effects were found in each portion of the course for DABU1/TBS1 (Tables XXXI and XXXII). In the ABS1/TBS1 of Design, the Scheffe separated the means of the students in the three Instruction Controls into a low to high scale for GL to ENCY to PPI (Figure 4-54). The three DABU1/TBS1 Processing Rates compared means in somewhat similar patterns. The ENCY students had the lowest Processing Rates. The GL students had a high total Processing Rate although they had a low Processing Rate during Design (Figures 4-55, 4-56, 4-57).

	ENCY	PPI	GL
INC	MED	HI	LO
INT	MED	HI	LO

Figure 4-54. Comparison of Means
ABS1/TBS1 - D
Experiments #3-#4

	ENCY	PPI	GL
INC	LO	MED	HI
INT	LO	MED	HI

Figure 4-55. Comparison of Means
DABU1/TBS1 - C
Experiments #3-#4

	ENCY	PPI	GL
INC	LO		
INT	LO		

Figure 4-56. Comparison of Means
DABU1/TBS1 - F
Experiments #3-#4

	ENCY	PPI	GL
INC			LO
INT	LO		LO

Figure 4-57. Comparison of Means
DABU1/TBS1 - D
Experiments #3-#4

In Bite Set 2, the differences in the Processing Rates are more apparent among the means of the rates of the Distinctly Accessed Bite Units than of the total Accesses (Tables XXX, XXXI). With the exception of the Processing Rate_{DA} in the Design portion, ENCY control or at least the ENCY-INT students have the lowest processing rates (Figures 4-58, 4-59, 4-60, 4-61).

	ENCY	PPI	GL
INC	LO		HI
INT	LO		HI

Figure 4-58. Comparison of Means
ABS2/TBS2 - F
Experiments #3-#4

	ENCY	PPI	GL
INC			HI
INT	LO		HI

Figure 4-59. Comparison of Means
DABU2/TBS2 - C
Experiments #3-#4

	ENCY	PPI	GL
INC	LO		HI
INT	LO		HI

Figure 4-60. Comparison of Means
DABU2/TBS2 - F
Experiments #3-#4

	ENCY	PPI	GL
INC	HI	LO	
INT			

Figure 4-61. Comparison of Means
DABU2/TBS2 - D
Experiments #3-#4

The Processing Rates in Bite Set 4 were limited to Design Schedule effects during the non-Design portion of the course. (See Tables XXXI, XXXII.) However, the ABS4/TBS4 did not show any differences between the rows or among the means under the Scheffe test. Otherwise, the Processing Rates were higher for the Incremental students during Fundamentals and Composite measures of DABU4/TBS4 (Figure 4-62).

	ENCY	PPI	GL
INC	HI	HI	HI
INT			

Figure 4-62. Comparison of Means
DABU4/TBS4 - C,F
Experiments #3-#4

The Design Bite Sets 5 and 6 showed the clearest consistent row (Design Schedule) effects for the Processing Rates. The Incremental students process more Bites and Bite Units per hour than Integral students (excepting possibly the PPI-INT students)(Figures 4-63, 4-64).

	ENCY	PPI	GL
INC	HI	HI	HI
INT		HI	

Figure 4-63. Comparison of Means
ABS5/TBS5 - D
DABU5/TBS5 - D
ABS6/TBS6 - D

	ENCY	PPI	GL
INC	HI	HI	HI
INT			

Figure 4-64. Comparison of Means
DABU6/TBS6 - D

4.3.7 The Performance Rates

The ANOVA table, Table XXXIII, and related graphs in Figures 4-66 through 4-71 are found on pages 218 through 224. The number of Post test and Retention 2 test points achieved per hour in the Bite Structure is most different between the rows, i.e., Experiment #3, Incremental students, earned more test points per hour than the Experiment #4 Integral Design Schedule students (Table XXXIII). The Scheffe acknowledged the row effect and further separated the means consistently into a low mean for the ENCY-INT students and a high for the ENCY-INC and PPI-INC students (Figure 4-65).

	ENCY	PPI	GL
INC	HI	HI	
INT	LO		

Figure 4-65. Comparison of Means
PfR(Post), PfR(Ret2)
Experiments #3-#4

4.3.8 Effective Learning

No ANOVA effects were found for any of the three ratios of test scores to total accesses in the Bite Structure (Table XXXIII). Each group of students achieved equivalent Effective Learning scores.

TABLE XXXIII

ANALYSIS OF VARIANCE EXPERIMENTS #3-#4
PERFORMANCE RATE AND
EFFECTIVE LEARNING

Parameter	$\bar{X}$	s	$\bar{X}_{11}$	$\bar{X}_{12}$	$\bar{X}_{13}$	$\bar{X}_{21}$	$\bar{X}_{22}$	$\bar{X}_{23}$	RxC F	ROWS F	COLS F
					PfR						
PTOT/TU	8.77	3.52	10.97	10.50	7.77	5.13	7.88	6.51		9.33^{1}_{34}	
R1TOT/TU	10.12	4.96	13.08	12.27	7.67	5.01	9.80	8.93			
R2TOT/TU	10.39	5.24	13.19	12.95	8.34	4.93	9.47	8.71		5.69^{1}_{32}	
					EL						
PTOT/AU	0.124	0.050	0.165	0.127	0.120	0.100	0.105	0.105			
R1TOT/AU	0.142	0.061	0.196	0.149	0.113	0.099	0.129	0.143			
R2TOT/AU	0.146	0.067	0.195	0.154	0.137	0.094	0.123	0.146			

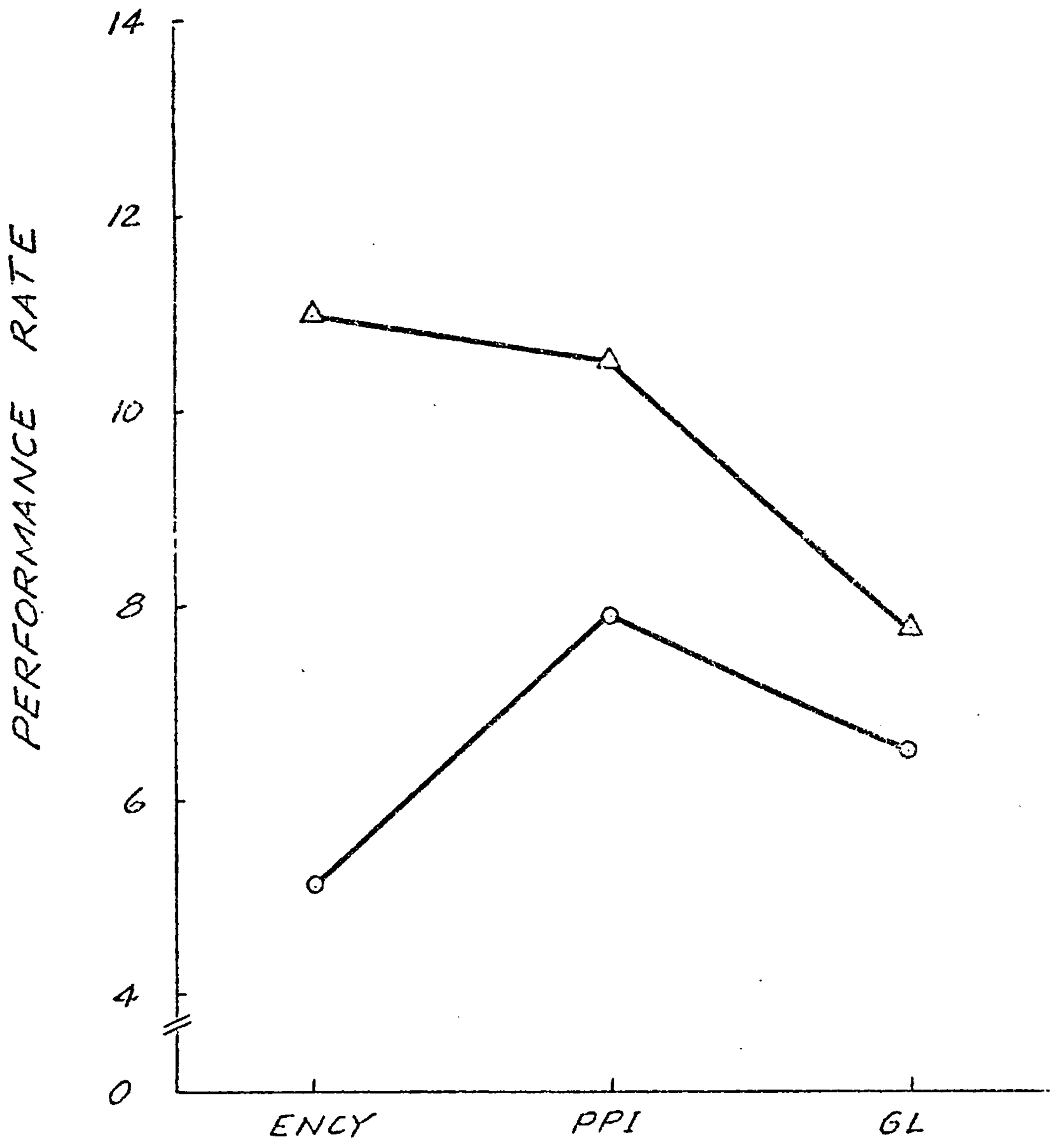


Figure 4-66. Means of PfR(PTOT)
Experiments #3-#4

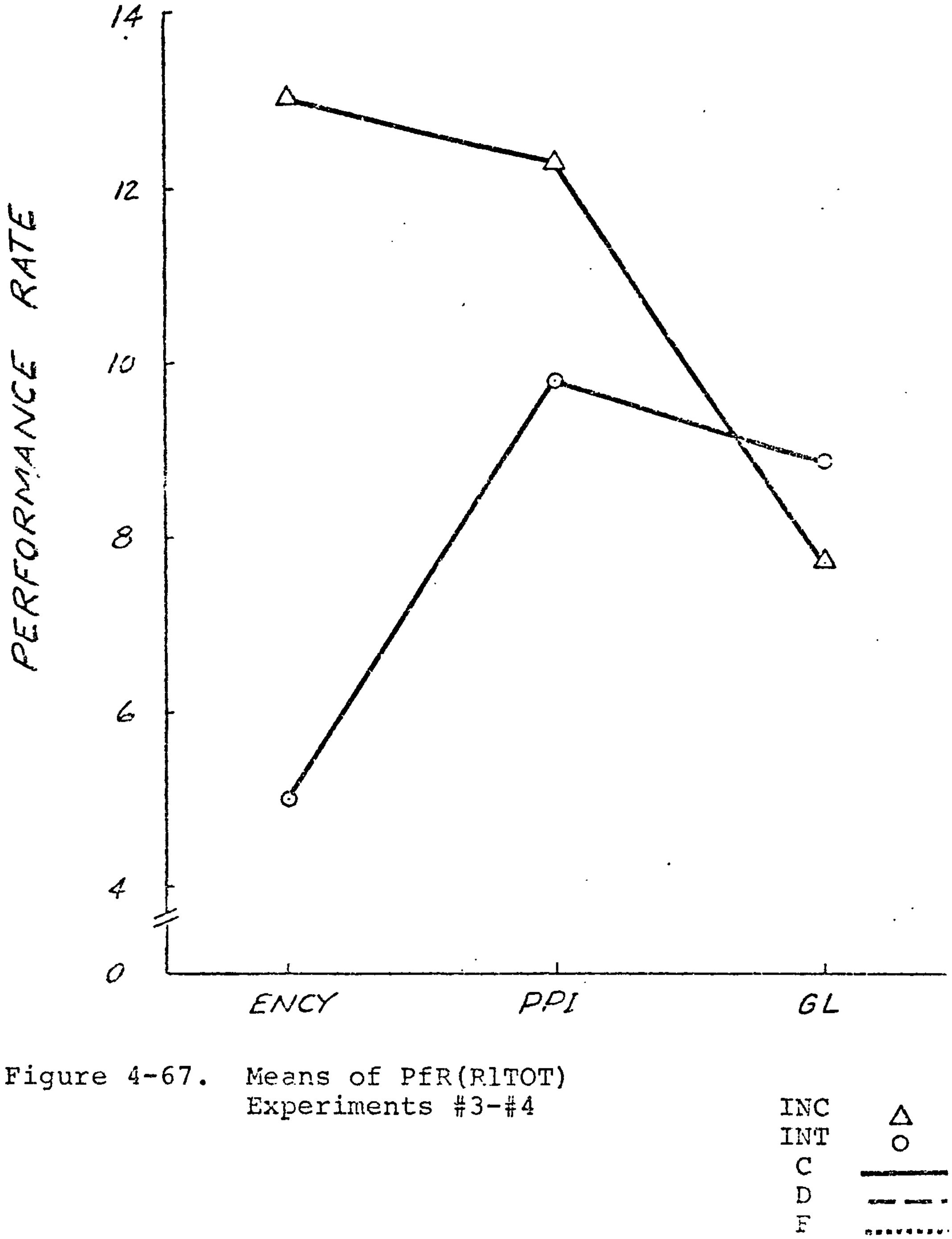


Figure 4-67. Means of PfR(R1TOT)
Experiments #3-#4

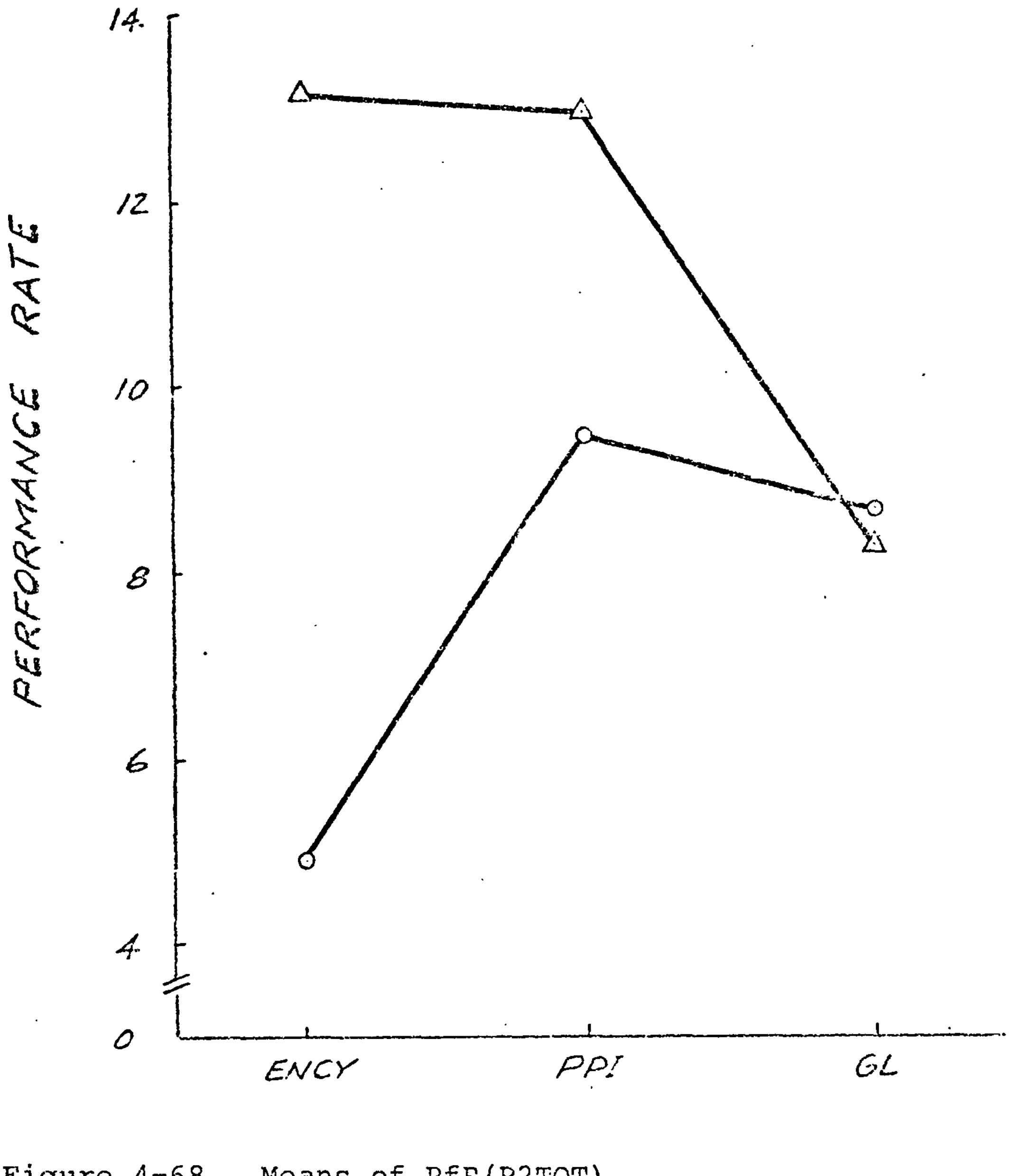


Figure 4-68. Means of PfR(R2TOT)
Experiments #3-#4

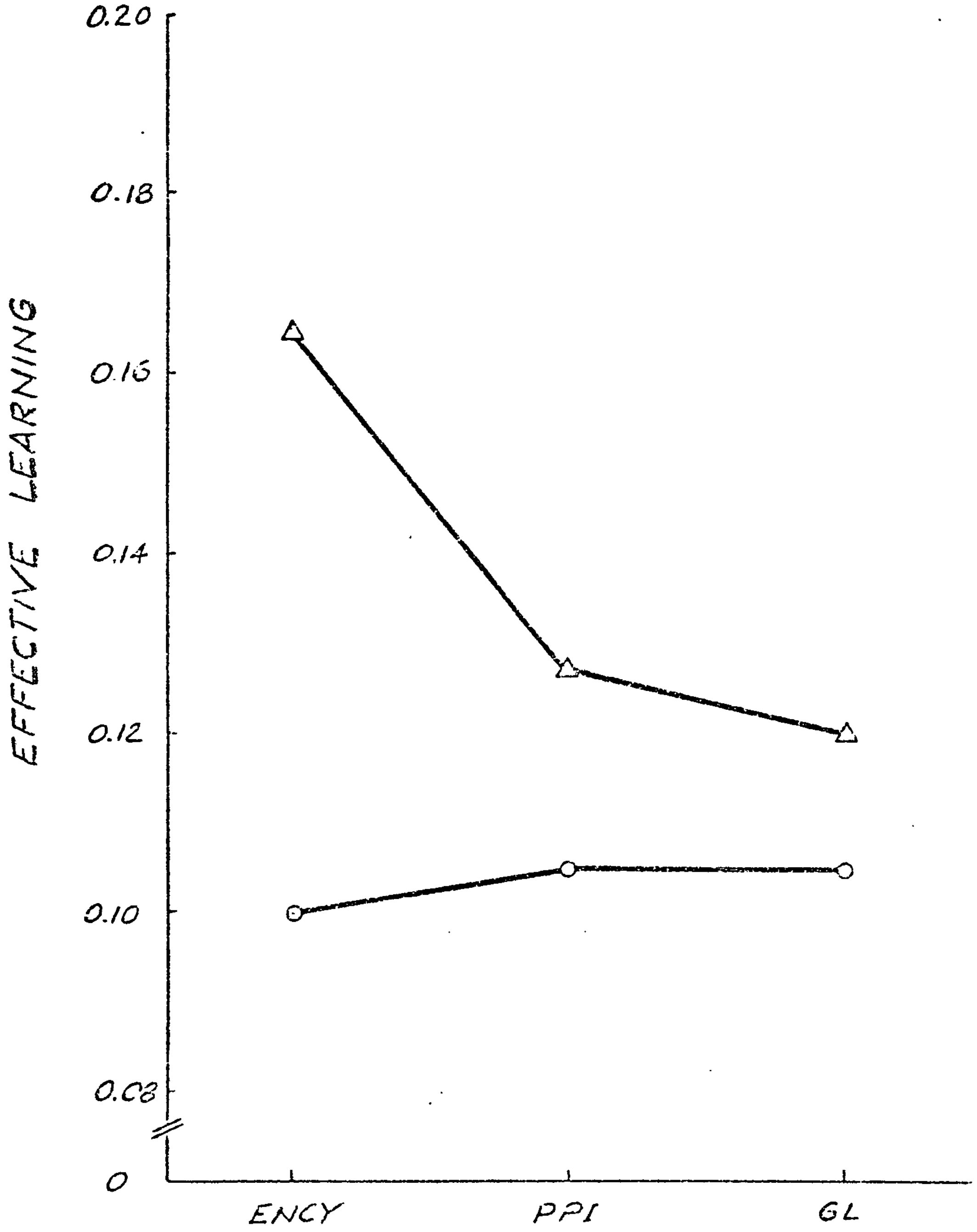
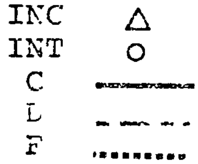


Figure 4-69. Means of EL(PTOT)
Experiments #3-#4



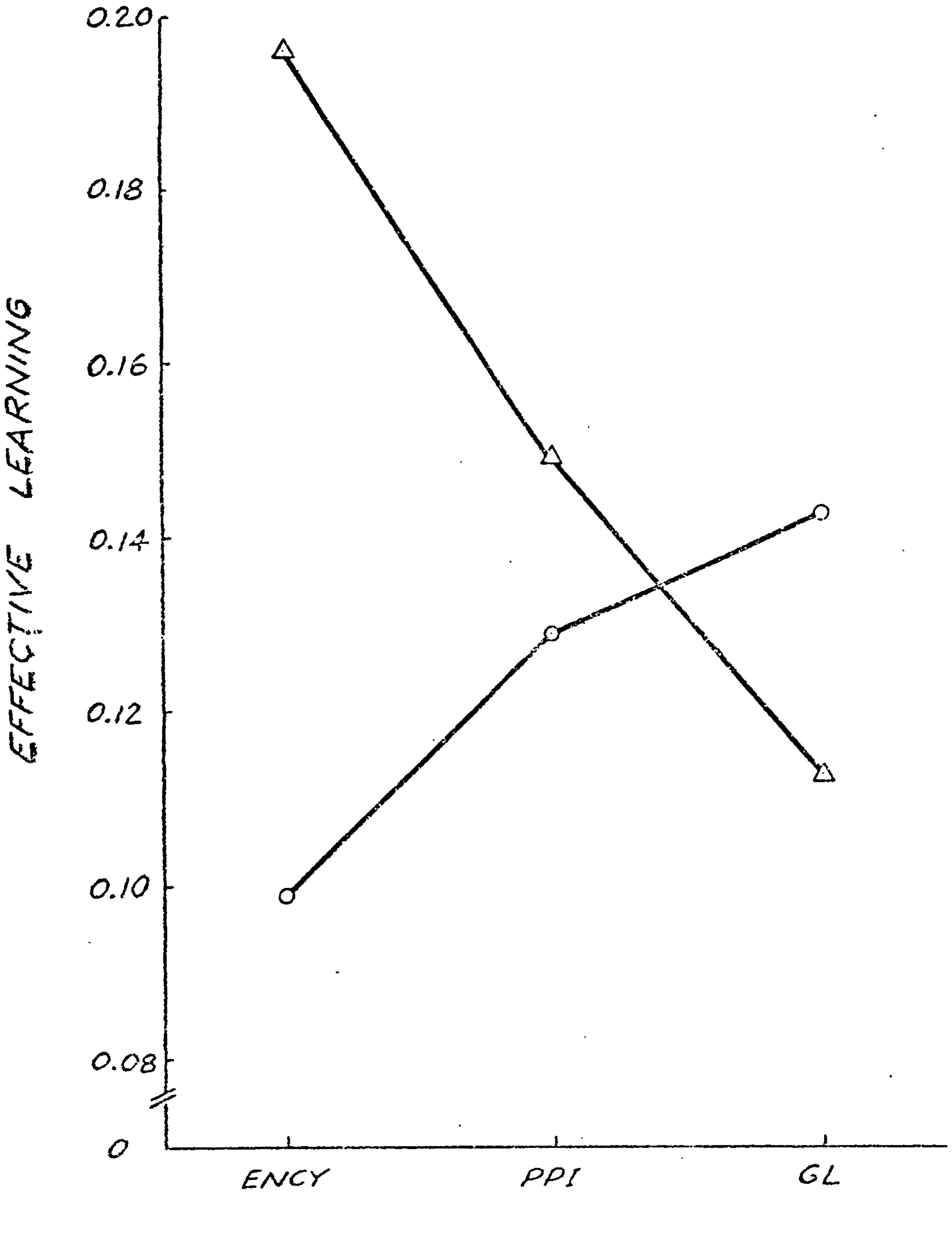


Figure 4-70. Means of EL(R1TOT)
Experiments #3-#4

INC △
INT ○
C
D
F

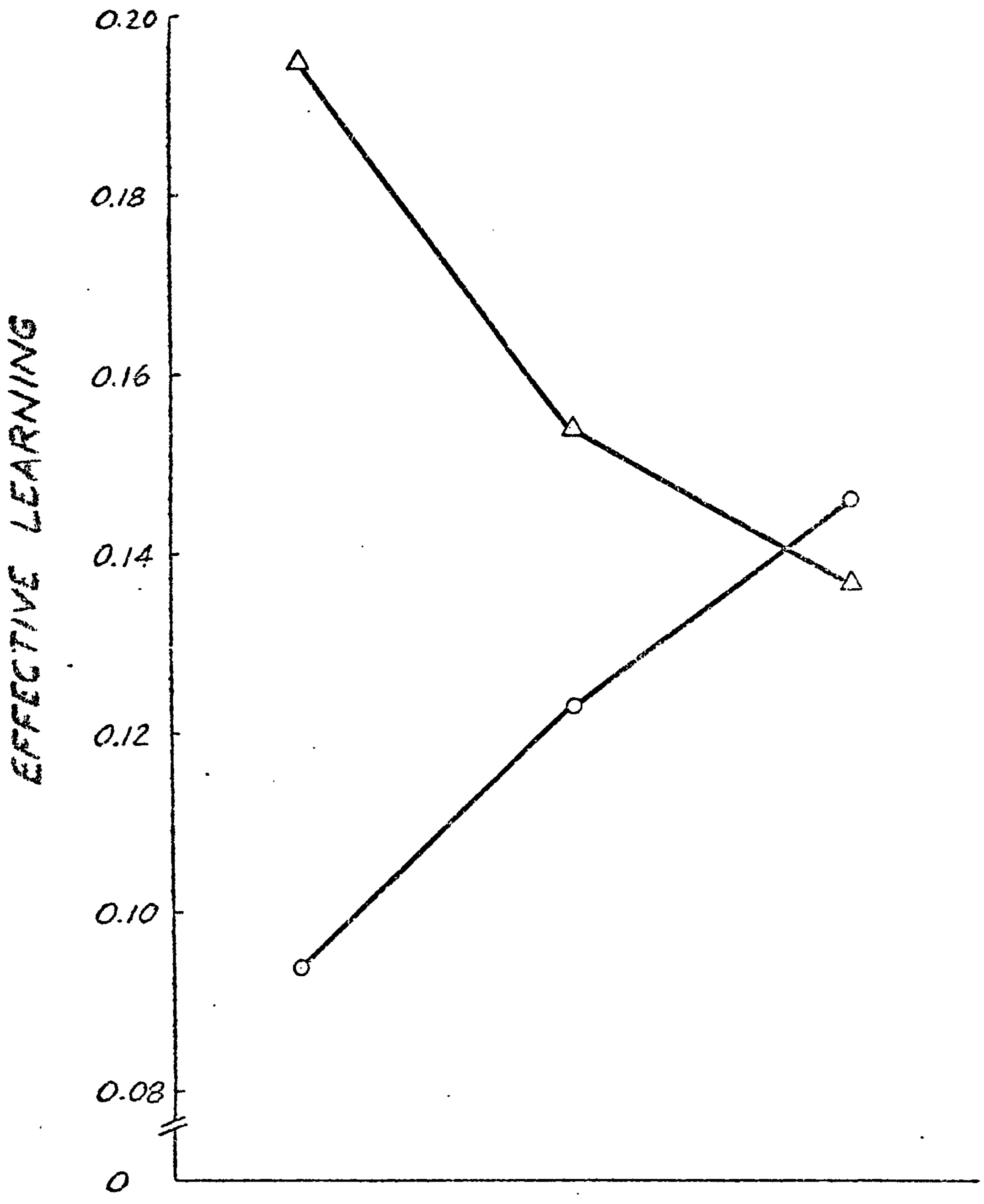


Figure 4-71. Means of EL(R2TOT)
Experiments #3-#4

INC △
INT ○
C
L
F

4.3.9 Effective Learning Capacities

Effective Learning Capacity (ELC) was defined as the product of an Effective Learning score (Test score / Accesses) and Time in the Universe. Graphs of the ELC means are in Figures 4-74 to 4-76 on pages 227 through 229. ANOVA effects were found for the ELC(Post) and the ELC(Retl)(Table XXXIV, page 226). Further, the differences among the means of the students were consistent from the one test to the other. The ENCY Instruction Control had the highest means (Figure 4-72). For the Retention 1 test, the GL-INT students had an equivalently high mean (Figure 4-73).

	ENCY	PPI	GL
INC	HI		
INT	HI		

Figure 4-72. Comparison of Means
ELC(Post)
Experiments #3-#4

	ENCY	PPI	GL
INC	HI		
INT	HI		HI

Figure 4-73. Comparison of Means
ELC(Retl)
Experiments #3-#4

TABLE XXXIV

ANALYSIS OF VARIANCE EXPERIMENTS #3-#4
EFFECTIVE LEARNING CAPACITY AND
EFFECTIVE LEARNING RATE

Parameter	$\overline{X}$	s	$\overline{X}_{11}$	$\overline{X}_{12}$	$\overline{X}_{13}$	$\overline{X}_{21}$	$\overline{X}_{22}$	$\overline{X}_{23}$	RxC F	ROWS F	COLS F
					ELC						
PTOT/PRU	0.674	0.236	0.806	0.591	0.599	0.911	0.587	0.714			4.56^{2}_{34}
R1TOT/PRU	0.761	0.256	0.958	0.689	0.565	0.883	0.713	0.969	3.51^{2}_{34}		4.21^{2}_{34}
R2TOT/PRU	0.790	0.328	0.929	0.714	0.662	0.846	0.698	1.035			
					ELR						
EL_{PTOT}/TU	0.025	0.014	0.035	0.028	0.024	0.011	0.020	0.017		8.12^{1}_{34}	
EL_{R1TOT}/TU	0.028	0.018	0.042	0.033	0.023	0.011	0.024	0.023		4.96^{1}_{34}	
EL_{R2TOT}/TU	0.029	0.019	0.042	0.035	0.027	0.011	0.022	0.023		6.69^{1}_{32}	

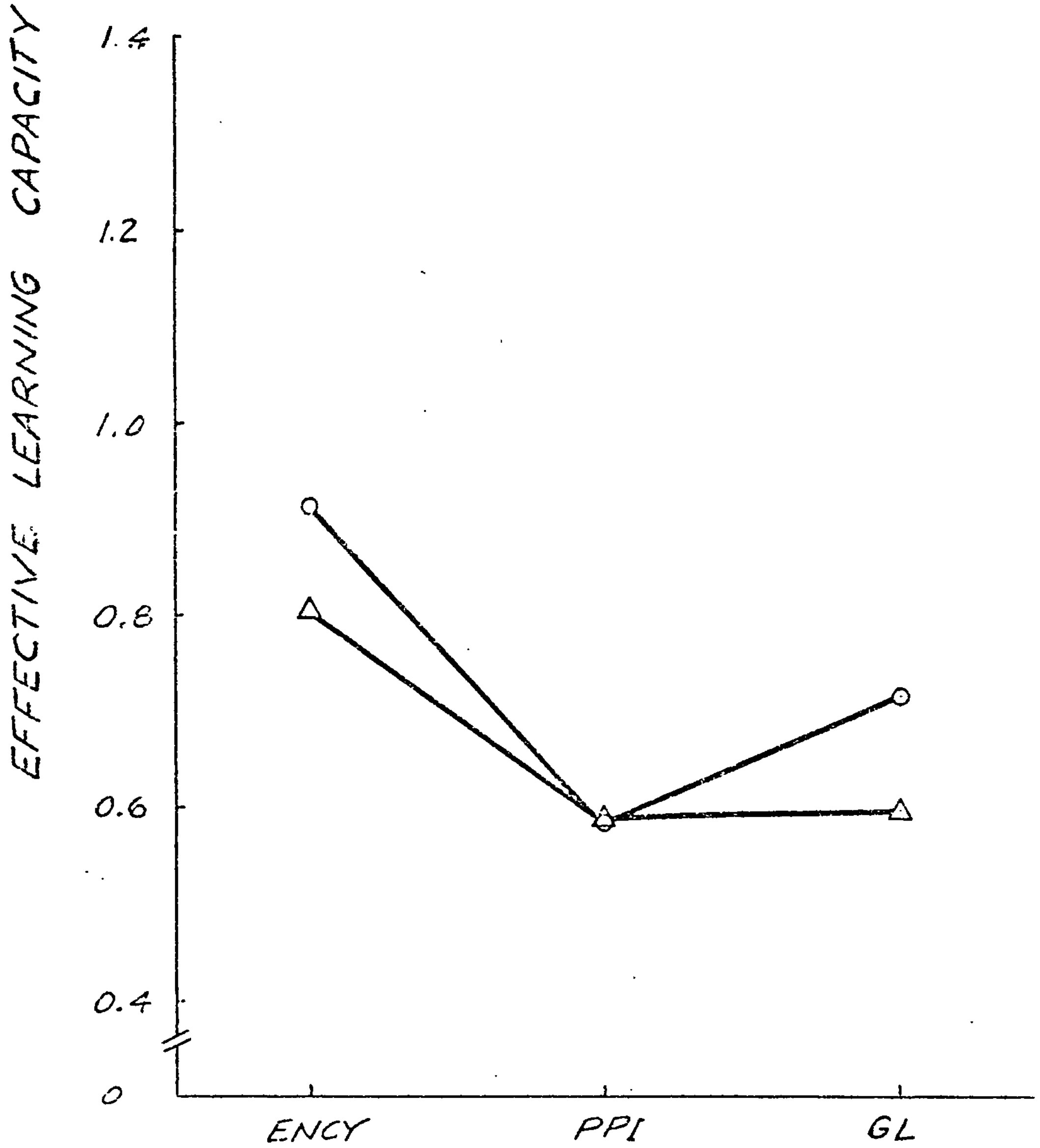
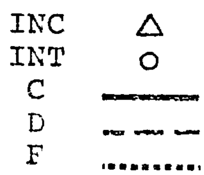


Figure 4-74. Means of ELC(PTOT)
Experiments #3-#4



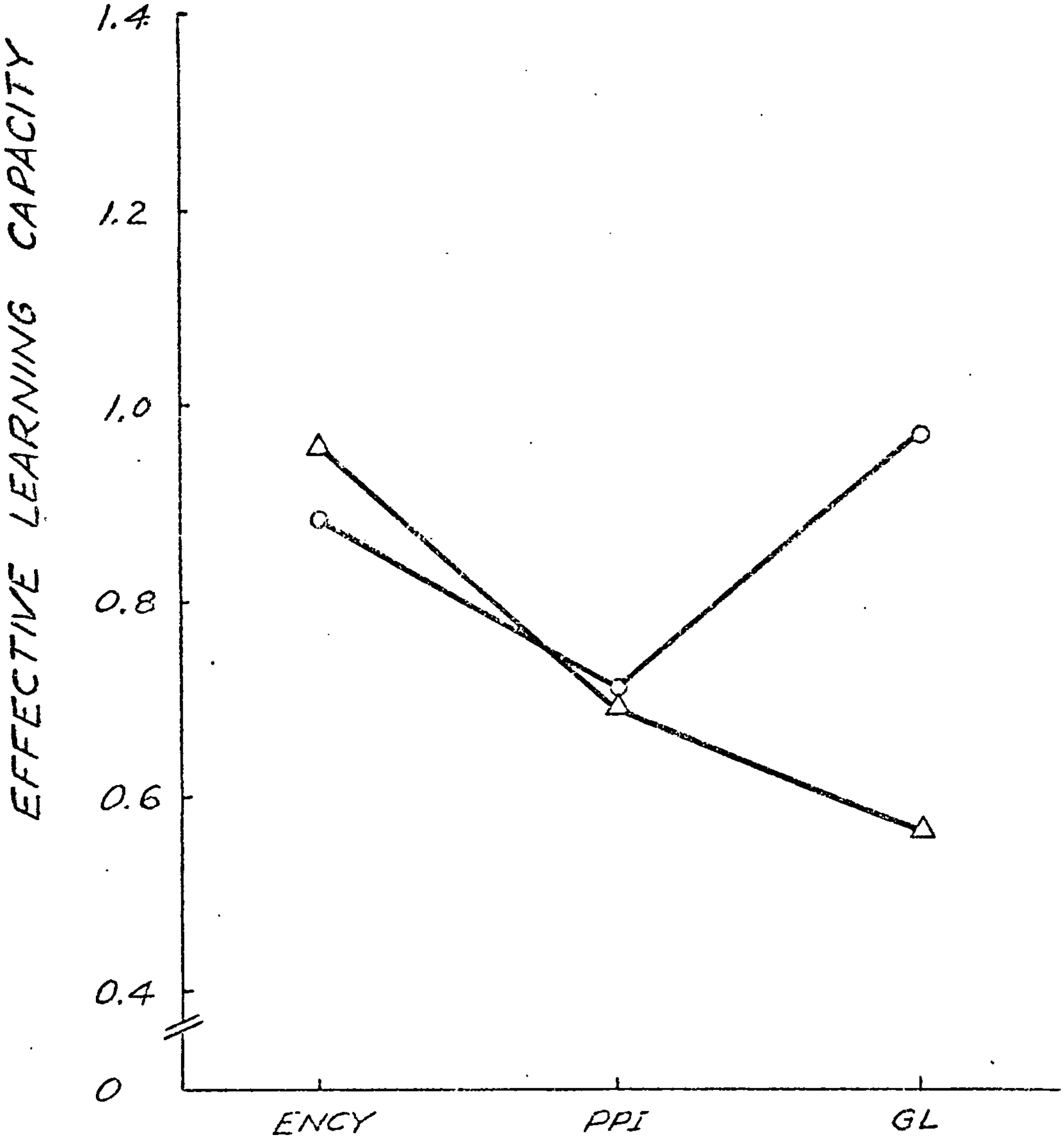


Figure 4-75. Means of ELC(R1TOT)
Experiments #3-#4

INC △
INT O
C

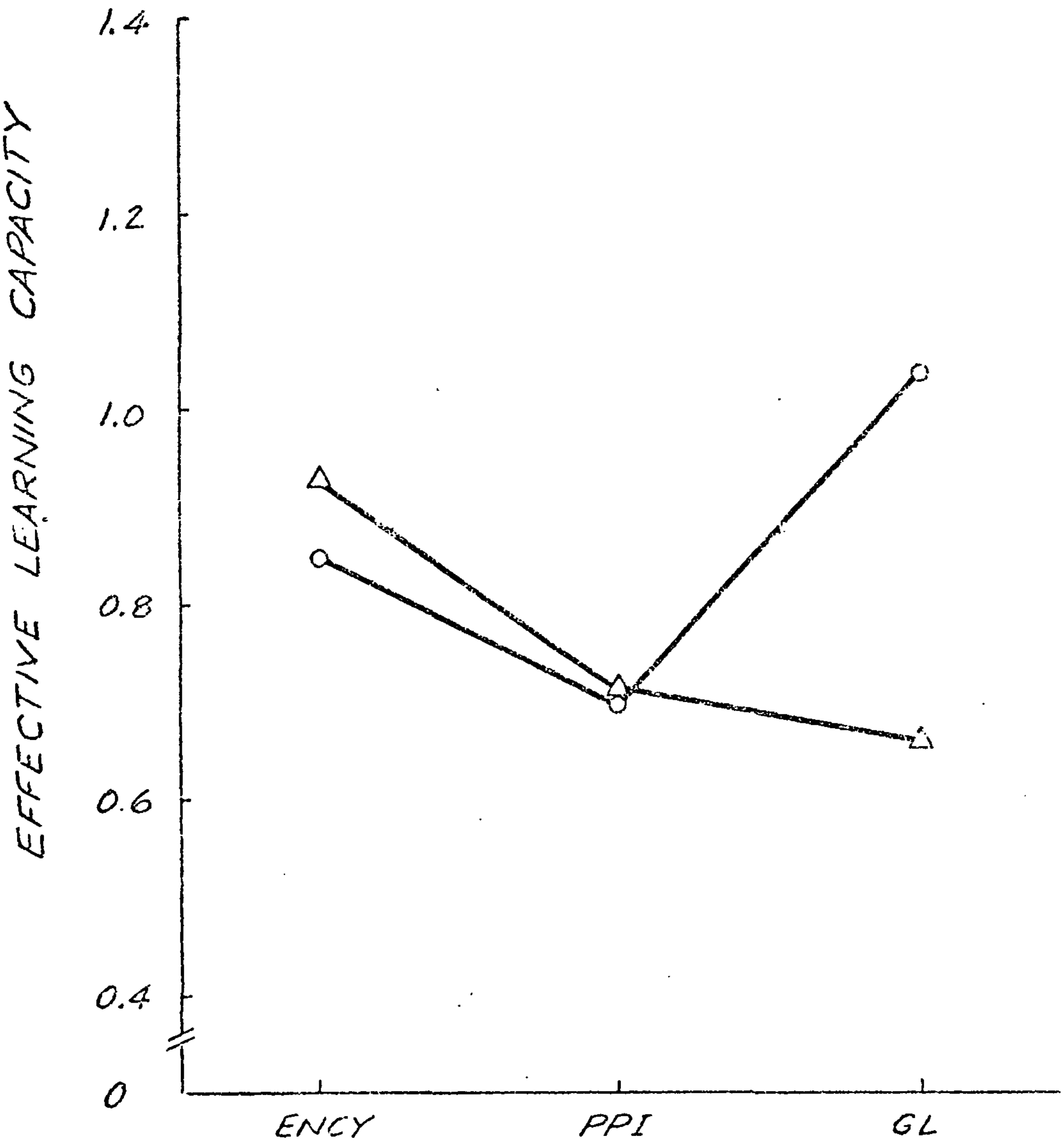
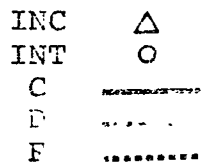


Figure 4-76. Means of ELC(R2TOT)
Experiments #3-#4



4.3.10 Effective Learning Rates

The Effective Learning Rates (ELR) were defined as the Effective Learning per hour in the Bite Structure or (Test/Accesses) / (Time in the Universe). Graphs of the ELR means are in Figures 4-78 through 4-80 on pages 231 through 233. The ANOVA results showed a consistent row effect for the three tests (Table XXXIV). In each case the Incremental Design Schedule students had higher ELR. However, note that GL-INC mean was more like that of the Integral students. It is also to be noted in each case that the extreme positions of the group means were those of the ENCY students. The ENCY-INC students' mean ELR was at the high position while the mean ELR of the ENCY-INT students was at the low position (Figure 4-77).

	ENCY	PPI	GL
INC	HI	HI	
INT			

Figure 4-77. Comparison of Means
ELR(Post), ELR(Ret1), ELR(Ret2)
Experiments #3-#4

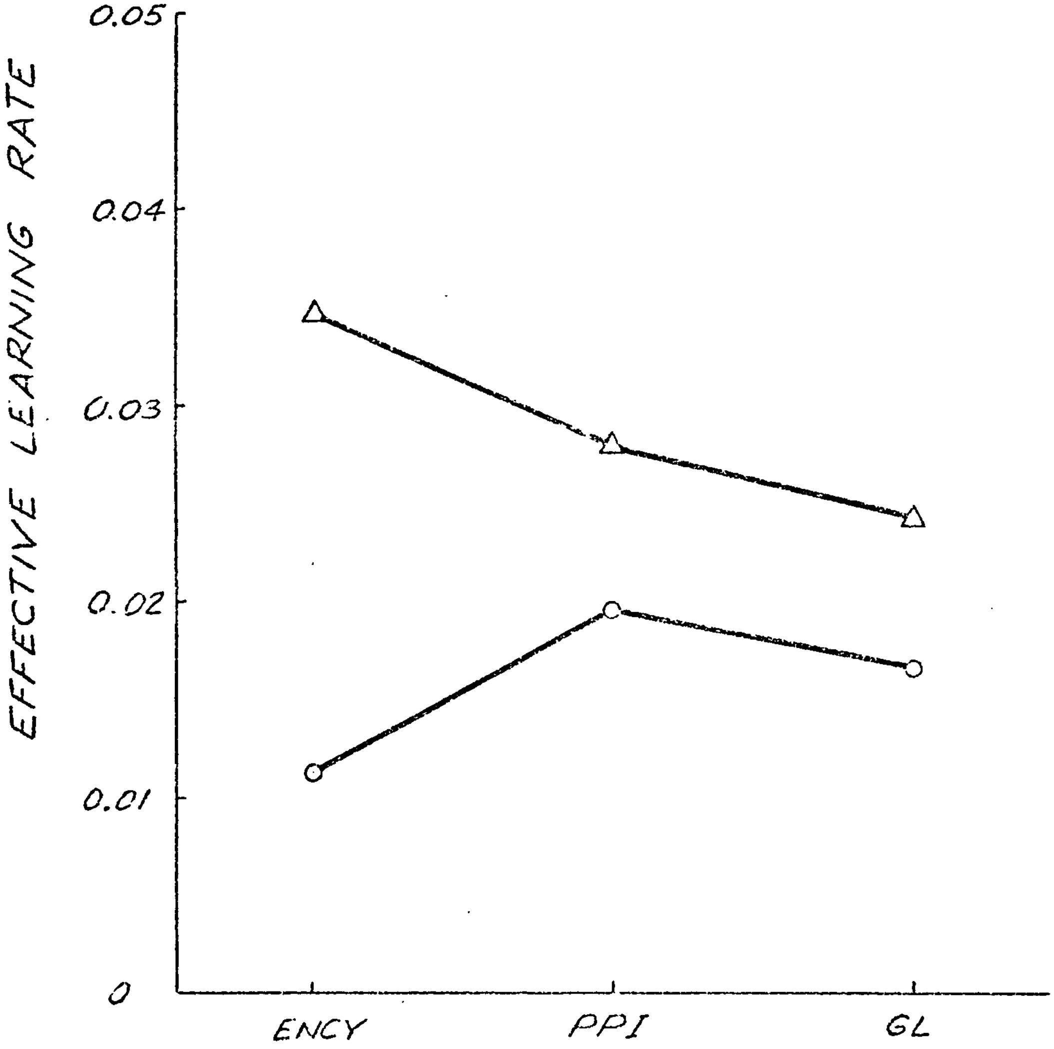


Figure 4-78. Means of ELR(PTCT)
Experiments #3-#4

INC △
INT ○
C
D
F

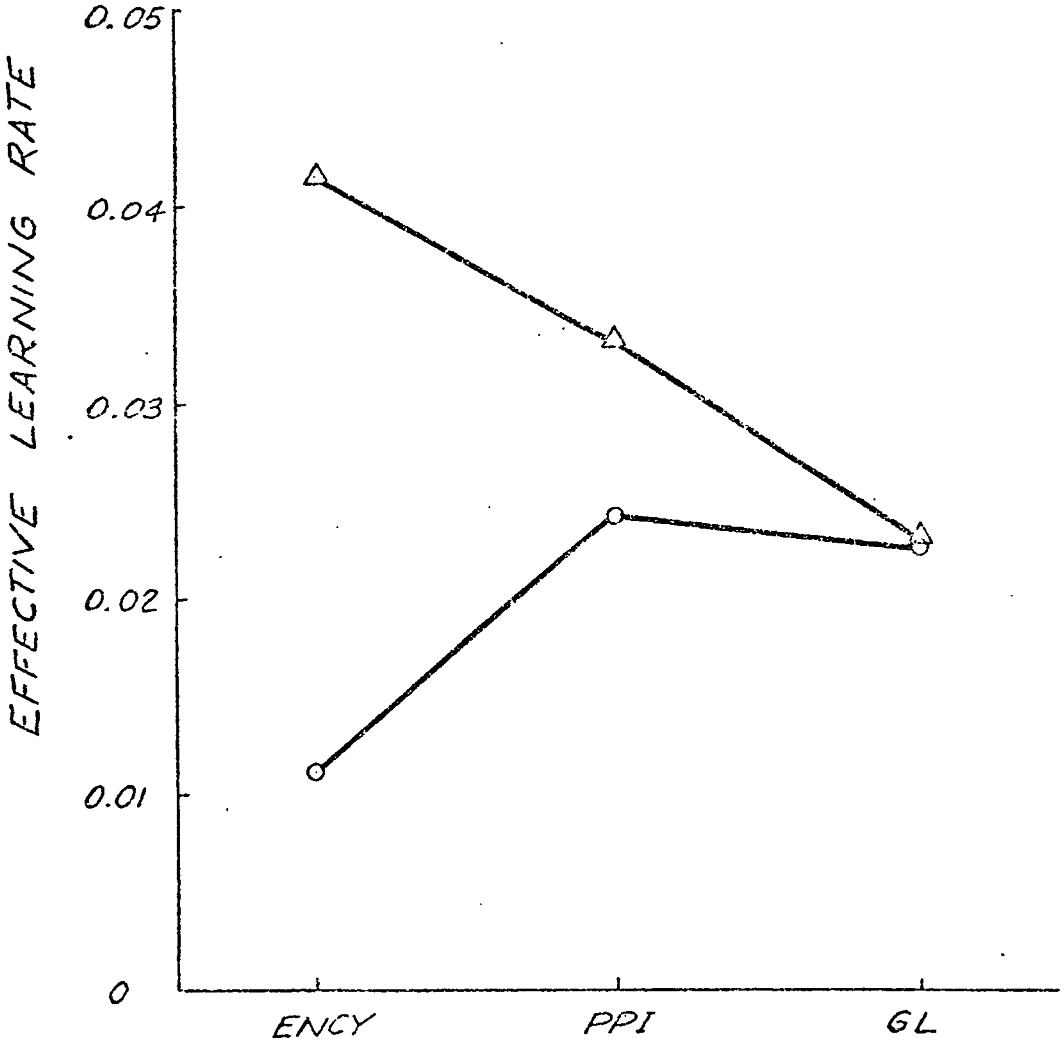
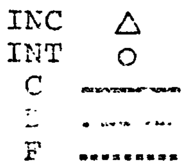


Figure 4-79. Means of ELR(R1TOT)
Experiments #3-#4



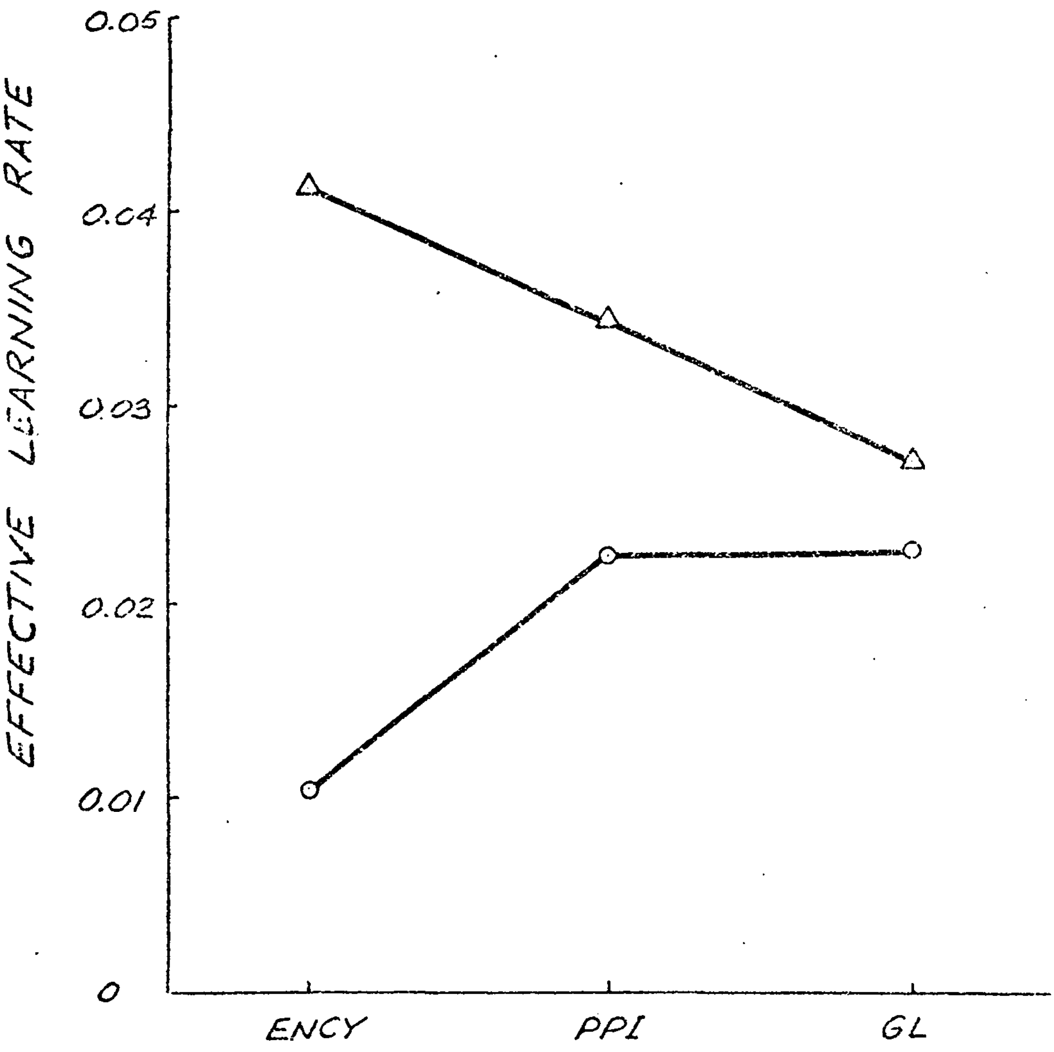


Figure 4-80. Means of ELR(R2TOT)
Experiments #3-#4

INC △
INT ○
C
D
F

4.4 DISCUSSION OF RESULTS OF EXPERIMENTS #3 AND #4

The first impression of the results of the grouped Experiments #3 and #4 was that these students seemed different from the students tested earlier in the Synnoetics Laboratory. Comments by the Laboratory staff and by the students themselves continually stressed that the subject matter of the course was considered to be "very difficult." The media was also mentioned as being unfamiliar by a number of students. Absenteeism from the scheduled appointments was a problem. While most students gave no reason for skipping the session, some did phone in plausible excuses. But serious student disturbances on the Wisconsin campus were a fact of life during 1969 and these students had some distance to walk from their regular Technical buildings to the Synnoetics Laboratory. Motivational differences, at least, must surely have existed between these subjects and the other experimental subjects.

Nevertheless, the results of Experiments #3 and #4 are not in conflict with the results of the earlier experiments.

4.4.1 The Universe Parameters

During the Design portion of the course, it would be expected that the Incremental students would spend more time and access than those who had to complete a design problem before receiving any feedback (the Integral students). It

Incremental and the

Integral students of ENCY control were equivalently low in total accesses to the Universe during Design. But it was in the time spent in the Universe where the differences, that most affected the compound parameters, appeared. The ENCY-INT students spent a decidedly longer time than any of the other groups doing the Fundamentals and Composite course. During Design, the Integral students, i.e., the Experiment #4 group, spent the most time. Here again ENCY-INT appears in the high group. This was not an expected result and may be attributable to the population of Experiment #4 students. Some students and faculty claim that fall semester work is not as well done as that done in the spring and these students worked in the Laboratory in the fall semester, whereas Experiment #3 students worked in the spring. Also there were three students in the two experiments who took a large number of sessions to finish the course compared with the average (Figure 4-81). Student 45, in ENCY-INT, took thirteen sessions. Student 46, in ENCY-INT, took fifteen sessions. Student 57, also in ENCY-INT, took ten sessions.

Experiment	Design Schedule	Average Sessions
3	Incremental	5.7
4	Integral	7.2

Figure 4-81. Average Number of Sessions for Course

These three students happened to form 60 percent of the valid ENCY-INT students for the Composite course. The other two students in this strategy took nine and four sessions respectively. This resulted in the average number of sessions of an ENCY-INT student being 10.2. Implied in the greater number of sessions phenomenon are greater amounts of accessing and time spent. This ENCY-INT deviation was therefore a major effect and to be kept in mind throughout the evaluation of the results. The negative correlation between high access during Design and Post Fundamentals test scores confirmed the expectation that a student who had to review a large amount in order to complete his design was probably unprepared in his fundamentals.

4.4.2 The Relative Access and Times Parameters

The major differences appeared in Bite Set 1. PPI Instructional Control, especially during Design, had the highest means for Relative Accesses and Times. No Design Schedule effect appeared during Design. The more expected result of high means across the Incremental cells may have been masked by the more ponderous Experiment #4 students. For the Composite Times and Accesses of the ENCY students to be included in the highest group, the ENCY students must have been just short of being differentiated as "high" in the Fundamentals and Design.

The high Bite Set 4 means belonged to the GL students for the Relative Accesses and Relative Times during Fundamentals. Bite Set 4 was very small, only eight Bite Units. But the number of Peripheral Bites available to the GL students was larger than that of the other Instruction Controls. These students may have availed themselves of this interconnected, redundant supply of PBs and interacted with the Bite Set in proportion to its content regardless of need or redundancy.

The most important Bite Set with respect to positive correlations with the test scores was Bite Set 1. In fact, accesses to other Bite Sets were more likely to work against good test scores. Thus the high access rate of the GL students in Bite Set 4 was a contributory cause of that same group's low test scores.

Bite Set 5 showed the expected high Incremental access and times caused by the Design Schedule during Design. Again the availability of the Bite Structure may have dictated the results. In Bite Set 5 GL had more Bites available (counting the interconnected Bites in other Bite Sets) than did the other controls (Table II, page 29). Within GL, the Design Schedule probably was responsible for the high GL-INC access, although "slower" students in this group may have contributed by accessing broadly and indiscriminately.

In Bite Set 6 the GL-INT students had the most Bites available to them and this could have accounted for the high mean for this cell. In order to have a relatively high access rate, a particular interaction strategy must have:

(1) relatively many Bites to access, and/or

(2) relatively little re-access of earlier Bite Sets.

[illegible] re-access Bite Sets 1

or 4 at all during Design. Students often commented in the interviews that the fundamentals did not make sense to them until they began to work their design problems. Other students remarked that in their desire to finish the course, they had hurried through the fundamentals and then had to return to them for information after they had begun to design.

4.4.3 The Bite Unit Parameters

Again with these parameters of the Utilization of the Bites in the Bite Units of the Bite Set and the number of Distinctly Accessed Bite Units in a Bite Set was seen the importance of the Bites in Bite Set 1 to good Post Test scores. Yet the differences among the six groups were not significant as measured by these two parameters over the Fundamentals, Design, and Composite of the course. This strengthened the view that these Experiments #3 and #4 students were exposing themselves to most of the concepts (Bite Units) available to them via their particular Interaction Strategy during Fundamentals. The number of Bite Units in Bite Set 1 was nearly equivalent so that the differences in use of Bite Set 1 would only be seen by the measures of accesses to Bites.

In Bite Set 2, the Instruction Control has effected the use of the Bite Set. Both in terms of utilization and the number of different Bite Units requested. ENCY students were the lowest consumers of Bite Set 2. This Bite Set was of moderate importance apparently as its usage does not correlate with the test scores excepting that if it were relatively highly accessed a student was more likely also to have a high number of unanswered questions on his Post Test. The same forced use of Bite Set 4 as was seen in Bite Set 2 has the PPI students utilizing an extra Bite Unit or two more than the other Instruction Controls. And as the PPI-INT students had a high number of unanswered questions, this high utilization of these two Bite Sets could not be said to have been beneficial.

Bite Set 6, in which the students met their first design problem was an important area of study. While there were no correlations with the test scores to support this argument, the comparison of the differences among the means of the Distinctly Accessed Bite Units of Bite Set 6 and of the Post Familiar test scores (Figures 4-36, 4-44) did confirm the relationship of the Design Schedule effect on this Bite Set and the level of skill with the similiar types of design problems on the Post Test.

The differences among the means of the Distinctly Accessed Bite Units in Bite Set 5 were largely a factor of the availability of Bite Units to the Interaction Strategies and the effects of the Design Schedule. A key interest here was that the ENCY students acted more as a unit than as two groups. Design Schedule seemed to have the least effect on ENCY students throughout the experiments.

4.4.4 The Standardized Test Scores

The fact that the Standardized scores were similar across the Interaction Strategies is reassuring in the light of the positive correlations the ACT scores had with the test scores. However, comparing the means test totals and the mean ACT scores group by group there are certain observations to be made. The numerically highest ACT Composite, English, Math, and Social Science scores are those of ENCY-INC. The numerically highest mean in each of the three tests and their subtotals (excepting Unanswered) was that of ENCY-INC. Further, the numerically lowest means on the Standardized scores and the Post and Retention Totals was that of either the GL-INC or the ENCY-INT groups. While the correlations were based on the individual relationships, it appears that there was a possibility of some slight effect attributable to the random grouping in which one group, ENCY-INC, may have had an "intellectual" edge on the GL-INC and ENCY-INT groups. This possibility must not be over-stressed as the range of ACT points between these "extreme" groups was only 3.1 points when the standard deviation was 4.3. But, at the very least, it is a curiosity.

4.4.5 The Test Scores

The difference among the means of the tests provided a rich source of comparisons. The GL students achieved the lowest means on the Post Total and the GL-INC students achieved [illegible] mean score on the Retention 1 test. The low Retention 1 score could have been the work of "slower" students with "lower" ACT scores or it could have been that they were affected by an independent or compounding property of the Interaction Strategy. The GL students also had the lowest mean RTBS1 during Fundamentals, the highest mean RTBS4 and RABS4 (which correlated negatively with Post tests) during Fundamentals. Either the test did not uniformly cover the fundamentals presented in the three Bite Sets or the GL Instruction Control permitted poor time and resource management. Another possible contribution to the low GL-INC scores could be that Experiment #3 was interrupted by the Easter vacation (Table III, page 31).. The GL students were the most seriously affected group (45 percent). In the interviews, students commented that as time went on they just wanted to finish. This reflects a somewhat disinterested, fatalistic, although understandable view. Therefore, the prolongation of the laboratory sessions by the Easter vacation may well have affected the GL test results unduly.

The difference in the Post test Familiar means (Integral students low) can be juxtaposed to the Integral students' high expenditure of time during Design, their low RTBS5, and their low utilization of Bite Sets 5 and 6. The implication is that the time in Design was spent re-accessing the fundamentals and/or just pondering how to proceed to solve the problems in Design. The Integral student had to attempt to solve the entire problem before he received any feedback

[illegible] ess. The Integral Design Schedule may be [illegible] poor tutoring system for this population of students. Or it may be poor only in the short term retention view. Or the entire matter may be distorted by the effects of the "slow" students found in ENCY-INT who took an excessive number of sessions to complete the course. Whatever the causes, the same causes are responsible for the high means of the Integral students on the Post Unanswered-questions subtotal.

The means of the Post test Totals of Experiment #1 and Experiments #3-#4 show the same relative relationships of the PPI-INC mean to the GL-INC mean, and the same relative relationship of the ENCY-INT mean to the PPI-INT mean (Figure 4-82). Recall that the mean of the PPI-INC of Experiment #1 was greater than the other means in Experiment #1, but the GL means of Experiments #3-#4 were lower than the others in that set (Lenahan and Clatur, 1969).

Comparing the Retention 1 means of Experiment #1 and Experiments #3-#4, the same relative relationship of ENCY-INC and PPI-INC is seen and the same relative relationship of the means of PPI-INT and GL-INT is seen (Figure 4-82). In this case, the mean of ENCY-INC in Experiment #1 was reported to be highest, whereas the Experiments #3-#4 results showed cell means equivalently high except for a low GL-INC (Lenahan and Clatur, 1969).

4.3.6 The Processing Rates

The processing rates are largely a function of Instructi[illegible]. The [illegible] students had to locate the

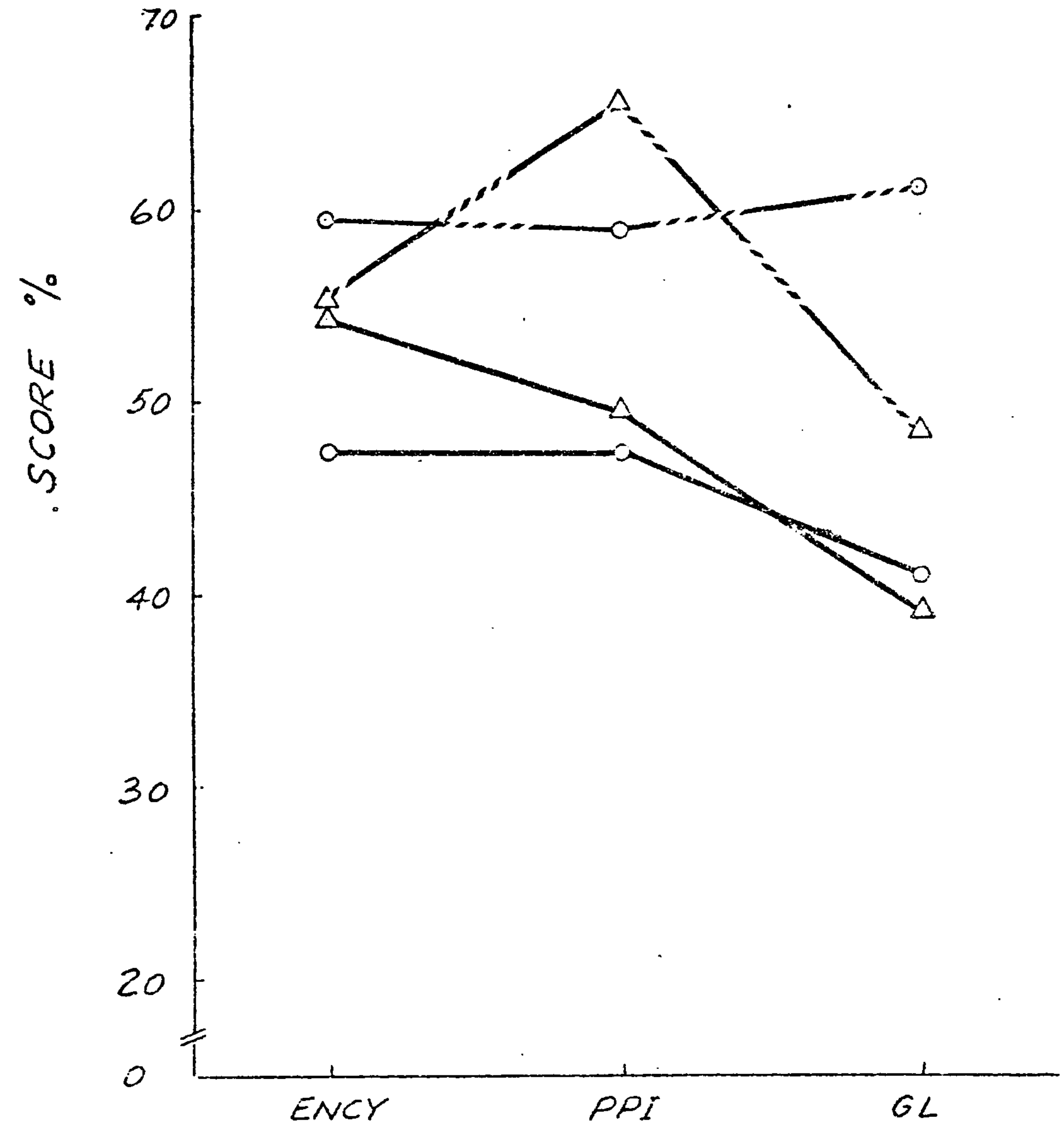


Figure 4-82. Means of PTOT
Experiments #1, #3-#4

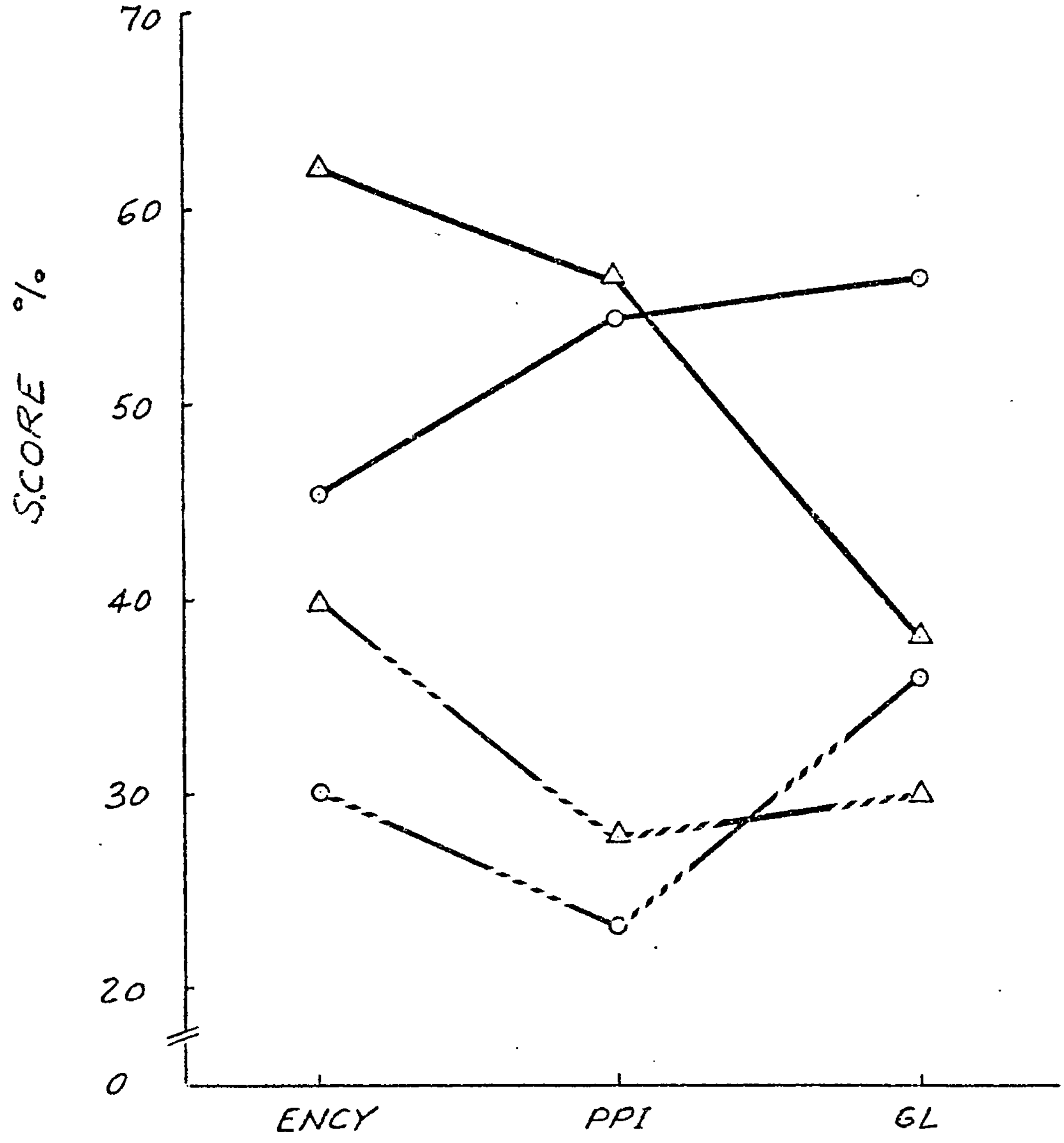


Figure 4-83. Means of R1TOT
Experiments #1, #3-#4

Bite they wished in an index and request it. The GL students could make such specific requests or they could rely on the NEXT BASIC BITE key to maneuver through the Bite Sets. The PPI student was dependent on the NEXT BITE key. Thus, it is no surprise that the PPI students rather consistently had the highest processing rates. The exceptions are in processing the DABUs. The GL students tended to process distinct Bite Units faster than the other students, the use of the NEXT BASIC BITE key taking them from one Bite Unit to the next (see page 24). The apparent Design Schedule effect during the processing of the Bite Set 4 during Fundamentals is unexpected, and, of course, not the result of the imposition of the Design Schedule. The relative ranks of the six means are most like those of the Processing Rate of the Universe and the Processing Rates of Bite Sets 5 and 6 during Design, i.e., the ENCY-INT and GL-INT cell means were numerically the lowest. The ENCY-INT group also had the highest mean TU during Fundamentals. Also the ENCY control students and GL control students utilized fewer Bite Units in BS4 than did the PPI students. So that while the PPI students were constrained to contact a selection of Bites in BS4 and dispatched them promptly, other students apparently chose fewer of the Bites and spent more time focussed on them. This is most especially the case for the "slow" Experiment #4 students. And those Experiment #4 students not under the PPI control amounted to the ENCY-INT and GL-INT students. Thus the apparent row effect is more likely an incidental factor of the Experiment #4 students' performance.

4.4.7 The Performance Rates

Here again the low mean for the ENCY-INT can be suspected because of the deviations from the average TU found in this group. The union of ENCY control and PPI control in a common high set of means could be supporting the effectiveness of the Incremental Schedule with this sample population of students. The high mean and low mean in the same Instruction Control, ENCY, either reaffirms the effectiveness of the Incremental Schedule or is related to the possible differences between the basic abilities of these two groups alluded to in Chapter 4.4.4. This arrangement of extreme mean positions is not seen in the other parameters and must therefore occur from compounded effects.

4.4.8 Effective Learning

The lack of significant differences in the three measures of Effective Learning is due to the fact that while there were no differences found among the Accesses to the Universe, the means of the two groups of GL students were numerically lower than the other cell means. The differences among the means of the test totals was greatest for the two GL Interaction Strategies. GL-INT and/or GL-INC achieved lower Post and Retention 1 scores. The relative ratios of the six groups were subsequently equivalent.

4.4.9 Effective Learning Capacities

The ELC is another parameter affected by the high mean TU of the ENCY-INT students. The higher the Time in the Universe, the higher the ELC, other factors being constant. And there being no significant differences among the Effective Learning scores, the differences in the ELC were the result of the Time in the Universe differences compounded with the more subtle individual differences among the test scores and accesses. Viewed as a measure of potential storage, the high mean ELC of the ENCY-INC is probably the most authentic of the three high mean groups. The others could be tainted with the possibility of the TU being greater because of ponderousness and uncertainty of the next choice of activity rather than being greater because the students were studying the presented information longer. It is the assumption of the latter that gives meaning to this parameter.

4.4.10 Effective Learning Rate

The three measures of ELR showed a consistent pattern in which Incremental ENCY and PPI students had higher rates of Effective Learning. This implies that those two Instruction Controls were equivalently effective systems of instruction provided that the Incremental Design Schedule was imposed. The most encouraging sign that this result is not confounded by the possibility of "slow" ENCY-INT students is that the PPI Instruction Control separated so decisively between the Incremental [illegible] groups. However, the two GL strategies not showing any difference between each other could be an effect of the GL-INC students being "slow" (Chapter 4.4.4). If this is the case, the effectiveness of the Incremental Schedule is only reinforced.

4.5 CONCLUSION

Instruction Control and Design Schedule were observed to affect the performance of students in learning the Sequential Logic Circuit Theory. Their performance was affected during the acquisition of the fundamentals of the course and during the application and/or re-acquisition of these fundamentals to the problems, both familiar and unfamiliar, in Sequential Logic Circuit designing. Instruction Control and Design Schedule were observed to affect the short-term and long-term retention of the fundamentals and designing skills. In particular, students whose learning was optionally self or machine-directed (Guided Learning) performed the poorest on the immediate test. The students whose problem-solving was done in partial solutions monitored by incremental checking performed better than the others on the test questions relating to the solutions of familiar types of problems. Similarly, these students were observed to have the fewer number of unanswered questions on the immediate or post test.

Students whose learning was optionally self or machine-directed, and whose problem-solving was done in partial solutions monitored by incremental checking performed the poorest on the first retention test.

No differences in performance by the students were observed as measured by the second long-term retention test.

The performance of all the students in the course was observed to be such that the longer the time taken in the course, the more likely the student was to obtain lower test scores; the higher the time and accesses of the student during acquisition in his first set to study, the more likely he was to obtain high test scores; the more accesses spent in his first problem-solving set, the more likely he was to obtain lower test scores; the more accesses the student took during his last problem-solving set, the more likely he was to perform well on the questions relating to familiar problems on the post test; and the higher the student's American College Testing Service scores were in the Composite, English, and Natural Science areas, the more likely the student was to achieve high post and retention test scores.

The students who directed their own learning were observed to access the least information and of these students, the ones who also solved their problems as unified, integral tasks were observed to spend the most time completing the course. The machine-directed students were observed to have generally the highest utilization of the information while the self-directed students generally had the lowest utilization of the information. The machine-directed students were also observed to have the highest rate of processing information.

The highest Performance Rates and Effective Learning Rates were observed among both the self-directed and machine directed students who solved their problems incrementally.

The highest Effective short-term Learning Capacity was observed among those students who directed their own learning.

Overall, the most effective instruction system for short-term learning was observed to be that in which the student directed his own learning and solved his problems in an incremental manner.

Chapter 5

SUMMARY AND PERSPECTIVE

"Those who wish to succeed must ask
the right preliminary questions"

\- Aristotle

In many ways this thesis has posed real-world problems in real time. Early assumptions as to the kind and amount of data available had to be modified as the file building proceeded. Early expectations of healthy cell frequencies for all parameters crashed in a vital area, the Retention 1 test of Experiment #2. And there were the usual over-ambition and over-extention. Thus there are many unreported results from many other ANOVAs that hopefully can be incorporated into some future study of a more detailed level of student performance within the Bite Structure. Another early assumption was that a subsequent project, beyond this thesis, might be to build a predictive model to infer the performance of the Experiments #3-#4 students based on the results obtained on the performance of Experiment #2 students. But, there were early indications from the differences between the results on the criterion tests that either the students must be considered as being from different populations or that there was some factor differentially affecting performance that was more apparent in Experiment #4 than in Experiment #3, and least apparent in Experiment #2.

5.1 STUDENTS AND ENVIRONMENT

The students in Experiment #2 were obtained from a fall semester electrical engineering course at the University of Wisconsin in 1968. The students in Experiments #3 and #4 were students from the Madison Vocational College. The Experiment #3 was conducted in the spring of 1969 and was interrupted by the Easter vacation. The Experiment #4 was conducted during the fall of 1969 when student rioting was a hazard. The vocational students also had about a mile further to walk from their regular buildings to the Laboratory than the university students.

Presumably the vocational and university students could have had different abilities for learning abstract subject matter. And some studies have indicated a possible instruction sequence by ability interaction effect (Stolurow, 1964 and Levin and Baker, 1963 cited by Oliver, 1971). And if the student is the one best able to recognize his own ability, then his own choice of instruction sequence may be the reason that some studies have indicated a positive effect for learner control (Mager and McCann, 1961 cited by Olivier, 1971).

However, other studies which have allowed the learner to determine his own instructional sequence, such as the ENCY and GL students could do in these experiments, have demonstrated little or no difference between the learner selected sequences and instructional sequences determined by a Gagne type analysis (Judd et al, 1970). The Gagne analysis, per se, was not used to sequence the PPI students. (The Gagne analysis of subject matter is largely suitable for gross hierarchical structuring of learning from signal, stimulus-response, chaining, verbal association, etc. to the higher levels of concept, principle, and problem-solving. And Gagne has not suggested any analytic procedures to work within concepts and principles.)

If there can be assumed to be ability differences between the two sets of experimental students, and if it can be assumed that the three different Instruction Controls did, in fact, result in different instruction sequences, then the results of these experiments could be examined against the hypothesis that different ability students learn better under different Instruction Controls. So for purposes of this discussion, it is assumed that the average Experiments #3-#4 student had lower ability, interest and motivation towards the experiment, and higher anxiety about being on campus and/or about the difficulty of the subject matter.

5.2 RESULTS AND DISCUSSION

There are a number of valuable similarities to be noted between the two sets of experiments that serve to sup-

[illegible] to [illegible]end the current understanding of the use of the computer as a learning tool. The differences serve the purpose of suggesting styles of learning more appropriate to differing ability and anxiety levels in students.

5.2.1 Similarities Between Experiments

In both cases, the total time spent in the course had a negative relation to performance on the Post test. This is probably a correlation most influenced by the very slow students of both sets of experiments who had excessive difficulty solving the design problems, both interactively during the lab sessions and unilaterally during the criterion tests. Only the accesses made during the Design portion of the course were negatively correlated with the Post test. High access during Design would be the result of high re-access among the Fundamentals. This was a particularly common strategy observed among the GL students. By relying on the NEXT BASIC BITE key, by not knowing for certain which Peripheral Bites were available, and by becoming discouraged with "NONE AVAILABLE" responses on occasion, the GL student cycled himself into a position of prematurely entering Design and subsequently having to re-access the Fundamentals. The re-accesses would also be made with a specific motive, to obtain an answer to a current difficulty. There would be little intent to retain the information so gleaned.

In both cases, high relative access to Bite Set 6 also had a negative correlation to performance on the Post test. This correlation was undoubtedly related to the first. Bite Set 6 contained the first set of problems so that a large amount of time or access there would indicate slowness in applying the fundamentals to the problem-solving. Also, those students who worked on Bite Set 6 and Bite Set 5 (the last Bite Set) in their last interactive session probably would have begun the Post test in a particularly tired and drained condition.

Both sets of students displayed a positive relationship between their performance on the Post Familiar or Post Transfer (Unfamiliar) portions of the immediate test and their Relative Access of Bite Set 5. This effect is due to the juxtaposition in time of the interactive problem-solving practice with the test problems. The students proceeded to the Post test only from a position of successful problem-solving. This would have enhanced their confidence and reinforced the most recent (successful) problem-solving performance. The memory of the successful problem-solving steps for each of the types of problems would be in the Short-term Memory sometimes referred to as Intermediate Memory. Information in Intermediate Memory is retained in some cases for 5-15 seconds, for 40 minutes, or up to 3 days before being consolidated, if indeed it is, in a retrievable form in the Long-term Storage (Norman, 1970). This being the case, then the more accesses retained in Intermediate Memory from the accesses to the last Bite Set (5) during the [illegible] Post test, the more images there would be to recall that are similar to the questions on the Familiar and Transfer sections of the test.

The Experiment #2 and Experiments #3-#4 students followed the same pattern in their performance in the Bite Structure during Fundamentals, i.e., the means of the respective Relative Time and Accesses in Bite Sets 1, 2, and 4 during Fundamentals were roughly the same. Both groups similarly apportioned their time and the amount of information viewed among the three Bite Sets during the acquisition of the fundamentals. The performances in Bite Set 4 showed some differences which are discussed in the next section. The performances of the two sets of experimental students were also very similar during Design in the two problem-solving Bite Sets. The mean Processing Rates are within 10 percent of each other from one experiment to the other, with the exception of the Processing Rates of Bite Sets 1 and 4 during Design.

The relative accesses of each of the three Instruction Controls maintains a reasonably consistent pattern from one Design Schedule to the other in similar areas of the Bite Structure (Table XXXV). Whether or not the numerical differences were great enough to appear as significant differences from cell mean to cell mean, the Design Schedules did maintain an interesting order-similarity for the Instruction Control activity. In BS1 the pattern of composite activity from highest to lowest was ENCY-PPI-GL in both sets of experi- [illegible]. In BS 2, there was a

TABLE XXXV

BITE STRUCTURE PARAMETER PATTERNS
NUMERICAL ORDER (HIGH TO LOW)
OF INSTRUCTION CONTROLS

Exp.	Parameter	Incremental Design Schedule			Integral Design Schedule		
2	RTBS1 C	ENCY	PPI	GL	ENCY	PPI	GL
3-4	RTBS1 C	ENCY	PPI	GL	ENCY	PPI	GL
2	RABS1 C	ENCY	GL	PPI	ENCY	PPI	GL
3-4	RABS1 C	ENCY	PPI	GL	ENCY	GL	PPI
2	RTBS2 C	PPI	ENCY	GL	PPI	ENCY	GL
3-4	RTBS2 C	PPI	ENCY	GL	ENCY	PPI	GL
2	RABS2 C	PPI	ENCY	GL	ENCY	PPI	GL
3-4	RABS2 C	PPI	ENCY	GL	ENCY	PPI	GL
2	RTBS4 C	PPI	GL	ENCY	PPI	GL	ENCY
3-4	RTBS4 C	GL	PPI	ENCY	GL	PPI	ENCY
2	RABS4 C	PPI	GL	ENCY	PPI	ENCY	GL
3-4	RABS4 C	GL	PPI	ENCY	GL	PPI	ENCY
2	RTBS5 C	PPI	GL	ENCY	PPI	GL	ENCY
3-4	RTBS5 C	GL	ENCY	PPI	PPI	GL	ENCY
2	RABS5 C	PPI	GL	ENCY	PPI	ENCY	GL
3-4	RABS5 C	GL	PPI	ENCY	PPI	ENCY	GL
2	RTBS6 C	ENCY	GL	PPI	GL	ENCY	PPI
3-4	RTBS6 C	GL	ENCY	PPI	GL	PPI	ENCY
2	RABS6 C	GL	ENCY	PPI	GL	ENCY	PPI
3-4	RABS6 C	PPI	GL	ENCY	GL	PPI	ENCY

TABLE XXXV (Continued)

Exp.	Parameter	Incremental Design Schedule			Integral Design Schedule		
2	UBS1 F	GL	PPI	ENCY	PPI	GL	ENCY
3-4	UBS1 F	PPI	GL	ENCY	ENCY	PPI	GL
2	UBS2 F	PPI	GL	ENCY	PPI	GL	ENCY
3-4	UBS2 F	PPI	GL	ENCY	PPI	GL	ENCY
2	UBS4 F	PPI	GL	ENCY	PPI	ENCY	GL
3-4	UBS4 F	PPI	GL	ENCY	PPI	ENCY	GL
2	UBS1 D	GL	PPI	ENCY	ENCY	PPI	GL
3-4	UBS1 D	ENCY	PPI	GL	GL	PPI	ENCY
2	UBS2 D	GL	ENCY	PPI	ENCY	GL	PPI
3-4	UBS2 D	ENCY	GL	PPI	PPI	GL	ENCY
2	UBS4 D	GL	ENCY	PPI	GL	PPI	ENCY
3-4	UBS4 D	ENCY	GL	PPI	PPI	GL	ENCY
2	UBS5 D	GL	PPI	ENCY	PPI	GL	ENCY
3-4	UBS5 D	GL	PPI	ENCY	PPI	ENCY	GL
2	UBS6 D	GL	PPI	ENCY	GL	PPI	ENCY
3-4	UBS6 D	GL	PPI	ENCY	GL	PPI	ENCY

close approximation to this pattern although with some ambivalence as to the relative order of the first two control groups. In Bite Sets 4 and 5, the pattern changed to the extent that ENCY made a circular shift to the lowest position leaving the sequence PPI-GL-ENCY for Experiment #2 and GL-PPI-ENCY for Experiments #3-#4. The interesting BS6 with its initial problem-solving was least conformable to patterns. For Experiment #2, either the GL or ENCY control was highest and the PPI was lowest, while for Experiments #3-#4, either the GL or PPI control was highest and ENCY was the lowest.

The sequence patterns under the Utilization of Bite Sets parameters were less stable. In general, during Fundamentals, the pattern was PPI-GL-ENCY while during Design it was (GL or ENCY) - PPI for the re-accesses to the Fundamentals and GL-PPI-ENCY in the problem-solving Bite Sets themselves.

This set of observations implies that the ENCY students took more time on fewer Bite Units before deciding to problem-solve, while the GL students spent the least time on the most Bite Units fairly regularly throughout the course.

In the sets of Processing Rates, there are many similarities between the two sets of experiments. Most of the specific rates of processing areas of the course show either the ENCY-INT students having the lowest mean rate or the PPI-INC students having the highest mean rate in the Scheffe results. And both of these results are in the same pattern, PPI-GL-ENCY, when the cell means are ordered simply by their value.

In Table XXXVI, the relative order of the Instruction Controls within each Design Schedule are shown. While the sequences did not often represent significant differences from one cell mean to the other, the repetition of certain sequences is to be noted. In both sets of experimental students, the Instruction Control alone did not produce a consistent relative position. Unlike the Bite Structure behavior patterns, one Design Schedule test score sequence was usually different from the other. In the 24 cases shown, under Incremental Design, ENCY students most often had the highest means while GL students most often had the lowest mean. However, the best matches between the two sets of experiments were found in those tests which involved Retention scores. Under the Integral Design Schedule, clear patterns of achievement are not so apparent. The GL students were often lowest but also, on occasion, they appear in the highest position. The pattern of achievement under Integral Design Schedule also is broken between the Post and Retention scores. At no time was ENCY-INT to be found low in a Post test; however, it tended to the lower positions in the Retention tests.

Instruction Control was a factor in student achievement as measured by the test score totals of both experimental sets. In Experiments #3-#4, significant differences between the

[illegible] on the Post Familiar subtotal

TABLE XXXVI

TEST SCORE PATTERNS, NUMERICAL ORDER
(HIGH TO LOW) OF INSTRUCTION
CONTROL

Exp.	Test	Incremental Design Schedule			Integral Design Schedule		
2	PTOT	GL	PPI	ENCY	PPI	ENCY	GL
3-4	PTOT^{s}	ENCY	PPI	GL	ENCY	PPI	GL
2	PFD	GL	PPI	ENCY	ENCY	PPI	GL
3-4	PFD	ENCY	PPI	GL	PPI	ENCY	GL
2	PFM	ENCY	PPI	GL	ENCY	PPI	GL
3-4	PFM	ENCY	PPI	GL	ENCY	PPI	GL
2	PTRS	GL	PPI	ENCY	PPI	ENCY	GL
3-4	PTRS	ENCY	PPI	GL	PPI	ENCY	GL
2	PUN^{-}	GL	ENCY	PPI	GL	ENCY	PPI
3-4	PUN^{-}	PPI	ENCY	GL	ENCY	PPI	GL
2	R1TOT*	ENCY	GL	PPI	PPI	GL	ENCY
3-4	R1TOT^{s}	ENCY	PPI	GL	GL	PPI	ENCY
2	R1FD*	ENCY	PPI	GL	PPI	ENCY	GL
3-4	R1FD	ENCY	PPI	GL	PPI	GL	ENCY

TABLE XXXVI (Continued)

Exp.	Test	Incremental Design Schedule			Integral Design Schedule		
2	R1FM*	ENCY	GL	PPI	PPI	GL	ENCY
3-4	R1FM	ENCY	PPI	GL	GL	ENCY	PPI
2							
2	R2TOT	PPI	ENCY	GL	ENCY	PPI	GL
3-4	R2TOT	ENCY	PPI	GL	GL	PPI	ENCY
2	STFT*-	ENCY	GL	PPI	PPI	GL	ENCY
3-4	STFT-	ENCY	PPI	GL	GL	PPI	ENCY
2	LTFT-	PPI	ENCY	GL	ENCY	GL	PPI
3-4	LTFT-	PPI	ENCY	GL	GL	PPI	ENCY
2	CONTOT[s]*	PPI	GL	ENCY	ENCY	PPI	GL
3-4	CONTOT	GL	PPI	ENCY	GL	PPI	ENCY

s ANOVA significant for column or interaction effects

* low all frequencies for ENCY

\- results reversed so that highness equates with "goodness" and on the Post Unanswered subtotal. The Incremental students were the most successful (Table XXXVII).

5.2.2 Differences Between the Experiments

Most of the differences found between the performances of the two sets of students were a matter of degree or proportion rather than a matter of contradiction. One contradiction was found in the behaviors in Bite Set 4. There are Instruction Control differences at a 5 percent significance level in UBS4 Composite and Fundamentals for both Experiment #2 and Experiments #3-#4. In Experiment #2, the GL students had the highest mean utilization while the PPI students had the lowest mean utilization. But in Experiments #3-#4, the PPI students had the highest mean utilization. The GL Instruction Control had one more Bite Unit available so that it is conceivable that some of its students requested the NEXT BASIC BITE key until the Bite Set was covered, thus obtaining a maximum utilization. If one examines the raw data of both sets of students it is clear that the PPI position difference was the result of five students in Experiment #2 obtaining low utilization scores. This was accomplished by their having answered quizzes correctly and branching through the Bite Set in fewer steps than others. In Experiments #3-#4, only one student did not utilize all the Bite Units available. This difference between the sets of students suggests further confirmation of the ability differences between the two groups.

TABLE XXXVII

COMPARISON OF TEST SCORE DESIGN SCHEDULES

Exp.	Test	Numerically Higher Mean
2	PTOT	INT
3-4	PTOT	INC
2	PFD	INT
3-4	PFD	INT
2	PFM	INC
3-4	PFM^s	INC
2	PTRS	INT
3-4	PTRS	INT
2	PUN^-	INT
3-4	PUN^{s-}	INC
2	$R1TOT^s$	INC
3-4	R1TOT	Equal
2	R1FD	INC
3-4	R1FD	INC
2	R1FM	INT
3-4	R1FM	INT
2	R2TOT	INT
3-4	R2TOT	Equal
2	$STFT^-$	INT
3-4	$STFT^-$	INT
2	$LTFT^-$	INT
3-4	$LTFT^-$	Equal
2	$CONTOT^s$	INC
3-4	CONTOT	INC

Bite Set 4 appears to have been a deceptive area of study. There were twice as many Bites available to the GL students as were available to the other students. This may have provided a trap for the students (mostly GL) whose high relative access was negatively related to Post test scores. Since there was scarcely any re-access to this Bite Set from any strategy, it can further be assumed that its content was either unforgettable, trivial, or unnecessary to the problems subsequently posed to the students.

Let the ratio of the values of parameters of Experiments #3-#4 to those of Experiment #2 be called the coefficient of similitude (CS) for that parameter. Then,

Experiment #3-#4 Parameter = CS * Experiment #2 Parameter

This coefficient provided further evidence of the ability difference (Table XXXVIII). The Experiments #3-#4 students spent half again as much time and accessing as the Experiment #2 students did (although at the same processing rate) to achieve about the same results on the Retention 1 test, within 10 percent on the Post tests, but only within 30 percent on the Retention 2 test.

The greatest differences between the two experimental groups were seen in their respective numerical ordering on the test scores (Table XXXIX). The one significant test score result found in Experiment #2 had to be dismissed because of low cell frequencies. The significant test score results in Experiments #3-#4 generally indicated that

TABLE XXXVIII

COEFFICIENTS OF SIMILITUDE (CS)

Parameter	CS	Parameter	CS
TU	1.5	R1FM	0.9
AU	1.5	R2TOT	0.7
$RTBS_i$, i-1,2,4 C,F	1.0	STFT	-0.9
RTBS1 D	1.5	LTFT	0.4
RTBS2 D	0.5	CONTOT	-0.03
RTBS4 D	0.3	PfR (PTOT)	0.5
$RTBS_i$, i=5,6 D	1.0	PfR (R1TOT)	0.6
PRU C,F,D	1.0	PfR (R2TOT)	0.4
$PRBS_i$, i=1,2,4 C,F i=2,5,6 D	1.0	EL (PTOT)	0.5
PRBS1 D	0.6	EL (R1TOT)	0.6
PRBS4 D	0.7	EL (R2TOT)	0.4
PTOT	0.8	ELC (PTOT)	0.8
PFD	0.9	ELC (R1TOT)	1.0
PFM	0.5	ELC (R2TOT)	0.7
PTRS	1.0	ELR (PTOT)	0.3
PUN	1.1	ELR (R1TOT)	0.4
R1TOT	1.0	ELR (R2TOT)	0.3
R1FD	1.1		

TABLE XXXIX

TEST TOTAL PATTERNS, NUMERICAL ORDER (HIGH TO LOW) OF INTERACTION STRATEGIES

Test	Order	1st	2nd	3rd	4th	5th	6th
Exp. #2							
	PTOT	PPI-INT	ENCY-INT	GL-INC	PPI-INC	ENCY-INC	GL-INT
	R1TOT	ENCY-INC	PPI-INT	GL-INC	GL-INT	PPI-INC	ENCY-INT
	R2TOT	ENCY-INT	PPI-INC	PPI-INT	ENCY-INC	= GL-INT	GL-INC
Exp. #3-#4							
	PTOT	ENCY-INC	PPI-INC	PPI-INT	GL-INT	GL-INC	= ENCY-INT
	R1TOT	ENCY-INC	PPI-INC	= GL-INT	PPI-INT	ENCY-INT	GL-INC
	R2TOT	ENCY-INC	PPI-INC	GL-INT	PPI-INT	ENCY-INT	GL-INC

= designates a "tie"

students under Incremental Design Schedule performed better than the others and that GL students performed poorer than either PPI or ENCY students. But the test score means were so very alike within each experiment that considering the standard deviations, one must be careful not to overdraw upon the few percent differences between scores. Ties are shown by an equal sign. The ENCY-INC students performed consistently the "best" in Experiments #3-#4. Consistently "second best" were the PPI-INC students, while the GL-INC students were consistently the "poorest", followed closely by the ENCY-INT students. Now these groupings matched the "differences" found in the ACT scores previously. The Experiment #2 students order less consistently. PPI-INT students and ENCY-INT students perform "better" than the others. Remember that the low rank of ENCY-INT on Retention 1 was due to only one student of that group attending the 8:30 lecture in which the test was given.

The Incremental Design Schedule interacting with any control except GL produced better results for the vocational students, while the Integral Design Schedule interacting with any control except GL produced "better" results for the university students. The implication is that Incremental feedback in problem-solving was more effective for learning by "slower" students. This counters the studies referred to in Chapter 1 that found lower-ability students not acting reliably in learner control mode, and doing better in linear rather than in branching programs. Of course, that study be referring to very much lower ability students, but it also may be that feedback schedule is more important a consideration than the Instruction Control.

This author had expected the GL students to perform much better. Other literature (Gagne and Brown, 1961) comparing the effectiveness of three instruction programs of a similar sort to those of this thesis found the "Guided Discovery" to be superior with "Discovery" and "Rule and Example" methods being least effective. However, those instruction strategies were largely differentiated on the basis of deductive or inductive approaches to the subject matter which may be another factor entirely than the question of who is controlling the learning process.

But decision-making is difficult, especially under anxiety. Both experimental sets of ENCY students reported difficulty in getting started and in understanding how to operate the index and console. The GL students must have decided "not to decide" whether to understand and to operate in the learning mode open to them. And, as is common, the delayed or unmade decision was a decision--to operate in the worst of both strategies instead of in the richness of the combined strategies.

5.3 CONCLUSIONS

A major concern of this thesis was who should control the process of individualized instruction via computer, the [illegible] or subject matter experts and/or learning specialists. Certainly the experts usually know more about the subject matter and the psychology of learning but if meaningfulness, motivation, and self-evaluation are considered, giving the control to the learner may be sound.

The findings of these sets of analysis are of three types: the effects of the structured organization of the subject matter upon the interactive instruction strategies, the effects of the structured organization of the subject matter on the test score results, and the effect of the interactive instruction strategies upon the test score results.

On the basis of the results of the two sets of experiments, it was demonstrated that a general pattern of the relative amounts of time and access to the fundamental information in the subject matter structure decreased among the Instruction Controls from a learner-control high, to machine-control, to a collaborative-control low. The ratios of concepts accessed to concepts available also formed a sequence pattern in the experiments. It was demonstrated that the utilization of available concepts decreased from machine-control to learner-control during the acquisition of the fundamentals. The utilization of re-accessed fundamental concepts during problem-solving was least for the machine-control group. Utilization of available concepts within the problem-solving areas was observed to sequence from the high utilization of the collaboratively-controlled students to the [illegible] control group. Generally, the machine-control students were observed to have the highest rate of processing the information, and the learner-control students the lowest rate. It was observed that learner-control students focussed on a more limited number of concepts with a relatively greater number of accesses being made to the related concepts. It was also observed that learner-control students took a relatively longer time than other students did before proceeding to problem-solve.

Certain parameters that measured the students' performances within the structured organization of the subject matter were observed to relate to student achievement as measured by the post and retention tests. In general, achievement was observed to correlate positively with the time a student spent acquiring the fundamentals of the course, and to correlate negatively with the time spent problem-solving. Also it was observed that better immediate test performance occurred in a learning strategy (particularly the machine-controlled) that lowered or discouraged the need to re-access fundamental information during problem-solving.

It was observed that the poorest test performance by both sets of students was that of students under the collaborative or guided-learning control. Vocational students who solved their problems in partial solutions with incremental feedback under either a learner or machine-control were observed to have the highest scores on the post test and the first retention test. There were no differences among the six strategies observed in the [illegible] the long-term retention test. When the test results were combined with the measures of time and accesses to the subject matter structure, both the students in the learner control and machine-control groups who solved their problems incrementally were observed to have the highest rate of effective learning. The university students were observed to demonstrate no significant differences among the means of the test scores alone for the six strategies, although the learner-control and machine-control groups who solved their problems integrally placed numerically the best overall for the three tests. However, in the combined effect of the second retention test results and the amount of time and accesses spent in the subject matter structure, it was observed that learner-control produced the most effective learning rates.

The fact that the machine-controlled instruction, known as Pre-Programmed Instruction in these experiments, was not observed to be superior to the other methods of instruction control is significant. If the subject matter and learning specialist did not devise a learning experience more effective than that which the student chose for himself, then there is scarce justification for the higher cost of the Pre-programmed Instruction. One of the major factors retarding the growth and use of CAI has been the lack of economic feasibility. The results of this study indicate that an elaborate, costly program with attention to particular [illegible] theory, pacing, or sequencing may be totally unnecessary and even less effective than a program structure in which subject matter is available at the request of the learner and in the sequence most meaningful to his prior state of knowledge.

5.4 RECOMMENDATIONS

As the results of this study began to accumulate, almost as many questions as answers arose out of the mounds of computer print-out. The following questions were beyond the scope of this thesis but are recommended as worthy of future investigation.

Were the instructional sequences selected by the ENCY, learner-control, students and the GL, collaboratively-controlled, students essentially any different from those presented to the Pre-Programmed Instruction students?

Were the instructional sequences selected by the vocational students under learner control essentially different from those selected by the university students?

What would these differences, if any, say about learner sequences chosen by experts and chosen by a group of learners?

What would the differences say about different abilities and learner sequences?

Should feedback control during problem-solving be different for learners with different abilities under otherwise similar circumstances?

Did the Experiment #3 students who were interrupted by Easter vacation perform differently as a group than those who were not interrupted from within their original strategy?

And if they performed differently, did the interruption serve as a consolidation period for improved performance or as an extinction period for decremented performance?

And did it matter whether the student had completed learning the fundamentals and had entered the problem-solving stage prior to the interruption?

On a more ambitious scale, a renewed study of the GL concept of instruction should be considered. The author feels that the possibilities of superior learner performance from a collaboratively-controlled instruction system are still valid. There is evidence that the GL student was handicapped in this experiment by a lack of proper understanding of how he could use the subject matter structure and perhaps by the subject matter information units not being extensive enough to tutor him as far as he wished in particular concepts. The points on which GL students requested peripheral information which was unavailable could be located from the Experiments #2, #3, and #4 data on the Master File with this object in mind. Another experiment pursuing the Guided Learning possibilities should also guarantee that the GL students know what information is available to them in the same way the ENCY students were informed.

If the missing standardized test scores could be located, a study could determine whether the ability differences between the vocational and university students should be considered significant. If this were truly the case, stronger conclusions concerning the relative effectiveness of incremental and integral feedback could be made.

Unfortunately, the cell frequencies might not support the investigations that would involve sub-cell study. But where possible such analyses would perhaps produce results that would give further insight into the preparation and use of CAI material.

SELECTED BIBLIOGRAPHY

SELECTED BIBLIOGRAPHY

Box, G. E. P. "Non-normality and Tests on Variances," Biometrika, 40:318-335, 1953.

Campbell, Vincent N. and Madalynne A. Chapman. "Learner Control vs. Program Control Instruction," Psychology in the Schools, 4:121-130, 1967.

Cohen, Jacob. "Multiple Regression as a General Data-Analytic System," Psychological Bulletin, 70:426-443, 1968.

Draper, N. and H. Smith. Applied Regression Analysis. New York: Wiley, 1967.

Filep, R. T. "Individualized Instruction and the Computer," AV Communications Review, 15:102-112, Spring 1967.

Finch, Glen (ed.). Educational and Training Media, A Symposium. Publication 789, Nat'l Academy of Science Nat'l Research Council, Washington, D.C., 1960.

Fitts, Paul M. and Michael I. Posner. Human Performance. Belmont, Calif.: Brooks/Cole Publishing Company, 1969.

Freire, Firmo. "Analysis of Behavior in an Interactive Human-Machine System." Unpublished Master's thesis, University of Houston, May 1972.

Fry, Edward B. Teaching Machines and Programmed Instruction. New York: McGraw-Hill Book Company, Inc., 1963.

Gagne, R. M. and L. T. Brown. "Some Factors in the Programming of Conceptual Learning," Journal of Experimental Psychology, 62:313-321, October 1961.

Goldstein, Leo S. and Lassar G. Gotkin. "A Review of Research: Teaching Machine vs. Programed Textbooks as Presentation Models," Journal of Programed Instruction, 1:30-36, 1962-66.

Hartley, James. "Linear and Skip-Branching Programmes: A Comparison Study," British Journal of Educational Psychology, 35:320-328, 1965.

________. "Optional and Controlled Branching Comparison Studies," Journal of Programed Instruction, 3:5-11, 1966.

Hemmerle, William J. Statistical Computations on a Digital Computer. London: Blaisdell Publishing, 1967.

Hickey, Albert E. Computer-Assisted Instruction: A Survey of the Literature. Third Edition. Technical Report No. 8 Office of Naval Research. Newburyport, Ma.: Entelek Incorporated, October 1968.

________. Instructional Strategies Appropriate to Computer-Assisted Instruction. Technical Report No. 9 Office of Naval Research. Newburyport, Ma: Entelek Incorporated, 1968.

Judd, W. A., C. V. Bunderson, and E. W. Bessent. "An Investigation of the Effects of Learner Control in Computer-Assisted Instruction Prerequisite Mathematics." Technical Report No. 5, Computer-Assisted Instruction Laboratory, The University of Texas, Austin, 1970.

Koryakov, V. G. "On the Use of Universal Electronic Computers for Programmed Instruction." Foreign Technology Div., Wright-Patterson AFB, Ohio. R-FTDMT-202. March, 1967.

Lenahan, John J. "Synthesis of an Interactive Human-Machine System." Unpublished Doctor's dissertation, University of Wisconsin, June, 1969.

________. Synnoetics Laboratory Report, Vol. 1, No. 2, 1970.

________. "Synnoetics Looks at Human-Machine Learning." Proceedings of Sixth National Conference of Computer Society of Canada, Kingston, Ontario, 1968.

________, and Clayton D. Clatur. "Interaction Strategy in a Computer-aided Design System." Proceedings of Fourth Australian Computer Conference, Adelaide, South Australia, 1969.

Mager, R. F. "Learner-Controlled Instruction 1958-1964," Journal of Programed Instruction, V. IV, No. 2, 1964.

Mayer, S. R. and R. L. Westfield. "A Field Tryout of a Teaching Machine for SAGE Operations." Operational Applications Laboratory, AF Cambridge Res. Center, Bedford, Mass. Technical Memo OAL-TM-58-16. October, 1958.

Norman, Donald A. (ed.). Models of Memory. New York: Academic Press, 1970.

Oliver, William P. "Learner and Program-Controlled Sequences of Computer-Assisted Instruction." Ontario Institute for Studies in Education, Toronto, Canada. February, 1971.

Pressey, Sidney L. School and Society. 23:373-376, 1926.

Scheffe, H. "A Method for Judging all Contrasts in the Analysis of Variance," Biometrika, 40:87-104, 1953.

Shuford, Emir H., Jr. and H. Massengill. "The Relative Effectiveness of Five Instructional Strategies." Contract AF 49(638)-1744. Lexington, Ma.: Shuford-Massengill Corp., June, 1967.

Slamecka, Norman J. (ed.). Human Learning and Memory. New York: Oxford University Press, 1967.

Smith, Karl U. and Margaret Smith. Cybernetic Principles of Learning and Educational Design. New York: Holt, Rinehart and Winston, 1966.

STATJOB User Manual for the 1108. Madison, Wisconsin: The University of Wisconsin Computing Center, June, 1970. (Mimeographed.)

Stolurow, Lawrence M. "Computer-Based Instruction." Training Research Lab. Rept. No. TR-9. Contract NONR-3985-04. July, 1965.

Suits, D. B. "Use of Dummy Variables in Regression Equations," Journal of American Statistical Association, 52:548-551, 1957.

APPENDIX A

DEFINITIONS OF EXPERIMENTAL PARAMETERS

Appendix A

DEFINITIONS OF EXPERIMENTAL PARAMETERS

1. THE BITE STRUCTURE PARAMETERS

Identification of any parameter was made via a prefix, a suffix and subscripts. The prefix and the suffix were always present in a parameter label; subscripts did not have to appear, but when they were present their maximum number was three.

In the identification of the parameters, the prefix indicates the parameter type, the suffix, its level of application and the subscripts, if any, its range.

Tables 1, 2, and 3 list the parameter's prefixes, suffixes and subscripts, respectively. Table 4 lists all the parameters defined. An asterix indicates those which were selected for the Group Summary Tape and subsequent analyses. These particular parameters are defined in the following paragraphs.

1.1 The Universe Level

The purpose of the parameters at this level was to provide overall information on how the student behaved during the entire learning process.

TABLE 1

BITE STRUCTURE PARAMETER PREFIXES

Prefixes	Meaning
N	Number
NF	Normalization Factor
U	Utilization
AU	Average Utilization
NU	Normalized Utilization
A	Accesses
RA	Relative Access
MRA	Mean Relative Access
NRA	Normalized Relative Access
T	Time
RT	Relative Time
MRT	Mean Relative Time
NRT	Normalized Relative Time
DA	Distinctly Accessed
M	Minimum

TABLE 2

BITE STRUCTURE PARAMETER SUFFIXES

Suffixes	Meaning
U	Universe
BS	Bite Set
BU	Bite Unit
BB	Basic Bite
PB	Peripheral Bite Type
B	Bite
C	Complete Sequential Logic Course
	Fundamentals Portion of Course
	[illegible] Portion of Course

TABLE 3

BITE STRUCTURE PARAMETER SUBSCRIPTS

Subscripts	Range
i	Bite Set
j	Bite Unit/Basic Bite
k	Peripheral Bite Type

TABLE 4

PARAMETER LABELS AND MEANING

Level	Label	Meaning
Universe	UU	Utilization of the Universe
	*TU	Time of the Universe
	*AU	Accesses to the Universe
Bite Set	NFBS	Normalization Factor of the Bite Set
	NBS	Number of Bite Sets
	*DABU	Distinctly Accessed Bite Units in Bite Set
	*UBS	Utilization of the Bite Set
	AUBS	Average Utilization of Bite Sets
	*NUBS	Normalized Utilization of the Bite Set
	ABS	Accesses to Bite Sets
	*RABS	Relative Access to Bite Sets
	MRABS	Mean Relative Access to a Bite Set
	*NRABS	Normalized Relative Access to a Bite Set
	TBS	Time of a Bite Set
	*RTBS	Relative Time of a Bite Set
	MRTBS	Mean Relative Time of a Bite Set
	*NRTBS	Normalized Relative Time of a Bite Set
Bite Unit	NFBU	Normalization Factor of the Bite Unit
	NBU	Number of Bite Units
	NB	Number of Bites
	UBU	Utilization of the Bite Unit
	AUBU	Average Utilization of Bite Units
	*NUBU	Normalized Utilization of a Bite Unit
	ABU	Accesses to Bite Units
	RABU	Relative Access to Bite Units

TABLE 4 (Continued)

Level	Label	Meaning
Bite Unit (Contd.)	MRABU	Mean Relative Access to a Bite Unit
	*NRABU	Normalized Relative Access to a Bite Unit
	TBU	Time of a Bite Unit
	RTBU	Relative Time of a Bite Unit
	MRTBU	Mean Relative Time of a Bite Unit
	*NRTBU	Normalized Relative Time of a Bite Unit
Basic Bite	NBB	Number of Basic Bites
	UBB	Utilization of a Basic Bite
	AUBB	Average Utilization of a Basic Bite
	ABB	Accesses to Basic Bites
	RABB	Relative Accesses to Basic Bites
	MRABB	Mean Relative Access to a Basic Bite
	TBB	Time of a Basic Bite
	RTBB	Relative Time of a Basic Bite
	MRTBB	Mean Relative Time of a Basic Bite
Peri- pheral Bite	NPB	Number of Peripheral Bites by Types
	UPB	Utilization of a Peripheral Bite Type
	AUPB	Average Utilization of a Peripheral Bite Type
	APB	Access to Peripheral Bite Types
	RAPB	Relative Access to Peripheral Bite Types
	MRAPB	Mean Relative Access to a Peripheral Bite Type
	TPB	Time of a Peripheral Bite Type
	RTPB	Relative Time of a Peripheral Bite Type
	MRTPB	Mean Relative Time of a Peripheral Bite Type

Time of the Universe (TU)

$$TU = \sum_{i=1}^{NBS} TBS_i \cdot$$

where:

TU = Time Spent on the Universe

TBS_i = Total Time Spent in Bite Set "i"

NBS = Total Number of Bite Sets

<u>Accesses to the Universe</u> (AU)

$$AU = \sum_{j=1}^{NBU_i} ABU_{i,1} \; ; \; i=1,2,\ldots,NBS$$

where:

AU = Total Number of Accesses to the Universe

$ABU_{i,j}$ = Total Number of Accesses to Bite Unit "j" in Bite Set "i"

NBU_i = Total Number of Bite Units in Bite Set "i"

NBS = Total Number of Bite Sets

1.2 The Bite Set Level

The purpose of the following parameters was to provide general information on student performance during the learning process of an area of study.

<u>Distinctly Accessed Bite Units in Bite Set</u> (DABU)

$DABU_i$ = The number of Bite Units Accessed at least once in the Bite Set "i"

<u>Utilization of the Bite Set</u> (UBS)

$$UBS_i = \frac{DABU_i}{NBU_i} \; ; \; i=1,2,\ldots,NBS$$

where:

UBS_i = Utilization of Bite Set "i"

$DABU_i$ = Distinctly Accessed Bite Units in Bite Set "i"

NBU_i = Total Number of Bite Units in Bite Set "i"

NBS = Total Number of Bite Sets

<u>Normalized Utilization of the Bite Set</u> (NUBS)

$$NUBS_i = NFBS_i * UBS_i \; ; \; i=1,2,...,NBS$$

where:

$NUBS_i$ = Normalized Utilization of Bite Set "i"

$NFBS_i$ = Normalization Factor of Bite Set "i"

UBS_i == Utilization of Bite Set "i"

NBS = Total Number of Bite Sets

<u>Relative Access to Bite Sets</u> (RABS)

$$RABS_i = \frac{ABS_i}{ABS} \; ; \; i=1,2,...,NBS$$

where:

$RABS_i$ = Relative Access to Bite Set "i"

ABS_i = Total Number of Accesses to Bite Set "i"

ABS = Total Number of Bite Set Accesses

NBS = Total Number of Bite Sets

<u>Normalized Relative Access to a Bite Set</u> (NRABS)

$$NRABS_i = NFBS_i * RABS_i \; ; \; i=1,2,...,NBS$$

where:

$NRABS_i$ = Normalized Relative Access to Bite Set "i"

$NFBS_i$ = Normalization Factor of Bite Set "i"

$RABS_i$ = Relative Access to Bite Set "i"

NBS = Total Number of Bite Sets

Relative Time of a Bite Set (RTBS)

$$RTBS_i = \frac{TBS_i}{TU} ; \; i=1,2,\ldots,NBS$$

where:

$RTBS_i$ = Relative Time Spent in Bite Set "i"

TBS_i = Time Spent in Bite Set "i"

TU = Time Spent in the Universe

NBS = Total Number of Bite Sets

Normalized Relative Time of a Bite Set (NRTBS)

$$NRTBS_i = NFBS_i * RTBS_i \; ; \; i=1,2,\ldots,NBS$$

where:

$NRTBS_i$ = Normalized Relative Time Spent in Bite Set "i"

$NFBS_i$ = Normalization Factor of Bite Set "i"

$RTBS_i$ = Relative Time Spent in Bite Set "i"

NBS = Total Number of Bite Sets

1.3 The Bite Unit Level

At this level, the interest lay on the observation of the relative meaning each distinct Bite Unit had to a student. By looking at these values, it could be determined which basic concepts (as represented by the Bite Units) were more readily assimilated by the student, and on what points did he encounter difficulty.

<u>Normalized Utilization of a Bite Unit</u> (NUBU)

$$NUBU_{i,j} = NFBU_{i,j} * UBU_{i,j} \; ; \; \begin{array}{l} i=1,2,\ldots,NBS; \\ j=1,2,\ldots,NBU_i \end{array}$$

where:

$NUBU_{i,j}$ = Normalized Utilization of Bite Unit "j" in Bite Set "i"

$NFBU_{i,j}$ = Normalization Factor of Bite Unit "j" in Bite Set "i"

$UBU_{i,j}$ = Utilization of Bite Unit "j" in Bite Set "i"

NBU_i = Total Number of Bite Units in Bite Set "i"

NBS = Total Number of Bite Sets

<u>Normalized Relative Access to a Bite Unit</u> (NRABU)

$$NRABU_{i,j} = NFBU_{i,j} * RABU_{i,j} \; ; \; \begin{array}{l} i=1,2,\ldots,NBS; \\ j=1,2,\ldots,NBU_i \end{array}$$

where:

$NRABU_i$ = Normalized Relative Access to Bite Unit "j" of Bite Set "i"

$NFBU_{i,j}$ = Normalization Factor of Bite Unit "j" in Bite Set "i"

$RABU_{i,j}$ = Relative Access to Bite Unit "j" in Bite Set "i"

NBU_i = Total Number of Bite Units in Bite Set "i"

NBS = Total Number of Bite Sets

<u>Normalized Relative Time of a Bite Unit</u> (NRTBU)

$$NRTBU_{i,j} = NFBU_{i,j} * RTBU_{i,j} \; ; \; \begin{array}{l} i=1,2,\ldots,NBS; \\ j=1,2,\ldots,NBU_i \end{array}$$

where:

$NRTBU_{i,j}$ = Normalized Relative Time of Bite Unit "j" in Bite Set "i"

$NFBU_{i,j}$ = Normalization Factor of Bite Unit "j" in Bite Set "i"

$RTBU_{i,j}$ = Relative Time Spent in Bite Unit "j" of Bite Set "i"

NBU_i = Total Number of Bite Units in Bite Set "i"

NBS = Total Number of Bite Sets

2. THE TEST SCORE PARAMETERS

There were three tests given to the students in Experiments #2, #3, and #4. These were the Post test given immediately after a student had completed his course in Sequential Logic, the first Retention test given after a two-week time lapse, and the second Retention test given after a five-week time lapse. Each of these tests was divided into certain sets of questions intended to provide meaningful subtotals that would relate to particular parts of the course. The tests, their combinations, and their abbreviations are in Table 5. Also included in this table are the abbreviations used for the standardized test scores obtained for some of the students.

TABLE 5

TEST SCORE ABBREVIATIONS

Abbreviation	Test
PTOT	Post Total
PFD	Post Fundamentals
PFM	Post Familiar
PTRS	Post Transfer
PUN	Post Unanswered
R1TOT	Retention 1 Total
R1FD	Retention 1 Fundamentals
R1FM	Retention 1 Familiar
R2TOT	Retention 2 Total
R2FD	Retention 2 Fundamentals
R2FM	Retention 2 Familiar
STFT = PTOT - R1TOT	Short-term Forgetting Totals
STFD = PFD - R1FD	Short-term Forgetting Fundamentals
STFM = PFM - R1FM	Short-term Forgetting Familiar
LTFT = PTOT - R2TOT	Long-term Forgetting Totals
LTFD = PFD - R2FD	Long-Term Forgetting Fundamentals
LTFM = PFM - R2FM	Long-term Forgetting Familiar
CONTOT = R2TOT - R1TOT	Consolidation Totals
CONFD = R2FD - R1FD	Consolidation Fundamentals
CONFM = R2FM - R1FM	Consolidation Familiar
PAPT	Programmer's Aptitude Test
ACTC	American College Testing - Composite
ACTE	American College Testing - English
ACTM	American College Testing - Mathematics
ACTNS	American College Testing - Natural Science
ACTSS	American College Testing - Social Science

3. COMPOUND PARAMETERS

These parameters were defined in order to observe the multiple effects of a student's performance as a result of his acquisition process, his application process, and his retrieval process. The parameters are listed with their meanings using previously defined parameters whenever the factor is unique (See Table 6).

TABLE 6

COMPOUND PARAMETERS

Abbreviation	Parameter	Units
PR	Processing Rate	Accesses per hour
PfR	Performance Rate	Percentage points per hour
EL	Effective Learning	Percentage points per access
ELC	Effective Learning Capacity	Effective Learning - hours
ELR	Effective Learning Rate	Effective Learning per hour

APPENDIX B

CONDENSATION OF EXPERIMENTAL PROCEDURES

Appendix B

CONDENSATION OF EXPERIMENTAL PROCEDURES

1. System Initialization

    A. Hardware

        Turn on all equipment and place in "ready" status.

    B. Software

        1. Initialize Synnoetics Executive III

        2. Set date and time

        3. Initialize

    C. Students

        1. Use Daily Timetable to find first two students

        2. Use Master Sign-up List (MSL) to:

            a. locate each student's number

            b. assign terminal (A or B)

            c. note course number of each student

        3. Prepare terminal for proper course

            a. set keyboard mask to cover all but allowed keys for this course

            b. place "student aids" near terminal

                (1) For ENCY

                    Indexes to Bite Structure
                    Simulator Instructions

                (2) For PPI

                    Simulator Instructions

(3) For GL

Table of Contents and Indexes to Bite Structure
Bite Structure Diagram
Simulator Instructions

2. Preparing Students

A. When Student Arrives

1. Meet student and briefly get acquainted.
2. Check name in the Daily Timetable.
3. Note date and hour, for each student, in proper comment section in MSL.
4. Determine, CAREFULLY and ACCURATELY, where in Bite Structure each student should begin the day's interaction. Refer to MSL.
5. Determine student's task number and session number.

B. When Both Terminals Free

1. Usher each student into assigned terminal.
2. Read and explain Student Instructions (unique for each course).
3. Have each student sign-in using exactly the same name used last week.
4. Begin student at appropriate place in subject matter (refer to MSL).
5. Write student's ID number at top of first page of keyboard-printer output.
6. Write experimenter warning time on blackboard.
7. Note "Time-On" for each student in MSL.

8. Initialize design simulators in system for each student.

3. During Interaction

A. Student Finishes Bite Set. If student claims to have finished Bite Set 1, 2, or 4, check that Area Practice has been done correctly. If student claims to have finished Bite Set 5 or 6, check that the design has been built and fully tested. Determine what student should do next.

B. Before Warning Time

1. Review REPORTS of two previous students by comparing them with actual course. Note any

p particularly significant behavior (or lack thereof) in MSL.

2. Note, in MSL, the progress made by student.

C. When Warning Time Arrives. Notify both students of approximately 10 minutes remaining.

4. Finishing Students

A. When Student Time Is Up

1. Notify both students that time is up and someone will be in to sign each of them off.

2. Enter each terminal with MSL and:

a. ask student to relate any problems or general comments and note these in MSL.

b. remind student not to remove any notes or other materials.

c. check that student knows next assigned time slot.

d. Note "Time-Off" for each student in MSL.

B. When Both Students Leave Terminals

1. Reset Hardware and Software systems.

2. Obtain a listing, REPORT, and a deck of punched cards of the student for the session just completed.

3. Use MSL and Daily Timetable to determine next student.

5. Error Procedures

Refer to Recovery Procedures and take appropriate steps to correct error.