1977

A study of positioning time in a combined manual and decision task.

Joseph S. Tsui
University of Windsor

A Study of Positioning Time in a Combined Manual and Decision Task

by

Joseph S. Tsui

A

Thesis

submitted to the Faculty of Graduate Studies

through the Department of Industrial Engineering

in partial fulfillment of the requirement for

the Degree of Master of Applied Science

at

University of Windsor

Windsor, Ontario, 1977

I wish to dedicate this thesis to my family.

Abstract

A Study of Positioning Time in a Cimbined Manual and Decision Task.

Twenty subjects, ten male and ten female, performed a Combined Manual and Decision Task involving Move and Positioning. Four distances of Move (7", 10", 13" and 16"), three levels of Lateral Clearance (0.008", 0.063" and 0.250") , and four levels of Informational Load (1, 2, 3, 4 bits) were used for these experiments. Data were also analysed for Same-sided Movements and Cross-body Movements. Index of Difficulty and Informational Load were found to be significant ($p<0.05$). Sex was not found to be a significant variable affecting performance time ($p>0.05$), whereas Direction of Move was, even in a narrow region of 10^{o} on either side of the 90^{o} angle of Move. Linear Regression Models for predicting performance have been developed using Distance, Clearance and Index of Difficulty. The latter (I) was found to be correlating adequately, simple to use and able to accomodate any motion strategy changes due to varying distances in the task.

ACKNOWLEDGEMENT

I am deeply grateful for the kind considerations that my family and friends have given me throughout the period I was writing this thesis. My special thoughts go to my father and to Miss Stella Hui who helped to accomplish the massive typing; to Miss Irene Shek for her constant encouragements and to Mr. Subash Arora for his generous help in completing the analytical work.

I wish also to extend my gratitude to Dr. A. Raouf for his unfailing encouragements and guidance and to the National Research Council for its financial support which has made this project possible.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

List of Appendix

CHAPTER I

INTRODUCTION

From the measurement and prediction point of view, work study researchers have classified industrial tasks into two main areas. Those which are simply manual in nature, repetitive and pattern-forming are termed "type I tasks" (Raouf 1973), whereas tasks in which the worker is required to exercise both his psycho-motor and decision making abilities are called type II tasks or 'combined decision and manual tasks' (Sadosky 1969, Raouf and Mehra 1974, Thomas et al 1974). Much work has been done and recorded with regard to the measurement and prediction of type I tasks. Relatively few useful findings, however, are available in the literature to the work-study practitioner of the behavior of type II task.

Psychologists (Posner 1962, Fitts and Radford 1966, Welford 1960) have attempted in the past two decades to understand the psychological and physiological processes involved in basic human decisions. In most cases, however, their experimental tasks do not simulate the industrial conditions and their findings are not directly applicable. In order to develop a methodology for establishing performance standards for type II tasks, it is necessary that our understanding of human performance of such tasks be increased.

Decision involved in type II tasks falls mainly into two categories:

1. in resolving 'time uncertainties' - the worker does not know in advance when a stimulus will occur to which he is to respond;
2. in resolving 'choice uncertainties' - the worker is uncertain from cycle to cycle about which stimulus will occur or which response is required from among a finite set of possible stimuli or responses.

When there is an explicit response for each stimulus, i.e. a 1:1 mapping of stimulus and response, the task is said to be information conserving. Much work in industry involves this kind of task such as in monitoring devices and inspection tasks.

Type II tasks investigated recently (Raouf 1973, Sethi 1975) involved only the simpler manual motions, Reach and Move. The more complicated element Positioning with decision-making as an added dimension has not been studied.

Fitts and Posner (1967) proposed an index of difficulty (I) as a parameter in measuring the performance times in positioning tasks. Other researchers have since tested its highly significant correlations with the performance times of pure manual or type I tasks, (Crossman 1954 Welford 1956 Hancock 1960). Its significance with type II tasks has as yet not been systematically studied.

The present thesis presents an investigation of the effect of informational load on combined decision and positioning tasks where information is conserved and only choice-uncertainties are involved with no preview of the stimulus signals. Under each informational load, the difficulty of the task is controlled by varying the distance of move and clearance for positioning. The use of the index of difficulty in predicting performance time of such tasks is also examined.

CHAPTER II

LITERATURE SURVEY

2.1 Introduction

To serve as a background to the present study, a survey of relevant work done in the following areas are presented in this chapter.

(1) Combined manual and decision tasks

(2) Information content of movement control

2.2 Combined Manual and Decision Tasks

Sadosky (1969) developed a methodology for predicting the mean cycle times for combined manual and decision tasks based on a critical path analysis technique. The task employed in his study included the manual elements Reach, Grasp, Move and Position occurring in parallel with a decision of choosing to press one out of four buttons. In such tasks when different components were performed simultaneously in a task cycle, a critical path could be traced as the longest time duration path in the cycle. Slack values also occurred as the differences in time between the critical path activities and the parallel non-critical path activities. From the critical path and these slack measures, Sadosky found that the extent of signal preview in the decision component interacted with the manual elements. The largest effect was with minimal preview and the effect lessened as the preview occurred earlier in the task cycle.

Thomas (1971) explored some probabilistic aspects of performance times for a combined manual and decision task. He used a task similar to that of Sadosky (1969) but with different probability distribution which governed the occurrence of each alternative from a set of four alternatives. He found that:

1. the operator always sought an optimum strategy as he learned the motion sequence of the task;
2. When the operator had fully learned, the performance times of the manual components of the task became normally distributed;
3. the decision component of the task might be considered as an isolated entity, its time as a function of the input uncertainty and the movement involved.

Raouf (1973) found that the information processing rate (IPR) varied amongst different individuals, even if experimental conditions which were known to affect performance times were kept constant. The performance times of the subjects were, however, relatively constant and were better estimates for combined manual and decision tasks.

Raouf and Mehra (1974) found that both the choice uncertainty and the magnitude of the manual element reach were significant variables affecting performance times. In an experiment in which three levels of reach (7 inches, 10 inches and 14 inches) and three levels of informational loads consisting of equiprobable stimuli (1 bit, 2 bits and 3 bits) were investigated, increase in performance times due to informational load was found to be highest for the reach of smallest magnitude and it decreased as magnitude of reach increased. For the same magnitude of reach, performance times increased as informational load increased.

Raouf and El-Sayed (1975) performed a similar experiment in which three informational loads (H), three distances of move (D) and two angles of move directions for each combination of informational load and distance were investigated. The angles included were 32 and 148 degrees at 7 inches reach, 55 and 125 degrees at 11 inches reach, and 66 and 114 degrees at 15 inches reach. In all these cases, it was found that the effect of angular differences on performance times was not significant, $(p>0.05)$

2.3 Information Content in Control of Movement

In the experiments of Bailey and Presgrave (1958), it was found that manual movement times was a joint function of the extent and required accuracy of movement. Fitts (1954) reported three experiments in an attempt to quantify the relationship of performance time with these movement parameters. The tasks employed were:

1. tapping alternately two plates separated by some distance,
2. the transfer of washers from one pin to another,
3. the transfer of pins from one hole to another.

He found that movement time was well predicted by the relationship

$$MT = a + b \log_2(2A/W)$$

where A was the amplitude of the movement (the distance from the centre of one target to the centre of the other), W was the width of the target in the tapping task or the tolerance in the other two tasks, and a and b were experimental constants. From the results he concluded that human motor system has a relatively constant information capacity defined as the rate at which one can produce consistently one class of movement from among several alternative movement classes, (Fitts, 1954). The human information capacity was found to be in the range of 10 bits per second. Following the reasoning of the information theory as discussed by Shannon and Weaver (1949), Fitts derived the information content of a movement as measured by the Index of Difficulty (I) = $\log_2(2A/W)$. The significant implication of the Index of Difficulty is the trade-off between distance of a movement and width of the target. According to Fitts, if the distance of a movement is doubled, the movement time remains constant if the width of the target is also doubled.

Various researchers have since tested the Fitts equation against empirical data and have found satisfactory compliance. Hancock, Langolf and Clark (1973) calculated I for all distance-tolerance combinations of Move and

Position for MTM-1 and compared these to the data card times. It was found that the correlation between I and time was r=0.80. The slope constant b in the associated regression equation $MT = a + b.\log_2(2A/W)$ was 3.0 *TMU/bit or 108 ms/bit which compared closely with values in the range of 100 ms/bit found by Fitts and Radford (1966). Keele (1968) performed similar analysis on the data of Bailey and Presgrave (1958) and obtained even higher linear correlation coefficient, r=0.97.

Fitts and Peterson (1964) extended the concept of the Index of Difficulty to a simple two-choice combined decision and manual task. The subjects were to hit one of the two targets separated by a horizontal distance with a stylus. The appearance of the visual stimulus on the side of the correct target was preceded by a warning signal. It was found that I had a small effect on reaction time alone. However, for a range of I between 2.6 to 7.6 bits per response, there was a high correlation between movement time and I (r=0.99).

Scholes (1970) conducted an experiment to investigate the effect of directions of movement on movement times and reaction times in discrete motor tasks. He found that:

1. direction of movement had a significant effect on movement time but not on reaction time,
2. there was a high position correlation between movement time, Index of Difficulty I and direction of movement.

*TMU - Time Measurement Unit = 1×10^{-5} hour.

However, in his experiment there was no response uncertainty involved in the subject's decision. The subjects were told before each cycle which direction to make the response. Reaction time was defined simply as the time-lapse between the on-coming of the visual stimulus and the beginning of the designated manual response.

One interpretation of the Index of Difficulty as proposed by Fitts (1954) and Fitts and Peterson (1964) is the maximum relative uncertainty that can be tolerated for a correct movement in a series having a specified average amplitude. Therefore the minimum mental organisation required of a particular correct movement is reflected by the choice of one from among k possible categories of amplitudes within which the movement is to terminate. The measurement of this accomplished by a binary Index of Difficulty made up of an accuracy to amplitude ratio,

$$I = \log_2(2A/W)$$

The choice of the particular denominator is arbitrary since the range of possible amplitudes must be inferred. Twice the amplitude in the numerator would ensure a positive value for ID as well as having the effect of adding one bit per response to its magnitude.

An alternative interpretation of the Fitts equation is by way of feedback control as proposed by Keele (1968) and similarly by Crossman and Goodeve (1963). Three assumptions are made in their proposal:

1. There is a minimum required time for processing feedback whereby the time for each successive corrective movement after the initial movement is made constant (t).
2. The initial movement time is less than that of the corrective movement by a constant (a) since the time to decide how far to make the initial movement is not included in this movement time.

From assumptions (1) and (2), the total movement time for the initial movement and n-1 subsequent corrective movements is

$$MT = (n-1)t + (t-a) \qquad \ldots\ldots(1)$$

3. The relative accuracy of a movement is constant. That is

$$X_i / X_{i-1} = K \qquad \ldots\ldots(2)$$

where X_i is the mean absolute distance from the centre of target after i^{th} corrective movement.

Under this assumption,

$$X_o = A \qquad \ldots\ldots(3)$$

where A is the amplitude of movement and

$$X_n = W/2 \qquad \ldots\ldots(4)$$

where W is the width of target and X_n is the last corrective movement terminating at about the edge of the target.

From equations (2), (3) and (4):

$$X_n = KX_{n-1} = K^2X_{n-2} = \ldots = K^nA \doteq W/2 \qquad \ldots\ldots (5)$$

and therefore:

$$n = \frac{-\log_2(2A/W)}{\log_2 K} \qquad \ldots\ldots (6)$$

From equations (6) and (1):

$$MT = b.\log_2(2A/W) - a \qquad \ldots\ldots (7)$$

Equation (7) is compatible with Fitts' equation because in Fitts experiments (1954) the best-fit line also intersects the movement time axis below the origin making (a) a negative value.

Since the choice of the numerator in Fitts' Index of Difficulty ID is arbitrary and since it reflects a rather ambiguous inferrence on the range of possible correct amplitude, other versions of ID have been suggested, Welford's (1960) Index of Difficulty (ID') is one of the more widely accepted.

$$ID' = K \log_2\left(\frac{A+W/2}{W}\right)$$

This formulation makes movement time dependent upon a kind of Weber fraction in that the subject is called upon to distinguish between the distances to the far and near edges of the target. Besides a better fit to the data points of Fitts, use of Welford's version has the effect of moving the best-fit line from intersecting the performance time axis at a negative quantity to pass through the origin which is more agreeable conceptually. (Performance Time at I = 0 cannot be negative).

Various methods have been proposed to predict performance times of combined decision and manual tasks. These include critical path analysis, information processiong rate and total task performance times. There is, however, no general agreement as to the proper methodology to be used. Combined decision and manual tasks investigated by recent researchers consist only of the simpler Move or "Reach" motions (Raouf 1973, Raouf and Khare 1975, Raouf and Mehra 1974, Sethi 1975). The more complicated Positioning tasks have been studied only in isolation from the decision element (MTM report 109, 110). The Index of Difficulty as proposed by Fitts and Peterson (1964) may be a useful concept in predicting performance time of complex motions, such as positioning, where both accuracy and amplitude are equally important factors. With this view of the state of the science in mind, the present study is designed to develop a prediction model for the combined decision and positioning task as well as to investigate the usefulness of the concept of Index of Difficulty.

CHAPTER III

EQUIPMENT AND EXPERIMENTAL DESIGN

3.1 Introduction

This chapter describes in detail the equipment set-up and experimental procedures employed in the study. The experiment was conducted in the Industrial Engineering laboratory at the University of Windsor. The task under study was combined decision and positioning in a discrete manner from cycle to cycle. Performance times of subjects were measured while doing such a task.

3.2 Performance Time

This is defined as the time elapsed between the appearance of the visual stimulus and the completion of the positioning response. It consists of the following elements:

1. Occurrence of stimulus
2. Detection of stimulus
3. Decision
4. Selection of response
5. Act of positioning
6. Completion of response

The above are illustrated in Fig. 3.1.

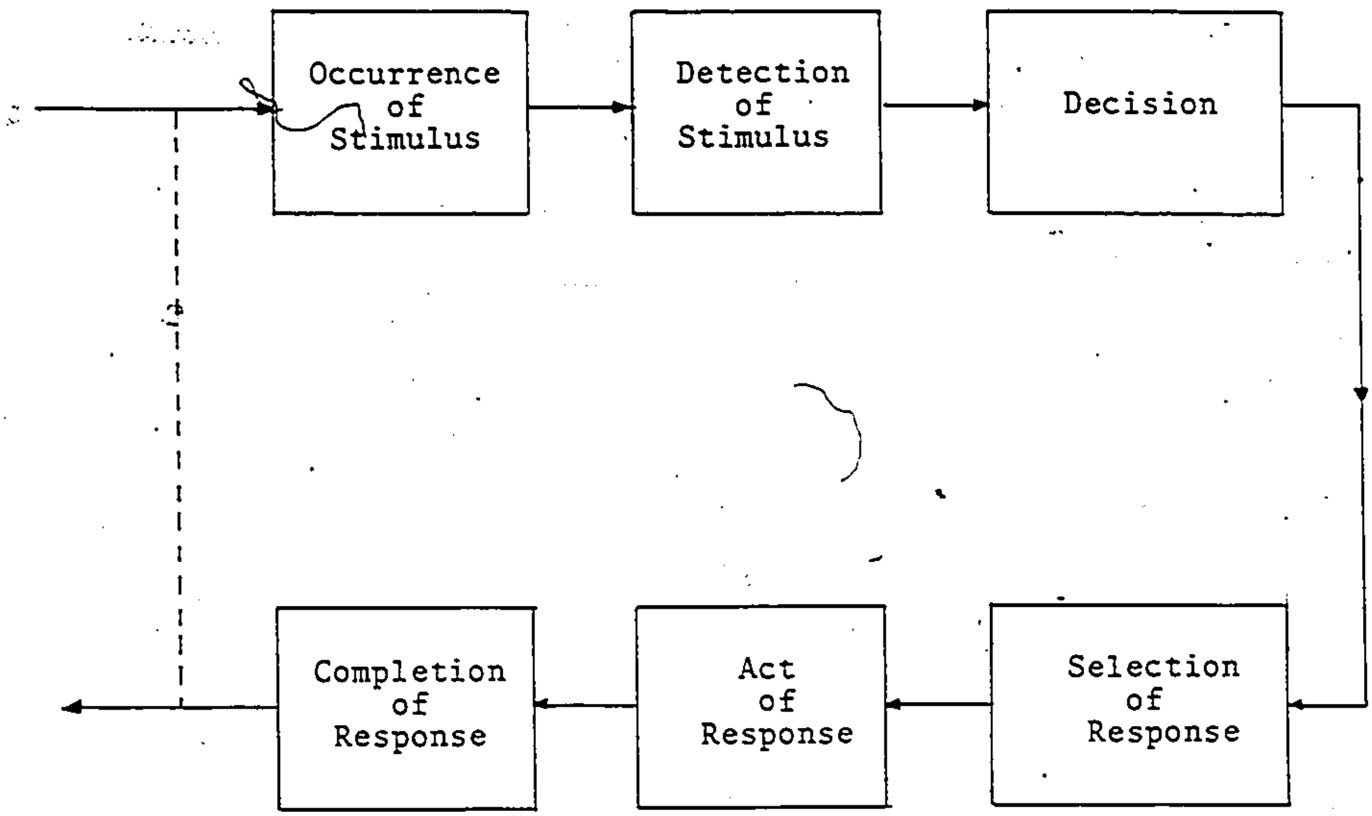


Figure 3.1 Block Diagram Showing Various Conceptual Elements in a Combined Decision and Manual Task.

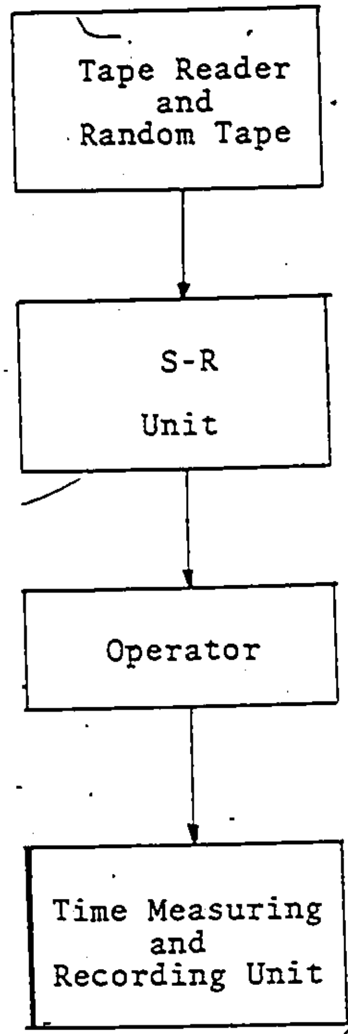


Figure 3.2 Diagram Showing the Block Layout of the Equipment

3.3 <u>Equipment Set-up</u> (See Figure 3.2)

The experiment consisted of the following units:

1. Signal-Reponse Unit
2. Tape Reader Unit
3. Time Measuring and Recording Unit

3.31 <u>Signal-Response Unit</u> (See Appendix A)

A special signal-response unit in the shape of a metal box with a changeable wooden top plate was designed and built for the experiment. The signal was provided by a random number displayed on a screen and the response was the positioning of a metal pin into one of the holes on the response top plate specified by the number displayed. The components of this unit are the following:

A. <u>The Signal Indicator</u>

The signal indicator was located about 4 inches above the pin-pocket. It transmitted and displayed the random numeric signals from the tape reader onto a rectangular screen of 1 inch by 6/8 inch. The number on the screen appeared as the subject lifted the metal pin from the pin-pocket. It stayed on until the subject had completed positioning the pin into the thus specified hole on the response top plate. If the pin was positioned into a wrong response hole, the number on the screen remained until a following pin(s) was lifted from the pin-pocket and positioned into the correct hole.

Since the counter in the Time Measuring Unit continued for as long as the signal was on, this feature allowed any error in positioning to be detected later in the analysis by virture of the extraordinary large performance time value of the particular error cycle.

B. The Pin System

The pin system consisted of six cylindrical metal pins 1/4 inch in diameter and 1-1/4 inches long. Each pin weighed about 8 grams. The pin stood vertically in the pin-pocket with about half of its length above the surface of the equipment. As it was removed and positioned into one of the holes on the response top plate, it dropped onto a conveyor-belt system which carried it again to the pin-pocket region. In the meantime, a subsequent pin was pushed up the pocket into position by a carrier-gear system. The time between the removal of one pin and the arrival of the second pin at its ready position was about 2700 milliseconds. This duration was designed to be sufficiently longer than any of the performance cycle time (the positioning performance time plus the return of the hand to the pin-pocket region) in the experiment. Such a feature ensured the discrete nature of the task while avoiding excessive idle time between cycles.

C. The Response Top Plate

The response top plate, 17 inches wide and 12 inches long, was fitted onto the equipment before each experimental run. This changeable feature facilitated investigation of the effect of clearance on positioning performance times by simply having different size holes on separate response plates. Three such plates were made having hole sizes of 0.258", 0.313" and 0.500" in diameter respectively. On each response plate, there were 16 holes of equal size which were equally spaced in the form of a square matrix 3 inches apart from each other. Numbers 1 to 15 and number 0 were labelled above the holes as shown in figure A.1 in Appendix A. The arrangement of these numbers was the same on each response plate throughout the experiment. Number 0 was included in this experiment because it was within the range of the BCD signals used by the tape reader and thus greatly facilitated the making of random number tapes.

3.32 Tape Reader Unit

The Tape Reader Unit consisted of two parts, the Random Number Tape and the Tape Reader.

A. Random Number Tape

This was a standard computer paper tape punched on any of the teletype punching machines using the IBM BCD system code. The RANDU[1] package of IBM 360 computer was used to generate uniformly distributed random numbers corresponding to the hole

1 See computer program listings in Appendix G

numbers used in different experimental runs. Tapes were prepared for 2, 4, 8, 16 holes tasks with equal probability of occurrence of each number in a set. Appendix B contains a listing of the hole numbers chosen for the different hole-alternatives tasks.

B. <u>Tape Reader</u>

For the present study, a SLO-SYN Tape Reader was employed which read the hole pattern on the random tape and transmitted corresponding electrical signals to the S-R unit. The signals were then decoded and displayed on the screen. The removal of the metal pin in the S-R unit triggered each number to be read by the tape reader and displayed.

The Tape Reader Unit as a whole controlled

(i) the number of hole alternatives N as a factor in the experimental condition,

(ii) the sequence of occurrence of the hole numbers.

3.33 <u>Time Measuring and Recording Unit</u>

This consisted of a Hewlett Packard 5326 A Timer Counter and a DIGITEC Paper Tape Punch Unit. The timer was triggered as a number appeared on the screen and shut off when a metal pin was positioned into the specific hole on the response top plate designated by the number displayed. The time so elapsed in milliseconds and the corresponding hole number were punched on a paper tape. This tape was later converted into computer data cards for the analysis.

Figure 3.2 shows the block layout of the equipment.

3.4 Experimental Design

In the present study, performance time (PT) as defined earlier was the response variable. The independent variables included:

1. Effect due to male and female differences (x)
2. Response parameters including the distance, the direction of move and clearance for pin positioning. These are defined as follows:

   Distance of Move (D) - distance in inches measured along the surface of the S-R equipment from the centre of the pin-pocket to the centre of the response hole on the top plate.

   Direction of Move(A) - the angle measured anticlockwise from the horizontal line intersecting the centre of the pin-pocket to the direction of move.

   Clearance (C) - the differences in inches between the diameter of the metal pin and the diameter of response holes on the top plate.
3. Informational Load in bits as defined by Shannon and Weaver (1969) for equiprobable stimulus and response in multichoice reaction task.

$$H \text{ (bits)} = \log_2 N$$

where N is the number of hole-alternatives in an experimental run.

3.41 Procedure

The study was conducted in one of the Industrial Engineering laboratories having normal air conditioning and adequate lighting. A pilot experiment was performed prior to the main study in order to guide in the design of experimental procedures and make final adjustments on the equipment features. Relevant findings in the pilot experiment will be summarised in a later section of this chapter.

Before the commencement of the actual test, each subject underwent a learning session in which he performed the combined decision and positioning task for the condition of 16 hole-alternatives and clearance (C1=0.008".) The learning session lasted for one hour and about 1300 task cycles were completed.

The combined decision and positioning task was comprised of the following steps:

1. Removed the pin from the pin-pocket with a combination of the right hand thumb, index and middle finger.
2. Detected the number shown on the screen.
3. Moved pin to the hole corresponding to the number shown on the screen.
4. Inserted pin into the hole until the fingers touch the wooden top plate.
5. Released pin.

After completing the above, the subject moved the hand back to the pin-pocket region and prepared to start the next cycle. A run for each experimental condition varied between 2 to 16 minutes depending on the number of hole alternatives employed in the condition. Appendix B lists the run time and number of cycles for each condition. To minimise fatigue, sufficient rest periods were proved between runs.

3.42 Instructions to the Subjects

To standardise the method of positioning and to accomodate differences due to individual physical features, the following instructions were given to the subjects before the start of the study.

1. The subject was to sit up-straight in front of the signal-response equipment with the centre line of his body aligned approximately with the centre line of the equipment. The subject was reminded from time to time to maintain this posture.
2. He was to sit at a height such that his lower right arm was in a horizontal position while touching the pin in the pin-pocket with his right hand fingers.
3. The distance from the equipment was to be such that he would extend his maximum reach without moving his shoulder while touching hole number one at the far left upper corner of the top plate.

4. The subject was to hold the pin with his thumb, index and middle finger and insert it into the specified hole. He (she) would release the pin only when his (her) fingers touched the wooden surface.

3.5 Pilot Experiment

Three male subjects were employed in this preliminary study, which consisted of two parts:

1. A learning experiment using the task of 16 hole-alternatives with the closest clearance (C_1 = 0.008").
2. A randomised factorial experiment with two levels of distance (D_1 = 7" and D_2 = 16"), three levels of clearance (C_1 = 0.008"; C_2 = 0.063" and C_3 = 0.250") and one level of informational load, that of four bits (16 hole-alternatives).

It was found that:

1. All three subjects achieved a fully learned state after a practice of 1200 task cycles. See Appendix C.
2. Performance times of the subjects varied significantly from each other.
3. Clearance was a significant factor while distance was not.
4. Compact experimental models, such as the Latin Square design, were found to be inapplicable because subject X distance interaction was found to be significant ($p>0.05$)

The ANOVA table of the pilot experiment performance times is presented in Appendix D.

With reference to the results and observations made during the pilot experiment, the main study was planned and conducted. Details of the main study are discussed in the following chapters.

CHAPTER IV

THE STUDY

4.1 Objectives

The following were the objectives of this study:

1. to examine the effect of informational load (H) on the combined decision and positioning task.
2. to examine how the positioning parameters of distance and clearance affect performance time.
3. to investigate differences in performance between male and female subjects, and
4. to examine the usefulness of the Index of Difficulty (Fitts and Peterson 1964) as a prediction parameter in the performance of such tasks.

4.2 Experimental Conditions

The factors included in the experiment were:

1. Four levels of Informational Load (H):

Number of hole-alternatives	corresponding to H
2	1 bit
4	2 bits
8	3 bits
16	4 bits

2. Three levels of Clearance (C)

C_1 = 0.008"

C_2 = 0.063"

C_3 = 0.250"

3. Four levels of Distance (D)

D_1 = 7"

D_2 = 10"

D_3 = 13"

D_4 = 16"

4. Four pairs of Angular Differences in movement (A) corresponding to the four distances (see Appendix B)

	A_1	A_2
at D_1	78°	102°
at D_2	82°	98°
at D_3	84°	96°
at D_4	85°	95°

A_1's referred to right-sided movements while A_2's referred to left-sided or cross-body movements.

The right-sided movements and the left-sided movements were analysed separately and the results compared. Within each category, two sets of conditions were investigated. The main conditions were the factorial combinations of three higher levels of informational load and all levels of clearance and distances represented diagramatically as follows:

H	C	D
H_2 = 2 bits	C_1 = 0.008"	D_1 = 7"
H_3 = 3 bits	C_2 = 0.063"	D_2 = 10"
H_4 = 4 bits	C_3 = 0.250"	D_3 = 13"
		D_4 = 16"

The Main Conditions

The supplemental conditions were the factorial combinations of one level of H (1 bit) with three levels of C and 2 levels of D (D_1 =7" and D_4=16") represented diagramatically as follows:

H	C	D
H_1 = 1 bit	C_1 = 0.008"	D_1 = 7"
	C_2 = 0.063"	D_4 = 16"
	C_3 = 0.250"	

The Supplementary Conditions

Combinations of C and D were rearranged according to Fitt's Index of Difficulty (I). To avoid confusion with the unit of informational load, the magnitude of I shall be called ibits in this report. The transformation was made as follows:

1 Fitts called the unit of Index of Difficulty bits although there is no established relationship with the 'bits' used in binary information uncertainty as in Shannon and Weaver (1949). The author wishes to avoid confusion between the two but at the same time retain the binary implications suggested by Fitts (1954); Fitts and Peterson (1964).

$I = \log_2 (2D/C)$

C,D	I ibits	Ranked Level of I
C_3D_1	5.807	1
C_3D_2	6.323	2
C_3D_3	6.701	3
C_3D_4	7.001	4
C_2D_1	7.808	5
C_2D_2	8.323	6
C_2D_3	8.701	7
C_2D_4	9.001	8
C_1D_1	10.808	9
C_1D_2	11.321	10
C_1D_3	11.699	11
C_1D_4	12.001	12

Table 4.1 Conversion of C and D parameters to Index of Difficulty (I)

In all conditions, one response variable, the performance times in milliseconds, was recorded and analysed.

4.21 Validity of Informational Load corresponding to Number of Hole Alternatives.

Shannon and Weaver (1949) derived the information 'uncertainty' in a stimulus set and termed it entropy H where

$$H = -\Sigma_i \, p_i \, \Sigma_j \, p_{ij} \, \log_2(pij) \text{ bits} \quad (1)$$

p_i is the probability that stimulus i occurs from a finite set of alternatives (i=1,...,n), and p_{ij} is the conditional probability of stimulus j occurring immediately after i. Employing this entropy measure, various researchers have found a positive linear relationship with performance times in choice reaction tasks.

When there is no sequential dependency of the stimuli, i.e. $p_{ij}=p_i$ for all i, equation (1) becomes

$$H = - \Sigma_j \; p_j \; \log_2(p_j) \text{ bits} \qquad (2)$$

In the present study, the set of numbers programmed to appear on the screen was the stimulus set and the holes corresponding to these numbers were the response set. There was a 1:1 correspondence of stimulus to response. Furthermore, the sequence of numbers in the stimulus set was randomised and also each number occurred with equal probability i.e. $p_j=1/n$, where n is the number of hole alternatives in the task. In this case equation (2) reduces to:

$$H = - \sum_{j=1}^{n} 1/n \log_2(1/n) \text{ bits}$$

$$= - n \; 1/n \; (-\log_2 n) \text{ bits}$$

$$= \log_2 n \text{ bits} \qquad (3)$$

Equation (3) is the measure of informational 'input' or 'load' used in the analysis of the present study. By varying the number (n) of the hole alternatives in the stimulus set, different levels of informational load were obtained.

4.22 Choice of Levels of H, C and D.

It was planned that the experimental conditions should cover the maximum range of parameter magnitudes normally encountered in real work situations which do not exert excessive mental and physical strain on the operator.

Bayha and Hancock (1971) reported that more than 16 alternatives in a stimulus set would cause mental overload and greatly reduce the efficiency of the worker in a repetitive kind of work. Commonly found also is the situation of 1:1 correspondence between stimulus and response such as in assembly work, sorting and monitoring devices. In view of the above, the number of hole alternatives planned in the study was therefore 16 or below and employing 1:1 stimulus-response correspondence.

MTM* system has classified closeness of fit in positioning tasks as follows:

	Lateral Clearance
Class 23	0.010" to 0.048" inclusive
Class 22	0.050" to 0.298" inclusive
Class 21	0.300" to 0.700" inclusive

* 'Engineered Work Measurement' by Karger and Bayha.

For ease of comparison and interpretation of results, the levels of clearance investigated in the present study were designed to fall within these categories also.

Move distances in the range of 7" to 16" were used because they are commonly found in work design and that they are within the maximum reach of the average worker.

4.3 Methodology

According to equation (3) in section 4.21; 2, 4, 8, 16 hole-alternatives sets corresponded to 1, 2, 3, 4 bits of informational load respectively provided that the alternatives in each set occurred with equal probability and were free from sequential dependence. Tapes were accordingly prepared to produce these stimulus sets. Hole numbers 2, 3 and hole numbers 14, 15 made up the 2 two-alternatives sets. Hole numbers 2, 3, 6, 7 and numbers 10, 11, 14, 15 made up the 2 four-alternatives sets. Hole numbers 1 to 8 and numbers 9 to 15 and 0 made up the 2 eight-alternatives sets, and finally, all 16 hole numbers were used in the sixteen- alternatives set. this scheme of stimulus-set planning is shown diagramatically in Appendix B. The distances of right-sided movements corresponded to hole numbers 3, 7, 11, 15 and that of left-sided movements corresponded to hole numbers 2, 6, 10, 14. The same holes were considered in each level of informational load and each level of clearance. Therefore, performance times data corresponding to these holes alone were collected and analysed. For instance in a eight-alternatives task at distances D_3=13" and D_4=16", data for four holes, numbers 2, 3, 6, 7, were collected in one run. Hole numbers 2 and 6 corresponded to D_4 and D_3 respectively of the left-sided movement. Hole numbers 6 and 7 corresponded to D_4 and D_3 respectively of the right-sided movement. Each subject performed a (3x3x4) factorial experiment for the main conditions and a (1x3x2) factorial experiment for the supplementary-conditions. Since data were collected simultaneously for both right-sided and left-sided movements as illustrated in the above example, the actual total number of experimental runs were twenty-one for each subject. The order of these twenty-one runs was randomised for each subject and by nature of the random occurrence of the numbers in the tapes, the conditions in each run were randomised within the run. The order of randomisations of the twenty-one runs for each subject is shown in Tables 4.2 to 4.5. (For instance, subject U.C. in Table 4.2 performed condition H = 1 bit and I = 12 in the first run and conditions H = 2 bits, I = 4 and H = 2 bits, I = 3 simultaneously in the second run, and so on.) This feature resulted in considerable savings in experimental time as well as minimising both the subject's boredom and fatigue.

The right-sided movements were analysed separately from the left-sided movements as if in two distinct classes. In each class, a factorial model was used to analyse the effects of the experiment and a performance time prediction model was developed.

Order Of Experimental Run	H.S. H	H.S. I	U.C. H	U.C. I	C.B. H	C.B. I	L.S. H	L.S. I	K.M. H	K.M. I
1	4	04,03,02,01	1	12	3	06,05	1	01	4	08,07,06,05
2	3	06,05	2	04,03	2	06,05	2	08,07	1	05
3	4	12,11,10,09	4	04,03,02,01	1	04	2	10,09	1	01
4	1	04	3	10,09	4	12,11,10,09	4	12,11,10,09	2	02,01
5	3	12,11	4	12,11,10,09	3	04,03	3	12,11	2	06,05
6	1	09	2	02,01	2	04,03	4	04,03,02,01	2	04,03
7	2	06,05	1	05	3	02,01	1	05	1	09
8	2	02,01	3	04,03	1	09	1	12	3	10,09
9	3	10,09	1	09	1	12	2	04,03	1	04
10	2	12,11	2	08,07	3	12,11	3	06,05	2	08,07
11	1	08	3	06,05	2	12,11	1	04	4	04,03,02,01
12	1	01	1	01	1	01	2	06,05	3	06,05
13	2	04,03	2	06,05	2	08,07	1	08	3	04,03
14	2	08,07	2	10,09	4	08,07,06,05	1	09	3	12,11
15	1	05	3	02,01	2	02,01	3	08,07	1	08
16	3	04,03	3	08,07	1	05	4	08,07,06,05	3	08,07
17	1	12	1	04	3	10,09	3	10,09	2	12,11
18	2	10,09	1	08	3	08,07	2	02,01	3	02,01
19	3	02,01	2	12,11	1	08	3	02,01	1	12
20	3	08,07	4	08,07,06,05	2	10,09	2	12,11	2	10,09
21	4	08,07,06,05	3	12,11	4	04,03,02,01	3	04,03	4	12,11,10,09

Table 4.2 Order of Run Randomisation for Five Female Subjects.

Terminology: H - Informational Load

I - Index of Difficulty

Order Of Experimental Run	L.J. H	L.J. I	L.S. H	L.S. I	P.C. H	P.C. I	S.I. H	S.I. I	T.M. H	T.M. I
1	3	08,07	4	08,07,06,05	3	06,05	2	08,07	2	12,11
2	3	04,03	1	08	1	09	4	12,11,10,09	2	04,03
3	2	04,03	3	12,11	4	08,07,06,05	2	02,01	2	06,05
4	4	12,11,10,09	3	10,09	3	02,01	4	08,07,06,05	4	04,03,02,01
5	2	12,11	3	06,05	4	04,03,02,01	1	05	3	06,05
6	2	02,01	1	12	1	04	1	09	1	09
7	1	12	2	06,05	3	04,03	3	10,09	4	08,07,06,05
8	2	10,09	3	04,03	2	08,07	3	08,07	3	02,01
9	4	04,03,02,01	2	02,01	2	12,11	3	12,11	3	04,03
10	1	04,	1	01	1	01	1	12	2	10,09
11	1	09	2	12,11	1	05	2	04,03	2	08,07
12	3	06,05	2	04,03	2	02,01	4	04,03,02,01	3	12,11
13	3	02,01	4	12,11,10,09	4	12,11,10,09	3	04,03	1	12
14	2	06,05	1	09	3	10,09	1	01	3	08,07
15	1	08	1	04	3	12,11	3	06,05	1	08
16	1	05	2	08,07	1	08	2	06,05	1	01
17	2	08,07	1	05	3	08,07	2	10,09	1	05
18	1	01	2	10,09	2	10,09	3	02,01	2	02,01
19	3	10,09	3	08,07	1	12	1	04	4	12,11,10,09
20	3	12,11	4	04,03,02,01	2	04,03	1	08	3	10,09
21	4	08,07,06,05	3	02,01	2	06,05	2	12,11	1	04

Table 4.3 Order of Run Randomisation for Five Female Subjects.

Terminology: H - Informational Load

I - Index of Difficulty

Order Of Experimental Run	T.J. H	T.J. I	J.S. H	J.S. I	M.M. H	M.M. I	P.A. H	P.A. I	T.P. H	T.P. I
1	1	08	3	08,07	2	02,01	2	10,09	3	08,07
2	1	12	3	10,09	2	04,03	1	01	3	02,01
3	1	09	2	12,11	3	02,01	1	09	2	12,11
4	4	08,07,06,05	2	06,05	3	06,05	1	12	2	06,05
5	3	10,09	3	06,05	3	08,07	2	06,05	3	06,05
6	2	08,07	1	01	1	09	1	05	1	01
7	4	04,03,02,01	1	09	1	05	3	06,05	1	09
8	2	02,01	2	02,01	2	08,07	2	12,11	1	12
9	1	05	3	12,11	2	12,11	3	08,07	1	05
10	3	06,05	1	12	3	12,11	4	12,11,10,09	2	10,09
11	3	08,07	4	04,03,02,01	3	04,03	2	02,01	4	12,11,10,09
12	1	01	1	05	1	12	2	04,03	2	04,03
13	3	12,11	2	10,09	1	08	3	10,09	4	08,07,06,05
14	2	06,05	4	12,11,10,09	2	10,09	3	12,11	2	02,01
15	2	12,11	2	04,03	3	10,09	4	08,07,06,05	1	08
16	2	04,03	2	08,07	1	04	3	02,01	1	04
17	3	04,03	1	04	2	06,05	1	04	4	04,03,02,01
18	4	12,11,10,09	3	02,01	1	01	1	08	3	10,09
19	1	04	1	08	4	12,11,10,09	3	04,03	3	04,03
20	2	10,09	4	08,07,06,05	4	08,07,06,05	2	08,07	3	12,11
21	3	02,01	3	04,03	4	04,03,02,01	4	04,03,02,01	2	08,07

Table 4.4 Order of Run Randomisation for Five Male Subjects.

Terminology: H-Informational Load

I-Index of Difficulty

Order Of Experimental Run	L.S. H	L.S. I	B.Z. H	B.Z. I	K.A. H	K.A. I	K.K. H	K.K. I	M.A. H	M.A. I
1	3	04,03	3	10,09	4	08,07,06,05	2	08,07	3	06,05
2	3	08,07	3	02,01	2	06,05	2	12,11	3	04,03
3	2	04,03	2	02,01	3	04,03	1	12	4	04,03,02,01
4	3	12,11	1	09	1	12	2	02,01	2	04,03
5	4	12,11,10,09	3	06,05	3	06,05	2	10,09	1	12
6	4	08,07,06,05	1	01	2	02,01	1	01	3	08,07
7	1	01	1	05	4	12,11,10,09	2	04,03	3	10,09
8	2	10,09	2	08,07	1	01	3	04,03	1	09
9	1	12	2	12,11	3	08,07	3	08,07	1	05
10	4	04,03,02,01	3	08,07	2	10,09	3	12,11	4	08,07,06,05
11	1	05	3	12,11	3	02,01	3	10,09	2	02,01
12	2	12,11	2	04,03	3	12,11	1	04	3	12,11
13	1	08	2	06,05	2	12,11	1	09	2	08,07
14	3	02,01	4	04,03,02,01	2	04,03	3	06,05	2	12,11
15	2	06,05	2	10,09	3	10,09	3	02,01	1	08
16	3	06,05	4	12,11,10,09	1	09	2	06,05	1	04
17	3	10,09	1	04	1	04	1	08	3	02,01
18	1	09	4	08,07,06,05	2	08,07	1	05	2	10,09
19	2	08,07	1	12	1	05	4	12,11,10,09	2	06,05
20	1	04	1	08	1	08	4	08,07,06,05	1	01
21	2	02,01	3	04,03	4	04,03,02,01	4	04,03,02,01	4	12,11,10,09

Table 4.5 Order of Run Randomisation for Five Male Subjects.

Terminology: H - Informational Load

I - Index of Difficulty

4.4. The Subjects

Ten male and ten female right-handed students at the University of Windsor were selected as subjects for this experiment. Their age range from nineteen to twenty-six.

Three of the male subjects performed in both the pilot experiment and the main study. For the pilot experiment the students were paid $10 each. For the main study, each subject was paid $15. All subjects were in good physical condition and were interested in the study. Each subject had about one hour of learning practices before the actual recording of data. The main study took about seven hours to complete which was divided into three sessions in successive days. The time of each experimental condition varied according to the number of hole-alternatives in the task. Sufficient rest periods were given to the subjects between conditions, (see Appendix B).

Before the actual recording of data, the subject was given twenty practice cycles to adapt himself/herself to each new experimental condition.

4.5 Data Collection

In each of the twenty-one experimental runs, performance times corresponding to each of the relevant response holes as described earlier (Appendix B, section 4.3 and 4.4 of text) were collected on data cards. Thirty cycle times were recorded for each response hole. A computer program (see Appendix F) was prepared to sort the time data into the different hole categories, screen out any errors and outlying points under the criteria of four standard deviations from the sample mean $(\mu \pm 46)$ Twenty data points were used for this analysis.

Errors made by the subjects in positioning into a wrong hole were few and far in between during the whole study, no consideration of its effect was therefore deemed necessary.

CHAPTER V

DATA ANALYSIS

5.1 Introduction

The analysis of experimental data was divided into two parts. Part 1 investigates the effects of informational load, clearance and sex differences on performance times at the four levels of distance separately (i.e. D=7", 10", 13" and 16"). The purpose was to establish the basic relationships among these factors while isolating the effect of the small angular differences associated with the distance levels. In part 2, such angular effect was assumed negligible across all distance levels. Studies by Scholes (1970) and El Sayed (1975) have indicated that small angular differences (7^o max in this study) in the narrow region on the same side of the 90^o angle of movement had negligible effect on movement times. The purpose of this part was to examine the combined effect of distance and clearance on performance times and the usefulness of the index of difficulty (I) as a prediction parameter for such tasks.

In both Parts 1 & 2, the ~~effects of the same~~ sided movements as explained in the previous chapter were first analysed separately and then compared. Analysis of variance (ANOVA) Newman. Kuel's test of significant means and variances of components analysis were employed. Part 1 also investigated the effects of different sided movements (angle of movement) at the four levels of distance whereas Part 2 compared the combined effect of clearance and distance with the integrated factor I. It should be noted here that only general directions of movements were considered in this study (same sided versus cross-body movements) and not the specific angular differences in degrees.

Graphs were plotted to illustrate the relationships of performance times with the various significant effects. Finally, prediction models were developed for each class of movement given the limitations of the experimental conditions of the present study. Histograms for every condition of each subject were plotted using a standard computer program (See Appendix G), a sample of which is presented in Appendix H. The means, standard deviations, maximum and minimum values of the performance times were also given by the same program. The Statistical Analysis System (SAS) computer package developed by Barr and Goodnight (1973) was used both in the ANOVA and prediction model analysis.

5.2 Analysis Models

Within each class of movement, a randomised factorial nested mixed model was used for the analysis of performance times.

Part 1

$$X_{ijkln} = \mu + \alpha_i + \beta_{j(i)} + \gamma_k + \delta_l + \alpha\gamma_{lk} + \cdots + \beta\gamma\delta_{jkl(i)} + \varepsilon_{n(ijkl)} \quad \ldots\ldots (1)$$

where α_i = Sex Difference (x) $i = 1,2$

X_1 = male

X_2 = female

$\beta_{jk(i)}$ = Subject nested within sex (s) $j = 1....10$

γ_k = Informational Load (H)

$k = 1,2,3,4$ for Distance $D_1 = 7''$ and

$D_4 = 16''$

H_1 = 1 bit

H_2 = 2 bits

H_3 = 3 bits

H_4 = 4 bits

$k = 1, 2, 3$ for Distance $D_2 = 10''$ and

$D_3 = 13''$

H_1 = 2 bits

H_2 = 3 bits

H_3 = 4 bits

δ_l = Clearance (c) $l = 1, 2, 3$

C_1 = 0.008"

C_2 = 0.063"

C_3 = 0.250"

$\varepsilon_{n(ijkl)}$ = residual including cell repetitions

X_{ijkln} is the performance time of the nth observation for the lth level of clearance, kth level of informational load, jth subject and ith sex.

$\alpha\gamma\delta$ in the above model were considered as fixed factors whereas β was random

In the analysis of the effect of the angle of movement, a randomised factorial nested mixed model was again used for each level of distance:

$$X_{ijklmn} = \mu + \alpha_i + \beta_{j(i)} + \gamma_k + \delta_l + \theta_m + \alpha\gamma_{ik} + \dots + \beta\gamma_{jk(i)} + \dots + \alpha\gamma\delta_{ikl} + \dots + \beta\delta\theta_{jlm(i)} + \dots + \varepsilon_{n(ijklm)} \quad \dots\dots\dots\dots(2)$$

where

θ_m = Angle of movement A, m = 1,2

for D_1 : $A_1 = 78°$, $A_2 = 102°$

for D_2 : $A_1 = 82°$, $A_2 = 98°$

for D_3 : $A_1 = 84°$, $A_2 = 96°$

for D_4 : $A_1 = 85°$, $A_2 = 95°$

γ_k = Informational Load (H)

for D_1 and D_4 , k = 1,2,3,4

and H_1 = 1 bit

H_2 = 2 bits

H_3 = 3 bits

H_4 = 4 bits

for D_2 and D_3 , k = 1,2,3

and H_1 = 2 bits

H_2 = 3 bits

H_3 = 4 bits

α, β, δ and ε are the same as in the previous models.

Part 2

$$X_{ijklmn} = \mu + \alpha_i + \beta_{j(i)} + \gamma_k + \delta_l + \lambda_m + \alpha\gamma_{ik} + \ldots$$
$$+ \beta\gamma_{jk(i)} + \ldots + \alpha\gamma\delta_{ikl} + \ldots + \ldots$$
$$+ \varepsilon_{n(ijklm)} \qquad \ldots\ldots(3)$$

where

α_i = Sex Difference (x), i=i,2
x_1 = male
x_2 = female

$\beta_{j(i)}$ = Subject(s) nested with sex, j = 1,...,10

γ_k = Informational Load (H), k = 1, 2, 3
H_1 = 2 bits
H_2 = 3 bits
H_3 = 4 bits

δ_l = clearance (C), l = 1, 2, 3
C_1 = 0.008"
C2 = 0.063"
C_3 = 0.250"

λ_m = distance (D), m = 1,2,3,4
D_1 = 7 inches
D_2 = 10 inches
D_3 = 13 inches
D_4 = 16 inches

$\varepsilon_{n(ijklm)}$ = residual including cell repetitions and the third and fourth order interaction terms

X_{ijklmn} is the performance time of the n^{th} observation for m^{th} level of distance, l^{th} level of clearance, k^{th} informational load, j^{th} subject and i^{th} sex.

$\alpha, \gamma, \delta, \lambda$ in the above model were considered as fixed factors whereas β was considered as random factor.

In the case where index of difficulty replaces C and D as an integrated factor in the experimental conditions, the following model was used.

$$X_{ijklm} = \mu + \alpha_i + \beta_{j(i)} + \gamma_k + \eta_l + \alpha\gamma_{ik} + \ldots + \beta\gamma_{jk(i)} + \ldots + \varepsilon_{m(ijkl)} \qquad \ldots\ldots\ldots(4)$$

where

η_l = index of difficulty (I), $l = 1, \ldots, 12$

I_1 = 5.808 ibits ; I_2 = 6.323 ibits ; I_3 = 6.701 ibits

I_4 = 7.001 ibits ; I_5 = 7.808 ibits ; I_6 = 8.323 ibits

I_7 = 8.701 ibits ; I_8 = 9.001 ibits ; I_9 =10.808 ibits

I_{10}=11.321 ibits ; I_{11}=11.699 ibits ; I_{12}=12.001 ibits

$\alpha, \beta, \gamma, \varepsilon$ are the same as in the previous model.

5.3 Validity of Analysis Model

Since data were obtained simultaneously for both the right-sided and left-sided movements and for each level of distance included in an experimental run, there were consequently some restrictions on the randomisation of all the experimental conditions. A goodness of fit test was applied to the analysis models (Draper and Smith) to see if they significantly deviate from the actual conditions of the experimental set-up. The pure error component - the repetition effect within each experimental cell, was isolated from the theoretical residual (i.e. excluding all interaction term) of the models. The lack of fit component - the remainder of residual after pure error, was tested against the pure error component for significance. Table 5.1 to 5.4 show the validity of models used in the separate classes of movement. Tables 5.5 to 5.8 show the model validity when angle of movement effect was considered.

As it is seen in the tables that the models used in every case were significant and that the lack of fit error was insignificant ($p > 0.05$). It is therefore concluded that models 1, 2, 3 and 4 were acceptable for the analysis.

	Source	d.f.	SS	MS	F-value	Findings at 5% Level
D_1	Total	4799	191717654			
	Regr.	258	92411185	358183	16.36	Significant
	Resid.	4541	99306469	21869		
	L of F	4522	98891787	21869	1.00	
	P.E.	19	414682	21825		
D_2	Total	3599	127327431			
	Regr.	198	55637196	280996	13.33	Significant
	Resid.	3401	71690235	21079		
	L of F	3382	71423562	21119	1.52	Not Significant
	P.E.	19	2-6673	14035		
D_3	Total	3599	153542315			
	Regr.	198	82955862	418969	20.18	Significant
	Resid.	3401	70586453	20754		
	L of F	3382	70273870	20778	1.2	Not Significant
	P.E.	19	312583	16451		
D_4	Total	4799	213418621			
	Regr.	258	110773134	429353	18.99	Significant
	Resid.	4541	102645487	22604		
	L of F	4522	102231925	22607	1.03	Not Significant
	P.E.	19	413562	21766		

Table 5.1 Validity of Model 1 at each level of Distance; Right-sided Movement.

	Source	d.f.	SS	MS	F-Value	Findings at 5% Level
D_1	Total	4799	236832117			
	Regr.	258	130794884	506957	21.71	Significant
	Resid.	4541	106037233	23351		
	L of F	4522	105776683	23392	1.70	Not Significant
	P.E.	19	260550	13713		
D_2	Total	3599	135007517			
	Regr.	198	59377408	299885	13.48	Significant
	Resid.	3401	75630109	22238		
	L of F	3382	74735479	22098	0.47	Not Significant
	P.E.	19	894670	47088		
D_3	Total	3599	157015000			
	Regr.	198	87084864	439822	21.39	Significant
	Resid.	3401	69930136	20562		
	L of F	3382	69465643	20540	0.84	Not Significant
	P.E.	19	464493	24447		
D_4	Total	4799	257546231			
	Regr.	258	142720890	553181	21.87	Significant
	Resid.	4541	114825341	25286		
	L of F	4522	114290769	25274	0.89	Not Significant
	P.E.	19	543572	28135		

Table 5.2 Validity of Model 1 at each level of Distance; Left-sided Movement.

Source	df	SS	ms	F-ratio	Findings at 5% level
Total	14399	603976797			
Regression	482	291528527	604830.9	26.94	Significant
Residual	13917	312448270	22450.8		
Lack of Fit	13898	311786929	22433.9	0.644	Not Significant
Pure Error	19	661341	34807.4		

Table 5.3 Valididty of Model 2, Right-sided Movement (Part 2)

Source	df	SS	ms	F-ratio	Findings at 5% level
Total	14399	601905609			
Regression	482	294894536	611814.3	27.55	Significant
Residual	13917	307011073	22203.9		
Lack of Fit	13898	306704390	22068.2	1.32	Not Significant
Pure Error	19	316683	16667.5		$F_{0.05}$=1.88

Table 5.4 Validity of Model 2, Left-sided Movement (Part 2)

Source	df	SS	ms	F-ratio	Findings at 5% level
Total	9599	445138420			
Regression	321	234740242	731278	32.25	Significant
Residual	9278	210398178	22677.1		
Lack of Fit	9259	210128627	22694.5	1.59	Not Significant $F_{0.05}=1.88$
Pure Error	19	269551	14186.9		

Table 5.5 Validity of Model 4, Angle of Movement effect for D_1

Source	df	SS	ms	F-ratio	Findings at 5% level
Total	7199	267849601			
Regression	239	114118206	477482	21.62	Significant
Residual	6960	153731395	22087.8		
Lack of Fit	6941	153094098	22050	0.657	Not Significant $F_{0.05}=1.88$
Pure Error	19	637297	33542		

Table 5.6 Validity of Model 4, Angle of Movement effect for D_2

Source	df	SS	ms	F-ratio	Findings at 5% level
Total	7199	299557865			
Regression Residual	239 6960	155679100 143878768	651376.9 20672.2	31.51	Significant
Lack of Fit Pure Error	6941 19	143526011 352757	20678.0 18566.2	1.11	Not Significant $F_{0.05}=1.88$

Table 5.7 Validity of Model 2, Angle of Movement effect for D_3

Source	df	SS	ms	F-ratio	Findings at 5% level
Total	9599	416481015			
Regression Residual	321 9278	227640576 188840439	709160.6 20353.6	34.84	Significant
Lack of Fit Pure Error	9259 19	188464655 375784	20354.7 19778.1	1.03	Not Significant $F_{0.05}=1.88$

Table 5.8 Validity of Model 2, Angle of Movement effect for D_4

CHAPTER VI

EXPERIMENTAL RESULTS AND DISCUSSION

6.1 Analysis of Variance:

The effects of the experiment were tested by the ANOVA procedure of the SAS package according to the analysis models in Chapter V. 5% significant level ($p<0.05$) was used in all cases.

Part 1 models:

1. It was found that for both the right-sided and left-sided movements and for all levels of the distance (D):

   a. The main effect of informational load (H) and clearance (C) were significant ($p<0.05$);

   b. Male and female difference was not significant ($p>0.05$);

   c. All first order interactions of sex (X) informational load (H) and clearance (C) were not significant ($p>0.05$);

2. The right-sided and left-sided movements were significantly different ($p<0.05$) at all levels of D.

Part 2 models:

For both right-sided and left-sided movements:

a. The main effects of informational load (H), clearance (C) and distance (D) were significant ($p<0.05$)

b. Male and female difference was not significant in the experimental task ($p>0.05$);

c. The index of difficulty (I) when used in place of C and D showed a significant effect ($p<0.05$);

d. The H x D interactions were significant which might be explained by the deviation of performance times between D_2 and D_3 as described in Appendix F (Motion Strategy).

It is clearly seen from the above analysis that the models used in the two Parts give similar results. The assumption that the angular effect associated with the levels of distance being negligible is validated.

Preparation of tables of EMS values as well as ANOVA tables of results are presented in Appendix D.

6.2 Test of means of Significant Effects:

The Newman Kuel's Test was applied to the significant effects obtained from the ANOVA. Again, 0.05 level of significance was used in all cases.

From the Part 1 models, it was found that for both the right-sided and left-sided movements, the mean performance times for each level of H (2, 3, 4 bits) were significantly different at each level of distance; the same was found for those of the three levels of clearance C. From the Part 2 models, index of difficulty and distance level means, however, behaved a little differently in the right-sided versus the left-sided movement.

Results of the Newman Kuel's Test on the two effects can be summarised as follows:

1. Right-sided Movement:

A) Distance (D)

Levels of D in ascending order of means:

1 3 2 4

B) Index of Difficulty (I)

1 5 3, 2 9 7 4 6 10 11 8 12

2. Left-sided Movement:

A) Levels of D in ascending order of means:

1 3 2 4

B) Index of Difficulty (I)

Levels of I in ascending order of means:

1 3 2 4 5 7 6 9 8 11 10 12

The insignificant difference between levels 2 and 3 of distance is probably due to the motion strategy difference across these levels (See Appendix F). There appears to be significant changes in the ascending order of the index of difficulty level means which may be traced directly to the effect of the distance component in the logarithmic transformation of the index.

6.3 Variance Components by Major Effects:

Detailed calculations of the component variances are presented in Appendix D. Only Part 2 models were used in this case. Results are summarised here in the following table:

	Component	Right-sided Movement	Left-sided Movement
ANALYSIS I	Subject Effect (S)	23.93%	29.44%
	Informational Load (H)	47.20%	53.82%
	Clearance (C)	16.10%	12.69%
	Distance (D)	12.75%	14.06%
ANALYSIS II	Subject Effect (S)	25.54%	30.77%
	Informational Load (H)	50.36%	56.27%
	Index of Difficulty (I)	24.10%	12.96%

Table 6.I Summary of Variance Components

Informational Load (H) is the single most significant effect in the present experimental model. It accounts for about one-half of the total variance in the model with the remainder divided between the effect of subject differences and the movement parameters (C and D or I). Informational Load is notably more significant for the left-sided movement than the right. In comparison, H in the left-sided movement account for 6% more of the total variance than in the right movement.

Index of Difficulty is comparable with the combination of clearance and distance in accounting for the variance in the model. There is however some indication of better accountability if the right-sided movement - a 16% difference from the combined C and D variance portion as compared to a 22% difference in the left-sided movement.

6.4 Effect of Informational Load on Performance Times

MTM values for the manual components of the experimental conditions was first intended to be used to highlight the effect of the Informational Load on performance time. However, it was found to be indequate in this instance because of the approximation in the MTM definition of Positioning tasks. Instead, extrapolation values from the regression models in Appendix D are listed here in Table 6.2 and 6.3 along with experimental values for comparision.

There is a marked increase in performance time between a purely manual task and one with two alternatives, and again between the 3-bit and 4-bit tasks. The former is a good indication of the effect of decision imposed on the manual task while the latter approaches the situation of mental overload as indicated by Bayha and Hancock (1971).

Expt.Cond. C	D	Extr.Value H_0=0 bit	Expt. Values H_1=1 bit	H_2=2 bits	H_3=3 bits	H_4=4 bits
1	1	790	894	938	1023	1145
	4	936	1002	1084	1063	1295
2	1	720	827	894	1095	1082
	4	808	937	1021	1091	1260
3	1	680	713	836	903	1000
	4	740	857	961	1035	1206
Ave.% increase			11.9	9.6	6.0	14.0

Table 6.2 Effect of Informational Load on Performance Times; Right-sided Movement.

Expt.Cond. C	D	Extr. Value H_0=0 bit	Expt. Values H_1=1 bit	H_2=2 bits	H_3=3 bits	H_4=4 bits
1	1	854	962	1029	1094	1247
	4	895	1020	1111	1165	1286
2	1	720	852	967	1042	1226
	4	808	940	1041	1101	1258
3	1	680	813	910	982	1154
	4	740	892	977	1057	1174
Ave.% increase			13.9	10.14	6.7	14.0

Table 6.3 Effect of Informational Load on Performance Times; Left-sided Movement.

6.5 Linear Regression:

Linear regression was used to develop prediction models for the performance time in the combined decision and positioning task. Here again, only Part 2 models were used to give meaningful results. Two approaches were used: considering C and D as separate factors and considering I in place of C and D.

Detailed tables of linear regression coefficients are given in Appendix E and only selective models are listed in this section:

a. Right-sided Movement:

Performance Time (ms) = 623.31 + 106.60H - 411.20C + 14.33D ...model 1

where H is the informational load in bits

C is the lateral clearance in inches

D is the distance of move in inches

R-square = 0.9104

Significance level of Fit = 0.0001

Standard Error of Regression = 35.13 ms

Maximum % deviation of residual = 7.2%

Performance Time (ms) = 523.72 + 102.60H + 25.08I ...model 2

where I is the index of difficulty in ibits

R-square = 0.8003

Significance level of Fit = 0.0001

Standard Error of Regression = 51.65 ms

Maximum % deviation of residual = 8.5%

B. Left-sided Movement

Performance Time (ms) = 769.58 + 105.89H - 419.63C + 5.57D ... model 3

R-square = 0.8970

Significance level of Fit = 0.0001

Standard Error of Regression = 35.42 ms

Maximum % deviation of residual = 7.2%

Performance Time (ms) = 592.34 + 105.90H + 22.36I ... model 4

R-square = 0.8939

Significance level of Fit = 0.0001

Standard Error of Regression = 35.41 ms

Maximum % deviation of residual = 6.3%

The mean values of experimental conditions, predicted values, Residuals, lower and upper 95% confidence limits for the means generated by the above four models are listed in Appendix H (computer print-out).

For the left-sided movement, the conditions of fit is comparable between using C and D separately or using a single factor I. For the right-sided movement, the correlation coefficient (R) difference is tested for significance using the Fisher's Z transformation ($\rho \neq 0$)*.

From model 1 : $R_1 = \sqrt{0.9104} = 0.9541$

From model 2 : $R_2 = \sqrt{0.8970} = 0.9470$

$$Z_1 = 1.1513 \log_{10}[(1+R_1)/(1-R_1)] = 1.875$$

$$Z_2 = 1.1513 \log_{10}[(1+R_2)/(1-R_2)] = 1.802$$

$$\sigma(Z_1 - Z_2) = \sqrt{\frac{1}{N_1-3} + \frac{1}{N_2-3}}$$

$$= \sqrt{\frac{2}{36}}$$

$$= 0.235$$

where N_1, N_2 are the sample size of the corresponding model, here $N_1 = N_2 = 36$

Hypothesis H_o : $\mu_{Z_1} = \mu_{Z_2}$ and H_I : $\mu_{Z_1} = \mu_{Z_2}$

Under hypothesis H_o:

$$z = \frac{Z_1 - Z_2 - 0}{\sigma(Z_1 - Z_2)}$$

$$= \frac{1.875 - 1.802 - 0}{0.235}$$

$$= 0.310$$

Using a two tail test of z in the normal distribution,

* ρ is the theoretical population correlation coefficient

and at 5% level of significance, R_1 and R_2 of the two models are not significantly different.

Comparison between the predicted values of the two sets of models are shown in tables 6.2 and 6.3. There is only a 3.5% average difference for the right-sided movement and an even less, 1.69% average difference for the left-sided movement.

For both the left-sided and right-sided movements, it is seen that coefficient of H is about four times higher than that of I. This indicates clearly that changes in informational load have much greater effects on total performance times than the parameters governing the manual component of the task.

6.6 Graphical Analysis

Graphs of Performance Time (PT) versus Informational Load (H) and Index of Difficulty (I) are shown in Fig. D.1 to Fig. D.10. Performance variations due to direction of movement (A) are shown in Fig. D.11 to Fig. D.22.

It is seen that Performance Time varies linearly with Informational Load at all levels of (I). However, the linearity of I with PT decreases as H increases such as indicated by the associated correlation factors. This implies that at higher levels of H, there is an increasing amount of parallel activity in the task (decision element occurring in parallel with the manual elements). Such a phenomenon is shown in the plots of PT versus I rather than PT versus H because the latter has a much greater effect on

Performance Times of such tasks.

Right-sided movements are in most cases accomplished faster than the cross-body movements (left-sided movements). Cross body movements involve the arm and forearm in motion about the shoulder joint whereas right-sided movements can be accomplished mainly by the forearm alone moving about the elbow. A larger mass and variety of muscles are involved in cross body movements compared to those in right-sided movements and therefore require longer performance time. The exceptions seen in the case H=4 bits and D = 16" can be explained by the fact that most subjects tended to shift their bodies toward the left as the experiment proceeded. This actually made the movement to the left-sided hole (#2) a straight forward move (a 90° move) while the right-sided hole (# 3) remained at some angle to the right. Such a shift was so natural with most subjects that it was impossible to prevent. This phenomena is not peculiar to the experimental task but can be observed whenever a person is doing work with one hand. The most natural position for doing such work appears to be some distance from the centre line of the body toward the working hand. For instance, writing with the right hand is most conveniently done at some distance towards the right.

6.7 Use of the Index of Difficulty

It is shown in section 6.5 that the Index of Difficulty is comparable with the separate factors of C and D in the linear regression of experimental data. Using I.D., R-square for the left-sided movement is 0.8983 and that for the right-sided movement is 0.8003. Again in Table 6.3 and 6.4, mean experimental performance times are compared to the predicted values obtained by using model 3 (C and D) and model 4 (I.D.) It is seen that the average % difference between the two models are 1.6% for the left-sided movement and 3.5% for the right-sided movement. The maximum deviation between the models is only 7.5%. Nevertheless, one significant advantage in the use of I over C and D is in the case when different motion strategies are inherent in the task. As in the present study, the subjects employed one motion strategy when he moved in the range of seven to ten inches, and another in the range of thirteen to sixteen inches (detailed discussion in Appendix F). With C and D, two significantly different linear models were required. However, one model using I was sufficient in relating to the data across both ranges. This feature can be explained by the logarithmic transformation of C and D to form the Index.

$$I = \log_2(2D/C) \text{ ibits}$$

Taking the logarithm of the ratio of D and C reduces the absolute magnitude of any changes in either D or C. As explained in Appendix F, it is the distance (m) from the decision region[1] to the response hole that is significantly affecting the manual performance time. The changes of m corresponding to those of D are conceivably less in tasks involving motion strategy changes. Thereby transforming D logarithmically, the changes of m are approximated.

1 region within which the first initial move ends and the second directional move to the response hole begins.

It is often the case in industrial tasks such as encountered in assembly lines where the work is comprised of a number of sub-tasks each involving a different narrow range of distance of movement. Motion strategy changes are therefore inherent in such tasks. A prediction model using I automatically accomodates these differences and is thus more simple to use than the conventional parameters of C and D.

Experimental Conditions			Mean Performance	Predicted Value (ms)		Absolute Difference in Predicted Values	% Difference in term of Observed Values
H	C	D		Model 3	Model 4		
2	1	1	938	926	1000	49	5.6
		2	1009	969	1013	19	2.0
		3	1009	1012	1022	15	1.6
		4	1084	1055	1030	50	5.2
	2	1	894	903	925	20	2.2
		2	976	946	937	9	0.9
		3	926	989	947	42	4.5
		4	1021	1032	955	77	7.5
	3	1	836	826	875	49	5.6
		2	932	869	888	19	2.0
		3	898	912	897	15	1.6
		4	961	955	905	50	5.2
3	1	1	1023	1028	1103	75	7.3
		2	1022	1071	1145	74	7.2
		3	1070	1114	1124	10	0.9
		4	1063	1157	1133	24	2.0
	2	1	965	1006	1027	21	2.1
		2	1095	1046	1040	9	0.8
		3	1011	1092	1050	42	4.1
		4	1091	1134	1057	77	7.0
	3	1	903	929	977	48	5.3
		2	997	972	990	18	1.8
		3	964	1015	1000	15	1.5
		4	1035	1058	1007	51	4.9
4	1	1	1145	1130	1205	79	6.5
		2	1167	1174	1218	44	3.7
		3	1225	1217	1227	10	0.8
		4	1295	1260	1235	25	1.9
	2	1	1082	1108	1129	21	1.9
		2	1150	1151	1142	9	0.7
		3	1188	1194	1152	42	3.5
		4	1260	1237	1159	78	6.1
	3	1	1000	1031	1079	48	4.8
		2	1094	1074	1092	18	1.6
		3	1130	1117	1102	15	1.3
		4	1206	1160	1109	21	4.2
						Average % difference ...	3.5%

Table 6.4 Right-sided movement, comparison between linear regression models 3 and 4.

Experimental Conditions			Mean Performance Time of Conditions M.S.	Predicted Value (M.S.)		Absolute Difference in Predicted Values	% Difference in term of Observed Values
H	C	D		Model 3	Model 4		
2	1	1	1029	1046	1017	29	2.8
		2	1077	1057	1034	23	2.1
		3	1048	1066	1051	15	1.4
		4	1111	1072	1067	5	0.4
	2	1	967	979	994	15	1.5
		2	1041	990	1010	20	1.9
		3	975	999	1027	28	2.8
		4	1041	1005	1044	39	3.7
	3	1	910	934	915	15	1.6
		2	999	945	932	13	1.3
		3	929	954	949	5	0.5
		4	977	961	966	5	0.5
3	1	1	1094	1152	1123	29	2.5
		2	1187	1163	1139	24	2.1
		3	1135	1172	1156	16	1.4
		4	1175	1178	1173	5	0.4
	2	1	1042	1085	1100	15	1.4
		2	1139	1096	1116	20	1.9
		3	1069	1105	1133	28	2.6
		4	1101	1111	1150	39	3.5
	3	1	982	1040	1021	19	1.9
		2	1075	1051	1038	13	1.2
		3	1025	1060	1055	5	0.4
		4	1057	1067	1072	5	0.4
4	1	1	1247	1257	1229	28	2.2
		2	1225	1269	1246	23	1.8
		3	1292	1277	1262	15	1.1
		4	1286	1284	1279	5	0.3
	2	1	1226	1190	1205	15	1.2
		2	1190	1202	1222	20	1.6
		3	1283	1210	1239	29	2.2
		4	1258	1217	1256	39	3.1
	3	1	1154	1145	1127	18	1.5
		2	1109	1157	1144	13	1.1
		3	1204	1165	1160	5	0.4
		4	1174	1172	1177	5	0.4
						Average % difference	1.6%

Table 6.5 Left-sided movement, comparison between linear regression models 3 and 4.

CHAPTER VII

CONCLUSIONS AND SUGGESTIONS FOR FURTHER STUDY

In this study, a combined decision and positioning task was investigated under laboratory conditions. The informational load was varied between one to four bits, lateral clearance for positioning between 0.008 inch to 0.25 inch, and distance of move between seven inches to sixteen inches. The task was discrete in nature and repetitive. The decision element in the task involved only resolving uncertainty in choosing among alternative responses which occurred with equal probability. From the analysis of the experimental data collected, the following conclusions can be made with respect to such a task within the limitations of the experimental conditions.

1. There is no significant difference in performance times between male and female operators in the task ($p>0.05$).
2. Information load is a highly significant factor in the total performance time of such a task. Performance time increases linearly and sharply accross the range of two to four bits of Informational Load.
3. Both clearance and distance of move are significant factors affecting performance time. Performance time decreases as clearance increases and increases as distance increases.

4. Positioning times into holes on the left side of the equipment is significantly different from those on the right side although the actual angular difference between the movements is 24 degrees at the maximum.

5. The index of difficulty I as defined by Fitts and Paterson (1964):

$$I = \log_2(2D/C)$$

where D = distance of movement

C = lateral clearance of positioning

is found to be a significant factor in affecting performance time.

6. The use of the index of difficulty (I) in a prediction model for the performance time of such a task is comparable with one using separate clearance and distance factors. Use of 'I' is recommended here for the following reasons:-

a) it is simpler in practical applications such as in establishing standard performance times when only one parameter needs to be specified.

b) the model automatically accommodates any changes in motion strategy when different distance-ranges are inherent in performing the task. (See Appendix F).

As part of the conclusion, two prediction models are presented here for further verification and investigation. Their practical significance is certainly subjected to the limitations of the experimental conditions in the study.

For the right-sided movement:

$$\text{Performance Time (ms)} = 523.72 + 102.60H + 25.08I$$

For the left-sided movement:

$$\text{Performance time (ms)} = 592.34 + 105.90H + 22.36I$$

where H = informational load in bits

I* = index of difficulty in ibits

Suggestions for Further Studies:

1. Verification of the prediction model proposed is needed by further studies before it can be applied to determine standard performance times of similar industrial tasks.
2. The use of I as a parameter in other combined decision and manual tasks needs to be explored.
3. The task in the present study is one of information conserving where there is a 1:1 mapping of stimulus and response. Information reduction and information creation tasks need to be further investigated.
4. The probability of occurrence of the alternatives in the present task follows a uniform distribution. The case where different distributions govern the occurrence of the alternatives has not yet been studied.

* unit defined in Chapter Four

Appendix A

Equipment Layout

1. Schematic Representation of the Stimulus-Response Unit.

2. Pictorial View of the equipment Layout.

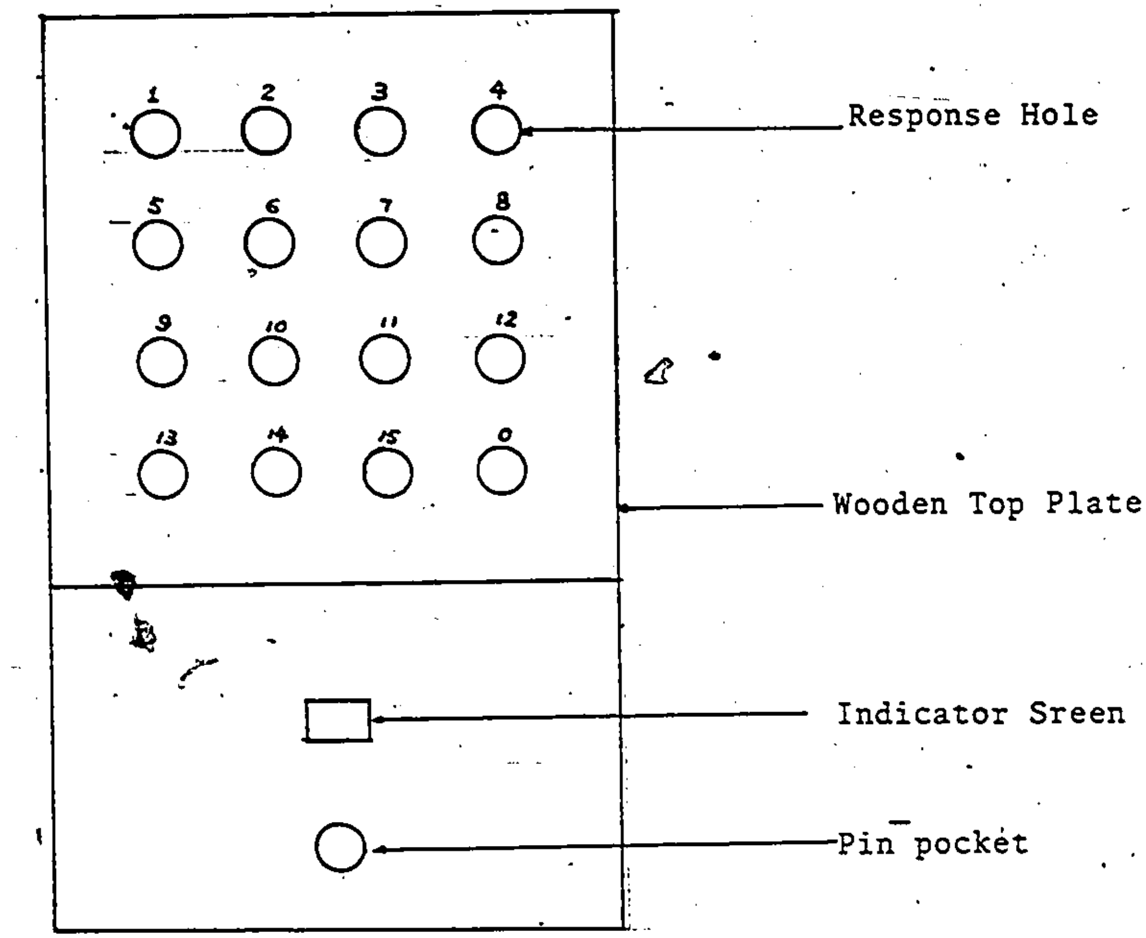


Figure A.1 Top View - S-R Unit

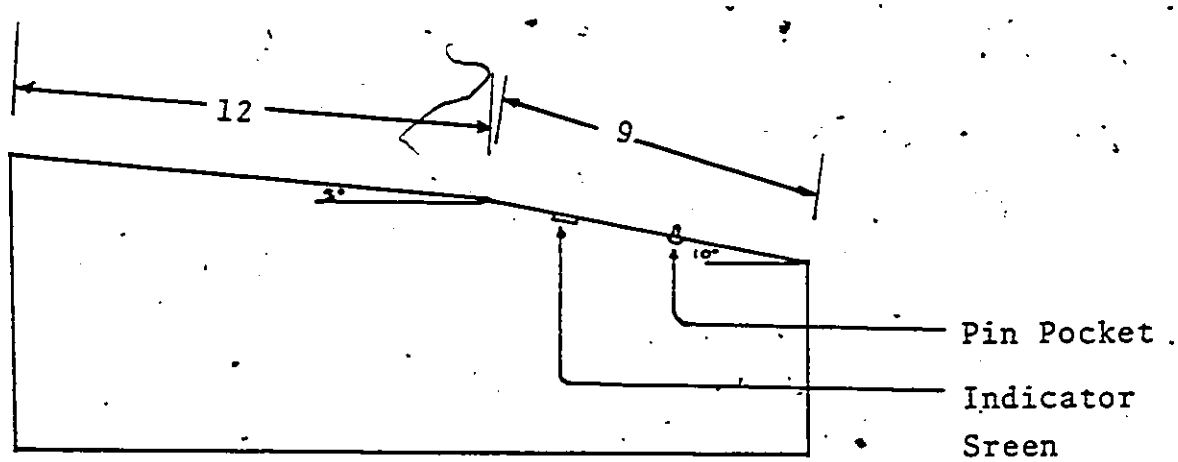


Figure A.2 Side View - S-R Unit

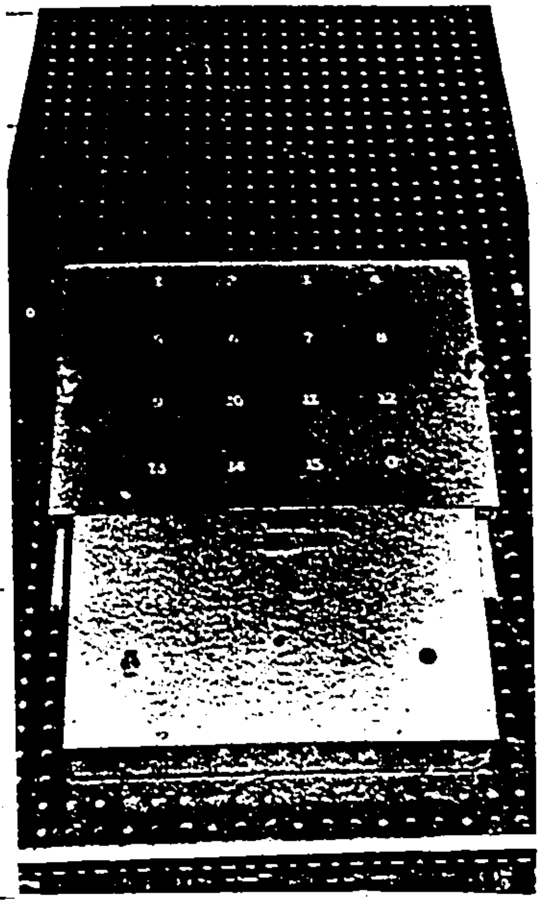


Fig. A.3 Signal-Response Unit

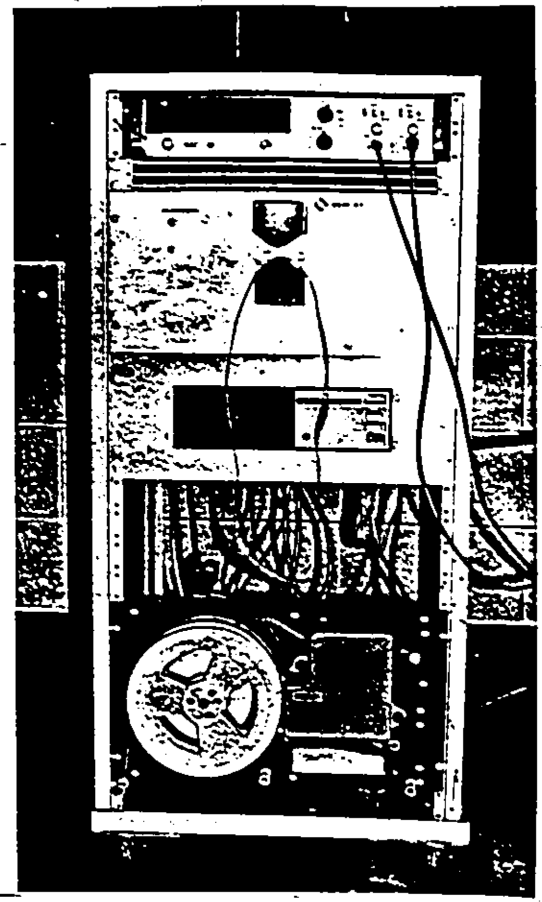


Fig. A.4 Tape-Reader, Time Measuring, and Recording Units.

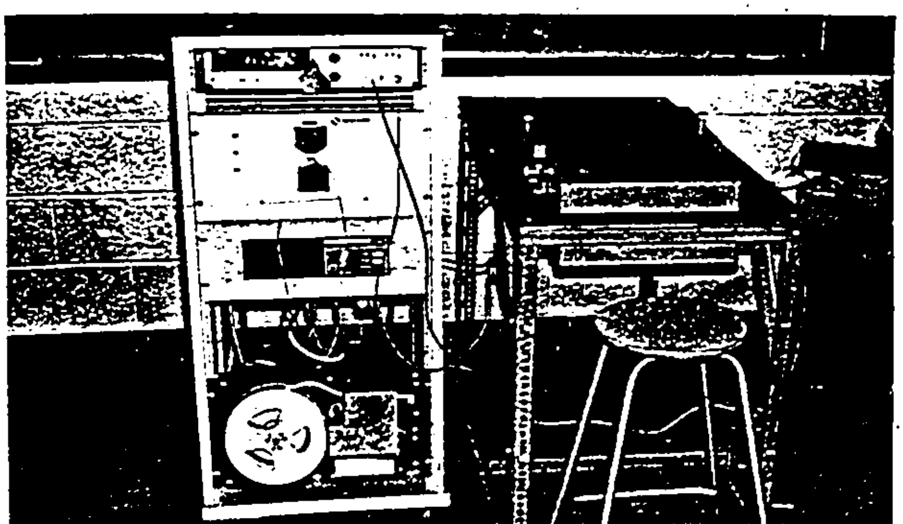


Fig. A.5 Equipment Layout.

Appendix B

Experimental Conditions and Procedure

1. Schematic Layout of Stimulus-Sets in Multiple-Alternatives Tasks.

2. Durations of Experimental Runs and Rest Periods.

H = 1 bit

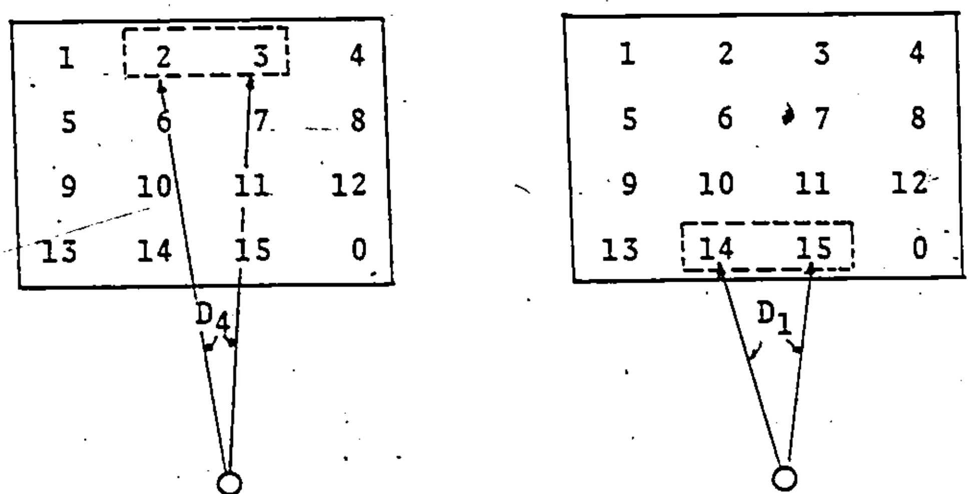


Figure B.1 Schematic Layout of Stimulus-sets in the Two-hole-alternatives Tasks.

H = 2 bits

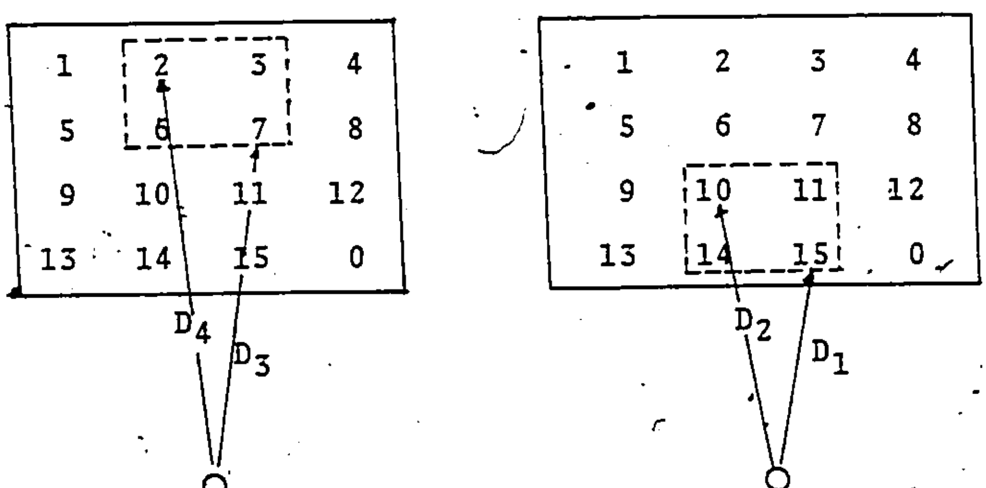


Figure B.2 Schematic Layout of Stimulus-sets in the Four-hole-alternatives Tasks.

H = 3 bits

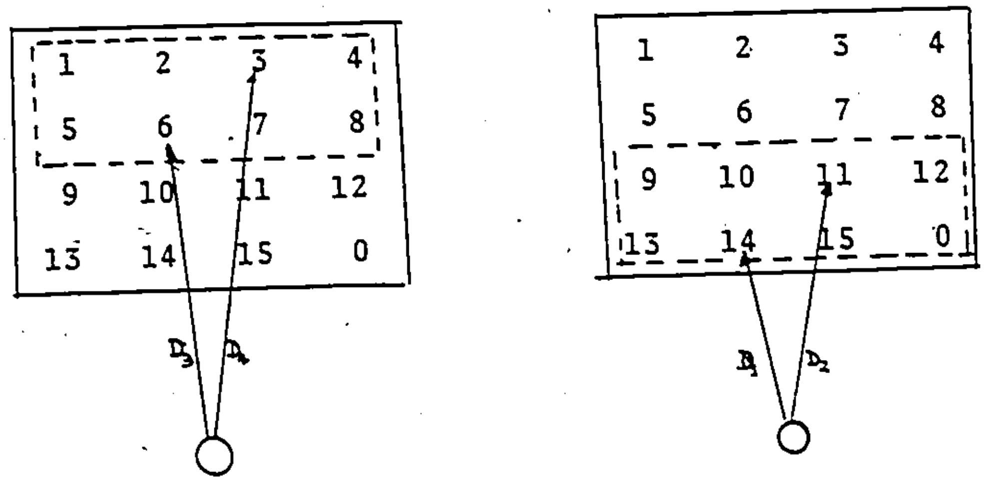


Figure B.3 Schematic Layout of Stimulus-sets in the Eight-hole-alternatives Tasks.

H = 4 bits

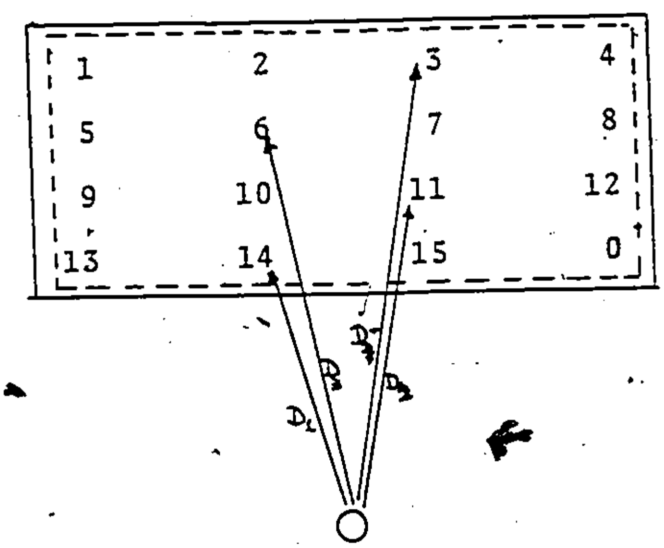


Figure B.4 Schematic Layout of stimulus-sets in the Sixteen-hole-alternatives Tasks.

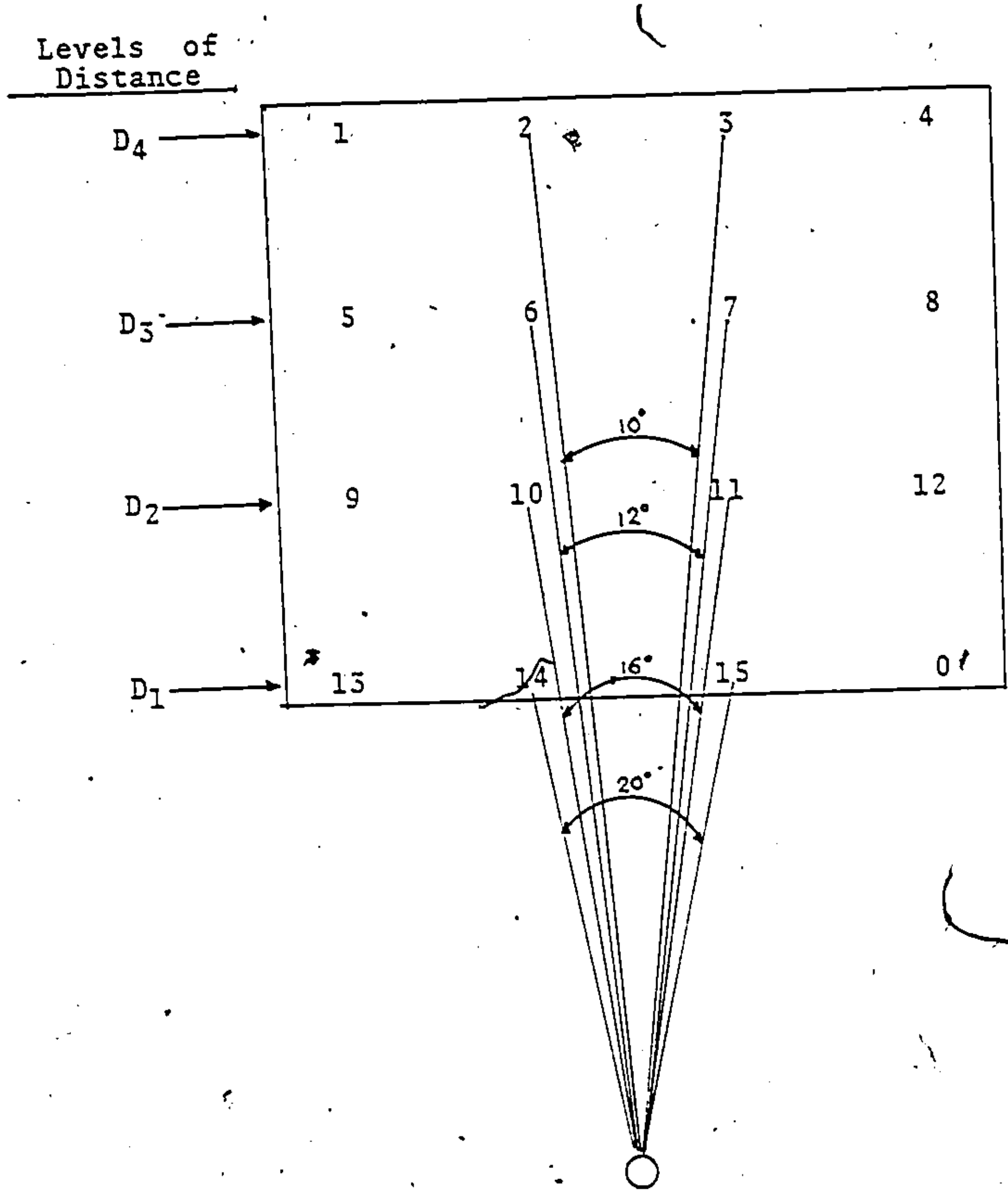


Figure B.5 Schematic Layout of the Angular Differences of Movement at each Distance tested.

Durations of Experimental Runs and Rest Periods

The approximate duration of each experimental run was planned keeping in mind the following conditions:

1. Each stimulus alternative in the experimental run occurred with equal probability.
2. When fully learned, the cycle time for the task converged to a narrow range around 0.045 minute irrespective of experimental conditions (see Appendix C).

Depending on the number of hole-alternatives in the task, a time limit was designed to collect about thirty performance times for each relevant response holes. Minimum rest period after each run was also planned accordingly and is shown below:

Number of Response holes (n)	Experimental Run-time (min.)	Rest Period After run (min.)
2	3	1
4	6	3
8	12	7
16	24	15

Table B.1 Experimental Run-times and Rest Periods.

Appendix C

Analysis of Learning Behavior

As part of the Pilot Study, three subjects performed the sixteen-hole-alternatives task with C_1 level of clearance. The tape was prepared such that the hole pattern occurred in sets of sixteen numbers within which each hole number occurred only once and the order of the numbers were randomised within each set. This feature allowed a practice-trial to be defined in this learning experiment in terms of the sets of sixteen task-cycles. A subject performed about 85 trials consisting of over 1300 task-cycles. The aggregate means and the standard deviations of the performance times within each set were plotted against trial sequence and are shown in Figure C.1.1 to Figure C.1.3 and Figure C.2.1 to Figure C.2.3 respectively.

From the scatter plots, it is seen that the subjects had learned the task fully in less than 1200 practice cycles. The above findings were supported by the observations made during the experiment at about the 1000th cycle,

1 the subject's hand motion which was irregular initially now became well defined from cycle to cycle. Hand-searching for the response hole was eliminated.

2. a pattern was established in which the subject moved his hand back to the pin-pocket area at a definite speed, and then waited to grasp the pin as it surfaced. The cycle of motion takes about 0.045 minute to complete which was a factor dependent solely on the movement cycle of the pin-conveyor system.

To ensure that the data of the main study were obtained while the subjects had attained fully learned state, best fit lines were fitted to the selected twenty data points of each experimental condition from the main study. It was found that less than 5% of all the regression lines had slopes significantly different from zero at the 5% level.

Histograms of the experimental conditions as in Appendix G also show that the distributions are in most cases normal by the X^2-square test.

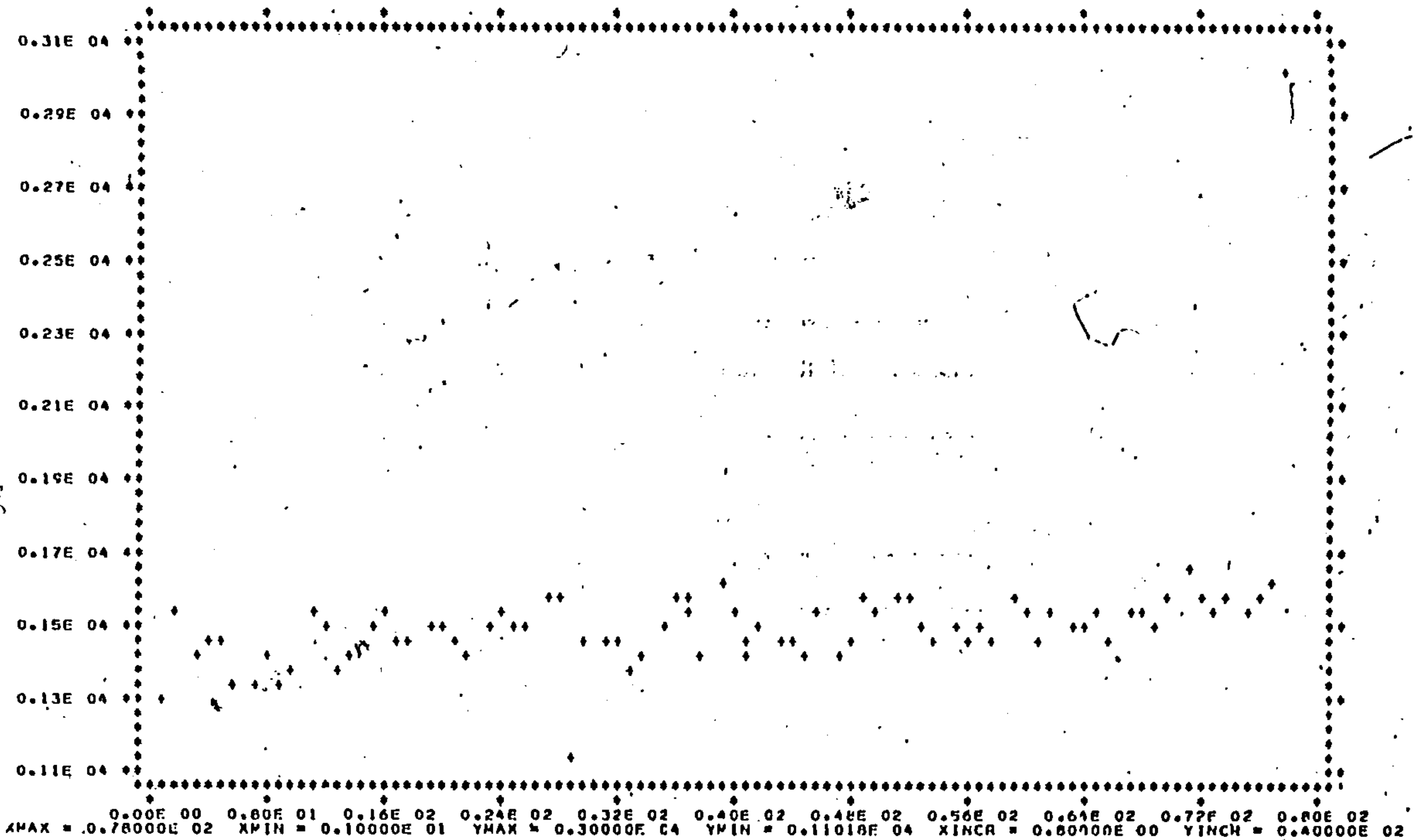


Fig. C.1.1 Mean Performance Time Vs Trial Sequence for Subject Z.E.

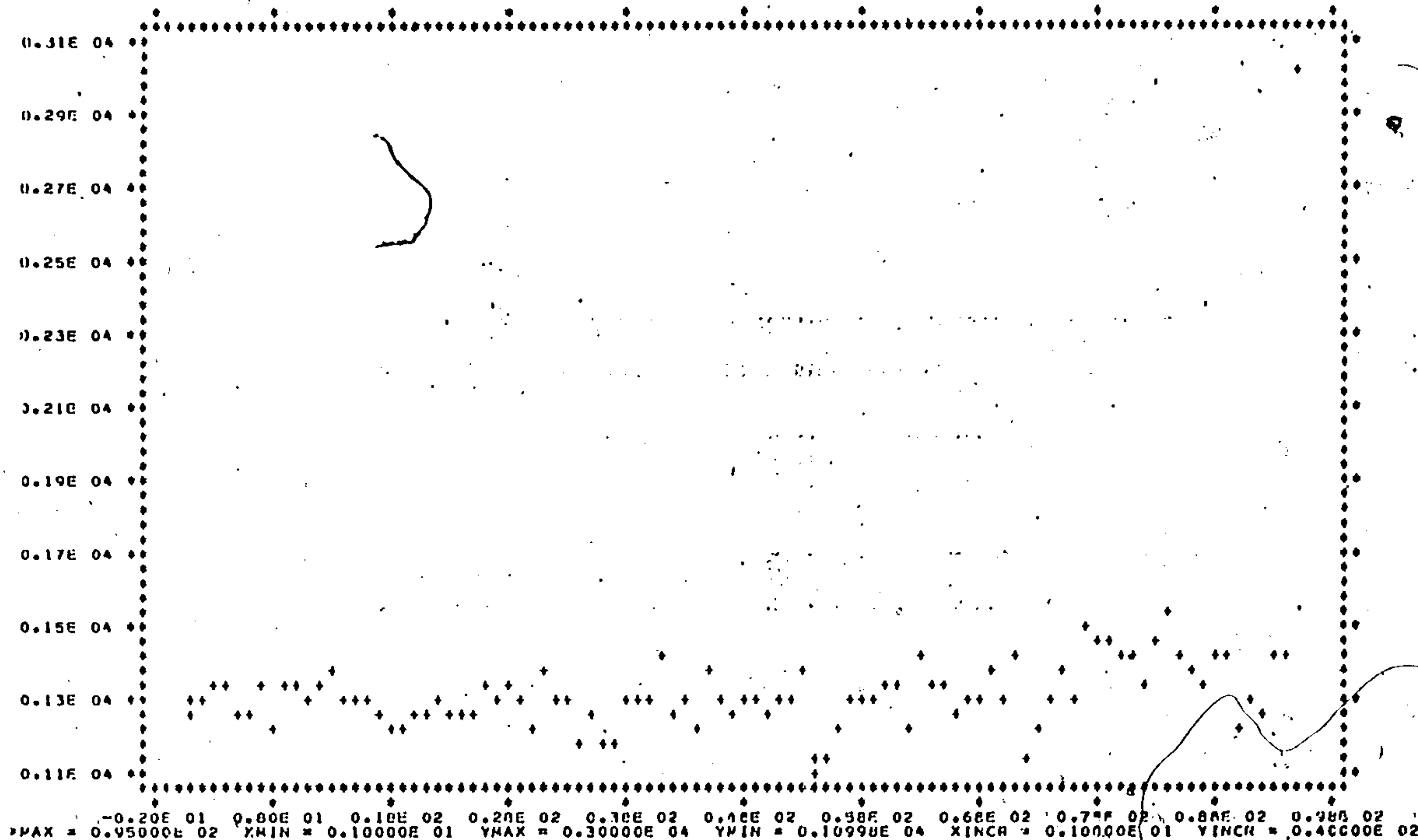


Fig. C.1.2 Mean Performance Time Vs Trial Sequence for Subject T.P.

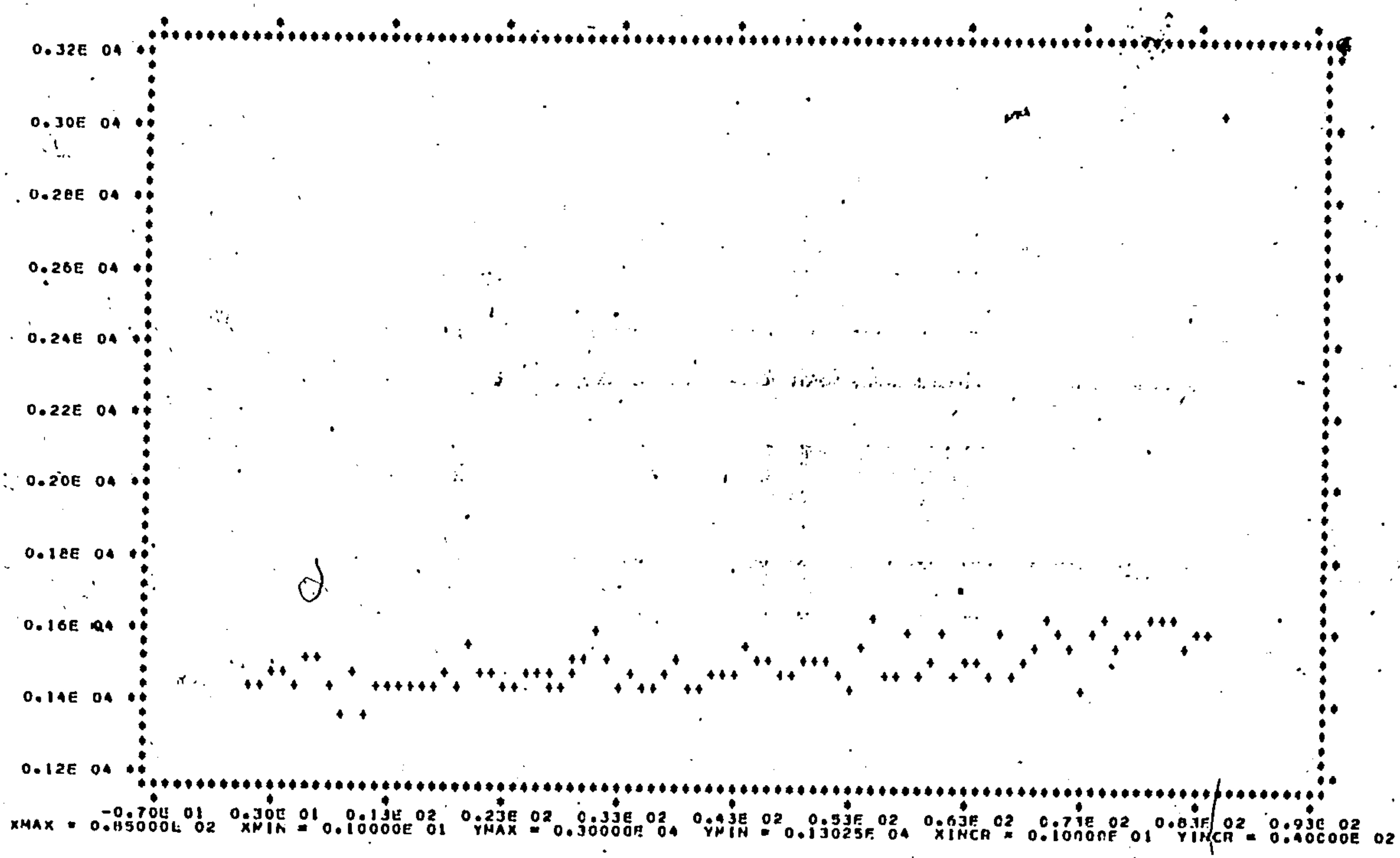


Fig. C.1.3 Mean Performance Time Vs Trial Sequence for Subject A.M.

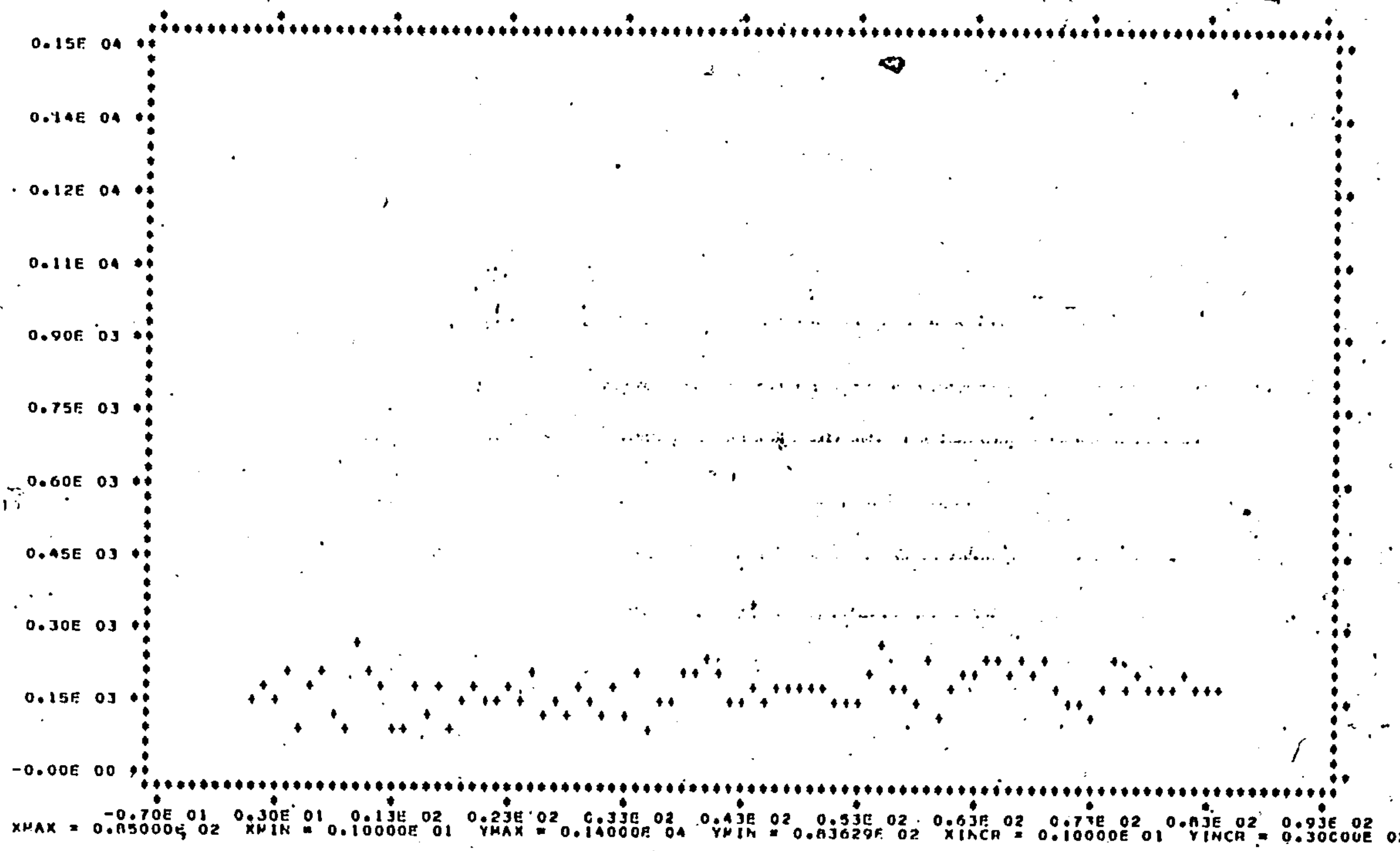


Fig. C.2.1 Standard Deviations of Practice-Trial Vs Trial Sequence for Subject A.M.

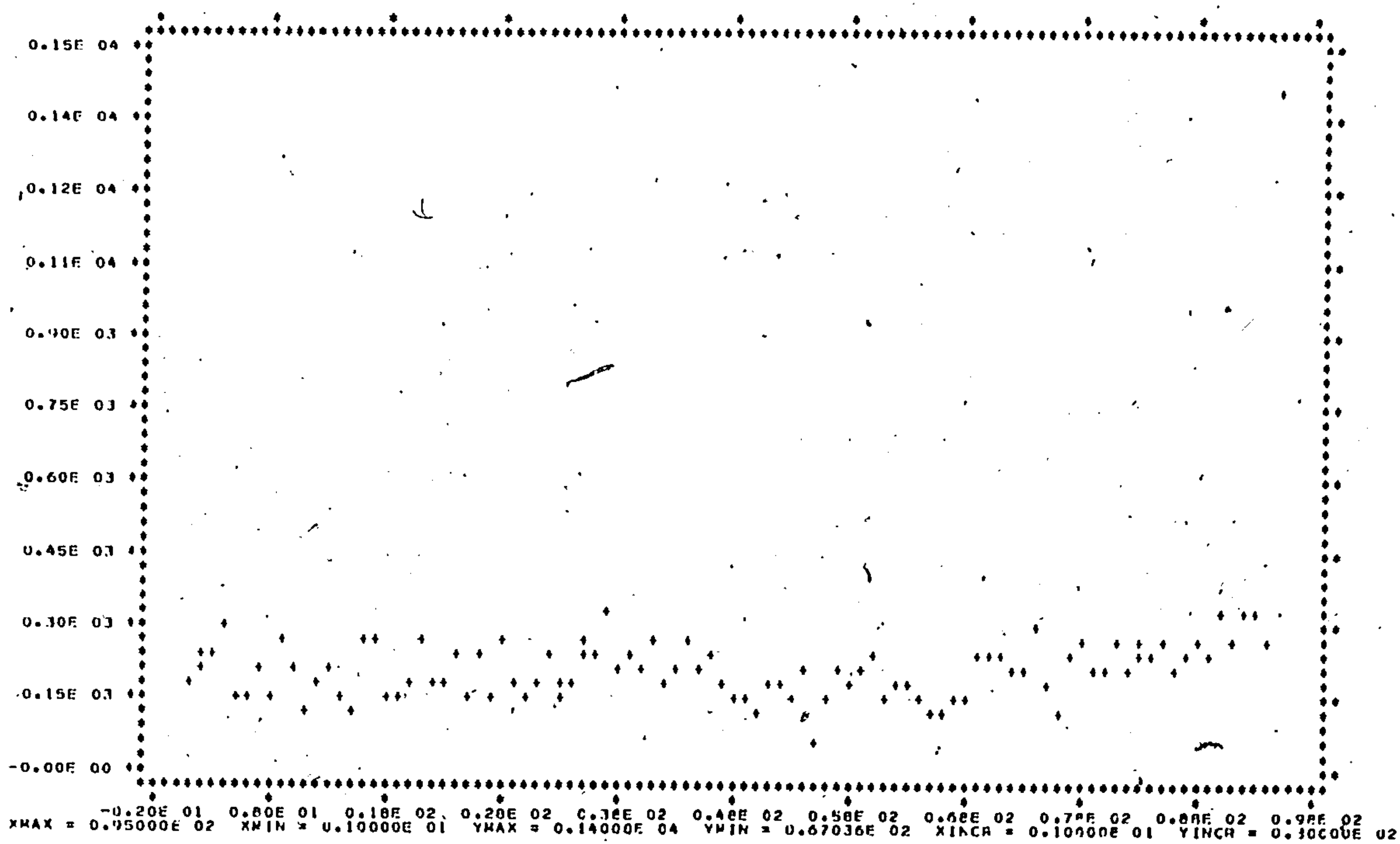


Fig. C.2.2 Standard Deviations of Practice-Trial Vs Trial Sequence for Subject T.P.

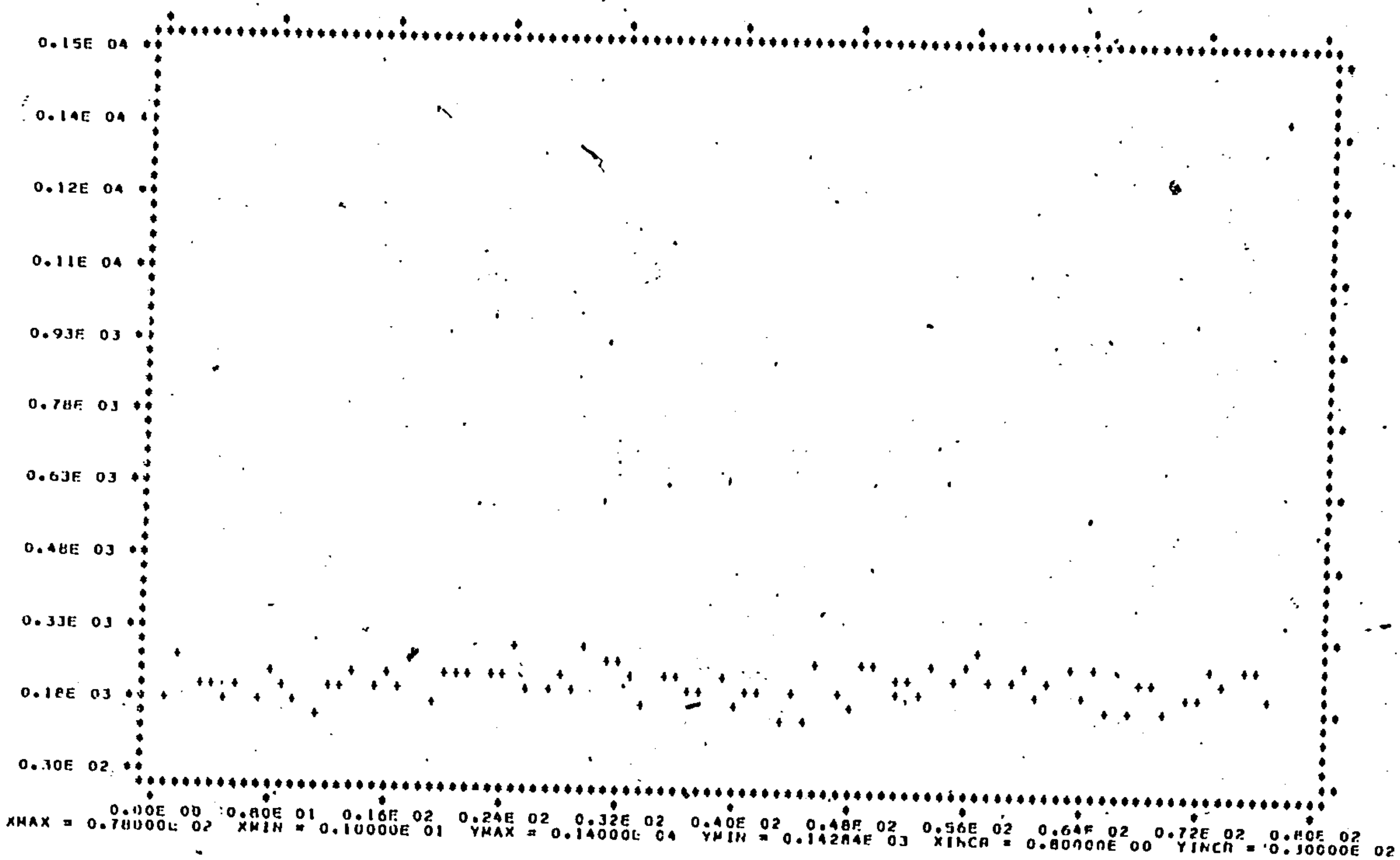


Fig. C.2.3 Standard Deviations of Practice Trial Vs Trial Sequence for Subject Z.E.

APPENDIX D

1. Tables of EMS Values
2. ANOVA Tables
3. Test of Means
4. Computations - Component Variances of Main Effects
5. Graphical Representation of Results

Tables of EMS Values

To determine the proper denominator in the F-test and to calculate variance components, EMS values of main effects as well as interaction terms were established (Hicks, 1973). Calculations of these EMS values are shown in the following tables.

Part 1 models:

Table D.1.1 EMS Values; Nested Mixed Model, Main Effects at Distance D_1 and D_4.

Effect	Symbol	Level	Type
Informational Load	H_i	4	Fixed
Clearance	C_j	3	Fixed
Subject	$S_{l(m)}$	10	Random
Sex	X_m	2	Fixed
Residual	$R_{n(ijklm)}$	20	Random

(contd.....)

Source	4 F i	3 F j	10 R l	2 F m	20 R n	EMS
H_i	0	3	10	2	20	$\sigma_R^2 + 60\sigma_{SH}^2 + 1200\phi_H$
C_j	4	0	10	2	20	$\sigma_R^2 + 80\sigma_{SC}^2 + 1600\phi_C$
X_m	4	3	10	0	20	$\sigma_R^2 + 240\sigma_S^2 + 2400\phi_X$
$S_{l(m)}$	4	3	1	1	20	$\sigma_R^2 + 240\sigma_S^2$
$H \times C_{ij}$	0	0	10	2	20	$\sigma_R^2 + 20\sigma_{SHC}^2 + 400\phi_{HC}$
$H \times X_{im}$	0	3	10	2	20	$\sigma_R^2 + 60\sigma_{HC}^2 + 600\phi_{HX}$
$H \times S_{il(m)}$	0	3	1	1	20	$\sigma_R^2 + 60\sigma_{HS}^2$
$C \times X_{jm}$	4	0	10	0	20	$\sigma_R^2 + 80\sigma_{CS}^2 + 800\phi_{CX}$
$C \times S_{jl(m)}$	4	0	1	1	20	$\sigma_R^2 + 80\sigma_{CS}^2$
$S \times H \times C_{ijl(m)}$	0	0	1	1	20	$\sigma_R^2 + 20\sigma_{SHC}^2$
$R_{n(ijlm)}$	1	1	1	1	1	σ_R^2

Table D.1.2 EMS Values; Nested Mixed Model, Main Effects at Distance D_2 and D_3.

Effects	Symbol	Levels	Type
Informational Load	H_i	3	Fixed
Clearance	C_j	3	Fixed
Subject	$S_{l(m)}$	10	Random
Sex	X_m	2	Fixed
Residual	$R_{n(ijlm)}$	20	Random

Source	3 F i	3 F j	10 R l	2 F m	20 R n	EMS
H_i	0	3	10	2	20	$\sigma_R^2 + 60\sigma_{SH}^2 + 1200\phi_H$
C_j	3	0	10	2	20	$\sigma_R^2 + 60\sigma_{SC}^2 + 1200\phi_C$
X_m	3	3	10	0	20	$\sigma_R^2 + 180\sigma_S^2 + 1800\phi_X$
$S_{l(m)}$	3	3	1	1	20	$\sigma_R^2 + 180\sigma_S^2$
$H \times C_{ij}$	0	0	10	2	20	$\sigma_R^2 + 20\sigma_{SHC}^2 + 400\phi_{AC}$
$H \times X_{im}$	0	3	10	0	20	$\sigma_R^2 + 60\sigma_{HS}^2 + 600\phi_{HX}$
$H \times S_{il(m)}$	0	3	1	1	20	$\sigma_R^2 + 60\sigma_{HS}^2$
$C \times X_{jm}$	3	0	10	0	20	$\sigma_R^2 + 60\sigma_{CS}^2 + 600\phi_{CX}$
$C \times S_{jl(m)}$	3	0	1	1	20	$\sigma_R^2 + 60\sigma_{CS}^2$
$SxHxC_{ijl(m)}$	0	0	1	1	20	$\sigma_R^2 + 20\sigma_{SHC}^2$
$R_{n(ijlm)}$	1	1	1	1	1	σ_R^2

Table D.1.3 EMS Values; Nested Mixed Model, Angular Effect at Distance $D_1=7''$ and $D_4=16''$

Effects	Symbol	Levels	Type
Angle	A_i	2	Fixed
Informational Load	H_j	4	Fixed
Clearance	C_k	3	Fixed
Subject	$S_{1(m)}$	10	Random
Sex	X_m	2	Fixed
Residual	$R_{p(ijklm)}$	20	Random

(to be continued, PTO.)

Source	F 2 i	F 4 j	F 3 k	R 10 l	F 2 m	R 20 p	E.M.S.
A_i	0	4	3	10	2	20	$\sigma_R^2 + 240\ \sigma_{SA}^2 + 4800\phi_A$
H_j	2	0	3	10	2	20	$\sigma_R^2 + 120\ \sigma_{SH}^2 + 2400\phi_H$
C_k	2	4	0	10	2	20	$\sigma_R^2 + 160\ \sigma_{SC}^2 + 3200\phi_C$
$S_{l(m)}$	2	4	3	1	1	20	$\sigma_R^2 + 480\ \sigma_S^2$
X_m	2	4	3	10	0	20	$\sigma_R^2 + 480\ \sigma_S^2 + 4800\phi_X$
$A \times H_{ij}$	0	0	3	10	2	20	$\sigma_R^2 + 60\ \sigma_{SAH}^2 + 1200\phi_{AH}$
$A \times C_{ik}$	0	4	0	10	2	20	$\sigma_R^2 + 80\ \sigma_{SAC}^2 + 1600\phi_{AC}$
$H \times C_{jk}$	3	0	0	10	2	20	$\sigma_R^2 + 40\ \sigma_{SHC}^2 + 1200\phi_{HC}$
$A \times X_{im}$	0	4	3	10	0	20	$\sigma_R^2 + 240\ \sigma_{SA}^2 + 2400\phi_{XA}$
$H \times X_{jm}$	2	0	3	10	0	20	$\sigma_R^2 + 120\ \sigma_{SH}^2 + 1200\phi_{XH}$
$C \times X_{km}$	2	4	0	10	0	20	$\sigma_R^2 + 160\ \sigma_{SC}^2 + 1600\phi_{XC}$
$S \times A_{il(m)}$	0	4	3	1	1	20	$\sigma_R^2 + 240\ \sigma_{SA}^2$
$S \times H_{jl(m)}$	2	0	3	1	1	20	$\sigma_R^2 + 120\ \sigma_{SH}^2$
$S \times C_{kl(m)}$	2	4	0	1	1	20	$\sigma_R^2 + 160\ \sigma_{SC}^2$
$S \times A \times H_{ijl(m)}$	0	0	3	1	1	20	$\sigma_R^2 + 60\ \sigma_{SAH}^2$
$S \times A \times C_{ikl(m)}$	0	4	0	1	1	20	$\sigma_R^2 + 80\ \sigma_{SAC}^2$
$S \times H \times C_{jkl(m)}$	2	0	0	1	1	20	$\sigma_R^2 + 40\ \sigma_{SHC}^2$
$R_{p(ijklm)}$	1	1	1	1	1	1	σ_R^2

Table D.1.4 EMS Values; Nested Mixed Model, Angular Effect at Distance D_2=10" and D_3=13"

Effects	Symbol	Levels	Type
Angle	A_i	2	Fixed
Informational Load	H_j	3	Fixed
Clearance	C_k	3	Fixed
Subject	$S_{l(m)}$	10	Random
Sex	X_m	2	Fixed
Residual	$R_{p(ijklm)}$	20	Random

(to be continued, PTO)

Source	F 2 i	F 3 j	F 3 k	R 10 l	F 2 m	R 20 p	EMS
A_i	0	3	3	10	2	20	$\sigma_R^2 + 180\ \sigma_{SA}^2 + 3600\ \phi_A$
H_j	2	0	3	10	2	20	$\sigma_R^2 + 120\ \sigma_{SH}^2 + 2400\ \phi_H$
C_k	2	3	0	10	2	20	$\sigma_R^2 + 120\ \sigma_{SC}^2 + 2400\ \phi_C$
$S_{l(m)}$	2	3	3	1	1	20	$\sigma_R^2 + 360\ \sigma_S^2$
X_m	2	3	3	10	0	20	$\sigma_R^2 + 360\ \sigma_S^2 + 3600\ \phi_X$
$A \times H_{ij}$	0	0	3	10	2	20	$\sigma_R^2 + 60\ \sigma_{SAH}^2 + 1200\ \phi_{AH}$
$A \times C_{ik}$	0	3	0	10	2	20	$\sigma_R^2 + 60\ \sigma_{SAC}^2 + 1200\ \phi_{AC}$
$H \times C_{jk}$	3	0	0	10	2	20	$\sigma_R^2 + 40\ \sigma_{SHC}^2 + 1200\ \phi_{HC}$
$A \times X_{im}$	0	3	3	10	0	20	$\sigma_R^2 + 180\ \sigma_{SA}^2 + 1800\ \phi_{XA}$
$H \times X_{jm}$	2	0	3	10	0	20	$\sigma_R^2 + 120\ \sigma_{SH}^2 + 1200\ \phi_{XH}$
$C \times X_{km}$	2	3	0	10	0	20	$\sigma_R^2 + 120\ \sigma_{SC}^2 + 1200\ \phi_{XC}$
$S \times A_{il(m)}$	0	3	3	1	1	20	$\sigma_R^2 + 180\ \sigma_{SA}^2$
$S \times H_{jl(m)}$	2	0	3	1	1	20	$\sigma_R^2 + 120\ \sigma_{SH}^2$
$S \times C_{kl(m)}$	2	3	0	1	1	20	$\sigma_R^2 + 120\ \sigma_{SC}^2$
$S \times A \times H_{ijl(m)}$	0	0	3	1	1	20	$\sigma_R^2 + 60\ \sigma_{SAH}^2$
$S \times A \times C_{ikl(m)}$	0	3	0	1	1	20	$\sigma_R^2 + 60\ \sigma_{SAC}^2$
$S \times H \times C_{jkl(m)}$	2	0	0	1	1	20	$\sigma_R^2 + 40\ \sigma_{SHC}^2$
$R_{p(ijklm)}$	1	1	1	1	1	1	σ_R^2

Part 2 model:

Table D.1.5 EMS Values; Nested Mixed Model, Distance and Clearance as Separate Factors.

Effects	Symbol	Levels	Type
Informational Load	H_i	3	Fixed
Clearance	C_j	3	Fixed
Distance	D_k	4	Fixed
Subject	$S_{1(m)}$	10	Fixed
Sex	X_m	2	Fixed
Residual	$R_{p(ijklm)}$	20	Random

(to be continued)

Source	3 F i	3 F j	4 F k	10 R l	2 F m	20 R n	E M S
H_i	0	3	4	10	2	20	$\sigma_R^2 + 240\ \sigma_{SH}^2 + 4800\phi_H$
C_j	3	0	4	10	2	20	$\sigma_R^2 + 240\ \sigma_{SC}^2 + 4800\phi_C$
D_k	3	3	0	10	2	20	$\sigma_R^2 + 180\ \sigma_{SD}^2 + 3600\phi_D$
X_m	3	3	4	10	0	20	$\sigma_R^2 + 720\ \sigma_S^2 + 7200\phi_X$
$S_{l(m)}$	3	3	4	1	1	20	$\sigma_R^2 + 720\ \sigma_S^2$
$H \times C_{ij}$	0	0	4	10	2	20	$\sigma_R^2 + 80\ \sigma_{SHC}^2 + 1600\phi_{HC}$
$H \times D_{ik}$	0	3	0	10	2	20	$\sigma_R^2 + 60\ \sigma_{SHD}^2 + 1200\phi_{DH}$
$H \times X_{im}$	0	3	4	10	0	20	$\sigma_R^2 + 240\ \sigma_{HS}^2 + 2400\phi_{HX}$
$H \times S_{il(m)}$	0	3	4	1	1	20	$\sigma_R^2 + 240\ \sigma_{HS}^2$
$C \times D_{ik}$	0	3	0	10	2	20	$\sigma_R^2 + 60\ \sigma_{SDC}^2 + 1200\phi_{CD}$
$C \times X_{jm}$	3	0	4	10	0	20	$\sigma_R^2 + 240\ \sigma_{CS}^2 + 2400\phi_{CX}$
$C \times S_{jl(m)}$	3	0	4	1	1	20	$\sigma_R^2 + 240\ \sigma_{CS}^2$
$D \times X_{km}$	3	3	0	10	0	20	$\sigma_R^2 + 180\ \sigma_{SD}^2 + 1800\phi_{DX}$
$D \times S_{kl(m)}$	3	3	0	1	1	20	$\sigma_R^2 + 180\ \sigma_{DS}^2$
$S \times H \times C_{ijl(m)}$	0	0	4	1	1	20	$\sigma_R^2 + 80\ \sigma_{SHC}^2$
$S \times C \times D_{jkl(m)}$	3	0	0	1	1	20	$\sigma_R^2 + 60\ \sigma_{SCD}^2$
$S \times H \times D_{ikl(m)}$	0	3	0	1	1	20	$\sigma_R^2 + 60\ \sigma_{SHD}^2$
$R_{n(ijklm)}$	1	1	1	1	1	1	σ_R^2

Table D.1.6 EMS Values; Nested Mixed Model, Distance and Clearance Combined in Index of Difficulty.

Effects	Symbol	Levels	Type
Informational Load	H_i	3	Fixed
Index of Difficulty	I_j	12	Fixed
Subject -	$S_{k(1)}$	10	Random
Sex	X_1	2	Fixed
Residual	R_m	20	Random

Source	3 F i	12 F j	10 R k	2 F 1	20 R m	E M S
H_i	0	12	10	2	20	$\sigma_R^2 + 240\ \sigma_{SH}^2 + 4800\ \phi_H$
I_j	3	0	10	2	20	$\sigma_R^2 + 60\ \sigma_{SI}^2 + 1200\ \phi_I$
$H \times I_{ij}$	0	0	10	2	20	$\sigma_R^2 + 20\ \sigma_{SHI}^2 + 400\ \phi_{HI}$
$S_{k(1)}$	3	12	1	1	20	$\sigma_R^2 + 720\ \sigma_S^2$
$S \times H_{ik(1)}$	0	12	1	1	20	$\sigma_R^2 + 240\ \sigma_{SH}^2$
$S \times I_{jk(1)}$	3	0	1	1	20	$\sigma_R^2 + 60\ \sigma_{SI}^2$
$S \times H \times I_{ijk(1)}$	0	0	1	1	20	$\sigma_R^2 + 20\ \sigma_{SHI}^2$
X_1	3	12	10	0	20	$\sigma_R^2 + 720\ \sigma_S^2 + 7200\ \phi_X$
$H \times X_{i1}$	0	12	10	0	20	$\sigma_R^2 + 240\ \sigma_{SH}^2 + 2400\ \phi_{HX}$
$I \times X_{j1}$	3	0	10	0	20	$\sigma_R^2 + 60\ \sigma_{SI}^2 + 600\ \phi_{IX}$
$R_{m(ijk1)}$	1	1	1	1	1	σ_R^2

ANOVA Tables

Table D.2.0	ANOVA of Performance Times for the Pilot Study.
Table D.2.1-D.2.8	ANOVA of Performance Times for the Part 1 Models at individual distances and directions of movement.
Tables D.2.9-D.2.12	ANOVA of Performance Times for the Part 1 Models at individual distances showing the effect due to right-sided versus left-sided movements.
Tables D.2.13-D.2.14	ANOVA of Performance Times for the Part 2 Models wherein clearance and distance are considered as separate factors.
Tables D.2.15-D.2.16	ANOVA of Performance Times for the Part 2 Models wherein Index of Difficulty I replaces C and D.

Table D.2.0 ANOVA of Performance Times, Pilot Study

Source	d.f.	M.S.	F-Value	E.M.S.	Prob>F	Findings at 5% level
S	2	511717.40	65.09	$\sigma_R^2 + 180\ \sigma_S^2$	0.0001	Significant
C	2	749820.30	176.90	$\sigma_R^2 + 60\ \sigma_{SC}^2 + 120\phi_C$	0.0001	Significant
SxC	4	4237.09	0.54	$\sigma_R^2 + 60\ \sigma_{SC}^2$	0.7259	Not significant
D	1	2663950.34	5.999	$\sigma_R^2 + 90\ \sigma_{SD}^2 + 180\phi_D$	0.0027	Significant
SxD	2	444040.08	56.48	$\sigma_R^2 + 90\ \sigma_{SD}^2$	0.0001	Significant
CxD	2	32024.80	1.09	$\sigma_R^2 + 30\sigma_{SDC}^2 + \phi_{CD}$	0.4351	Not significant
SxDxC	4	29115.37	3.70	$\sigma_R^2 + 30\ \sigma_{SDC}^2$		
R	522	7861.30		σ_R^2		

Table D.2.1 ANOVA of Performance Times ; D_1= 7" ; Right-sided Movement.

Source	d.f.	M.S.	F-Value	E M S	Prob>F	Findings at 5% Level
H	3	13416658.4	124.873	$\sigma_R^2 + 60\sigma_{SH}^2 + 1200\phi_H$	0.0001	Significant
C	2	5933177.7	53.837	$\sigma_R^2 + 80\sigma_{SC}^2 + 1600\phi_C$	0.0001	Significant
X	1	104546.4	0.087	$\sigma_R^2 + 240\sigma_S^2 + 2400\phi X$	0.7692	Not Significant
HxC	6	37694.6	0.553	$\sigma_R^2 + 20\sigma_{SHC}^2 + 400\phi_{HC}$	0.7683	Not Significant
HxX	3	76976.4	0.063	$\sigma_R^2 + 60\phi_{HX}$	0.9779	Not Significant
CxX	2	5337.5	0.048	$\sigma_R^2 + 80\sigma_{CS}^2 + 800\phi_{CX}$	0.9530	Not Significant
S	18	1213352.7		$\sigma_R^2 + 240\sigma_S^2$		
HxS	54	107442.8		$\sigma_R^2 + 60\sigma_{HS}^2$		
CxS	36	110206.2		$\sigma_R^2 + 80\sigma_{CS}^2$		
SxHxC	108	68132.4		$\sigma_R^2 + 20\sigma_{SHC}^2$		
R	4560	21868.7		σ_R^2		

Table D.2.2 ANOVA of Performance Times; $D_2 = 10''$; Right-sided Movement.

Source	d.f.	M.S.	F-Value	E M S	Prob>F	Findings at 5% Level
H	2	8265963.1	91.967	$\sigma_R^2 + 60\sigma_{SH}^2 + 1200\phi_H$	0.0001	Significant
C	2	2667147.4	37.777	$\sigma_R^2 + 60\sigma_{SC}^2 + 1200\phi_C$	0.0001	Significant
X	1	651157.5	0.561	$\sigma_R^2 + 180\sigma_S^2 + 1800\phi_X$	0.5302	Not Significant
HxC	4	115079.7	1.631	$\sigma_R^2 + 20\sigma_{SHC}^2 + 400\phi_{AC}$	0.1748	Not Significant
HxX	2	77697.7	0.670	$\sigma_R^2 + 60\sigma_{HS}^2 + 600\phi_{HX}$	0.9352	Not Significant
CxX	2	30961.9	0.439	$\sigma_R^2 + 60\sigma_{CS}^2 + 600\phi_{CX}$	0.6539	Not Significant
S	18	1161239.3		$\sigma_R^2 + 240\sigma_S^2$		
HxS	36	89879.3		$\sigma_R^2 + 60\sigma_{HS}^2$		
CxS	36	70603.2		$\sigma_R^2 + 60\sigma_{CS}^2$		
SxHxC	72	70573.4		$\sigma_R^2 + 20\sigma_{SHC}^2$		
R	3420	21040.0		σ_R^2		

Table D.2.3 ANOVA of Performance Times ; $D_3 = 13$; Right-sided Movement.

Source	d.f.	M.S.	F-Value	E M S	Prob>F	Findings at 5% Level
H	2	23611207.4	193.951	$\sigma_R^2 + 60\sigma_{SH}^2 + 1200\phi_H$	0.0001	Significant
C	2	3382416.8	65.021	$\sigma_R^2 + 60\sigma_{SC}^2 + 1200\phi_C$	0.0001	Significa-t
X	1	1703503.5	1.632	$\sigma_R^2 + 180\sigma_S^2 + 1800\phi_X$	0.5302	Not Significant
HxC	4	125100.5	1.781	$\sigma_R^2 + 20\sigma_{SHC}^2 + 400\phi_{AX}$	0.1410	Not Significant
HxX	2	82798.9	0.079	$\sigma_R^2 + 60\sigma_{HS}^2 + 600\phi_{HX}$	0.9236	Not Significant
CxX	2	3847.4	0.074	$\sigma_R^2 + 60\sigma_{CS}^2 + 600\phi_{CX}$	0.9284	Not Significant
S	18	1044052.6		$\sigma_R^2 + 240\sigma_S^2$		
HxS	36	121737.8		$\sigma_R^2 + 60\sigma_{HS}^2$		
CxS	36	52020.1		$\sigma_R^2 + 60\sigma_{CS}^2$		
SxHxC	72	70231.1		$\sigma_R^2 + 20\sigma_{SHC}^2$		
R	3420	20583.2		σ_R^2		

Table D.2.4 ANOVA of Performance Times; $D_4 = 16"$; Right-sided Movement.

Source	d.f.	M.S.	F-Value	E M S	Prob>F	Findings at 5% level
H	3	22350109.0	175.472	$\sigma_R^2 + 60\sigma_{SH} + 1200\phi_H$	0.0001	Significant
C	2	6012831.6	83.576	$\sigma_R^2 + 80\sigma_{SC}^2 + 1600\phi_C$	0.0001	Significant
X	1	656838.0	0.450	$\sigma_R^2 + 240\sigma_S^2 + 2400\phi_X$	0.5171	Significant
HxC	6	57296.7	0.957	$\sigma_R^2 + 20\sigma_{SHC}^2 + 400\phi_{HC}$	0.5411	Not Significant
HxX	3	183733.5	0.126	$\sigma_R^2 + 60\phi_{HX}$	0.9428	Not Significant
CxX	2	103554.0	1.439	$\sigma_R^2 + 80\sigma_{CS}^2 + 800\phi_{CX}$	0.2494	Not Significant
S	18	1458656.1		$\sigma_R^2 + 240\sigma_S^2$		
HxS	54	127371.1		$\sigma_R^2 + 60\sigma_{HS}^2$		
CxS	36	71944.9		$\sigma_R^2 + 80\sigma_{CS}^2$		
SxHxC	108	59866.4		$\sigma_R^2 + 20\sigma_{SHC}^2$		
R	4560	21996.1		σ_R^2		

Table D.2.5 ANOVA of Performance Times; $D_1 = 7''$; Left-sided Movement.

Source	d.f.	M.S.	F-Value	E M S	Prob>F	Findings at 5% Level
H	3	23837535.2	189.055	$\sigma_R^2 + 60\sigma_{SH}^2 + 1200\phi_H$	0.0001	Significant
C	2	5605790.4	60.748	$\sigma_R^2 + 80\sigma_{SC}^2 + 1600\phi_C$	0.0001	Significant
X	1	632343.7	0.455	$\sigma_R^2 + 240\sigma_S^2 + 2400\phi_X$	0.5150	Not Significant
HxC	6	142744.7	1.497	$\sigma_R^2 + 20\sigma_{SHC}^2 + 400\phi_{HC}$	0.1865	Not Significant
HxX	3	57179.6	0.041	$\sigma_R^2 + 60\phi_{HX}$	0.9880	Not Significant
CxX	2	7330.6	0.079	$\sigma_R^2 + 80\sigma_{CS}^2 + 800\phi_{CX}$	0.9233	Not Significant
S	18	138991-.3		$\sigma_R^2 + 240\sigma_S^2$		
HxS	54	126035.3		$\sigma_R^2 + 60\sigma_{HS}^2$		
CxS	36	92279.0		$\sigma_R^2 + 80\sigma_{CS}^2$		
SxHxC	108	95586.0		$\sigma_R^2 + 20\sigma_{SHC}^2$		
R	4560	23310.9		σ_R^2		

Table D.2.6 ANOVA of Performance Times; D_2= 10" ; Left-sided Movement.

Source	d.f.	M.S.	F-Value	E M S	Prob>F	Findings at 5% Level
H	2	5775180.0	50.128	$\sigma_R^2 + 60\sigma_{SH}^2 + 1200\phi_H$	0.0001	Significant
C	2	3145608.1	49.293	$\sigma_R^2 + 60\sigma_{SC}^2 + 1200\phi_C$	0.0001	Significant
X	1	687965.2	0.450	$\sigma_R^2 + 180\sigma_S^2 + 1800\phi_X$	0.5174	Not Significant
HxC	4	57911.8	0.802	$\sigma_R^2 + 20\sigma_{SHC}^2 + 400\phi_{AC}$	0.5299	Not Significant
HxX	2	22590.6	0.015	$\sigma_R^2 + 60\sigma_{HS}^2 + 600\phi_{HX}$	0.9863	Not Significant
CxX	2	111696.1	1.750	$\sigma_R^2 + 60\sigma_{CS}^2 + 600\phi_{CX}$	0.6539	Not Significant
S	18	1529752.1		$\sigma_R^2 + 240\sigma_S^2$		
HxS	2	115207.7		$\sigma_R^2 + 60\sigma_{HS}^2$		
CxS	36	63814.3		$\sigma_R^2 + 60\sigma_{CS}^2$		
SxHxC	72	72210.1		$\sigma_R^2 + 20\sigma_{SHC}^2$		
R	3420	22375.7		σ_R^2		

Table D.2.7 ANOVA of Performance Times; D_3 = 13" ;Left-sided Movement.

Source	d.f.	M.S.	F-Value	E M S	Prob>F	Findings at 5% Level
H	2	23611207.4	193.951	$\sigma_R^2 + 60\sigma_{SH}^2 \quad +1200\phi_H$	0.0001	
H	2	23611207.4	193.951	$\sigma_R^2 + 60\sigma_{SH}^2 \quad +1200\phi_H$	0.0001	Significant
C	2	3382416.8	65.021	$\sigma_R^2 + 60\sigma_{SC}^2 \quad +1200\phi_C$	0.0001	Significant
X	1	1703503.5	1.632	$\sigma_R^2 +180\sigma_S^2 \quad +1800\phi_X$	0.2157	Not Significant
HxC	4	125100.5	1.781	$\sigma_R^2 + 20\sigma_{SHC}^2 \quad +400\phi_{AC}$	0.1410	Not Significant
HxX	2	82798.9	0.079	$\sigma_R^2 + 60\sigma_{HS}^2 \quad +600\phi_{HX}$	0.9236	Not Significant
XxC	2	3847.4	0.074	$\sigma_R^2 + 60\sigma_{CS}^2 \quad +600\phi_{CX}$	0.9284	Not Significant
S	18	1044052.6		$\sigma_R^2 +240\sigma_S^2$		
HxS	2	121737.8		$\sigma_R^2 + 60\sigma_{HS}^2$		
CxS	36	52020.1		$\sigma_R^2 + 60\sigma_{CS}^2$		
SxHxC	72	70231.1		$\sigma_R^2 + 20\sigma_{SHC}^2$		
R	3420	20583.2		σ_R^2		

Table D.2.8 ANOVA of Performance Times; D_4 = 16"; Left-sided Movement.

Source	d.f.	M.S.	F-Value	E M S	Prob>F	Findings at 5% Level
H	3	17659828.5	177.400	$\sigma_R^2 + 60\sigma_{SH}^2 + 1200\phi_H$	0.0001	Significant
C	2	6061015.3	113.308	$\sigma_R^2 + 80\sigma_{SC}^2 + 1600\phi_C$	0.0001	Significant
X	1	928767.9	0.632	$\sigma_R^2 + 240\sigma_S^2 + 2400\phi_C$	0.6322	Not Significant
HxC	6	68956.7	1.259	$\sigma_R^2 + 20\sigma_{SHC}^2 + 400\phi_{HC}$	0.2815	Not Significant
HxX	3	320240.0	0.218	$\sigma_R^2 + 60\phi_{HX}$	0.8828	Not Significant
CxX	2	63687.4	1.190	$\sigma_R^2 + 80\sigma_{CS}^2 + 800\phi_{CX}$	0.3159	Not Significant
S	18	1469015.1		$\sigma_R^2 + 240\sigma_S^2$		
HxS	54	99547.9		$\sigma_R^2 + 60\sigma_{HS}^2$		
CxS	36	53491.5		$\sigma_R^2 + 80\sigma_{CS}^2$		
SxHxC	108	54752.3		$\sigma_R^2 + 20\sigma_{SHC}^2$		
R	4560	18648.6		σ_R^2		

Table D.2.9 ANOVA of Performance Times ; Effect due to Direction of Movement; Distance $D_1 = 7$ inches.

Source	d.f.	M.S.	F-Value	E M S	Prob>F	Findings at 5% level
X	1	625562.2	0.24	$\sigma_R^2 + 480\ \sigma_S^2 + 4800\phi_X$	0.6282	Not significant
H	3	36435364.1	190.79	$\sigma_R^2 + 120\ \sigma_{SH}^2 + 2400\phi_H$	0.0001	Significant
C	2	11530155.2	69.17	$\sigma_R^2 + 160\ \sigma_{SC}^2 + 3200\phi_C$	0.0011	Significant
A	1	16588649.8	164.59	$\sigma_R^2 + 240\ \sigma_{SA}^2 + 4800\phi_A$	0.0001	Significant
XxA	1	111327.8	1.10	$\sigma_R^2 + 240\ \sigma_{SA}^2 + 2400\phi_{XA}$	0.3079	Not significant
AxH	3	808829.5	19.03	$\sigma_R^2 + 60\sigma_{SAH}^2 + 1200\phi_{AH}$	0.0001	Significant
AxC	2	8812.9	0.25	$\sigma_R^2 + 80\sigma_{SAC}^2 + 1600\phi_{AC}$	0.7859	Not significant
S(X)	18	2502477.2		$\sigma_R^2 + 480\ \sigma_S^2$		
SxA(X)	18	100787.8		$\sigma_R^2 + 240\ \sigma_{SA}^2$		
SxAxH(X)	54	808829.5		$\sigma_R^2 + 60\ \sigma_{SAH}^2$		
SxAxC(X)	36	35791.4		$\sigma_R^2 + 80\ \sigma_{SAC}^2$		
R	9275	19933.6		σ_R^2		

Table D.2.10 ANOVA of Performance Times; Effect due to Direction of Movement; Distance $D_2 = 10''$.

Source	d.f.	M.S.	F-Value	E M S	Prob>F	Findings at 5% level
X	1	1338869.8	0.52	$\sigma_R^2 + 360\ \sigma_S^2 + 3600\phi_X$	0.5123	Not significant
H	2	13888905.8	81.13	$\sigma_R^2 + 120\ \sigma_{SH}^2 + 2400\phi_H$	0.0001	Significant
C	2	5780705.7	54.09	$\sigma_R^2 + 120\ \sigma_{SC}^2 + 2400\phi_C$	0.0001	Significant
A	1	5514653.3	53.94	$\sigma_R^2 + 180\ \sigma_{SA}^2 + 3600\phi_A$	0.0001	Significant
XxA	1	253.0	0.0002	$\sigma_R^2 + 180\ \sigma_{SA}^2 + 1800\phi_{XA}$	0.9598	Not significant
AxH	2	152236.5	4.49	$\sigma_R^2 + 60\ \sigma_{SAH}^2 + 1200\phi_{AH}$	0.0178	Significant
AxC	2	32049.7	1.16	$\sigma_R^2 + 60\ \sigma_{SAC}^2 + 1200\phi_{AC}$	0.3242	Not significant
S(X)	18	2588758.7	117.80	$\sigma_R^2 + 360\ \sigma_S^2$	0.0001	Significant
SxA(X)	18	102232.2		$\sigma_R^2 + 180\ \sigma_{SA}^2$		
SxAxH(X)	36	33902.3		$\sigma_R^2 + 60\ \sigma_{SAH}^2$		
SxAxC(X)	36	27547.4		$\sigma_R^2 + 80\ \sigma_{SAC}^2$		
R	6928	21926.1		σ_R^2		

Table D.2.11 ANOVA of Performance Times; Effect due to Direction of Movement; Distance D_3 = 13 inches.

Source	d.f.	M.S.	F-Value	E M S	Prob>F	Findings at 5% level
X	1	1824801.3	1.06	$\sigma_R^2 + 360\ \sigma_S^2 + 3600\phi_X$	0.3190	Not significant
H	2	41075158.1	202.94	$\sigma_R^2 + 120\ \sigma_{SH}^2 + 2400\phi_H$	0.0001	Significant
C	2	6633071.2	79.47	$\sigma_R^2 + 120\ \sigma_{SC}^2 + 2400\phi_C$	0.0001	Significant
A	1	6467897.7	53.14	$\sigma_R^2 + 180\ \sigma_{SA}^2 + 3600\phi_A$	0.0001	Significant
XxA	1	244981.3	2.01	$\sigma_R^2 + 180\ \sigma_{SA}^2 + 1800\phi_{XA}$	0.1702	Not significant
AxH	2	226301.2	5.57	$\sigma_R^2 + 60\ \sigma_{SAH}^2 + 1200\phi_{AH}$	0.0079	Significant
AxC	2	26715.3	1.20	$\sigma_R^2 + 60\ \sigma_{SAC}^2 + 1200\phi_{AC}$	0.3126	Not significant
S(X)	18	1729.69.2	85.20	$\sigma_R^2 + 360\ \sigma_S^2$	0.0001	Significant
SxA(X)	18	121704.9		$\sigma_R^2 + 180\ \sigma_{SA}^2$		
SxAxH(X)	36	40629.4		$\sigma_R^2 + 60\ \sigma_{SAH}^2$		
SxAxC(X)	36	22235.1		$\sigma_R^2 + 80\ \sigma_{SAC}^2$		
R	6928	20349.0		σ_R^2		

Table D.2.12 ANOVA of Performance Times; Effect due to Direction of Movement; Distance D_4 = 16".

Source	d.f.	M.S.	F-Value	E M S	Prob>F	Findings at 5% level
X	1	1573860.0	0.5425	$\sigma_R^2 + 480\ \sigma_S^2 + 4800\phi_X$	0.5229	Not significant
H	3	39832043.2	204.88	$\sigma_R^2 + 120\sigma_{SH}^2 + 2400\phi_H$	0.0001	Significant
C	2	12071927.7	116.17	$\sigma_R^2 + 160\ \sigma_{SC}^2 + 3200\phi_C$	0.0001	Significant
A	1	272038.3	10.08	$\sigma_R^2 + 240\ \sigma_{SA}^2 + 4800\phi_A$	0.0001	Significant
XxA	1	11745.9	0.435	$\sigma_R^2 + 240\ \sigma_{SA}^2 + 2400\phi_{XA}$	0.5241	Not Significant
AxH	3	177894.3	5.471	$\sigma_R^2 + 60\ \sigma_{SAH}^2 + 1200\phi_{AH}$	0.0027	Significant
AxC	2	1919.3	0.08915	$\sigma_R^2 + 80\ \sigma_{SAC}^2 + 1600\phi_{AC}$	0.9144	Not significant
S(X)	18	2900690.1	166.50	$\sigma_R^2 + 480\ \sigma_S^2$	0.0001	Significant
SxA(X)	18	26981.2		$\sigma_R^2 + 240\ \sigma_{SA}^2$		
SxAxH(X)	54	32510.5		$\sigma_R^2 + 60\ \sigma_{SAH}^2$		
SxAxC(X)	36	21528.1		$\sigma_R^2 + 80\ \sigma_{SAC}^2$		
R	9275	17442.8		σ_R^2		

Table D.2.13 ANOVA of Performance Times; Right-sided Movement; Distance and Clearance Considered Separately.

Source	d.f.	M.S.	F-Value	E M S	Prob>F	Findings at 5% level
H	2	51261249.1	266.741	$\sigma_R^2 + 240\ \sigma_{SH}^2 + 4800\phi_H$	0.0001	Significant
C	2	13993948.4	83.23	$\sigma_R^2 + 240\ \sigma_{SC}^2 + 4800\phi_C$	0.0001	Significant
D	3	13226158.9	99.53	$\sigma_R^2 + 180\ \sigma_{SD}^2 + 3600\phi_D$	0.0001	Significant
X	1	1853945.5	0.47	$\sigma_R^2 + 720\ \sigma_S^2 + 7200\phi_X$	0.5065	Not significant
XxH	2	845.9	0.004	$\sigma_R^2 + 240\ \sigma_{SH}^2 + 2400\phi_{XH}$	0.9989	Not significant
XxC	2	46633.8	0.277	$\sigma_R^2 + 240\ \sigma_{SC}^2 + 2400\phi_{XC}$	0.7630	Not significant
XxD	3	135041.6	1.02	$\sigma_R^2 + 180\ \sigma_{SD}^2 + 1800\phi_{XD}$	0.3939	Not significant
HxC	4	80713.6	0.51	$\sigma_R^2 + 80\ \sigma_{SHC}^2 + 1600\phi_{HC}$	0.7302	Not significant
HxD	6	700933.4	9.34	$\sigma_R^2 + 60\ \sigma_{SHD}^2 + 1200\phi_{HD}$	0.001	Significant
CxD	6	107646.3	2.54	$\sigma_R^2 + 60\ \sigma_{SHC}^2 + 1200\phi_{DC}$	0.0242	Significant
S(X)	18	3914487.7	175.43	$\sigma_R^2 + 720\ \sigma_S^2$	0.0001	Significant
SxC(X)	36	168138.4		$\sigma_R^2 + 240\ \sigma_{SC}^2$		
SxD(X)	54	132889.8		$\sigma_R^2 + 180\ \sigma_{SD}^2$		
SxH(X)	36	192550.3		$\sigma_R^2 + 240\ \sigma_{SH}^2$		
SxHxC(X)	72	157686.3		$\sigma_R^2 + 80\ \sigma_{SHC}^2$		
SxDxC(X)	108	42398.9		$\sigma_R^2 + 60\ \sigma_{SDC}^2$		
SxHxD(X)	108	75060.3		$\sigma_R^2 + 60\ \sigma_{SHD}^2$		
R	13936	22196.3		σ_R^2		

Table D.2.14 ANOVA of Performance Times; Left-sided Movement; Distance and Clearance Considered Separately.

Source	d.f.	M.S.	F-Value	E M S	Prob>F	Findings at 5% level
H	2	54802174.8	290.31	$\sigma_R^2 + 240\ \sigma_{SH}^2 + 4800\phi_H$	0.0001	Significant
C	2	14396445.6	106.52	$\sigma_R^2 + 240\ \sigma_{SC}^2 + 4800\phi_C$	0.001	Significant
D	3	2223893.5	12.32	$\sigma_R^2 + 180\ \sigma_{SD}^2 + 3600\phi_D$	0.001	Significant
X	1	4276213.9	0.9496	$\sigma_R^2 + 720\ \sigma_S^2 + 7200\phi_X$	0.6555	Not significant
XxH	2	66895.8	0.36	$\sigma_R^2 + 240\ \sigma_{SH}^2 + 2400\phi_{XH}$	0.8127	Not significant
XxC	2	53297.8	0.39	$\sigma_R^2 + 240\ \sigma_{SC}^2 + 2400\phi_{XC}$	0.6823	Not significant
XxD	3	102421.2	0.57	$\sigma_R^2 + 180\ \sigma_{SD}^2 + 1800\phi_{XD}$	0.6431	Not significant
HxC	4	192427.9	0.97	$\sigma_R^2 + 80\ \sigma_{SHC}^2 + 1600\phi_{HC}$	0.5692	Not significant
HxD	6	1593796.7	18.00	$\sigma_R^2 + 60\ \sigma_{SHD}^2 + 1200\phi_{HD}$	0.0001	Significant
CxD	6	27288.5	0.71	$\sigma_R^2 + 60\ \sigma_{SDC}^2 + 1200\phi_{DC}$	0.6457	Not significant
S(X)	18	4502763.9	200.31	$\sigma_R^2 + 720\ \sigma_S^2$	0.0001	Significant
SxC(X)	36	135157.9		$\sigma_R^2 + 240\ \sigma_{SC}^2$		
SxD(X)	54	180583.1		$\sigma_R^2 + 180\ \sigma_{SD}^2$		
SxH(X)	36	188952.3		$\sigma_R^2 + 240\ \sigma_{SH}^2$		
SxHxC(X)	72	198436.4		$\sigma_R^2 + 80\ \sigma_{SHC}^2$		
SxDxC(X)	108	38527.0		$\sigma_R^2 + 60\ \sigma_{SDC}^2$		
SxHxD(X)	108	88524.4		$\sigma_R^2 + 60\ \sigma_{SHD}^2$		
R	13936	22467.7		σ_R^2		

Table D.2.15 ANOVA of Performance Times; Right-sided Movement; Index of Difficulty Considered.

Source	d.f.	M.S.	F-Value	E M S	Prob>F	Findings at 5% level
X	1	1853945.5	0.47361	$\sigma_R^2 + 720\ \sigma_S^2 + 7200\phi_X$	0.5065	Not significant
H	2	51361249.1	13.12	$\sigma_R^2 + 240\ \sigma_{SH}^2 + 4800\phi_H$	0.0005	Significant
I	11	6210204.7	69.05	$\sigma_R^2 + 60\ \sigma_{SI}^2 + 1200\phi_I$	0.0001	Significant
XxI	11	654745.8	0.73	$\sigma_R^2 + 60\ \sigma_{SI}^2 + 600\phi_{IX}$	0.7121	Not significant
XxH	2	845.9	0.004	$\sigma_R^2 + 240\ \sigma_{SH}^2 + 2400\phi_{HX}$	0.9960	Not significant
HxI	22	240248.0	3.47	$\sigma_R^2 + 20\ \sigma_{SHI}^2 + 400\ \phi_{HI}$	0.0001	Significant
S(X)	18	3914487.7	178.53	$\sigma_R^2 + 720\ \sigma_S^2$	0.0001	Significant
SxH(X)	36	192550.3		$\sigma_R^2 + 240\ \sigma_{SH}^2$		
SxI(X)	198	89939.9		$\sigma_R^2 + 60\ \sigma_{SI}^2$		
R	13702	21925.7		σ_R^2		

Table D.2.16 ANOVA of Performance Times; Left-sided Movement; Index of Difficulty Considered.

Source	d.f.	M.S.	F-Value	E M S	Prob>F	Findings at 5% level
X	1	4276213.9	0.95	$\sigma_R^2 + 720\ \sigma_S^2 + 7200\phi_X$	0.6555	Not significant
H	2	54802174.8	290.03	$\sigma_R^2 + 240\ \sigma_{SH}^2 + 4800\phi_H$	0.0001	Significant
I	11	3238936.6	34.15	$\sigma_R^2 + 60\ \sigma_{SI}^2 + 1200\phi_I$	0.0001	Significant
XxI	11	59893.4	0.63	$\sigma_R^2 + 60\ \sigma_{SI}^2 + 600\phi_{IX}$	0.8015	Not significant
XxH	2	66895.8	0.35	$\sigma_R^2 + 240\ \sigma_{SH}^2 + 2400\phi_{HX}$	0.7902	Not significant
HxI	22	490578.3	5.99	$\sigma_R^2 + 20\ \sigma_{SHI}^2 + 400\phi_{HI}$	0.0001	Significant
S(X)	18	4502763.9	203.06	$\sigma_R^2 + 720\ \sigma_S^2$	0.0001	Significant
SxH(X)	36	188952.3		$\sigma_R^2 + 240\ \sigma_{SH}^2$		
SxI(X)	198	94838.8		$\sigma_R^2 + 60\ \sigma_{SI}^2$		
R	13702	22173.5		σ_R^2		

Test of Means

Newman Kuel's Range Test (Hicks, 1973) is applied to the means of performance times at different levels of effects found significant ($p<0.05$) in the ANOVA. (The means are listed in the ANOVA computer printout in Appendix G).

Notations to be used in this section are:

S.E. = Standard Error = $\sqrt{\dfrac{\text{Error Mean Square}}{\text{number of observations in each level of effect}}}$

d.f. = degree of freedom of error

L.S.R. = Least Square Range

St.R = Studentised Ranges at 5% level of significance and at error degree of freedom

H = Informational load levels

I = Index of Difficulty

C = Clearance levels

D = Distance of move

S = Significant ($p<0.05$)

N.S. = Not significant ($p>0.05$)

Part 1 - Effect of informational load and clearance analysed at four levels of distance (D) separately

A.1 Informational load (H) at D=7"

	Right Sided Movement				Left Sided Movement			
(H) in ascending order	1	2	3	4	1	2	3	4
Means	831	889	964	1076	871	935	1006	1209
S.E.		9.46					10.24	
d.f.		54					54	
St.R.		2.84	3.42	3.76			2.84	3.42
L.S.R.		26.87	32.35	35.57			29.08	35.02

Right Sided Movement		Left Sided Movement	
4 Vs 3 = 110> 26.87	S	4 Vs 3 = 203>29.08	S
3 Vs 2 = 75> 32.35	S	3 Vs 2 = 71>29.08	S
2 Vs 1 = 58> 26.87	S	2 Vs 1 = 64>29.08	S

SUMMARY: All levels of H are significantly different from all other levels ($p<0.05$) for both the right sided and left sided movements

A.2. Informational load H at D = 10"

	Right Sided Movement			Left Sided Movement		
(H) in ascending order	2	3	4	2	3	4
Means	972	1071	1104	1039	1133	1175
S. E.		8.65			9.79	
d. f.		36			36	
St.R		2.86	3.44		2.86	3.44
L.S.R.		24.74	29.76		27.99	33.68

Right Sided Movement		Left Sided Movement	
4 Vs 3 = 33>24.74	S	4 Vs 3 = 42>27.99	S
3 Vs 2 = 99>24.74	S	3 Vs 2 = 94>27.99	S

SUMMARY: All levels of H are significantly different from all other levels ($p<0.05$) for both right sided and left sided movements.

A.3 Informational load (H) at D = 13"

	Right Sided Movement			Left Sided Movement		
(H) in ascending order	2	3	4	2	3	4
Means	944	1015	1181	985	1076	1260
S.E.		10.05			10.07	
d.f.		36			36	
St.R.		2.86	3.44		2.86	3.44
L.S.R.		28.74	34.57		28.80	34.64

Right Sided Movement		Left Sided Movement	
4 Vs 3 = 166>28.74	S	4 Vs 3 = 184>28.80	S
3 Vs 2 = 71>28.74	S	3 Vs 2 = 91>28.80	S

SUMMARY: All levels of H are significantly different from all other levels ($p<0.05$) for both right sided and left sided movements.

A.4 Informational load (H) at D = 16"

(H) in ascending order	Right Sided Movement 1	2	3	4	Left Sided Movement 1	2	3	4
Means	831	889	964	1076	991	1043	1111	1236
S.E.	10.30				9.11			
d.f.	54				54			
St.R.		2.84	3.42	3.76		2.84	3.42	3.76
L.S.R.		29.25	35.23	38.73		25.87	31.15	34.25

Right Sided Movement		Left Sided Movement	
4 Vs 3 = 112>29.25	S	4 Vs 3 = 125>25.87	S
3 Vs 2 = 75>29.25	S	3 Vs 2 = 68>25.87	S
2 Vs 1 = 58>29.25	S	2 Vs 1 = 52>25.87	S

<u>SUMMARY:</u> All levels of H are significantly different from all other levels ($p<0.05$) for both right sided and left sided movements.

B.1 Clearance (C) at D = 7"

(C) in ascending order	Left Sided Movement 3	2	1	Right Sided Movement 3	2	1
Means	1015	1078	1123	913	981	1035
S.E.	8.30			7.60		
d.f.	36			36		
St.R.	2.86	3.44		2.86	3.44	
L.S.R.	23.74	28.55		21.74	26.14	

Left Sided Movement		Right Sided Movement
1 Vs 2 = 45>23.74	S	1 Vs 2 = 54>21.74
2 Vs 3 = 63>23.74	S	2 Vs 3 = 68>21.74

<u>SUMMARY:</u> All levels of (C) are significantly different from all other levels ($p<0.05$) for both right sided and left sided movements.

B.2 Clearance (C) at D = 10"

	Left Sided Movement			Right Sided Movement		
(C) in ascending order	3	2	1	3	2	1
Means	1061	1123	1163	1008	1074	1099
S.E.		7.67			7.29	
d.f.		36			36	
St.R.		2.86	3.44		2.86	3.44
L.S.R.		21.93	26.38		20.85	25.08

1 Vs 2 = 40>21.93 S   1 Vs 2 = 25>20.85 S

2 Vs 3 = 62>21.93 S   2 Vs 3 = 66>20.85 S

SUMMARY: All levels of (C) are significantly different from all other levels ($p<0.05$) for both right sided and left sided movements.

B.3 Clearance (C) at D = 13"

	Left Sided Movement			Right Sided Movement		
(C) in ascending order	3	2	1	3	2	1
Means	1053	1110	1159	997	1042	1101
S.E.		6.68			6.58	
d.f.		36			36	
St.R.		2.86	3.44		2.86	3.44
L.S.R.		19.10	22.98		18.82	22.64

1 Vs 2 = 49>19.10 S   1 Vs 2 = 59>18.82 S

2 Vs 3 = 57>19.10 S   2 Vs 3 = 45>18.82 S

SUMMARY: All levels of (C) are significantly different from all other levels ($p<0.05$) for both the right sided and left sided movements.

B.4 Clearance (C) at D = 16"

(C) in ascending order	Left Sided Movement 3	2	1	Right Sided Movement 3	2	1
Means	1069	1134	1191	1068	1124	1181
S.E.		7.74			6.68	
d.f.		36			36	
St.R.	2.86	3.44		2.86	3.44	
L.S.R.	22.14	26.63		19.10	22.98	

Left Sided Movement		Right Sided Movement	
1 Vs 2 = 57>22.14	S	1 Vs 2 = 57>19.10	S
2 Vs 3 = 65>22.14	S	2 Vs 3 = 56>19.10	S

SUMMARY: All levels of (C) are significantly different from all other levels ($p<0.05$) for both right sided and left sided movements.

Part 2 -Effect of Distance and Index of Difficulty as analysed according to the Part 2 models.

A. Right-sided Movement

1 Index of Difficulty (I)

The means of Performance Times are arranged in ascending order as follows:

Level of I	1	5	3	2	9	7	4	6	10	11	8	12
Means	913	980	997	1008	1035	1041	1067	1073	1099	1101	1123	1181

$$\text{Standard Error (S.E.)} = \sqrt{\frac{\text{Error Mean Square}}{\text{number of observations in each I}}}$$

$$= \sqrt{\frac{89939.9}{1200}}$$

$$= 8.66$$

From standard tables, for d.f.=198; and at 5% level of significance, the Studentised Ranges are:

2.77 3.32 3.63 3.86 4.03 4.77 4.29 4.39 4.47 4.55

Therefore the Least Square Ranges are:

23.97 28.75 31.44 33.43 34.90 36.11 37.15 38.02 38.71 39.40

8 vs 12 = 58 > 23.97 Significantly different

Therefore 12 is significantly different from all other levels

8 vs 11 = 22 < 23.97 Not significantly different

8 vs 10 = 24 < 28.75 Not significantly different

8 vs 6 = 50 > 31.44 Significantly different

Therefore 8 is significantly different from levels 1,5,3,2,9,7,4,6

11 vs 10 = 2 < 23.97 Not significantly different

11 vs 6 = 28 < 28.75 Not significantly different

11 vs 4 = 34 > 31.44 Significantly different

Therefore 11 is significantly different from levels 1,5,3,2,9,7

10 vs 6 = 26 > 23.97 Significantly different

Therefore 10 is significantly different from levels 1,5,3,2,9,7,4,6

6 vs 4 = 6 < 23.97 Not significantly different

6 vs 7 = 32 > 28.75 Significantly different

Therefore 6 is significantly different from levels 1,5,3,2,9,7

4 vs 7 = 26 > 23.97 Significantly different

Therefore 4 is significantly different from levels 1,5,3,2,9,7

7 vs 9 = 6 < 23.97 Not significantly different

7 vs 2 = 33 > 28.75 Significantly different

Therefore 7 is significantly different from levels 1,5,3,2

9 vs 2 = 27 > 23.97 Significantly different

Therefore 9 is significantly different from levels 1,5,3,2

2 vs 3 = 11 < 23.97 Not significantly different

2 vs 5 = 28 < 28.75 Not significantly different

2 vs 1 = 95 > 31.44 Significantly different

Therefore 2 is significantly different from level 1

3 vs 5 = 17 < 23.97 Not significantly different

3 vs 1 = 87 > 28.75 Significantly different

Therefore 3 is significantly different from level 1

5 vs 1 = 67 > 23.97 Significantly different

Therefore 5 is significantly different from level 1

The above results can be summarised as follows:

Level of I in ascending order of means

1 5 3 2 9 7 4 6 10 11 8 12

2 Distance (D)

The means of the Performance Times in ascending order:

Levels of distance D	1	3	2	4
Means	976	1047	1060	1124

$$\text{Standard Error (S.E.)} = \sqrt{\frac{132890}{3600}}$$

$$= 7.15$$

From standard tables, for d.f.=54 and at 5% level of significance, the Studentised Ranges are: 2.84 3.42 3.76

The Least Square Ranges are : 20.31 24.45 26.88

1 vs 4	= 148 > 26.88	Significantly different
3 vs 4	= 77 > 24.45	Significantly different
2 vs 4	= 64 > 20.31	Significantly different
1 vs 2	= 84 > 24.45	Significantly different
3 vs 2	= 13 < 20.31	Not significantly different
1 vs 3	= 71 > 20.31	Significantly different

Graphical representation of the above results:

Level of D in ascending order of D: 1 <u>3 2</u> 4

B. Left-sided Movement

1 Index of Difficulty (I)

The means of Performance Times in ascending order are:

Level of I	1	3	2	4	5	7	6	9	8	11	10	12
Means	1015	1053	1061	1069	1079	1109	1123	1123	1134	1159	1163	1191

$$\text{Standard Error(S.E.)} = \sqrt{\frac{\text{Error Mean Square}}{\text{number of observations in each level of ID}}}$$

$$= \sqrt{\frac{94839}{1200}}$$

$$= 8.89$$

From standard tables; for d.f.=198 and at 5% level of significance, the Studentised Ranges are:

2.77 3.32 3.63 3.86 4.03 4.17 4.29 4.39 4.47 4.55

The Least Square Ranges are:

24.63 29.51 32.27 34.32 35.83 37.07 38.14 39.03 39.74 49.45

12 vs 10 = 28 > 24.63 Significantly different

Therefore 12 is significantly different from all other levels.

10 vs 11 = 4 < 24.63 Not significantly different

10 vs 8 = 29 < 29.51 Not significantly different

10 vs 9 = 40 > 32.27 Significantly different

Therefore 10 is significantly different from 1,3,2,4,5,7,6,9

11 vs 8 = 25 > 24.63 Significantly different

Therefore 8 is significantly different from all other levels with lower means.

8 vs 9 = 11 < 24.63 Not significantly different

8 vs 6 = 11 < 29.51 Not significantly different

8 vs 7 = 24 < 32.27 Not significantly different

8 vs 5 = 55 > 34.32 Significantly different

Therefore 8 is significantly different from levels 1,3,2,4,5

9 vs 6 = 0 < 24.63 Not significantly different

9 vs 7 = 13 < 29.51 Not significantly different

9 vs 5 = 44 > 32.27 Significantly different

Therefore 9 is significantly different from levels 1,3,2,4,5

6 vs 7 = 13 < 24.63 Not significantly different

6 vs 5 = 44 > 29.51 Significantly different

Therefore 6 is significantly different from levels 1,3,2,4,5

7 vs 5 = 31 > 24.63 Significantly different

Therefore 7 is significantly different from all levels with lower means.

5 vs 4 = 10 < 24.63 Not significantly different

5 vs 2 = 18 < 29.51 Not significantly different

5 vs 3 = 26 < 32.27 Not significantly different

5 vs 1 = 64 > 34.32 Significantly different

Therefore 5 is significantly different from level 1.

4 vs 2 = 8 < 24.63 Not significantly different

4 vs 3 = 16 < 29.51 Not significantly different

4 vs 1 = 54 > 34.32 Significantly different

Therefore 4 is significantly different from level 1.

2 vs 3 = 8 < 24.63 Not significantly different

2 vs 1 = 46 > 29.51 Significantly different

Therefore 2 is significantly different from level 1.

3 vs 1 = 38 > 24.63 Significantly different

The graphical summary of the results is as follows:

Level of I

1 3 2 4 5 7 6 9 8 11 10 12

2 Distance (D)

The means of Performance Times in ascending order:

Levels of D	1	3	2	4
Means	1072	1106	1115	1131

$$\text{Standard Error (S.E.)} = \sqrt{\frac{180583}{3600}}$$

$$= 7.08$$

From standard tables; for d.f.=54 and at 5% level of significance, the Studentised Ranges are: 2.84 3.42 3.76

The Least Square Ranges are : 20.11 24.21 26.62

1 vs 4 = 59 > 26.62 Significantly different

3 vs 4 = 25 > 24.21 Significantly different

2 vs 4 = 16 < 20.11 Not significantly different

1 vs 2 = 43 > 24.21 Significantly different

3 vs 2 = 9 < 20.11 Not significantly different

1 vs 3 = 34 > 20.11 Significantly different

Graphical representation of the results:

Level of D: 1 3 2 4

Computation - Component Variances of Main Effects

This section utilises Part 2 models only as the basis for the computation of effect component variances.

A. Right-sided Movement

1. Clearance and Distance as separate factors, from ANOVA table D.2.13 :

$$S_R^2 = 22196.3 \quad .....(1)$$

$$S_R^2 + 720\ S_S^2 = 3914487.7 \quad .....(2)$$

$$S_R^2 + 240\ S_{SH}^2 = 192550.3 \quad .....(3)$$

$$S_R^2 + 240\ S_{SH}^2 + 4800\ \phi_H = 51361249.1 \quad .....(4)$$

$$S_R^2 + 180\ S_{SD}^2 = 132889.8 \quad .....(5)$$

$$S_R^2 + 180\ S_{SD}^2 + 3600\ \phi_D = 13226158.9 \quad .....(6)$$

$$S_R^2 + 240\ S_{SC}^2 = 168138.4 \quad .....(7)$$

$$S_R^2 + 240\ S_{SC}^2 + 4800\ \phi_C = 13993948.4 \quad .....(8)$$

where S_R^2, S_S^2, S_{SH}^2, S_C^2, S_{SC}^2, S_{SD}^2, ϕ_H, ϕ_C, ϕ_D are estimates of variances of the corresponding effects in the mixed model.

From (1) and (2) $\quad S_S^2 = 5405.96$

From (3) and (4) $\quad \phi_H = 10660.15$

From (5) and (6) $\quad _D = 3637.02$

From (7) and (8) $\quad _C = 2880.38$

$$\text{Total Variance} = S_S^2 + \phi_H + \phi_D + \phi_C$$

$$= 22583.5$$

%-age variance attributed to subject differences

(S) = 23.93

%-age variance attributed to effect of Informational Load (H) = 47.20

%-age variance attributed to Distance effect

(D) = 16.10

%-age variance attributed to Clearance effect

(C) = 12.75

2. Index of Difficulty (I) as a factor replacing C and D.

From ANOVA table D.2.16 :

$$S_R^2 = 21925.7 \quad .....(1)$$

$$S_R^2 + 720\ S_S^2 = 3914487.7 \quad .....(2)$$

$$S_R^2 + 240\ S_{SH}^2 = 192550.3 \quad .....(3)$$

$$S_R^2 + 240\ S_{SH}^2 + 4800\phi_H = 51361249.1 \quad .....(4)$$

$$S_R^2 + 60\ S_{SI}^2 = 89939.9 \quad .....(5)$$

$$S_R^2 + 60\ S_{SI}^2 + 1200\phi_I = 6210204.7 \quad .....(6)$$

where S_R^2, S_S^2, S_I^2, S_{SI}^2, S_{SH}^2, ϕ_H, ϕ_I are estimates of variances of the corresponding effect, in the mixed model.

From (1) and (2) S_S = 5406.34

From (3) and (4) $_H$ = 10660.15

From (5) and (6) $_I$ = 5100.22

Total variance $= S_S^2 + \phi_H + \phi_I$

$= 21166.71$

%-age of variance attributed to subject differences

(S) = 25.54

%-age of variance attributed to effect of Informational Load (H) = 50.36

%-age of variance attributed to effect of Index of Difficulty (I) = 24.10

B. <u>Left-sided Movement</u>

1. Clearance and Distance as separate factors. From ANOVA table D.2.15 :

$$S_R^2 = 22467.7 \quad .....(1)$$

$$S_R^2 + 720\, S_S^2 = 4502763.9 \quad .....(2)$$

$$S_R^2 + 240\, S_{SH}^2 = 188952.3 \quad .....(3)$$

$$S_R^2 + 240\, S_{SH}^2 + 4800\phi_H = 54802174.8 \quad .....(4)$$

$$S_R^2 + 180\, \sigma_{SD}^2 = 180583.1 \quad .....(5)$$

$$S_R^2 + 180\ \sigma_{SD}^2 + 3600\ \phi_D = 2223893.5 \ldots\ldots(6)$$

$$S_R^2 + 240\ \sigma_{SC}^2 = 135157.9 \ldots\ldots(7)$$

$$S_R^2 + 240\ \sigma_{SC}^2 + 4800\ \phi_C = 14396445.6 \ldots\ldots(8)$$

From (1) and (2) S_S^2 = 6222.63

From (3) and (4) ϕ_H = 11377.75

From (5) and (6) ϕ_D = 567.59

From (7) and (8) ϕ_C = 2971.10

Total variance = $S_I^2 + \phi_H + \phi_D + \phi_C$

= 21138.67

%-age variance attributed to subject difference (S) = 29.44

%-age variance attributed to effect of Informational Load (H) = 53.82

%-age variance attributed to effect of Distance (D) = 2.69

%-age variance attributed to effect of Clearance (C) = 14.06

2. Index of Difficulty (I) as a factor replacing C and D.

From ANOVA table D.2.14:

$$S_R^2 = 22173.5 \ldots\ldots(1)$$

$$S_R^2 + 720\ S_S^2 = 4502763.9 \ldots\ldots(2)$$

$$S_R^2 + 240\ S_{SH}^2 = 188952.3 \ldots\ldots(3)$$

$$S_R^2 + 240\ S_{SH}^2 + 4800\ \phi_H = 54802174.8 \quad .....(4)$$

$$S_R^2 + 60\ S_{SI}^2 = 94838.8 \quad .....(5)$$

$$S_R^2 + 60\ S_{SI}^2 + 1200\ \phi_I = 3238936.6 \quad .....(6)$$

From (1) and (2) $S_S^2 = 6223.04$

From (3) and (4) $\phi_H = 11377.75$

From (5) and (6) $\phi_I = 2620.08$

Total variance $= S_S^2 + \phi_H + \phi_I$

$= 20220.87$

%-age variance attributed to Subject Difference

(S) = 30.77

%-age variance attributed to effect of Informational Load (H) = 56.27

%-age variance attributed to effect of Index of Difficulty (I) = 12.96

Graphical Representations of Results

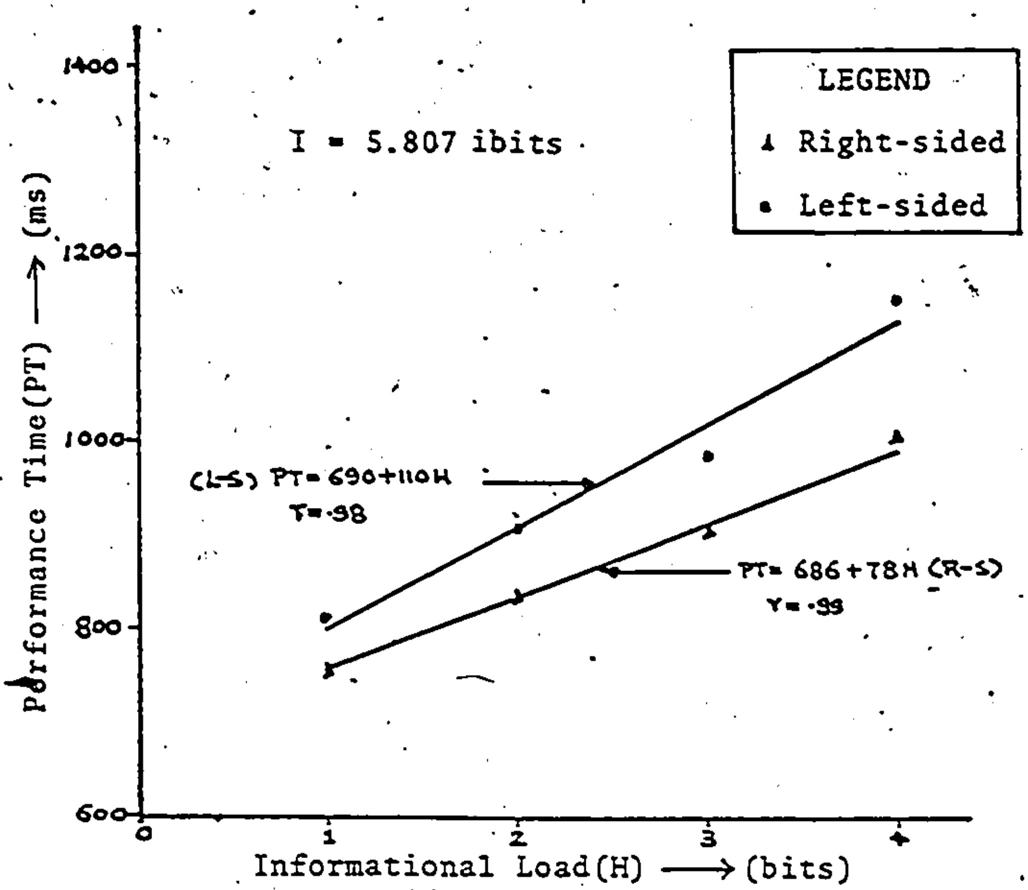


Figure D.1 Performance Time vs. Informational Load for all subjects

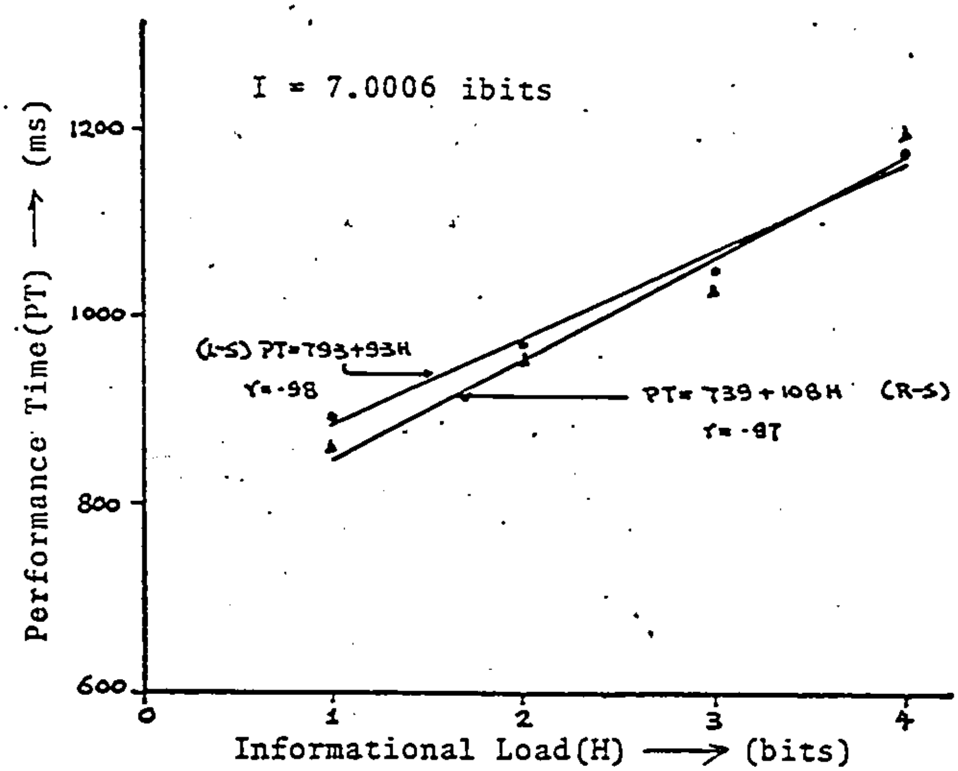


Figure D.2 Performance Time vs. Informational Load for all subjects

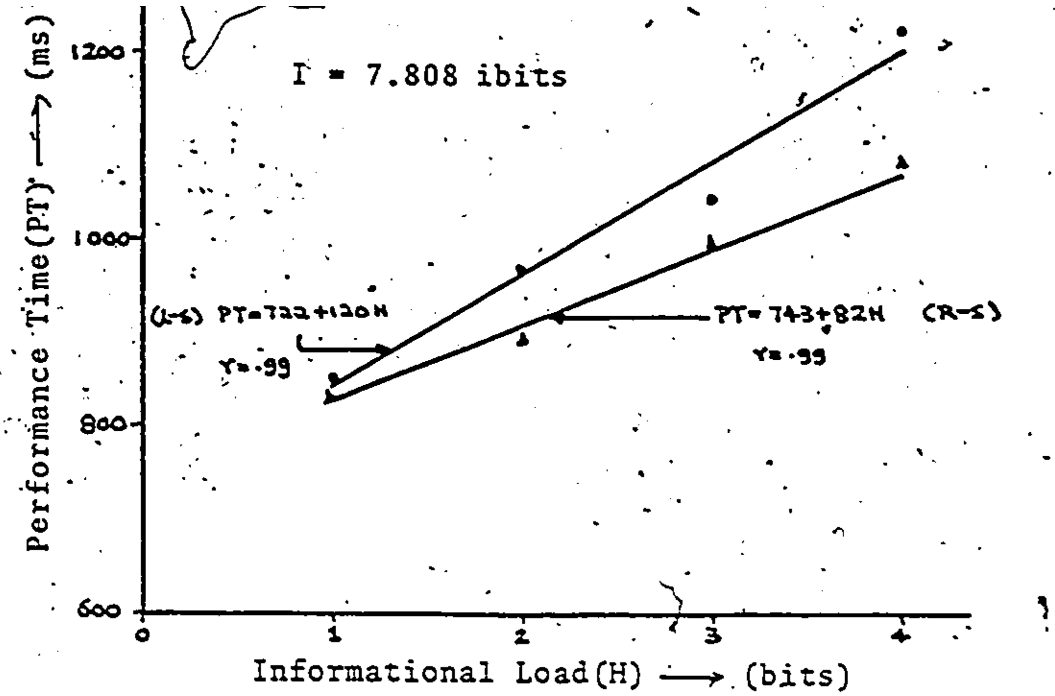


Figure D.3 Performance Time vs. Informational Load for all subjects

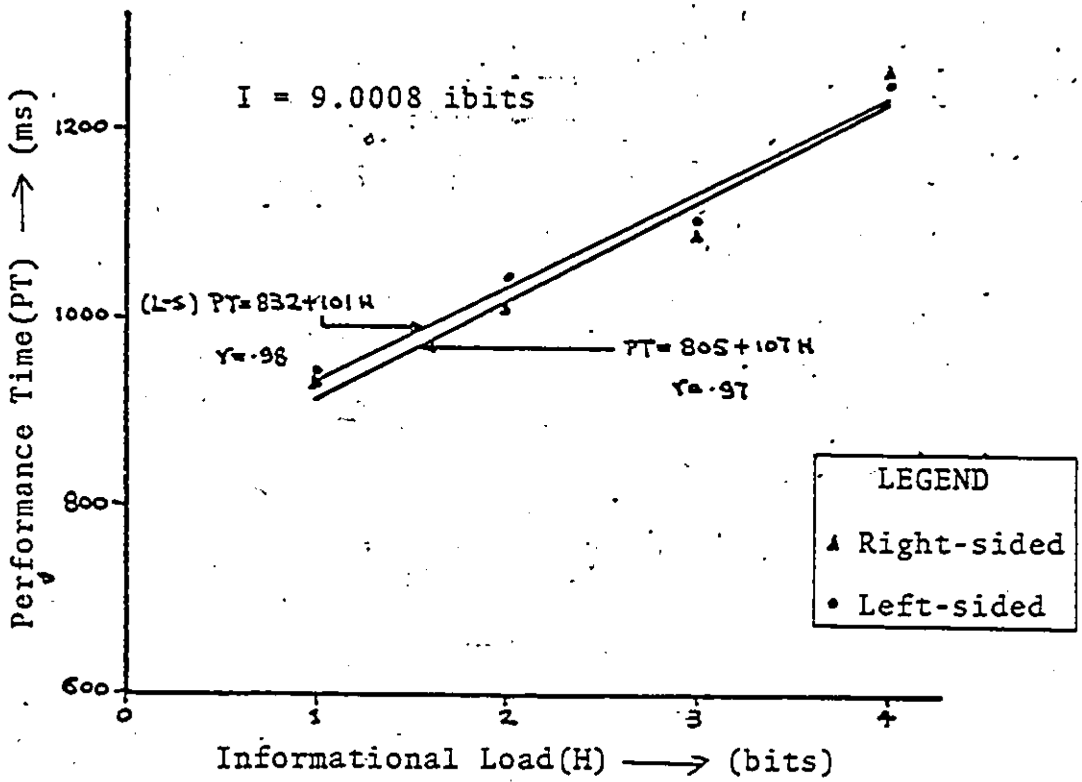


Figure D.4 Performance Time vs. Informational Load for all subjects

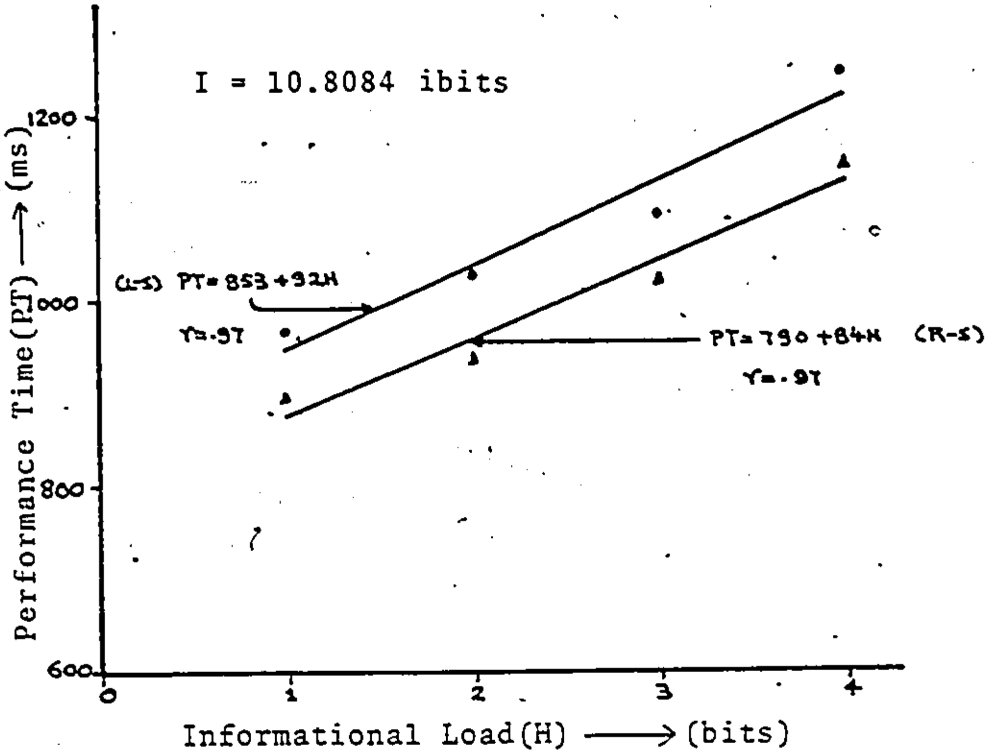


Figure D.5 Performance Time vs. Informational Load for all subjects

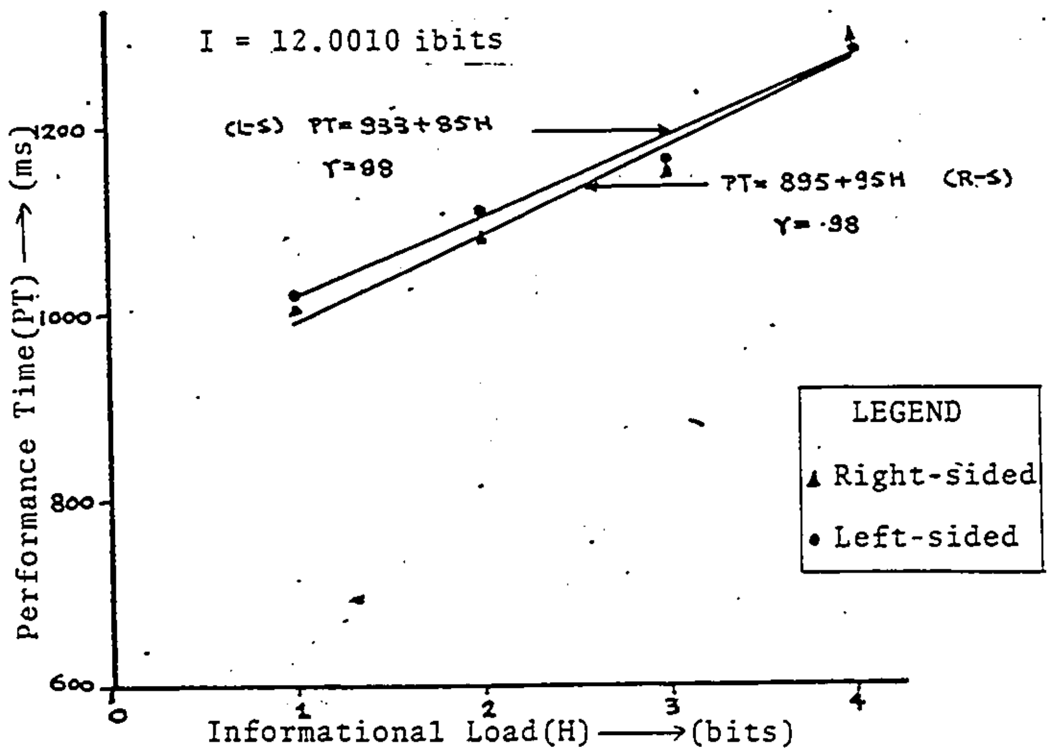


Figure D.6 Performance Time vs. Informational Load for all subjects

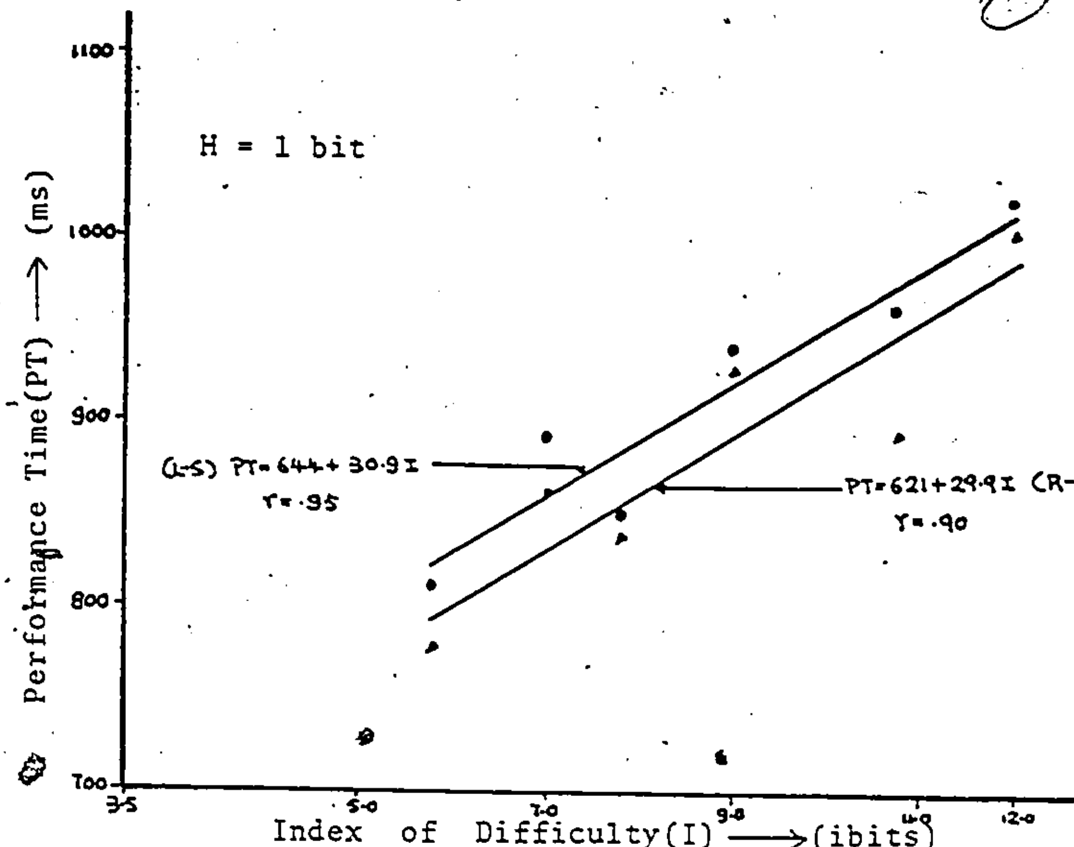


Figure D.7 Performance Time vs. Index of Difficulty

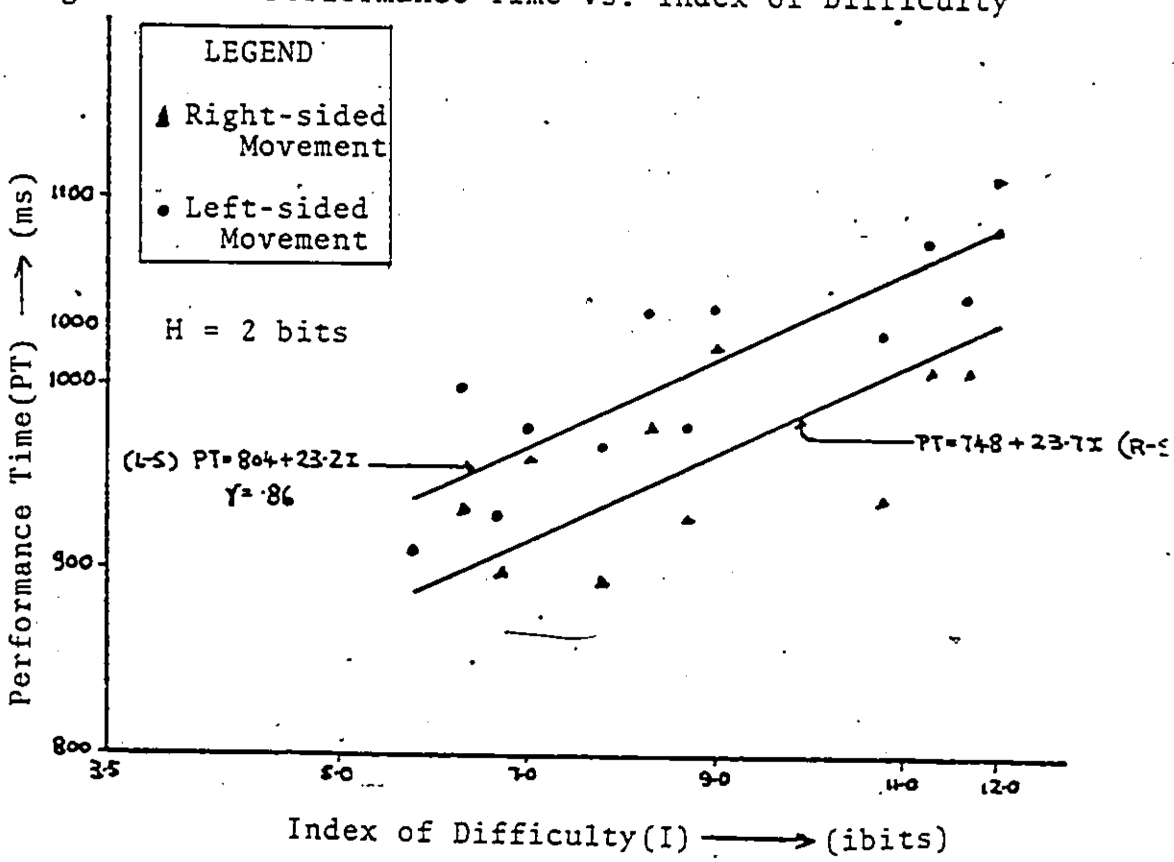


Figure D.8 Performance Time vs. Index of Difficulty

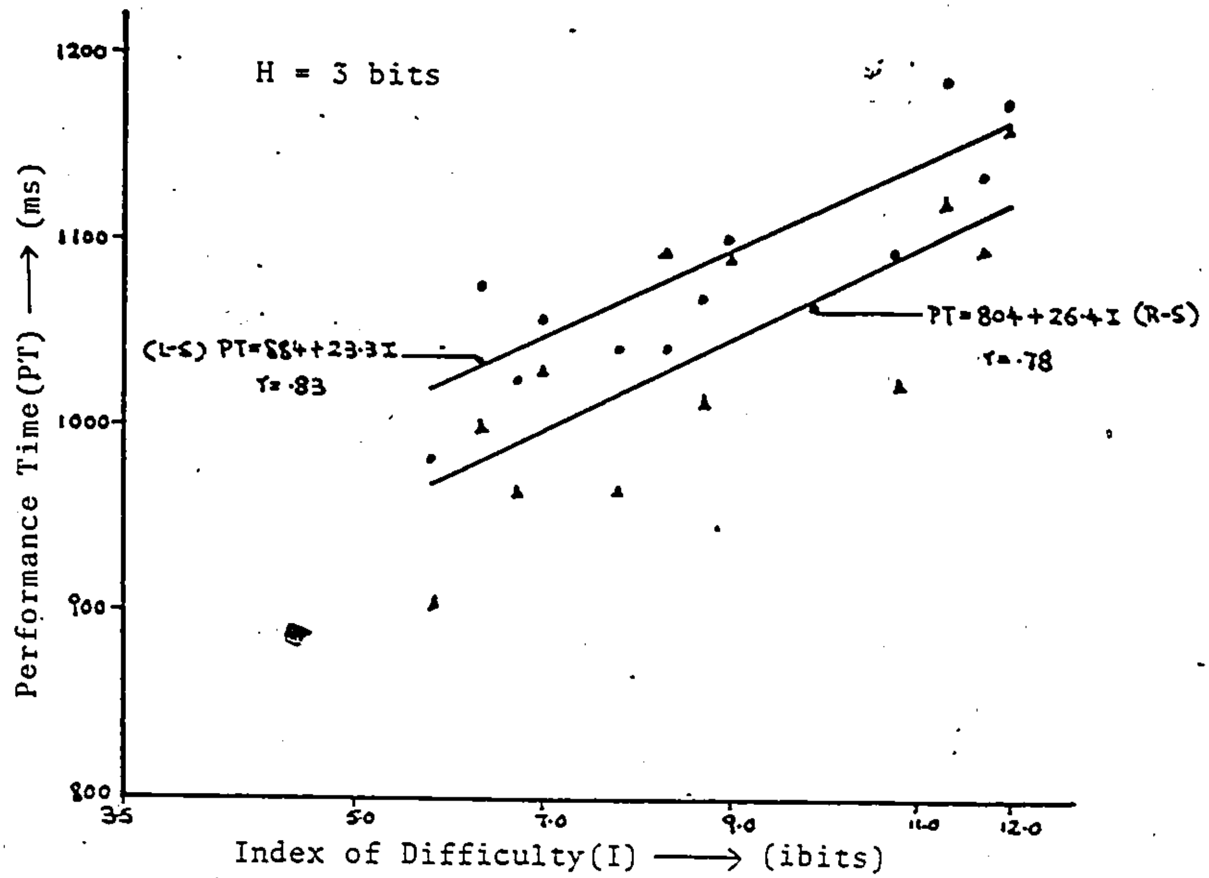


Figure D.9 Performance Time vs. Index of Difficulty

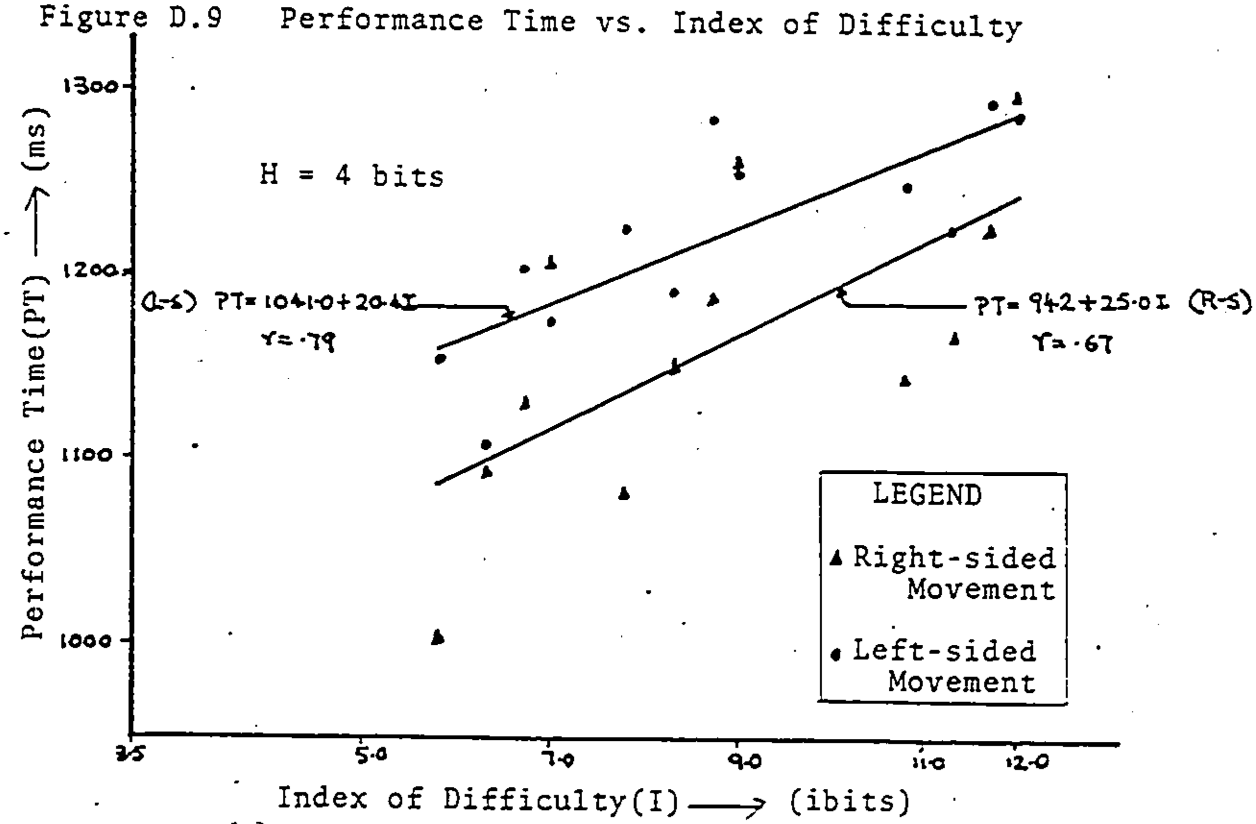


Figure D.10 Performance Time vs. Index of Difficulty

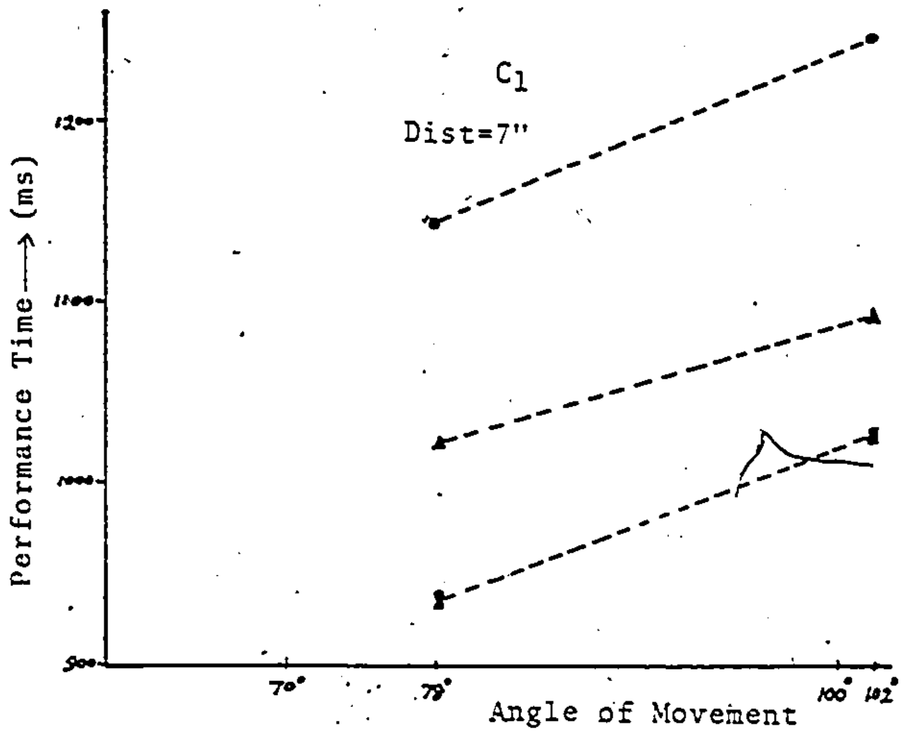


Figure D.11 Performance Time vs. Angle of Movement

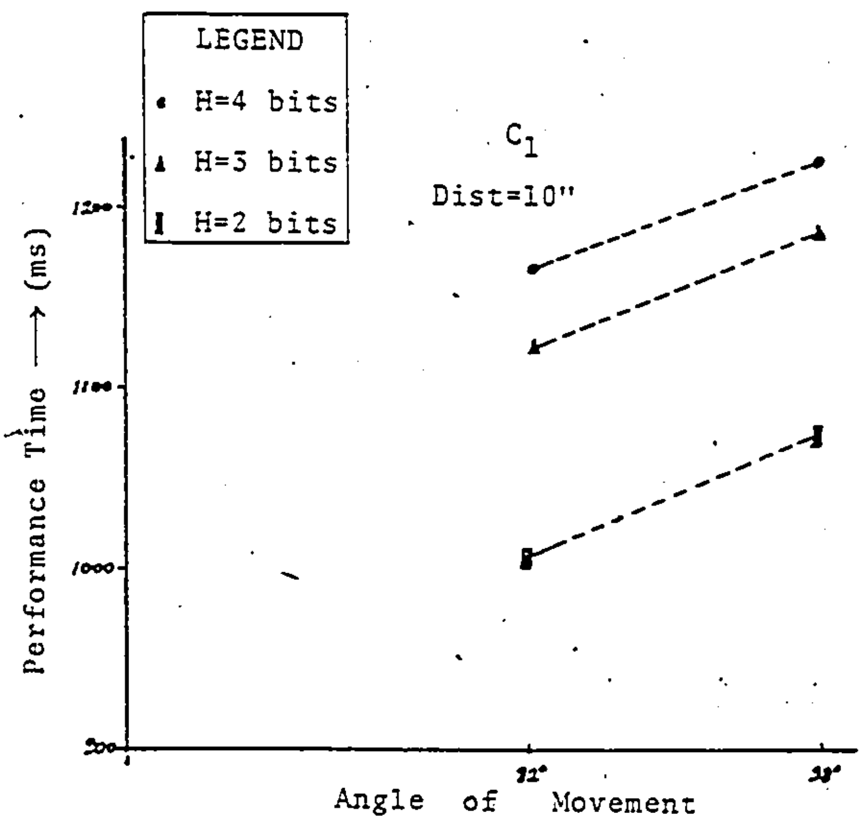


Figure D.12 Performance Time vs. Angle of Movement

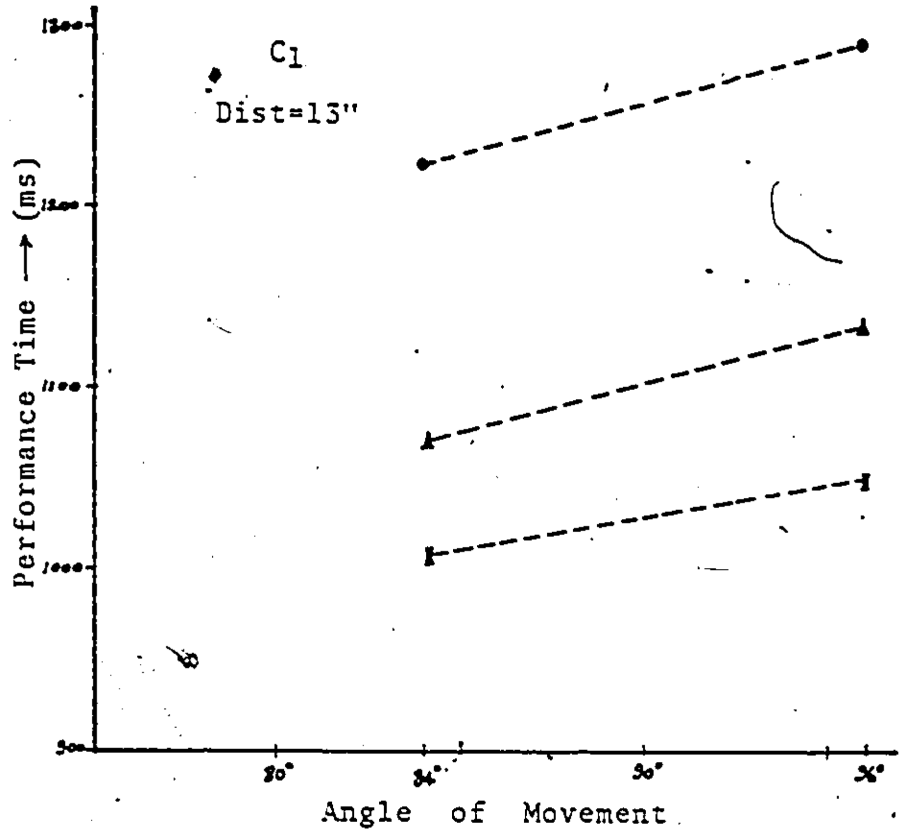


Figure D.13 Performance Time vs. Angle of Movement

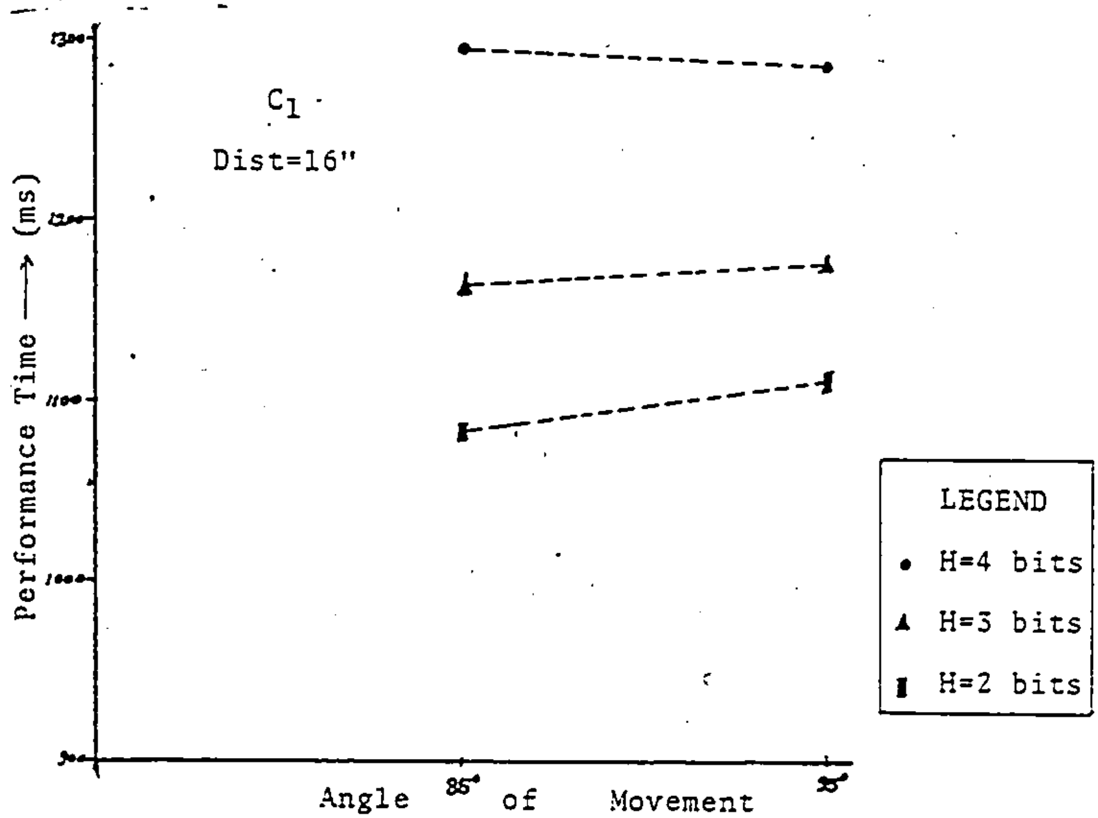


Figure D.14 Performance Time vs. Angle of Movement

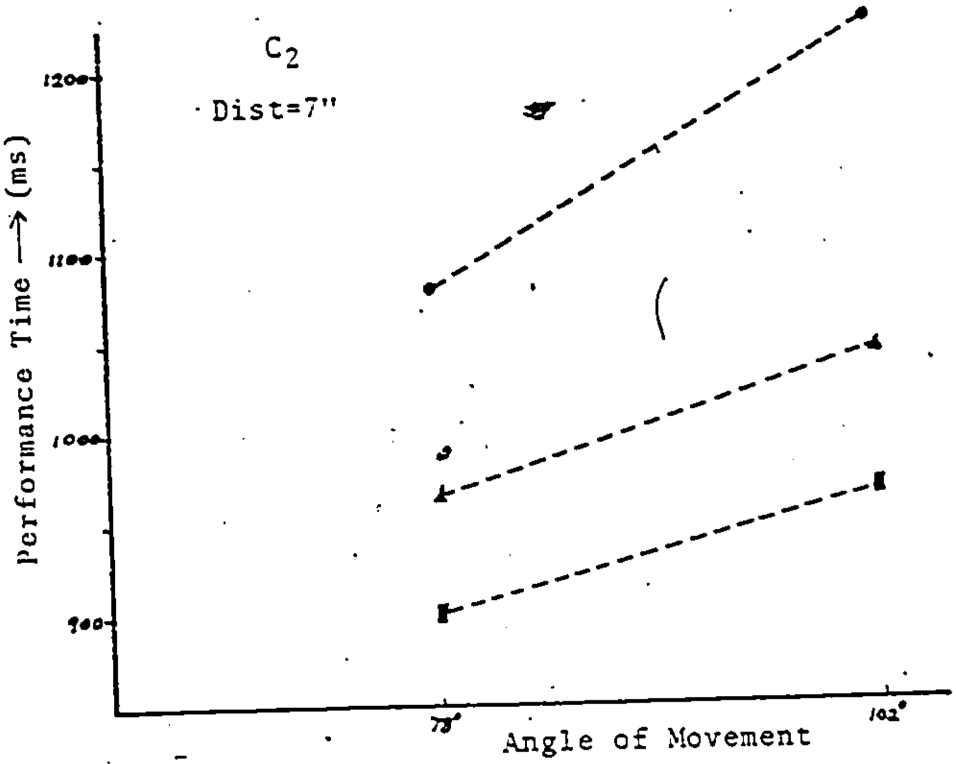


Figure D.15 Performance Time vs. Angle of Movement

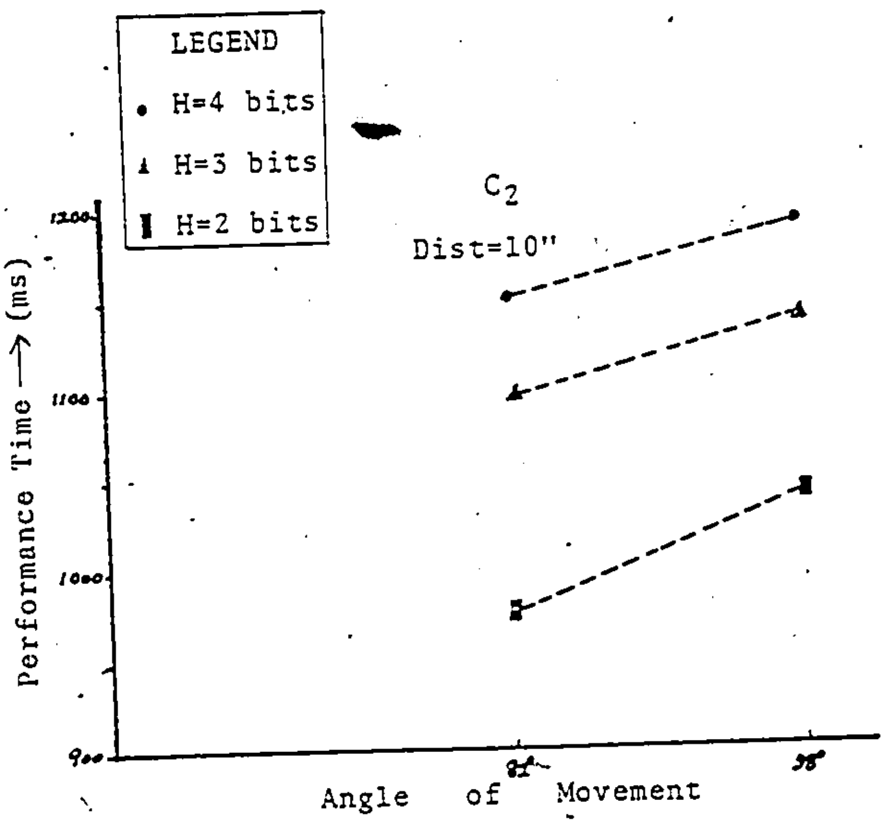


Figure D.16 Performance Time vs. Angle of Movement

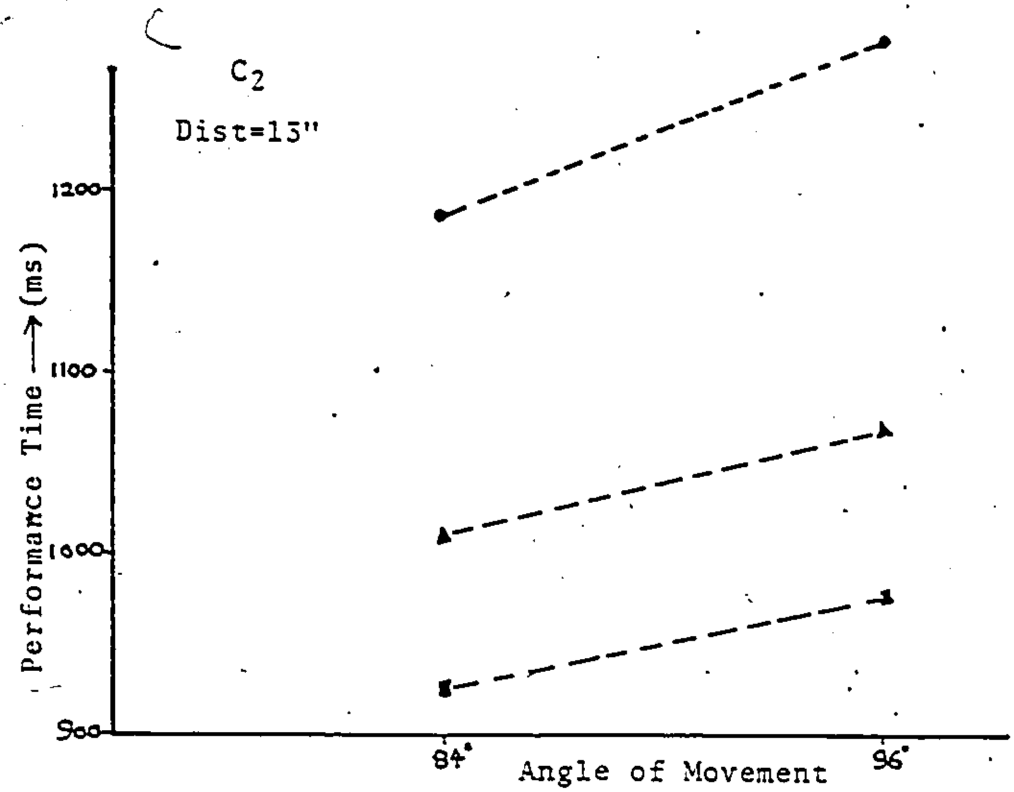


Figure.D.17 Performance Time vs..Angle of Movement

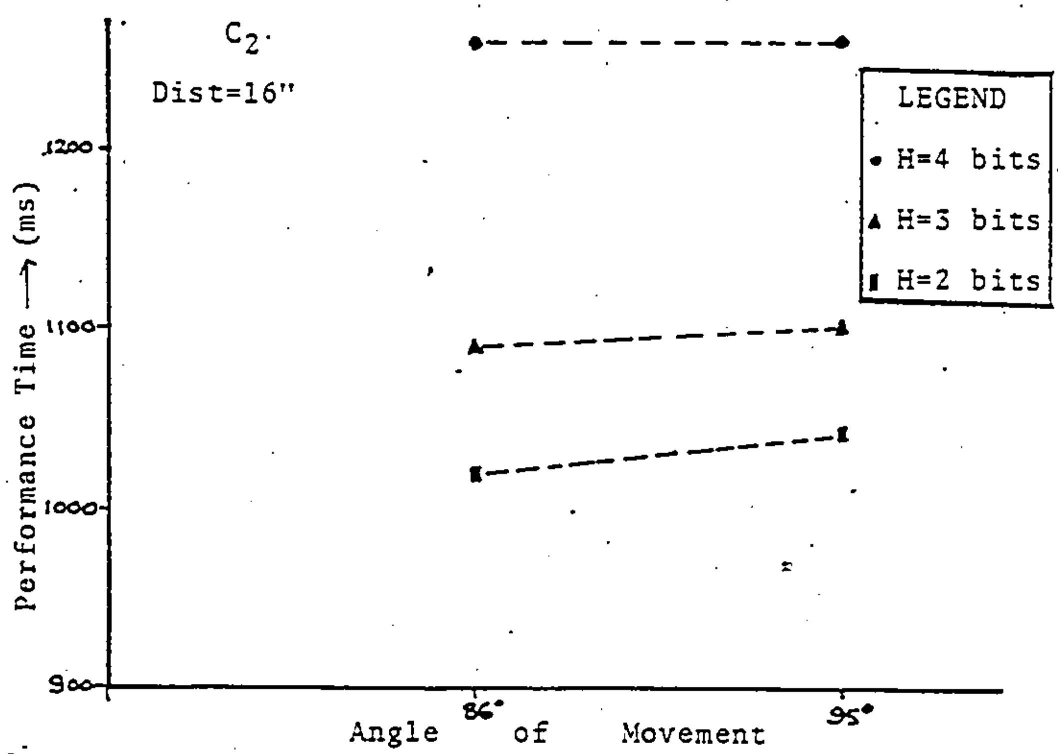


Figure D.18 Performance Time vs. Angle of Movement

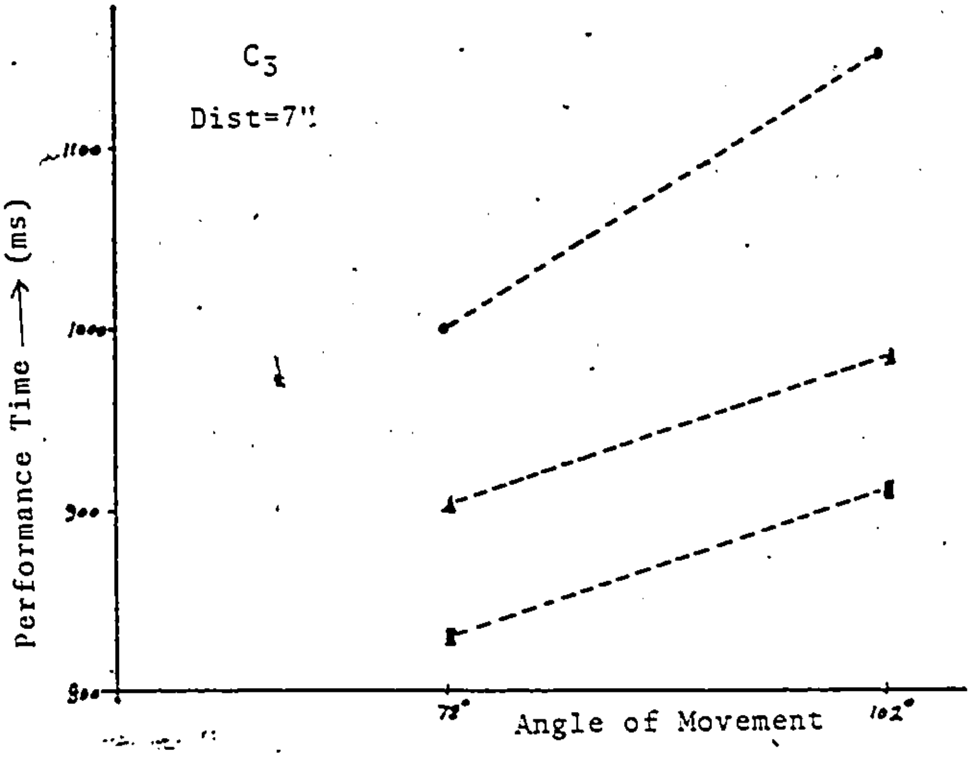


Figure D.19 Performance Time vs. Angle of Movement

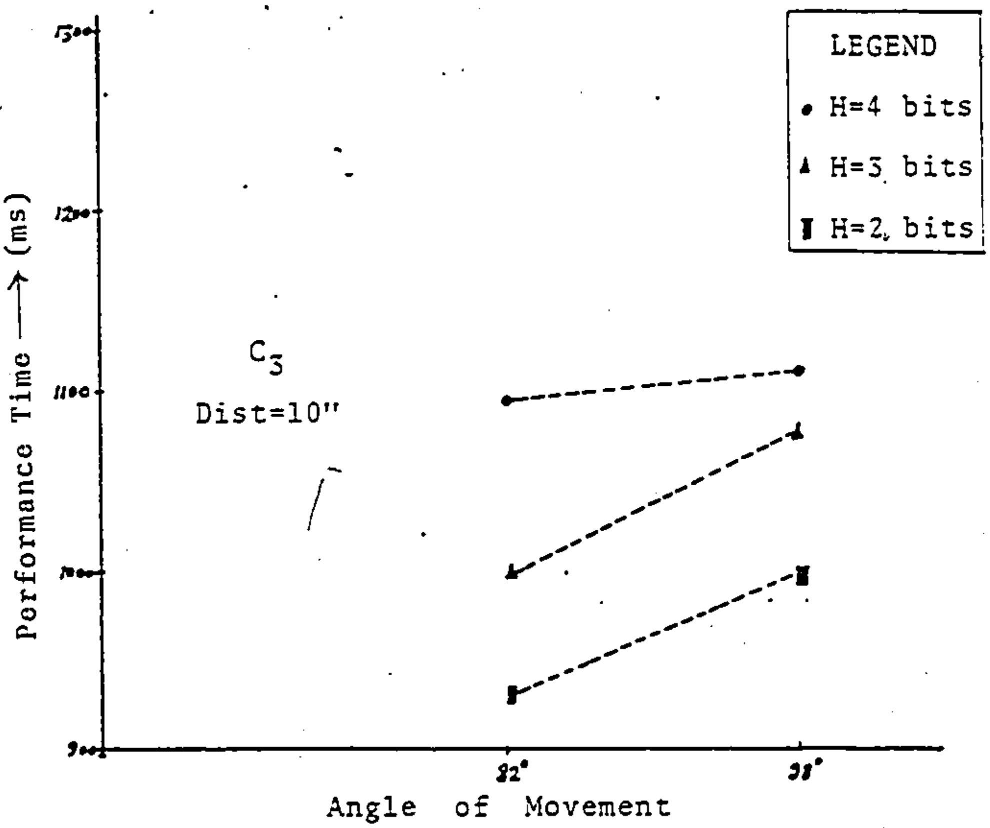


Figure D.20 Performance Time vs. Angle of Movement

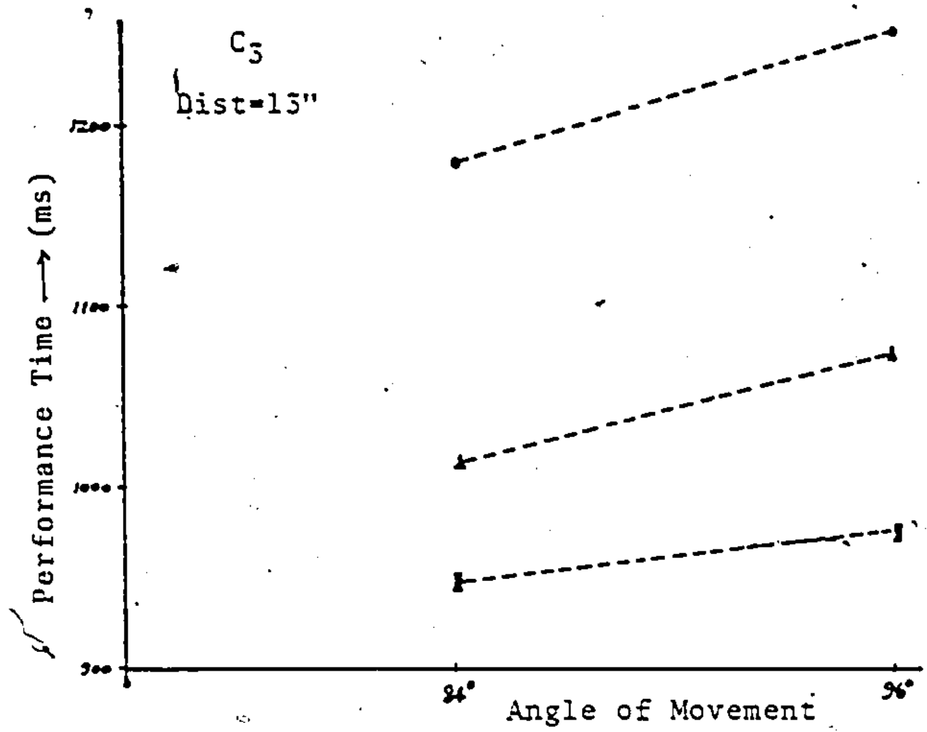


Figure D.21 Performance Time vs. Angle of Movement

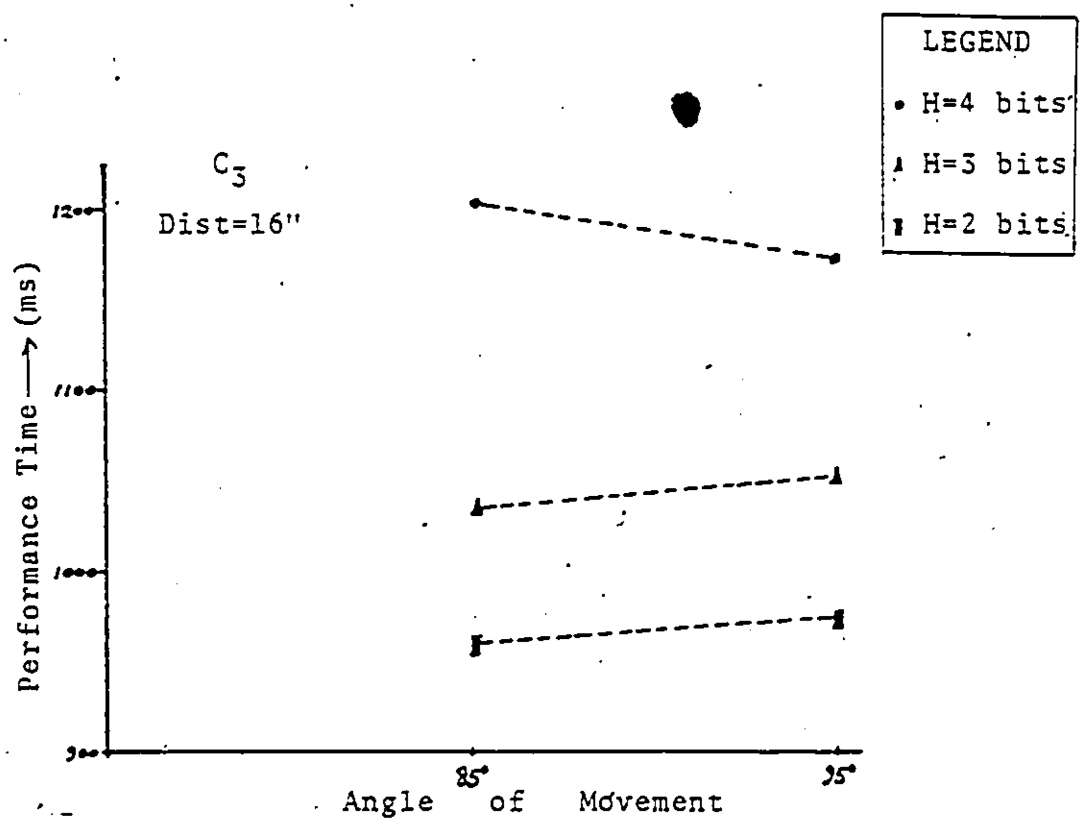


Figure D.22 Performance Time vs. Angle of Movement

Appendix E

Tables of Linear Regression Models

Linear Regression Procedures of the SAS-package were used in fitting linear models of Performance Times in terms of combinations of significant experimental effects. The goodness of fit and model coefficients are given in tabular form to facilitate comparison between Right-sided and Left-sided Movements and across levels of effects. Terminology used in this section is as follows:

PT = Performance Times in milliseconds

H = Informational Load in bits

C = Lateral Clearance in inches

D = Movement Distance in inches

I = Index of Difficulty (Fitt's version : $I = \log_2[2D/C]$) in bins

b = Regression Intercept with the PT-axis

b_1 = Coefficient of H in model

b_2 = Coefficient of C in model

b_3 = Coefficient of D in model

b_4 = Coefficient of I in model

S.E. = Standard Error

R-Square - meaning the square of multiple correlation. i.e. ratio of variance accounted for by the model to the total variance.

Significance Level of Fit - probability greater than the F-ratio taken as the MS of regression to the MS of residual.

Maximum % Residual - the maximum a-solute difference between the actual value and the predicted value expressed as the percentage of the actual.

Table E.1 $PT = b + b_1 H + b_2 C + b_3 D$

		b	b_1	b_2	b_3	Significance Level of Fit	R-Square	S.E. of Regression	Max. % Residual
Right-Sided Movement	'b'-values	623.31	106.60	-411.20	14.33	0.0001	0.9104	35.13	7.2
	S.E. of 'b'-values	30.61	7.17	56.47	1.75				
Left-Sided Movement	'b'-values	769.58	105.89	-419.63	5.57	0.0001	0.8970	35.42	7.2
	S.E. of 'b'-values	30.86	7.23	56.93	1.76				

Table E.2 $PT = b + b_1 H + b_4 I$

		b	b_1	b_4	Significance Level of Fit	R-Square	S.E. of Regression	Max. % Residual
Right-Sided Movement	'b'-values	523.72	102.60	25.08	0.0001	0.8003	51.65	8.5
	S.E. of 'b'-values	48.70	10.54	4.10				
Left-Sided Movement	'b'-values	592.34	105.90	22.36	0.0001	0.8939	35.41	6.3
	S.E. of 'b'-values	33.39	7.23	2.81				

Table E.3 $PT=b+b_1H$ for different levels of clearance(C) and distance(D

		Levels of C,D	b	b_1	Significance Level of Fit	R-Square	S.E. of Regression
Right-Sided Movement	'b'-values	C_3D_1	685.63	78.03	0.0068	0.9815	16.93
		C_3D_4	739.35	108.07	0.0142	0.9651	16.49
		C_2D_1	743.17	82.14	0.0057	0.9841	32.49
		C_2D_4	804.89	106.98	0.0170	0.9593	34.82
		C_1D_1	789.97	83.66	0.0190	0.9553	26.60
		C_1D_4	895.42	95.30	0.0111	0.9756	25.78
	Standard Error of 'b'-values	C_3D_1	20.75	7.58			
		C_3D_4	39.79	14.53			
		C_2D_1	20.20	7.38			
		C_2D_4	42.65	15.57			
		C_1D_1	35.04	12.79			
		C_1D_4	31.58	11.53			
Left-Sided Movement	'b'-values	C_3D_1	690.75	109.57	0.0142	0.9812	32.95
		C_3D_4	790.50	92.77	0.0041	0.9983	33.55
		C_2D_1	722.24	119.91	0.0120	0.9796	15.95
		C_2D_4	831.92	101.35	0.0130	0.9875	29.36
		C_1D_1	853.39	91.86	0.0226	0.9483	33.92
		C_1D_4	933.04	84.98	0.0076	0.9796	19.38
	Standard Error of 'b'-values	C_3D_1	40.36	14.74			
		C_3D_4	19.54	7.14			
		C_2D_1	41.10	15.01			
		C_2D_4	35.97	13.13			
		C_1D_1	41.55	15.17			
		C_1D_4	23.74	8.67			

Table B.4 $PT = b + b_2 C + b_3 D$ for different levels of H

		Levels of H (bits)	b	b_2	b_3	Significance Level of Fit	R-Square	S.E. of Regression
Right-Sided Movement	'b'-values	1	805.92	-500.13	11.24	0.0114	0.9474	24.06
		2	855.92	-382.01	12.34	0.0013	0.7858	34.53
		3	954.71	-458.87	11.40	0.0032	0.7281	43.07
		4	982.71	-392.72	19.25	0.0001	0.9654	16.67
	Standard Error of 'b'-values	1	28.77	94.90	2.18			
		2	37.05	96.12	2.97			
		3	46.22	119.91	3.70			
		4	17.89	46.42	1.44			
Left-Sided Movement	'b'-values	1	868.94	-488.41	8.41	0.0749	0.8225	41.39
		2	988.99	-417.77	5.61	0.0061	0.6818	37.26
		3	1074.35	-419.06	5.26	0.0098	0.6437	40.29
		4	1198.47	-422.06	5.85	0.0017	0.7723	30.08
	Standard Error of 'b'-values	1	49.50	163.25	3.76			
		2	39.99	103.73	3.21			
		3	43.23	112.16	3.47			
		4	32.28	83.73	2.59			

Table B.5 $PT = b + b_4 I$ for different levels of H

		Levels of H (bits)	b	b_4	Significance Level of Fit	R-Square	S.E. of Regression
Right-Sided Movement	'b'-values	1	620.29	30.00	0.0169	0.8015	36.76
		2	748.00	23.77	0.0034	0.5983	44.87
		3	804.49	26.43	0.0032	0.6030	49.38
		4	942.08	25.04	0.0150	0.4589	62.61
	Standard Error of 'b'-values	1	67.16	7.47			
		2	55.70	6.16			
		3	61.29	6.78			
		4	77.72	8.60			
Left-Sided Movement	'b'-values	1	643.80	30.84	0.0050	0.9021	26.63
		2	804.17	23.29	0.0006	0.7324	32.41
		3	884.89	23.34	0.0009	0.7046	34.80
		4	1041.01	20.44	0.0027	0.6197	36.87
	Standard Error of 'b'-values	1	45.70	5.08			
		2	40.24	4.45			
		3	43.20	4.78			
		4	45.77	5.06			

Appendix F

Motion Strategy

During the experiment, it was observed that as each subject progressed toward fully learned state, he developed a pattern of movement forming a motion strategy which he considered to be the most efficient. Although individuals varied in this self-developed motion strategy, there was, however, one feature common to all subjects. The subject began the task cycle by picking up the pin from the pin-pocket and as he focused his eyes on the indicator screen, his hand moved quickly a certain distance from the pin-pocket in the direction of the hole on the top plate. It then slowed down in a region some distance from the pin-pocket as he began the eye-search for the direction of the final move to the appropriate hole. The above strategy can be illustrated by using the simplest two-hole-alternatives task at D=16" and D=7".

Consider first the task involving hole numbers 2 and 3. The subject picked up the pin from the pin-pocket, made a fast move to a certain distance d_1 toward the two holes as he was detecting the number on the screen. He slowed down in a region bound by the dotted line around point P_1. At this point of time, he had just completed detection of the number and began eye-searching and mentally preparing for the next and final 'move' to the appropriate hole. If hole numbers 14 and 15 were involved instead, a similar motion pattern was observed but the hand slowed down in a region around P_2, a distance d_2 away from the pin-pocket.

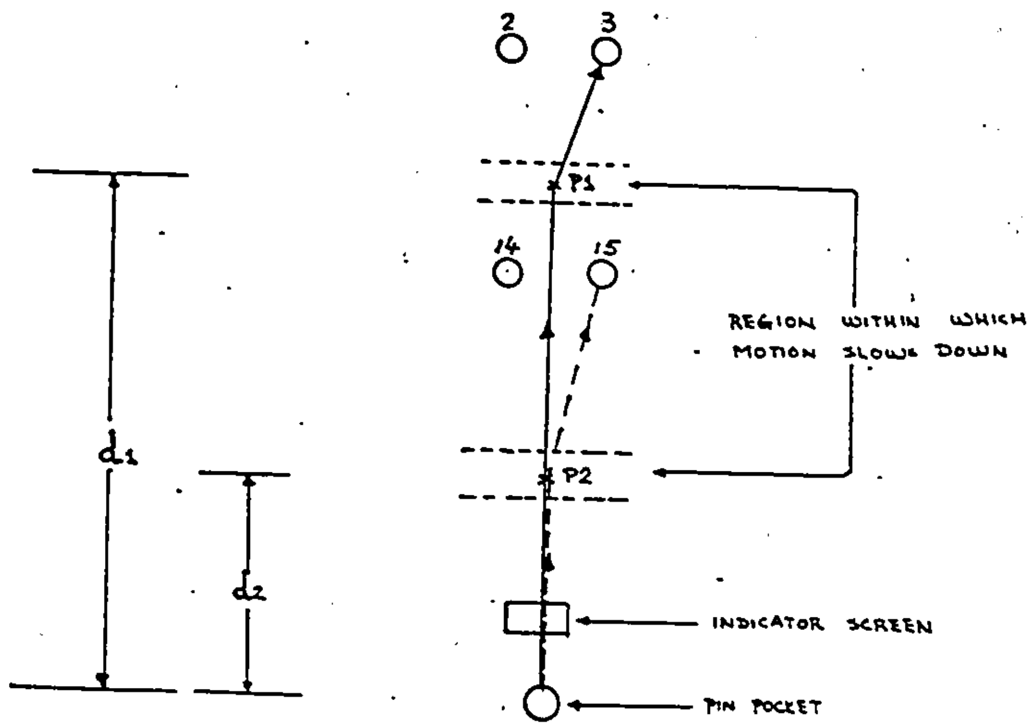


Figure F.1 Motion Strategy for the two-hole-alternatives tasks when number 3 or number 15 is shown on the screen.

In both cases, it was conceivable that the fast initial move was an overlearned motion resembling a simple reflex action after picking up the pin in the particular task concerned. During that motion, eye focus, detection and choice-time were critical relative to the manual motion time. Distances d_1 and d_2 were thus independent of the time it took for such move. In the latter part of the motion (P_1 to hole number 3 or P_2 to hole number 15), however, visual and kinesthetic feedback was essential in controlling the movement and producing the accuracy of positioning required by the task. In such cases, distance of movement together with clearance became critical factors in the motion time.

This observation was comparable with that of Thomas (1971) when he noted that his subjects developed a motion strategic of two almost distinct moves; an initial fast move to an indefinite position at a point near the most likely response button as perceived by the subject, and a shorter move to the final destination.

In the present study, it was found that the performance times for D_3=13" were consistently lower than those for D_2=10" at all three levels of clearance C and at H=2 bits and H-3 bits. This feature is shown graphically in Figure F.2 to F.4. Distance of Move has been found in all previous researches to have positive correlation with performance time in combined decision and manual tasks, (Raouf and Sethi 1974), nevertheless, the present pecularity can be explained with reference to motion strategy of different tasks as described earlier.

For the four-hole-alternatives and the eight-hole-alternatives tasks used in this experiment, (corresponding to H=2 bits and H=3 bits respectively), two different sets of response holes were used for distances D_3 and D_4 as against D_1 and D_2.

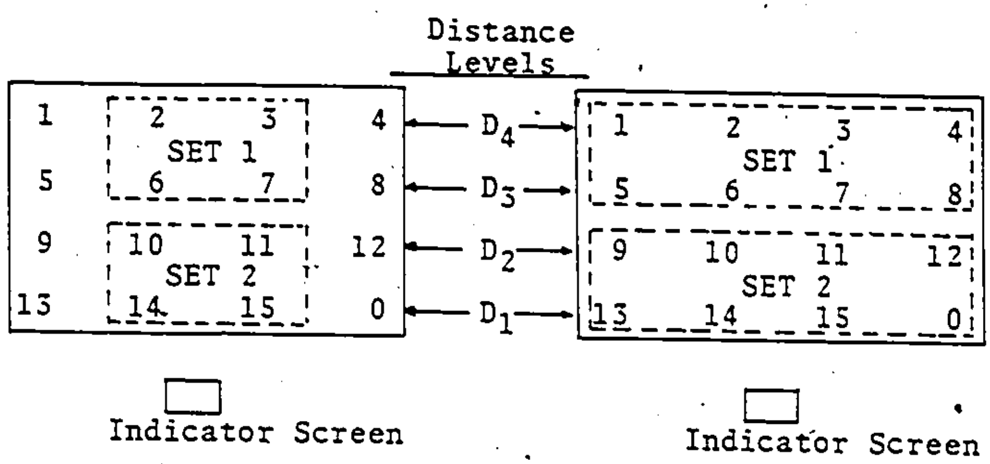


Figure F.5a

Figure F.5b

Figure F.5 Different Response sets for D_3 and D_4 levels as against D_1 and D_2 levels.

Considering the four-hole-alternatives task with the two sets of response holes as in Figure F.5a, the following situation was observed and is illustrated as in Figure F.6. For D_1 and D_2 levels, the first 'move' ended at around P_1 and continued along m_1 or m_2 depending on the stimulus number. For D_3 and D_4 levels, the first 'move' ended at around P_2 and continued along m_3 or m_4 depending again on the stimulus number. Due to the relative location of P_1 and P_2, the distance m_2 was actually longer than m_3. Since distance was significant only in the latter part of the total task motion (i.e. along the m's) as explained earlier,

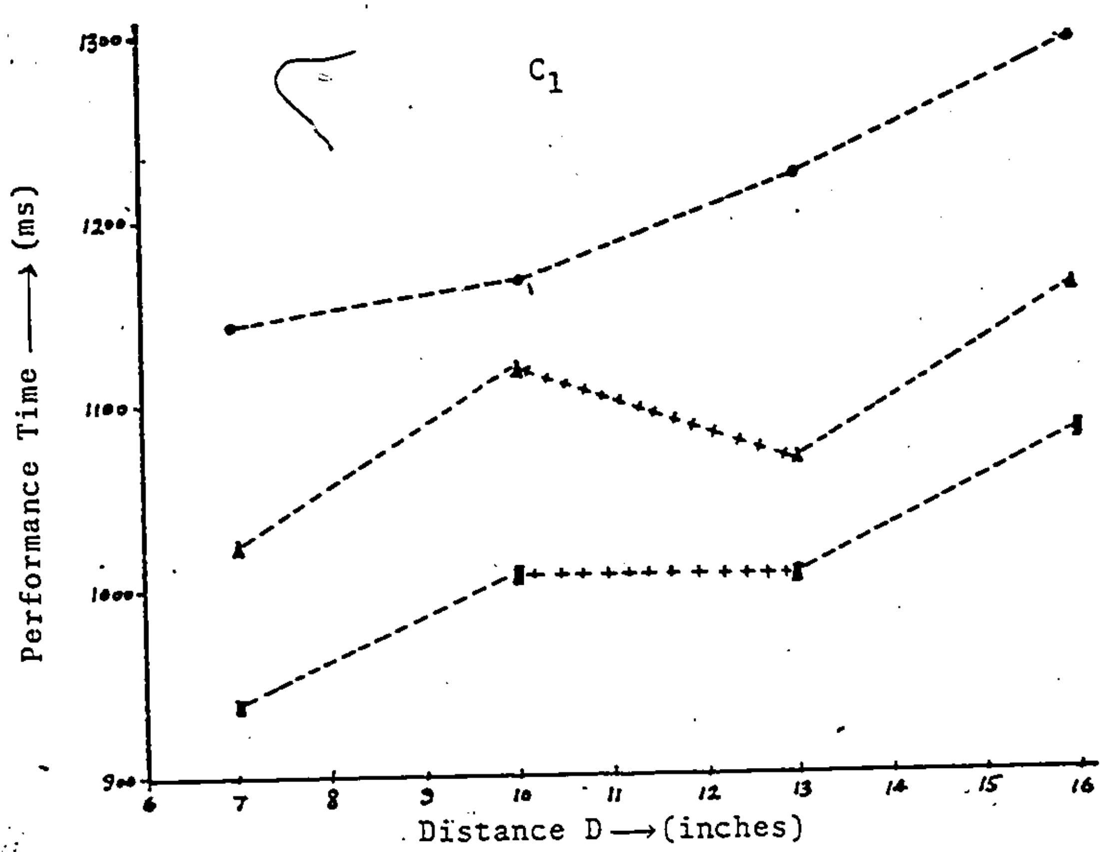


Figure F.2 Performance Time vs. Distance (Right-sided Movement)

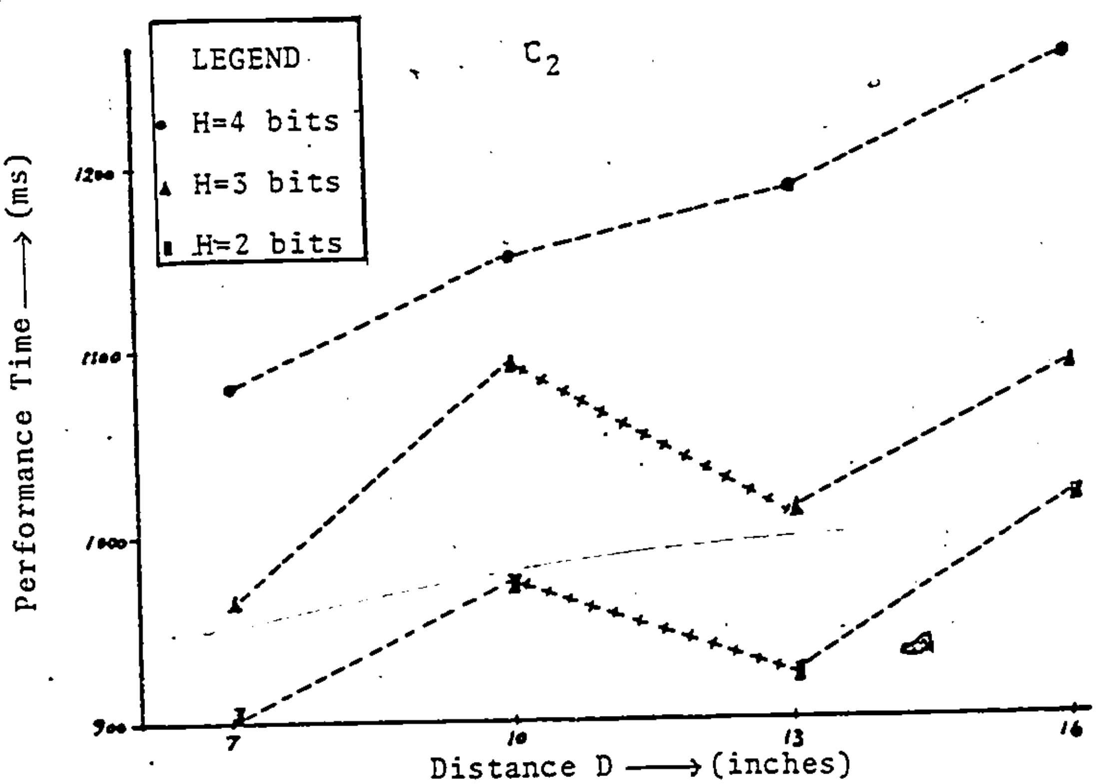


Figure F.3 Performance Time Distance (Right-sided Movement)

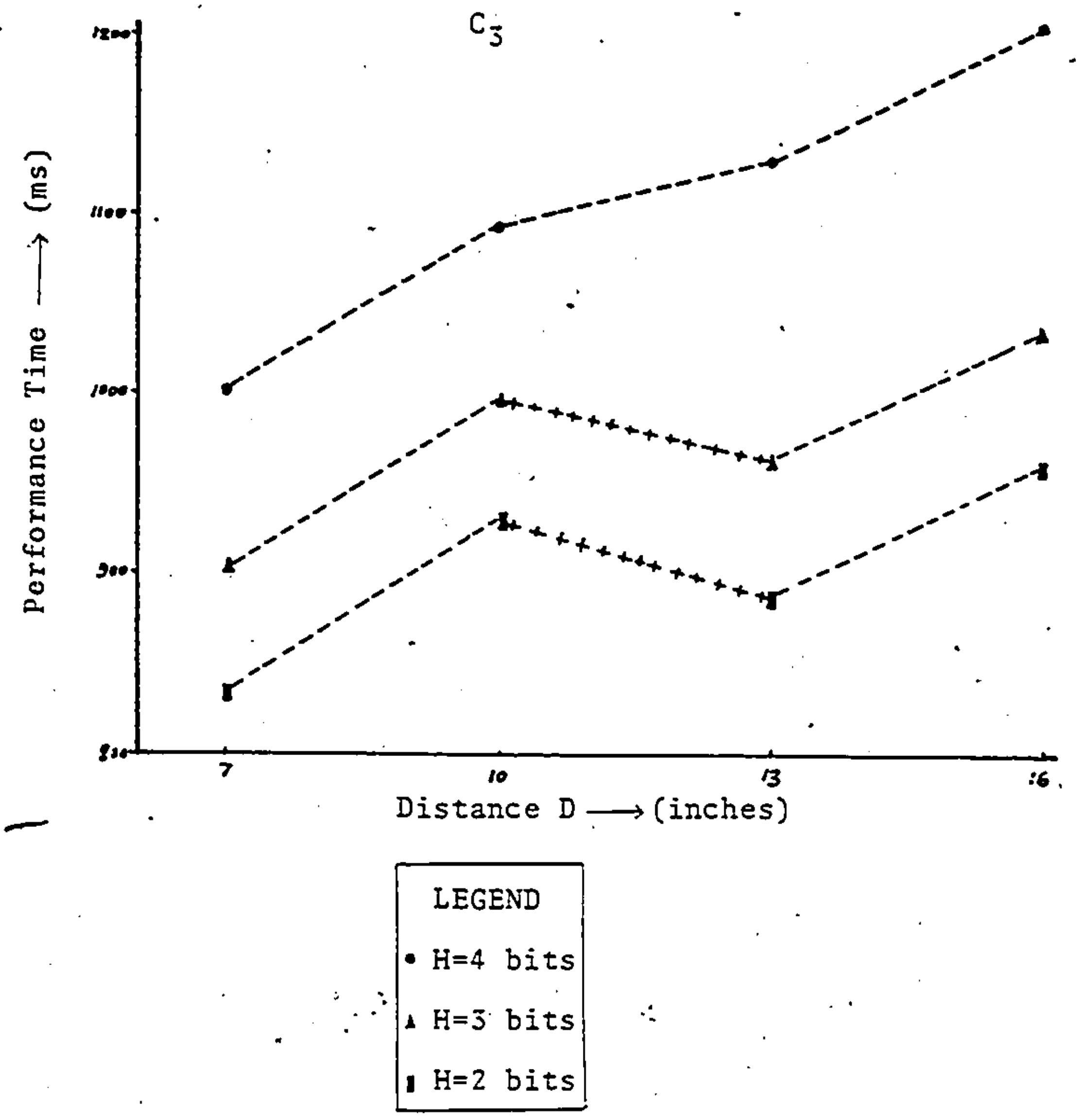


Figure F.4 Performance Time vs. Distance (Right-sided Movement)

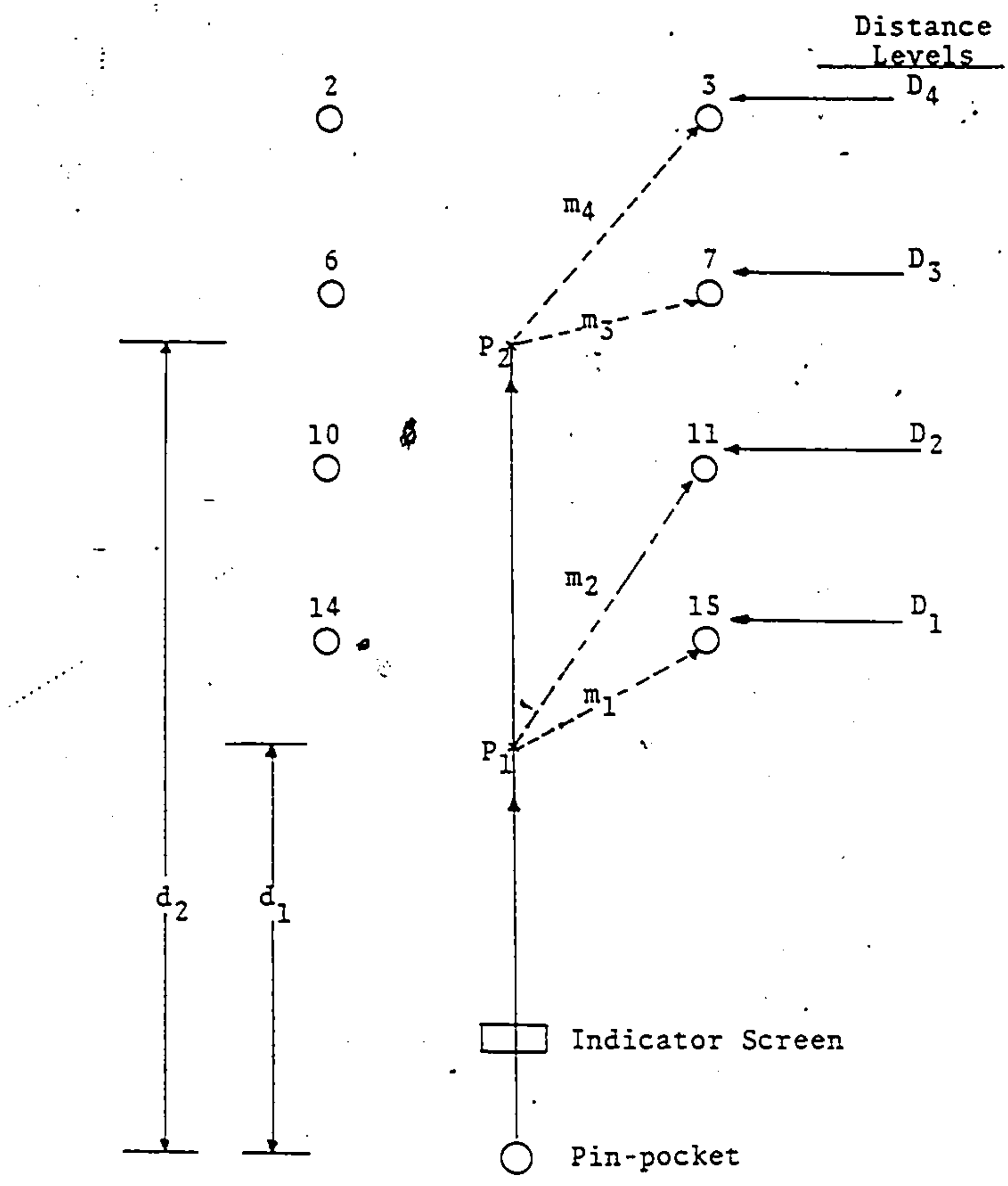


Figure F.6 Motion Strategy corresponding to different response sets used in the four-hole-alternatives tasks.

the time taken to move to hole number 7 in the upper response set could conceivably be shorter than that to hole number 11 in the lower set. According to motion strategy postulated here, it was therefore not the total distance D_2 or D_3 that was directly related to performance times but the distances m_2 or m_3 beginning at P_2 or P_3 that were significant.

In the case of the sixteen-hole-alternatives task, (i.e. H=4 bits), all the holes were included in the response set. The first 'move' for every task cycle ended at about the same region some distance from the pin-pocket, thus the second 'move' to any hole began at about the same point. The ratio of the m distances in this case approximated that of the D distances and consistant increases of performance times with distance D resulted. This feature is shown in Figure F.2 to F.4 in contrast with the pecularity at H=2 bits and H=3 bits.

<u>Error in Prediction Model Due to Motion Strategy Difference</u>

To examine the effect of the deviation between D_2 and D_3 as in Figure F.2 to Figure F.4. Two sets of least square linear regressions were developed, one from the data of levels D_1 and D_2, the others from the data of levels D_3 and D_4. These two sets are compared with the model in which all four levels of D are included simultaneously. Only Right-sided Movement is considered in this section. Results of the Left-sided Movement are expected to be similar. The model coefficients, the corresponding standard errors and the measure of fitness of the two sets are presented in the following tables for comparison.

From Table F.1, it is seen that the three best fit lines are significantly different from one another. The intercept coefficients 'b's of the models with 2-D levels are 3s (standard deviations) and 7s away on either side of the 4-D model. The coefficient b_3 of D for the D_3D_4 model is almost double that for the 4-D model. Plots of the best fit lines for the three levels of H at C_1 level of clearance and for the three different models are shown in Figure F.7. 95% confidence limits for the three models are also given by the dotted lines. It is clearly evident here that the three models are distinctly different from one another, and prediction equations have therefore to be developed for D_1D_2 levels and D_3D_4 levels separately when D and C are considered as separate motion parameters.

From Table F.2, however, when index of difficulty (I) replaces C and D, the coefficients 'b's of the three models are similar. The standard errors of regressions and coefficients are also comparable. The best fit lines for the three models when H=2 bits are plotted in Figure F.7. The corresponding 95% confident limits of the two 2-D models are also given. It is shown here surprisingly that the three lines are actually very close to one another and the 95% condifence bounds almost completely overlap. It suggests therefore that the 4-D model is adequate in relating the performance times to the index of difficulty even though differences in motion strategy are inherent in the experimental design.

Table F.1 $PT = b + b_1H + b_2C + b_3D$

			b	b_1*	b_2	b_3	Significance Level of Fit	R-Square	S.E. of Regression
MODEL 1	All 4 Levels of D	'b'-values	623.31	106.60	-411.20	14.33	0.0001	0.9104	35.14
		S.E. of 'b'-values	30.61	7.17	56.47	1.75			
MODEL 2	D_1, D_2	'b'-values	733.09	93.91	-407.10	14.44	0.0001	0.8965	34.74
		S.E. of 'b'-values	56.53	10.03	78.95	5.46			
MODEL 3	D_3, D_4	'b'-values	403.74	117.22	-403.59	25.74	0.0001	0.9439	30.78
		S.E. of 'b'-values	75.75	8.89	69.96	4.84			

* Terminology used here are the same as in Appendix E.

Table E.2 $PT = b + b_1H + b_4I$

			b	b_1	b_4	Significance Level of Fit	R-Square	S.E. of Regression
MODEL 1	All 4 Levels of D	'b'-values	523.72	102.60	25.08	0.0001	0.8003	52.44
		S.E. of 'b'-values	48.70	10.54	4.10			
MODEL 2	D_1, D_2	'b'-values	562.00	87.98	22.92	0.0001	0.8153	44.89
		S.E. of 'b'-values	58.64	12.95	5.11			
MODEL 3	D_3, D_4	'b'-values	523.89	117.23	22.87	0.0001	0.8660	45.97
		S.E. of 'b'-values	63.52	13.27	5.26			

Terminology used here are the same as in Appendix E.

H = 2 bits

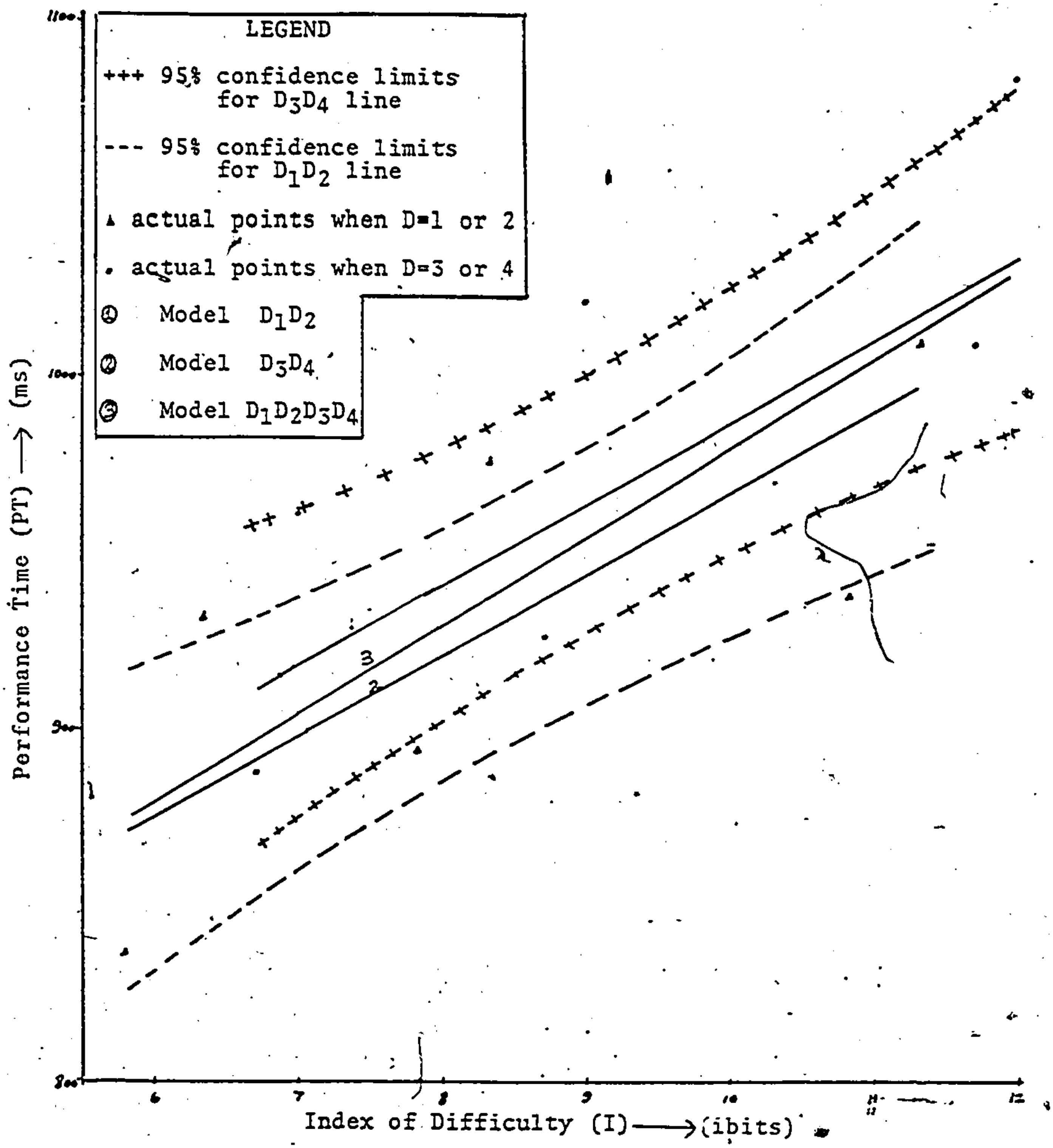


Figure F.7 Performance Time vs. Index of Difficulty for H=2 bits

APPENDIX G

Computer Programs and Printouts

1. Master Program to Organise and Store Experimental Data on Tape

```
      INTEGER XTEMP(7,150),YTEMP(7,150),CONDNO,SUBNO,IN,OUT
      INTEGER X(7,150),Y(7,150),COUNT(16),TIME(16,250),HOLE
      REAL XX(250),YY(250),DATA(10,4,6,2,20)
      INTEGER HIN(24,10),HOUT(24,10),SEX
      INTEGER YSTORE(7),XSTORE(7)
      INTEGER XCORR(7,150),YCORR(7,150)
      INTEGER ANGLE,PAIR
      COMMON/AREA1/X,Y,COUNT,TIME,ICARD
      COMMON/AREA2/IN,OUT,SEX,SUBNC,CONDNO,IPAR,YY,XX,STDEV,TMEAN,
     1 MNDS,SDMS,DATA,ANGLE
      REWIND 1
      REWIND 2
      DO 31 J=1,10
      READ(5,800)(HIN(I,J),HOUT(I,J),I=1,24)
   31 CONTINUE
      SEX=2
      DO 99 SUBNO=1,10
      WRITE (6,500)SUBNO
      ICOND=1
      DO 88 CONDNO=1,21
      ICARD=0
      DO 2 J=1,300
      IF(J.GE.150)GO TO 37
      IF(SUBNO.EQ.10.AND.CONDNO.EQ.18)GO TO 32
      IF(J.EQ.1.AND.CONDNO.EQ.1.AND.SUBNO.NE.1)GO TO 21
      IF(J.EQ.1.AND.CONDNO.NE.1)GO TO 21
      READ(1,100,END=999,ERR=9999) (Y(I,J),X(I,J),I=1,7),IDS,IDC
      IF(SUBNO.EQ.10.AND.IDC.EQ.18)GO TO 30
      GO TO 23
   32 IF(J.GT.1)GO TO 34
      DO 33 J1=1,150
      READ(1,100)(YCORR(I,J1),XCORR(I,J1),I=1,7),IDS,IDC
      IF(IDC.NE.0)GO TO 34
   33 CONTINUE
   34 READ(5,100)(Y(I,J),X(I,J),I=1,7),IDS,IDC
      GO TO 23
   21 DO 22 M1=1,7
      Y(M1,1)=YSTORE(M1)
   22 X(M1,1)=XSTORE(M1)
      GO TO 11
   23 IF(IDS.EQ.0.AND.IDC.EQ.0)GO TO 11
      IF (CONDNO.NE.IDC)GO TO 66
   11 ICARD=ICARD+1
      DO 9 I1=1,7
      IF(X(I1,J).EQ.0)X(I1,J)=15
      XTEMP(I1,J)=X(I1,J)
    9 YTEMP(I1,J)=Y(I1,J)
      K=7
      L=1
    1 Y(K,J)=YTEMP(L,J)
      X(K,J)=XTEMP(L,J)
      K=K-1
      L=L+1
      IF(K.EQ.0) GO TO 2
      GO TO 1
   37 M=J-(J-1)+149
      READ(1,100,END=999)(Y(I,M),X(I,M),I=1,7),IDS,IDC
      IF(IDC.NE.0)GO TO 66
    2 CONTINUE
   66 DO 24 ISTORE=1,7
      IF(X(ISTORE,J).EQ.0)X(ISTORE,J)=16
      YSTORE(ISTORE)=Y(ISTORE,J)
   24 XSTORE(ISTORE)=X(ISTORE,J)
  999 CONTINUE
   30 N2=ICARD
      N1=N2/2
      DO 4 K=1,N1
      DO 3 M=1,7
      XTEMP(M,K)=X(M,K)
      X(M,K)=X(M,N2-K+1)
      X(M,N2-K+1)=XTEMP(M,K)
      YTEMP(M,K)=Y(M,K)
      Y(M,K)=Y(M,N2-K+1)
    3 Y(M,N2-K+1)=YTEMP(M,K)
    4 CONTINUE
    5 DO 6 I=1,16
    6 COUNT(I)=0
      CALL ARRAY
```

```
      PAIR=0
      DO 77 I=1,16
      IF(I.NE.2.AND.I.NE.3.AND.I.NE.14.AND.I.NE.15)GO TO 77
      IF (COUNT(I).EQ.0.)GO TO 77
      PAIR=PAIR+1
      IPARI=COUNT(I)
      SUM=0.
      DO 25 I1=1,IPARI
   25 SUM=TIME(I,I1)+SUM
      MNBS=SUM/IPARI
      SUMSQ=C.
      DO 26 I2=1,IPARI
   26 SUMSQ=(TIME(I,I2)-MNBS)**2+SUMSQ
      SDBS=SQRT(SUMSQ/(IPARI-1))
      IPAR=0
      DO 27 I3=1,IPARI
      CRIT=IABS(TIME(I,I3)-MNBS)/SDBS
      IF(CRIT.GE.4.)GO TO 27
      IPAR=IPAR+1
      YY(IPAR)=TIME(I,I3)
      XX(IPAR)=IPAR
   27 CONTINUE
      IN=HIN(ICOND,SUBNO)
      OUT=HOUT(ICOND,SUBNO)
      IF(I.EQ.3.OR.I.EQ.15) ANGLE=1
      IF(I.EQ.2.OR.I.EQ.14)ANGLE=2
      CALL CREAT
      WRITE(6,6000)ICOND,I
      IF(PAIR.EQ.2.OR.PAIR.EQ.4)ICOND=ICOND+1
      WRITE(6,3000)
      DO 105 IR=1,20
      WRITE(2,5000)SEX,SUBNO,IN,OUT,ANGLE,IR,DATA(SUBNO,IN,OUT,
     1 ANGLE,IR)
  105 WRITE(6,2000)SEX,SUBNO,IN,OUT,ANGLE,IR,DATA(SUBNO,IN,OUT,
     1 ANGLE,IR)
      WRITE(6,4000)STDEV,TMEAN
   77 CONTINUE
   88 CONTINUE
   99 CONTINUE
      GO TO 888
 9999 WRITE(6,600)
  888 ENDFILE 1
      ENDFILE 2
  100 FORMAT(7(1X,I6,1X,I2),2X,I2,4X,I2)
  500 FORMAT ('1*************SUBJECT NUMBER',I4,'**********************')
  600 FORMAT(1X,'ERROR WHILE READING TAPE')
  800 FORMAT(24(I1,I1,1X))
 2000 FORMAT(1X,6I10,5X,F7.1)
 3000 FORMAT('1         SEX    ','  SUBJ. NO.','H,IN=LOG2(N)','  H,OUT=ID','
     1  ANGLE    ',5X,'     TIME     ')
 4000 FORMAT(1X,'STANDARD DEVIATION =',F6.0,'MEAN OF SAMPLE =',F6.0)
 5000 FORMAT(6I2,F7.1)
 6000 FORMAT('1  CONDITION NUMBER  ',I4,10X,'HOLE NUMBER  ',I3)
      STOP
      END
```



```
*OPTIONS IN EFFECT*  ID,EBCDIC,SOURCE,NOLIST,NODECK,LOAD,NOMAP
*OPTIONS IN EFFECT*  NAME = MAIN    , LINECNT =      80
*STATISTICS*    SOURCE STATEMENTS =      129,PROGRAM SIZE =     23746
*STATISTICS*  NO DIAGNOSTICS GENERATED
```

```
      SUBROUTINE ARRAY
      INTEGER X(7,150),Y(7,150),COUNT(16),TIME(16,250),HOLE
      COMMON/AREA1/X,Y,COUNT,TIME,ICARD
      DO 3 J=1,ICARD
      DO 2 I=1,7
    1 IF(Y(I,J).LT.500.OR.Y(I,J).GT.2000) GO TO 2
      HOLE=X(I,J)
      COUNT(HOLE)=COUNT(HOLE)+1
      K=COUNT(HOLE)
      TIME(HOLE,K)=Y(I,J)
    2 CONTINUE
    3 CONTINUE
      RETURN
      END
```


FORTRAN IV G LEVEL 21 ARRAY DATE = 76101 03/04/14 PAGE 00

```
*OPTIONS IN EFFECT*  ID,EBCDIC,SOURCE,NOLIST,NODECK,LOAD,NOMAP
*OPTIONS IN EFFECT*  NAME = ARRAY    , LINECNT =       80
*STATISTICS*     SOURCE STATEMENTS =       14,PROGRAM SIZE =       540
*STATISTICS*  NO DIAGNOSTICS GENERATED
```

```
      SUBROUTINE CREAT
      COMMON/AREA2/IN,OUT,SEX,SUBNO,CONDNO,IPAR,YY,XX,STDEV,TMEAN,
     1 MNBS,SDBS,DATA,ANGLE
      INTEGER ANGLE
      INTEGER SUBNO,CONDNO,IN,OUT,SEX
      REAL XX(250),YY(250),DATA(10,4,6,2,20)
      IX1=13579
      IX2=12345
      IF (IPAR.GT.20) GO TO 1
      DO 2 I=1,IPAR
    2 DATA(SUBNO,IN,OUT,ANGLE,I)=YY(I)
    3 IPAR=IPAR+1
      IF(IPAR.GT.20)GO TO 5
      CALL RANDU(IX1,IY1,R1)
      IX1=IY1
      CALL RANDU(IX2,IY2,R2)
      IX2=IY2
      V=(-2.0*ALOG(R1))**0.5*COS(6.283*R2)
      DATA(SUBNO,IN,OUT,ANGLE,IPAR)=V*SDBS+MNBS
      GO TO 3
    1 I20=IPAR/2+10
      DO 4 I=1,20
      DATA(SUBNO,IN,OUT,ANGLE,I)=YY(I20)
      I20=I20-1
    4 CONTINUE
    5 TSUM=0.
      DO 6 I1=1,20
    6 TSUM=DATA(SUBNO,IN,OUT,ANGLE,I1)+TSUM
      TMEAN=TSUM/20.
      SUMSQ=0.
      DO 7 I2=1,20
    7 SUMSQ=(DATA(SUBNO,IN,OUT,ANGLE,I2)-TMEAN)**2+SUMSQ
      STDEV=SQRT(SUMSQ/19.)
      RETURN
      END
```

2. Program Subroutine FDHINT to plot Histogram for every experimental condition

```
      SUBROUTINE FDHINT (X.N.NTYPE.TITLE)
C       (1)--   X = THE INPUT VECTOR. ORDERED L TO H
C       (2)--   N = THE NUMBER OF OBSERVATIONS  < X(N) >
C       (3)--   NTYPE < 0 ==> FD TABLE:GREATER THAN ZERO ==>FD TABLE&HIST
C       (4)--   TITLE = ONE CARD OF INFORMATION AS A HEADING
      COMMON/$FDHIT/JINT.F.MAX.MIN.RANGE.XINT.EMEAN.INTMEN.ESTDVN.EMED
      COMMON/FDH$$$/Y.CMID
      REALCHINMN(20).CMID(20).TITLE(20).CUMFP(20).LINE/'- - '/
      INTEGERF(20).D(20).FD(20).CUMF(20).FD2(20).CHINFQ(20).Y(20).GO.TOP
     *.BOT.RANGE.X(N).SUMFD.SUMFD2.FACTOR.CLINT1.XINT.B.INTVL(8)/1.2.3.5
     *.7.10.15.20/.EXCLS(20.2)
      INTEGERXXMAXX/Z7FFFFFFF/
      LOGICALJUMP
      SUMFD=0
      SUMFD2=0
      N2=N/2
      TOP=X(N)
      BOT=X(1)
      RANGE=TOP-BOT
      FACTOR=1
      I=1
C CALCULATE INTERVAL WIDTH ==> 10 TO 20 INTERVALS. MAXIMIZED
      IF(RANGE.GT.19)GOTO10003
      INT=RANGE
      GOTO10005
10003 CLINT1=RANGE/FACTOR
      DO90004I=1.8
      INT=CLINT1/INTVL(I)
      IF(INT.EQ.0)GOTO10004
      IF(INT.GE.10.AND.INT.LT.19)GOTO10005
90004 CONTINUE
      FACTOR=FACTOR*10
      GOTO10003
10004 FACTOR=FACTOR/10
      IF(FACTOR.NE.0)GOTO10003
      PRINT50000
50000 FORMAT('-CAN''T COMPUTE SUITABLE INTERVAL WIDTH')
      RETURN
10005 JINT=INT+1
      XINT=INTVL(I)*FACTOR
C CALCULATE STARTING VALUE FOR BOTTOM OF FIRST INTERVAL
      NBOT=BOT/XINT
      GO=XINT*NBOT
      IF(BOT.LT.0)GO=GO-XINT
      IF(FACTOR.GT.1)FACTOR=1
      IF(GO+XINT.LE.BOT)GO=GO+XINT
      EXCLS(1.1)=GO
      NXINT=XINT-1
      EXCLS(1.2)=GO+NXINT
      CMID(1)=GO+NXINT/2.
      IF(GO+XINT*JINT.LT.TOP)JINT=JINT+1
      DO90006K=2.JINT
      KM1=K-1
      EXCLS(K.1)=EXCLS(KM1.1)+XINT
      EXCLS(K.2)=EXCLS(KM1.2)+XINT
90006 CMID(K)=CMID(KM1)+XINT
C CALCULATE FREQUENCIES IN THE INTERVALS
      K=1
      NCUMF=0
      PRCNT=100./N
C**********CALCULATION OF MEAN. ST. DEVN.. AND MEDIAN ******************
      EMEAN=0.
      DO800I=1.N
800   EMEAN=EMEAN+X(I)
      EMEAN=EMEAN/N
      SUM=0.
      DO801I=1.N
801   SUM=SUM+(EMEAN-X(I))**2
      ESTDVN=SQRT(SUM/(N-1))
      EMED=X(N2+1)
      IF(N2*2.EQ.N)EMED=(EMED+X(N2))/2.
      MAX=0
      MIN=XXMAXX
      JUMP=.TRUE.
C********** FIT OBSERVATION INTO PROPER CLASS *************************
      DO90008I=1.JINT
      B=EXCLS(I.2)
      IF(EMEAN.GT.B)INTMEN=I+1
      NFI=0
      DO90007J=K.N
```

```
      IF(X(J).GT.B)GOTO10008
90007 NFI=NFI+1
      IF(I.NE.JINT)NFI=0
10008 F(I)=NFI
      IF(NFI.GT.MAX)MAX=NFI
      IF(MIN.GT.NFI)MIN=NFI
      IF(NFI.LT.5)JUMP=.FALSE.
      K=J
      NCUMF=NCUMF+NFI
      CUMFP(I)=NCUMF*PRCNT
90008 CUMF(I)=NCUMF
      PRINT43.TITLE.TOP.BOT.RANGE.XINT.EMEAN.INTMEN.ESTDVN.IMED
C********** CALCULATE DEVIATION FROM MEAN. FD. FDSQUARED **************
      DO80001I=1.JINT
      IJ=I-INTMEN
      D(I)=IJ
      IJF=F(I)*IJ
      FD(I)=IJF
      SUMFD=SUMFD+IJF
      IJFIJ=IJF*IJ
      FD2(I)=IJFIJ
80001 SUMFD2=SUMFD2+IJFIJ
      WRITE(6.40005)(LINE.I=1.33)
      K=JINT+1
      DO80002I=1.JINT
      L=K-I
      FPRCT=F(L)*100./N
80002 PRINT40004.L.EXCLS(L.1).EXCLS(L.2).CMID(L).F(L).FPRCT.D(L).FD(L).F
     *D2(L).CUMF(L).CUMFP(L)
      PRINT40005.(LINE.I=1.33)
      PRINT40055.SUMFD.SUMFD2
      IF(JUMP)GOTO77777
      CALLCHIGRP(F.JINT.Y.NINT.CHINFQ)
      IF(NINT.NE.1)GOTO80003
      PRINT40021
      GOTO902
80003 PRINT46.NINT.(CHINFQ(I).I=1.NINT)
      GOTO779
77777 NINT=JINT
      DO777I=1.NINT
777   CHINFQ(I)=F(I)
779   J=1
      K=0
CALCULATION OF CHISQ TESTS
      DO708L=1.NINT
      XF=0.
      K=CHINFQ(L)+K
      DO707I=J.K
      XI=X(I)
      IF(XI.LT.EMEAN)INTMEN=L
C           POSSIBLE ERROR HERE
  707 XF=XF+XI
      CHINMN(L)=XF/(K-J+1)
708   J=K+1
      MAXFQ=CHINFQ(INTMEN)
      EU=N*1./NINT
      CHINML=0.
      CHIUNF=0.
      DO901I=1.NINT
      IF=CHINFQ(I)
      XF=IF
      CHIXMN=CHINMN(I)
      XG=XF/MAXFQ*0.3989423
      XX=ABS(CHIXMN-EMEAN)/ESTDVN
      EN=0.3989423*EXP(-0.5*XX*XX)
      CHINML=CHINML+(XG-EN)**2/EN
901   CHIUNF=CHIUNF+(XF-EU)**2/EU
      PRINT491.CHINML.CHIUNF
902   IF(NTYPE.GT.0)CALLHISTGM(TITLE.NTYPE.N)
      RETURN
43    FORMAT('1FREQUENCY DISTRIBUTION FOR'.20A4/'0   MAXIMUM ='.I10.'
     * MINIMUM ='.I10.'          RANGE='.I10.'         INTERVAL WIDTH ='.I10/'0
     *MEAN ='.G12.5.'  IN INTERVAL'.I3.'.        ST. DVN. ='.G12.5.'      MED
     *IAN ='.G12.5///'-INT. NO.'.T25.'EXACT LIMITS'.T49.'MID-POINT'.T70.
     *'F'.9X.'FX'.10X.'D'.9X.'FD'.5X.'F*D**2'.T122.'CUM F - %'/)
   46 FORMAT('0  REGROUPED FOR CHISQ TESTS TO GIVE'.I3.' INTERVALS WITHF
     *REQUENCIES OF'/'0'.6X.20I6)
  491 FORMAT('0  CHISQ NORMAL ='.G12.3.'        CHISQ UNIFORM ='.G12.5)
40004 FORMAT('0'.I5.T13.4X.I10.' TO'.1X.I10.7X.G12.5.3X.I8.3X.F8.2.3(3X.
     *I8).2X.I8.1X.F6.2)
40005 FORMAT(' '.33A4/)
40055 FORMAT(87X.'SUMS   =   '.I6.I11)
40021 FORMAT('-CHISQR TESTS BY-PASSED BECAUSE OF TOO FEW DATA POINTS')
      END
```

```
      SUBROUTINECHIGRP(F.JINT.Y.NINT.CHINFO)
      INTEGERF(JINT).Y(JINT).CHINFO(JINT)
      NINT=JINT
      DO 598 I=1.JINT
  598 Y(I)=F(I)
  597 IF(NINT.GT.3)GO TO 599
      IF(NINT.GT.2)GO TO 777
      IF(Y(1).LT.5.OR.Y(2).LT.5)GO TO 4
    2 DO 3 I=1.NINT
    3 CHINFO(I)=Y(I)
      RETURN
    4 NINT=1
      CHINFO(1)=Y(1)+Y(2)
      RETURN
  777 IF(Y(1).GE.5.AND.Y(2).GE.5.AND.Y(3).GE.5)GO TO 2
      IF(Y(1).LT.5)GO TO 6
      Y(2)=Y(2)+Y(3)
      IF(Y(2).LT.5)GO TO 4
    5 NINT=2
      GO TO 2
    6 Y(1)=Y(1)+Y(2)
      Y(2)=Y(3)
      IF(Y(2).LT.5.OR.Y(2).LT.5)GO TO 4
      GO TO 5
  599 IHALF=NINT/2
      KSPOT=2
      L=1
      M=Y(1)
  600 IF(M.GE.5)GO TO 601
      M=M+Y(KSPOT)
      KSPOT=KSPOT+1
      GO TO 602
  601 CHINFO(L)=M
      L=L+1
      M=Y(KSPOT)
      KSPOT=KSPOT+1
  602 IF(KSPOT.LE.IHALF)GO TO 600
      CHINFO(L)=M
      L=L+1
      J=L
      M=Y(NINT)
      KSPOT=NINT-1
  700 IF(M.GE.5)GO TO 701
      M=M+Y(KSPOT)
      KSPOT=KSPOT-1
      GO TO 770
  701 CHINFO(L)=M
      L=L+1
      M=Y(KSPOT)
      KSPOT=KSPOT-1
  770 IF(KSPOT.GT.IHALF)GO TO 700
      NMJK=J-1
      IF(M.GE.5.AND.CHINFO(NMJK).GE.5)GO TO 702
      KFSPOT=KSPOT+1
      IF(NMJK.NE.KFSPOT)GO TO 778
      M=Y(KFSPOT+1)
      L=L-1
  778 CHINFO(NMJK)=CHINFO(NMJK)+M
      L=L-1
      GO TO 703
  702 CHINFO(L)=M
  703 M=(L-NMJK)/2
      IF(IABS(M).EQ.0)GO TO 99999
      DO 704 I=1.M
      IK=L+1-I
      IM=NMJK+I
      NSKIP=CHINFO(IM)
      CHINFO(IM)=CHINFO(IK)
      CHINFO(IK)=NSKIP
99999 NINT=L
      IF(CHINFO(NMJK).GE.5)RETURN
      DO 705 I=1.L
  705 Y(I)=CHINFO(I)
      GO TO 597
      END
```

```
      SUBROUTINEHISTGM(TITLE,LINES,IN)
      INTEGERF(20),Y(20),JUNK(5)
      REALCMID(20),TITLE(20),LINE/'- - '/,BLANK/'  '/,$$$$/'$$$$'/,GRAPH
     1(20)
      COMMON/$FDHIT/JINT,F,MAX,MIN,JUNK
      COMMON/FDH$$$/Y,CMID
      DO 333 III=1,20
  333 GRAPH(III)=BLANK
30000 WRITE(6,40006)TITLE
60002 IF(MIN.EQ.0)MIN=1
      NMAX=MAX-MIN+1
      SCALE=FLOAT(LINES-7)/FLOAT(NMAX)
      SC=1./SCALE
    4 DO 334 J=1,JINT
  334 Y(J)=(F(J)*SCALE+.5)
      N=LINES/30
      IF((LINES-N*30).LE.3*(N-1))N=N-1
      NSKIP=N*33+30-LINES
  297 IF(NSKIP.NE.0)PRINT40020,(I,I=1,NSKIP)
  298 K=(MAX*SCALE+1.5)
      FREQ=MAX*100./IN
      LINES=LINES-7
      DO 80005 I=1,LINES
      LL=K-I
      IF(LL.EQ.0)GO TO 60001
      DO 80004 J=1,JINT
80004 IF(Y(J).EQ.LL)GRAPH(J)=$$$$
      WRITE(6,40007)FREQ,GRAPH
80005 FREQ=FREQ-SC*100./IN
      M=7+5*JINT/4
60001 WRITE(6,40005)(LINE,I=1,M)
      WRITE(6,40008)(CMID(M),M=1,JINT,3)
      WRITE(6,40009)(CMID(M),M=2,JINT,3)
      WRITE(6,40010)(CMID(M),M=3,JINT,3)
      LINES=LINES+7
50001 RETURN
40005 FORMAT(' ',33A4/)
40006 FORMAT('1HISTOGRAM FOR ',20A4//)
40007 FORMAT(F9.2,9X,20A5)
40008 FORMAT('    FREQ ',6X,7(G12.5,3X))
40009 FORMAT(' ',19X,7(G12.5,3X))
40010 FORMAT(' ',24X,7(G12.5,3X))
40020 FORMAT(' ',A1)
      END

$ENTRY
```

3. Sample Histogram of Experimental Data including Distribution Statistics ....10 subjects

STANDARD DEVIATION = 128. MEAN OF SAMPLE = 876.
FREQUENCY DISTRIBUTION FOR HISTOGRAM OFPERFORMANCE TIMEFOR MAINSTUDY

MAXIMUM = 1147 MINIMUM = 730 RANGE= 417 INTERVAL WIDTH = 30

MEAN = 876.30 IN INTERVAL 6, ST. DVN. = 128.20 MEDIAN = 829.00

INT. NO.	EXACT LIMITS		MID-POINT	F	FX	D	FD	F*D**2	CUM F	- X
15	1140 TO	1169	1154.5	1	5.00	9	9	81	20	100.00
14	1110 TO	1139	1124.5	1	5.00	8	8	64	19	95.00
13	1080 TO	1109	1094.5	0	0.00	7	0	0	18	90.00
12	1050 TO	1079	1064.5	1	5.00	6	6	36	18	90.00
11	1020 TO	1049	1034.5	0	0.00	5	0	0	17	85.00
10	990 TO	1019	1004.5	1	5.00	4	4	16	17	85.00
9	960 TO	989	974.50	2	10.00	3	6	18	16	80.00
8	930 TO	959	944.50	0	0.00	2	0	0	14	70.00
7	900 TO	929	914.50	1	5.00	1	1	1	14	70.00
6	870 TO	899	884.50	0	0.00	0	0	0	13	65.00
5	840 TO	869	854.50	2	10.00	-1	-2	2	13	65.00
4	810 TO	839	824.50	3	15.00	-2	-6	12	11	55.00
3	780 TO	809	794.50	3	15.00	-3	-9	27	8	40.00
2	750 TO	779	764.50	3	15.00	-4	-12	48	5	25.00
1	720 TO	749	734.50	2	10.00	-5	-10	50	2	10.00
						SUMS =	-5	355		

REGROUPED FOR CHISQ TESTS TO GIVE 3 INTERVALS WITHFREQUENCIES OF

5 9 6

CHISQ NORMAL = 0.71059E-01 CHISQ UNIFORM = 1.3000

1

SEX	SUBJ. NO.	H.IN=LOG2(N)	H.OUT=ID	CYCLE	TIME
1	2	2	5	1	964.0
1	2	2	5	2	744.0
1	2	2	5	3	730.0
1	2	2	5	4	781.0
1	2	2	5	5	818.0
1	2	2	5	6	1072.0
1	2	2	5	7	779.0
1	2	2	5	8	865.0
1	2	2	5	9	824.0
1	2	2	5	10	900.0
1	2	2	5	11	834.0
1	2	2	5	12	1017.0
1	2	2	5	13	788.0
1	2	2	5	14	770.0
1	2	2	5	15	864.0
1	2	2	5	16	788.0
1	2	2	5	17	1113.0
1	2	2	5	18	1147.0
1	2	2	5	19	973.0
1	2	2	5	20	755.0

HISTOGRAM FOR   HISTOGRAM OFPERFORMANCE TIMEFOR MAINSTUDY

172

```
  15.00             $$$$ $$$$ $$$$
  13.93             $$$$ $$$$ $$$$
  12.86             $$$$ $$$$ $$$$
  11.79             $$$$ $$$$ $$$$
  10.71             $$$$ $$$$ $$$$
   9.64        $$$$ $$$$ $$$$ $$$$ $$$$                     $$$$
   8.57        $$$$ $$$$ $$$$ $$$$ $$$$                     $$$$
   7.50        $$$$ $$$$ $$$$ $$$$ $$$$                     $$$$
   6.43        $$$$ $$$$ $$$$ $$$$ $$$$                     $$$$
   5.36        $$$$ $$$$ $$$$ $$$$ $$$$      $$$$           $$$$ $$$$      $$$$      $$$$ $$$$
   4.29        $$$$ $$$$ $$$$ $$$$ $$$$      $$$$           $$$$ $$$$      $$$$      $$$$ $$$$
   3.21        $$$$ $$$$ $$$$ $$$$ $$$$      $$$$           $$$$ $$$$      $$$$      $$$$ $$$$
   2.14        $$$$ $$$$ $$$$ $$$$ $$$$      $$$$           $$$$ $$$$      $$$$      $$$$ $$$$
   1.07        $$$$ $$$$ $$$$ $$$$ $$$$      $$$$           $$$$ $$$$      $$$$      $$$$ $$$$
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  FREQ      734.50         824.50         914.50         1004.5         1094.5
                 764.50         854.50         944.50         1034.5         1124.5
                      794.50         884.50         974.50         1064.5         1154.5
```

1

2

STANDARD DEVIATION = 94. MEAN OF SAMPLE = 766.
FREQUENCY DISTRIBUTION FOR HISTOGRAM OFPERFORMANCE TIMEFOR MAINSTUDY

MAXIMUM = 986 MINIMUM = 606 RANGE= 380 INTERVAL WIDTH = 30

MEAN = 766.05 IN INTERVAL 6. ST. DVN. = 94.319 MEDIAN = 742.00

INT. NO.	EXACT LIMITS		MID-POINT	F	FX	D	FD	F*D**2	CUM F - X	
13	960 TO	989	974.50	1	5.00	7	7	49	20	100.00
12	930 TO	959	944.50	0	0.00	6	0	0	19	95.00
11	900 TO	929	914.50	2	10.00	5	10	50	19	95.00
10	870 TO	899	884.50	1	5.00	4	4	16	17	85.00
9	840 TO	869	854.50	0	0.00	3	0	0	16	80.00
8	810 TO	839	824.50	1	5.00	2	2	4	16	80.00
7	780 TO	809	794.50	1	5.00	1	1	1	15	75.00
6	750 TO	779	764.50	3	15.00	0	0	0	14	70.00
5	720 TO	749	734.50	5	25.00	-1	-5	5	11	55.00
4	690 TO	719	704.50	2	10.00	-2	-4	8	6	30.00
3	660 TO	689	674.50	3	15.00	-3	-9	27	4	20.00
2	630 TO	659	644.50	0	0.00	-4	0	0	1	5.00
1	600 TO	629	614.50	1	5.00	-5	-5	25	1	5.00
						SUMS =	1	185		

REGROUPED FOR CHISQ TESTS TO GIVE 3 INTERVALS WITHFREQUENCIES OF

6, 9 5

CHISQ NORMAL = 0.48514E-01 CHISQ UNIFORM = 1.3000

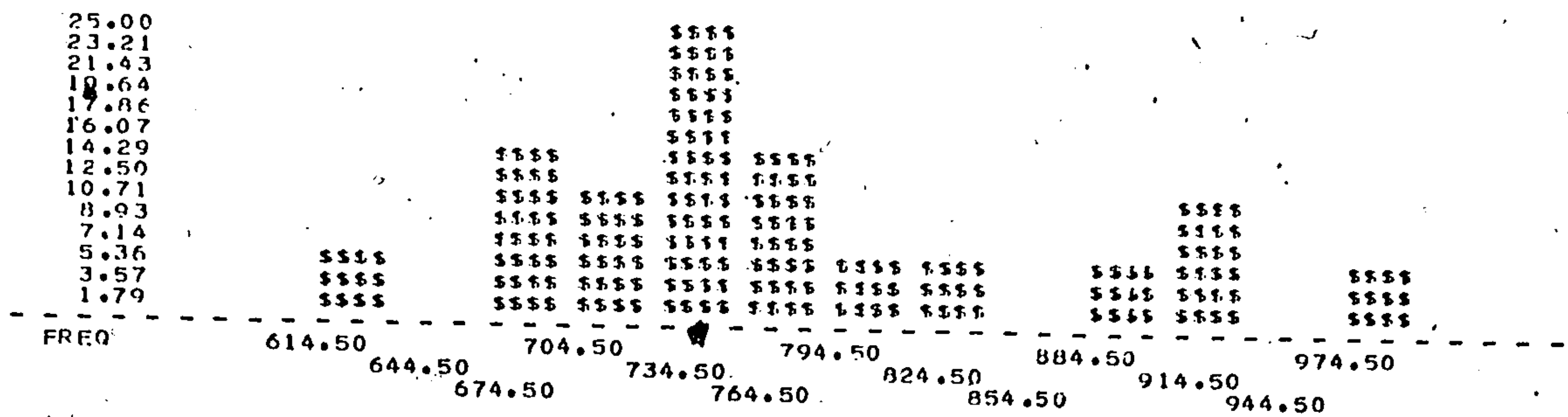
2

SEX	SUBJ. NO.H.IN=LOG2(N)	H.OUT=ID	CYCLE	TIME
1	2	1	2	1	986.0
1	2	1	2	2	743.0
1	2	1	2	3	679.0
1	2	1	2	4	755.0
1	2	1	2	5	899.0
1	2	1	2	6	739.0
1	2	1	2	7	731.0
1	2	1	2	8	760.0
1	2	1	2	9	704.0
1	2	1	2	10	681.0
1	2	1	2	11	681.0
1	2	1	2	12	906.0
1	2	1	2	13	741.0
1	2	1	2	14	766.0
1	2	1	2	15	693.0
1	2	1	2	16	907.0
1	2	1	2	17	606.0
1	2	1	2	18	729.0
1	2	1	2	19	801.0
1	2	1	2	20	824.0

2

HISTOGRAM FOR

HISTOGRAM OFPERFORMANCE TIMEFOR MAINSTUDY



3

STANDARD DEVIATION = 143. MEAN OF SAMPLE = 952.
FREQUENCY DISTRIBUTION FOR HISTOGRAM OFPERFORMANCE TIMEFOR MAINSTUDY

MAXIMUM = 1291 MINIMUM = 791 RANGE= 500 INTERVAL WIDTH = 30

MEAN = 951.60 IN INTERVAL 6. ST. DVN. = 143.18 MEDIAN = 910.50

INT. NO.	EXACT LIMITS		MID-POINT	F	FX	D.	FD	F*D**2	CUM F - %
18	1290 TO	1319	1304.5	1	5.00	12	12	144	20 100.00
17	1260 TO	1289	1274.5	0	0.00	11	0	0	19 95.00
16	1230 TO	1259	1244.5	0	0.00	10	0	0	19 95.00
15	1200 TO	1229	1214.5	0	0.00	9	0	0	19 95.00
14	1170 TO	1199	1184.5	0	0.00	8	0	0	19 95.00
13	1140 TO	1169	1154.5	2	10.00	7	14	98	19 95.00
12	1110 TO	1139	1124.5	1	5.00	6	6	36	17 85.00
11	1080 TO	1109	1094.5	1	5.00	5	5	25	16 80.00
10	1050 TO	1079	1064.5	1	5.00	4	4	16	15 75.00
9	1020 TO	1049	1034.5	0	0.00	3	0	0	14 70.00
8	990 TO	1019	1004.5	0	0.00	2	0	0	14 70.00
7	960 TO	989	974.50	0	0.00	1	0	0	14 70.00
6	930 TO	959	944.50	0	0.00	0	0	0	14 70.00
5	900 TO	929	914.50	5	25.00	-1	-5	5	14 70.00
4	870 TO	899	884.50	1	5.00	-2	-2	4	9 45.00
3	840 TO	869	854.50	4	20.00	-3	-12	36	8 40.00
2	810 TO	839	824.50	3	15.00	-4	-12	48	4 20.00
1	780 TO	809	794.50	1	5.00	-5	-5	25	1 5.00
						SUMS =	5	437	

REGROUPED FOR CHISQ TESTS TO GIVE 3 INTERVALS WITHFREQUENCIES OF

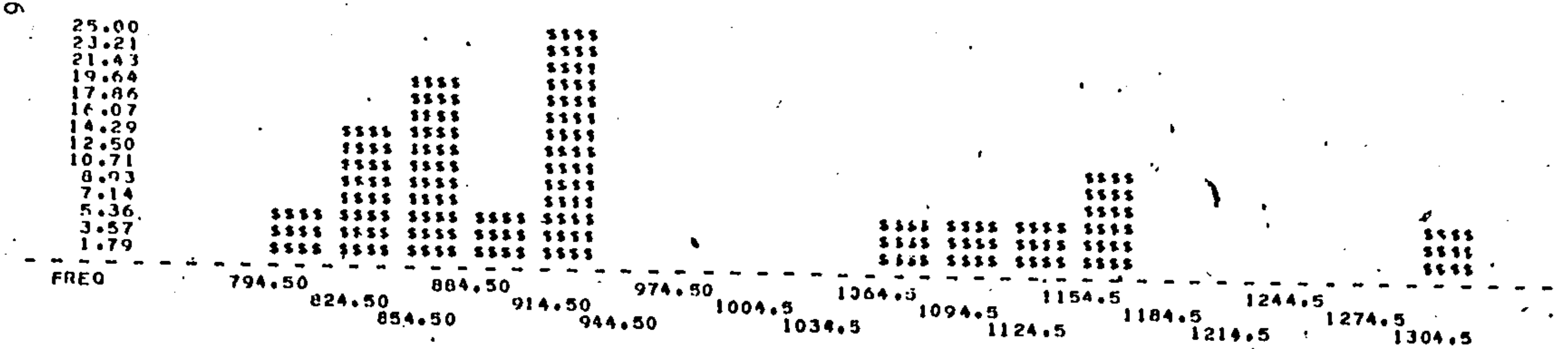
8 7 5

CHISQ NORMAL = 0.28225 CHISQ UNIFORM = 0.70000

SEX	SUBJ. NO.	H.IN=LOG2(N)	H.OUT=ID	CYCLE	TIME
1	2	1	6	1	861.0
1	2	1	6	2	835.0
1	2	1	6	3	874.0
1	2	1	6	4	912.0
1	2	1	6	5	1104.0
1	2	1	6	6	1159.0
1	2	1	6	7	1067.0
1	2	1	6	8	859.0
1	2	1	6	9	867.0
1	2	1	6	10	844.0
1	2	1	6	11	921.0
1	2	1	6	12	1291.0
1	2	1	6	13	919.0
1	2	1	6	14	1151.0
1	2	1	6	15	812.0
1	2	1	6	16	915.0
1	2	1	6	17	909.0
1	2	1	6	18	817.0
1	2	1	6	19	791.0
1	2	1	6	20	1124.0

3

HISTOGRAM FOR HISTOGRAM OFPERFORMANCE TIMEFOR MAINSTUDY



4

STANDARD DEVIATION = 130. MEAN OF SAMPLE = 815.
FREQUENCY DISTRIBUTION FOR HISTOGRAM OFPERFORMANCE TIMEFOR MAINSTUDY

MAXIMUM = 1275 MINIMUM = 691 RANGE= 584 INTERVAL WIDTH = 50

MEAN = 815.45 IN INTERVAL 4. ST. DVN. = 130.31 MEDIAN = 778.50

INT. NO.	EXACT LIMITS	MID-POINT	F	FX	D	FD	F*D**2	CUM F - X
13	1250 TO 1299	1274.5	1	5.00	9	9	81	20 100.00
12	1200 TO 1249	1224.5	0	0.00	8	0	0	19 95.00
11	1150 TO 1199	1174.5	0	0.00	7	0	0	19 95.00
10	1100 TO 1149	1124.5	0	0.00	6	0	0	19 95.00
9	1050 TO 1099	1074.5	0	0.00	5	0	0	19 95.00
8	1000 TO 1049	1024.5	0	0.00	4	0	0	19 95.00
7	950 TO 999	974.50	0	0.00	3	0	0	19 95.00
6	900 TO 949	924.50	1	5.00	2	2	4	19 95.00
5	850 TO 899	874.50	4	20.00	1	4	4	18 90.00
4	800 TO 849	824.50	3	15.00	0	0	0	14 70.00
3	750 TO 799	774.50	4	20.00	-1	-4	4	11 55.00
2	700 TO 749	724.50	5	25.00	-2	-10	20	7 35.00
1	650 TO 699	674.50	2	10.00	-3	-6	18	2 10.00
					SUMS =	-5	131	

REGROUPED FOR CHISQ TESTS TO GIVE 3 INTERVALS WITHFREQUENCIES OF

7 7 6

CHISQ NORMAL = 0.89644E-01 CHISQ.UNIFORM = 0.10000E 00

SEX	SUBJ. NO.	H.IN=LOG2(N)	H.OUT=ID	CYCLE	TIME
1	2	1	5	1	836.0
1	2	1	5	2	756.0
1	2	1	5	3	886.0
1	2	1	5	4	814.0
1	2	1	5	5	733.0
1	2	1	5	6	932.0
1	2	1	5	7	727.0
1	2	1	5	8	795.0
1	2	1	5	9	720.0
1	2	1	5	10	893.0
1	2	1	5	11	762.0
1	2	1	5	12	848.0
1	2	1	5	13	876.0
1	2	1	5	14	752.0
1	2	1	5	15	740.0
1	2	1	5	16	860.0
1	2	1	5	17	718.0
1	2	1	5	18	695.0
1	2	1	5	19	1275.0
1	2	1	5	20	691.0

4

HISTOGRAM FOR

HISTOGRAM OFPERFORMANCE TIMEFOR MAINSTUDY

```
25.00              $$$$
23.21              $$$$
21.43              $$$$
19.64              $$$$ $$$$      $$$$
17.86              $$$$ $$$$      $$$$
16.07              $$$$ $$$$      $$$$
14.29              $$$$ $$$$ $$$$ $$$$
12.50              $$$$ $$$$ $$$$ $$$$
10.71         $$$$ $$$$ $$$$ $$$$ $$$$
 8.93         $$$$ $$$$ $$$$ $$$$ $$$$
 7.14         $$$$ $$$$ $$$$ $$$$ $$$$
 5.36         $$$$ $$$$ $$$$ $$$$ $$$$                                    $$$$
 3.57         $$$$ $$$$ $$$$ $$$$ $$$$ $$$$                               $$$$
 1.79         $$$$ $$$$ $$$$ $$$$ $$$$ $$$$                               $$$$
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 FREQ      674.50    824.50    974.50    1124.5    1274.5
              724.50    874.50    1024.5    1174.5
                 774.50    924.50    1074.5    1224.5
```

5

STANDARD DEVIATION = 76. MEAN OF SAMPLE = 669.
FREQUENCY DISTRIBUTION FOR HISTOGRAM OFPERFORMANCE TIMEFOR MAINSTUDY

MAXIMUM = 784 MINIMUM = 517 RANGE= 267 INTERVAL WIDTH = 15

MEAN = 669.00 IN INTERVAL 11. ST. DVN: = 76.438 MEDIAN = 670.00

INT. NO.	EXACT LIMITS		MID-POINT	F	FX	D	FD	F*D**2	CUM F	- %
19	780 TO	794	787.00	1	5.00	8	8	64	20	100.00
18	765 TO	779	772.00	3	15.00	7	21	147	19	95.00
17	750 TO	764	757.00	0	0.00	6	0	0	16	80.00
16	735 TO	749	742.00	0	0.00	5	0	0	16	80.00
15	720 TO	734	727.00	1	5.00	4	4	16	16	80.00
14	705 TO	719	712.00	2	10.00	3	6	18	15	75.00
13	690 TO	704	697.00	0	0.00	2	0	0	13	65.00
12	675 TO	689	682.00	2	10.00	1	2	2	13	65.00
11	660 TO	674	667.00	3	15.00	0	0	0	11	55.00
10	645 TO	659	652.00	1	5.00	-1	-1	1	8	40.00
9	630 TO	644	637.00	1	5.00	-2	-2	4	7	35.00
8	615 TO	629	622.00	1	5.00	-3	-3	9	6	30.00
7	600 TO	614	607.00	1	5.00	-4	-4	16	5	25.00
6	585 TO	599	592.00	0	0.00	-5	0	0	4	20.00
5	570 TO	584	577.00	2	10.00	-6	-12	72	4	20.00
4	555 TO	569	562.00	1	5.00	-7	-7	49	2	10.00
3	540 TO	554	547.00	0	0.00	-8	0	0	1	5.00
2	525 TO	539	532.00	0	0.00	-9	0	0	1	5.00
1	510 TO	524	517.00	1	5.00	-10	-10	100	1	5.00
						SUMS, =	2	498		

REGROUPED FOR CHISQ TESTS TO GIVE 3 INTERVALS WITHFREQUENCIES OF

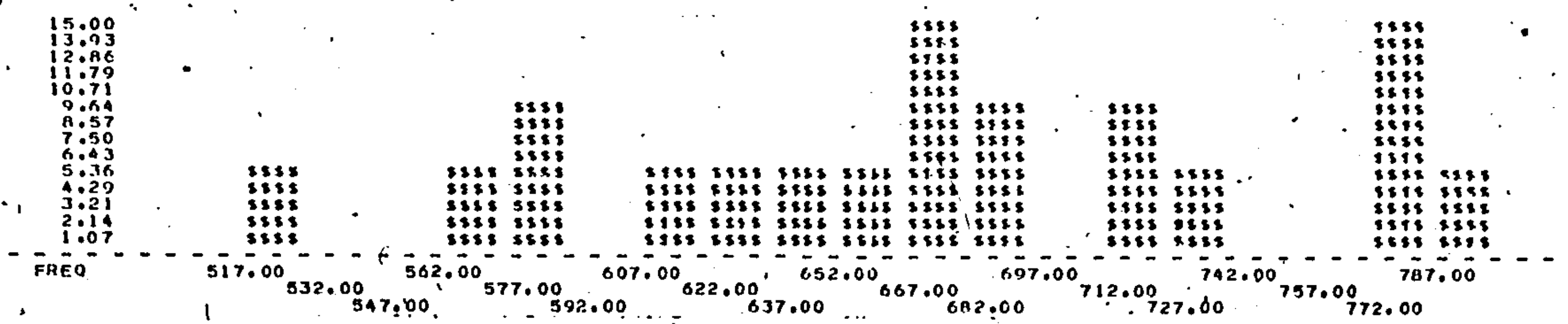
5 10 5

CHISQ NORMAL = 0.64774E-02 CHISQ UNIFORM = 2.5000

SEX	SUBJ. NO.	H.IN=LOG2(N)	H.OUT=IO	CYCLE	TIME
1	2	1	1	1	517.0
1	2	1	1	2	584.0
1	2	1	1	3	660.0
1	2	1	1	4	784.0
1	2	1	1	5	611.0
1	2	1	1	6	623.0
1	2	1	1	7	671.0
1	2	1	1	8	779.0
1	2	1	1	9	722.0
1	2	1	1	10	681.0
1	2	1	1	11	773.0
1	2	1	1	12	769.0
1	2	1	1	13	669.0
1	2	1	1	14	779.0
1	2	1	1	15	713.0
1	2	1	1	16	567.0
1	2	1	1	17	631.0
1	2	1	1	18	579.0
1	2	1	1	19	680.0
1	2	1	1	20	649.0

5

HISTOGRAM FOR HISTOGRAM OFPERFORMANCE TIMEFOR MAINSTUDY



STANDARD DEVIATION = 97. MEAN OF SAMPLE = 890.
FREQUENCY DISTRIBUTION FOR HISTOGRAM OFPERFORMANCE TIMEFOR MAINSTUDY

6

MAXIMUM = 1118 MINIMUM = 782 RANGE= 336 INTERVAL WIDTH = 20

MEAN = 890.20 IN INTERVAL 6, ST. DVN. = 96.610 MEDIAN = 867.50

INT. NO.	EXACT LIMITS		MID-POINT	F	FX	D	FD	F*D**2	CUM F - %
17	1100 TO	1119	1109.5	1	5.00	11	11	121	20 100.00
16	1080 TO	1099	1099.5	0	0.00	10	0	0	19 95.00
15	1060 TO	1079	1069.5	1	5.00	9	9	81	19 95.00
14	1040 TO	1059	1049.5	0	0.00	8	0	0	18 90.00
13	1020 TO	1039	1029.5	1	5.00	7	7	49	18 90.00
12	1000 TO	1019	1009.5	0	0.00	6	0	0	17 85.00
11	980 TO	999	989.50	1	5.00	5	5	25	17 85.00
10	960 TO	979	969.50	0	0.00	4	0	0	16 80.00
9	940 TO	959	949.50	1	5.00	3	3	9	16 80.00
8	920 TO	939	929.50	0	0.00	2	0	0	15 75.00
7	900 TO	919	909.50	2	10.00	1	2	2	15 75.00
6	880 TO	899	889.50	1	5.00	0	0	0	13 65.00
5	860 TO	879	869.50	3	15.00	-1	-3	3	12 60.00
4	840 TO	859	849.50	1	5.00	-2	-2	4	9 45.00
3	820 TO	839	829.50	2	10.00	-3	-6	18	8 40.00
2	800 TO	819	809.50	4	20.00	-4	-16	64	6 30.00
1	780 TO	799	789.50	2	10.00	-5	-10	50	2 10.00
						SUMS =	0	426	

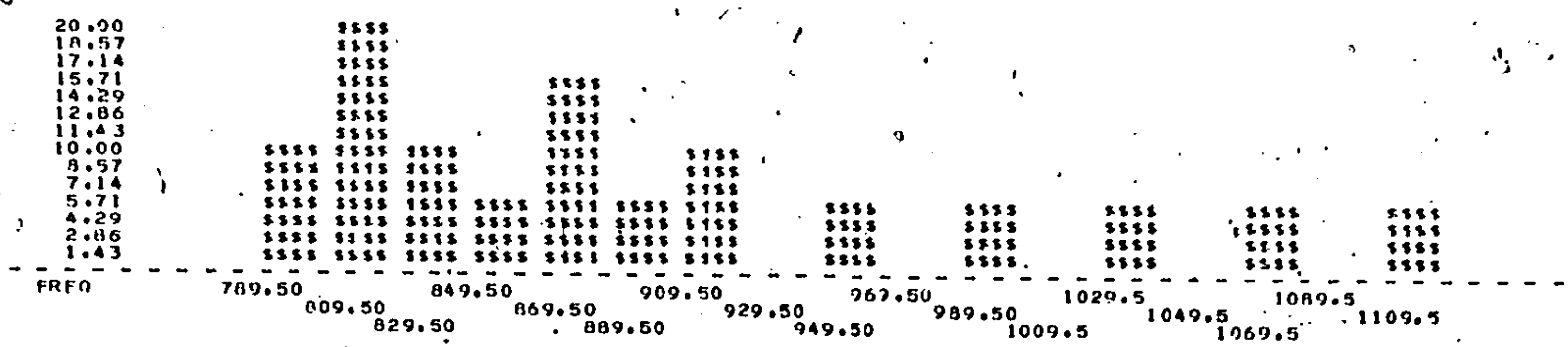
REGROUPED FOR CHISQ TESTS TO GIVE 3 INTERVALS WITHFREQUENCIES OF

6 6 8

CHISQ NORMAL = 0.39923 CHISQ UNIFORM = 0.40000

SEX	SUBJ. NO.	H.IN=LOG2(N)	H.OUT=ID	CYCLE	TIME
1	2	3	2	1	782.0
1	2	3	2	2	804.0
1	2	3	2	3	877.0
1	2	3	2	4	1118.0
1	2	3	2	5	1077.0
1	2	3	2	6	831.0
1	2	3	2	7	1023.0
1	2	3	2	8	865.0
1	2	3	2	9	899.0
1	2	3	2	10	916.0
1	2	3	2	11	807.0
1	2	3	2	12	858.0
1	2	3	2	13	823.0
1	2	3	2	14	900.0
1	2	3	2	15	814.0
1	2	3	2	16	804.0
1	2	3	2	17	870.0
1	2	3	2	18	795.0
1	2	3	2	19	954.0
1	2	3	2	20	987.0

HISTOGRAM FOR HISTOGRAM OFPERFORMANCE TIMEFOR MAINSTUDY



STANDARD DEVIATION = 65. MEAN OF SAMPLE = 825.
FREQUENCY DISTRIBUTION FOR HISTOGRAM OFPERFORMANCE TIMEFOR MAINSTUDY

MAXIMUM = 1070 MINIMUM = 698 RANGE= 372 INTERVAL WIDTH = 20

MEAN = 824.70 IN INTERVAL 8. ST. DVN. = 84.805 MEDIAN = 824.50

INT. NO.	EXACT LIMITS		MID-POINT	F	FX	D	FD	F*D**2	CUM F	- %
20	1060 TO	1079	1069.5	1	5.00	12	12	144	20	100.00
19	1040 TO	1059	1049.5	0	0.00	11	0	0	19	95.00
18	1020 TO	1039	1029.5	0	0.00	10	0	0	19	95.00
17	1000 TO	1019	1009.5	0	0.00	9	0	0	19	95.00
16	980 TO	999	989.50	0	0.00	8	0	0	19	95.00
15	960 TO	979	969.50	0	0.00	7	0	0	19	95.00
14	940 TO	959	949.50	0	0.00	6	0	0	19	95.00
13	920 TO	939	929.50	0	0.00	5	0	0	19	95.00
12	900 TO	919	909.50	2	10.00	4	8	32	19	95.00
11	880 TO	899	889.50	1	5.00	3	3	9	17	85.00
10	860 TO	879	869.50	2	10.00	2	4	8	16	80.00
9	840 TO	859	849.50	1	5.00	1	1	1	14	70.00
8	820 TO	839	829.50	4	20.00	0	0	0	13	65.00
7	800 TO	819	809.50	1	5.00	-1	-1	1	9	45.00
6	780 TO	799	789.50	2	10.00	-2	-4	8	8	40.00
5	760 TO	779	769.50	2	10.00	-3	-6	18	6	30.00
4	740 TO	759	749.50	1	5.00	-4	-4	16	4	20.00
3	720 TO	739	729.50	1	5.00	-5	-5	25	3	15.00
2	700 TO	719	709.50	1	5.00	-6	-6	36	2	10.00
1	680 TO	699	689.50	1	5.00	-7	-7	49	1	5.00
						SUMS =	-5	347		

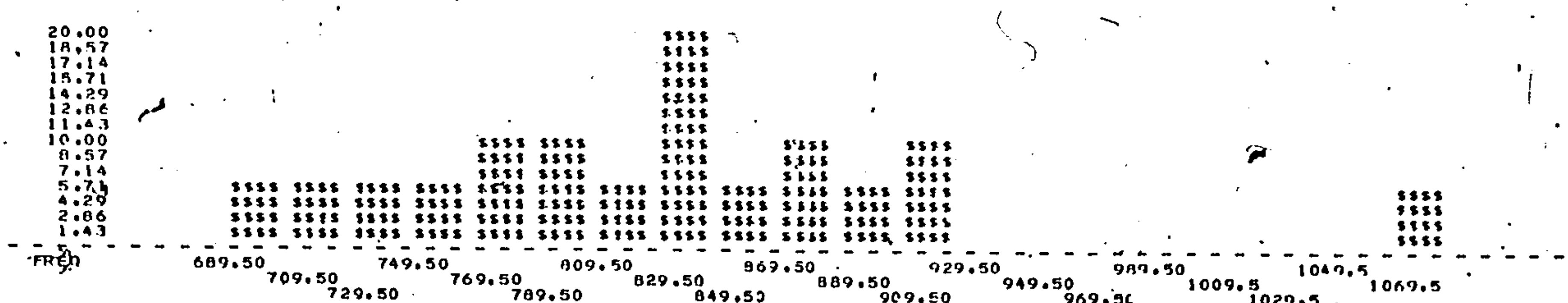
REGROUPED FOR CHISQ TESTS TO GIVE 3 INTERVALS WITHFREQUENCIES OF

6 7 7

CHISQ NORMAL = 0.14492 CHISQ UNIFORM = 0.10000E 00

SEX	SUBJ. NO.	H.IN=LOG2(N)	H.OUT=ID	CYCLE	TIME
1	2	2	2	1	837.0
1	2	2	2	2	837.0
1	2	2	2	3	776.0
1	2	2	2	4	813.0
1	2	2	2	5	724.0
1	2	2	2	6	698.0
1	2	2	2	7	902.0
1	2	2	2	8	826.0
1	2	2	2	9	823.0
1	2	2	2	10	765.0
1	2	2	2	11	1070.0
1	2	2	2	12	756.0
1	2	2	2	13	705.0
1	2	2	2	14	789.0
1	2	2	2	15	849.0
1	2	2	2	16	913.0
1	2	2	2	17	867.0
1	2	2	2	18	891.0
1	2	2	2	19	789.0
1	2	2	2	20	866.0

HISTOGRAM FOR HISTOGRAM OFPERFORMANCE TIMEFOR MAINSTUDY



STANDARD DEVIATION = 95. MEAN OF SAMPLE = 964.
FREQUENCY DISTRIBUTION FOR HISTOGRAM OFPERFORMANCE TIMEFOR MAINSTUDY

MAXIMUM = 1215 MINIMUM = 858 RANGE= 357 INTERVAL WIDTH = 20

MEAN = 964.25 IN INTERVAL 7. ST. DVN. = 94.831 MEDIAN = 946.00

INT. NO.	EXACT LIMITS		MID-POINT	F	FX	D	FD	F*D**2	CUM F - %
19	1200 TO	1219	1209.5	1	5.00	12	12	144	20 100.00
18	1180 TO	1199	1199.5	0	0.00	11	0	0	19 95.00
17	1160 TO	1179	1169.5	0	0.00	10	0	0	19 95.00
16	1140 TO	1159	1149.5	1	5.00	9	9	81	19 95.00
15	1120 TO	1139	1129.5	0	0.00	8	0	0	18 90.00
14	1100 TO	1119	1109.5	0	0.00	7	0	0	18 90.00
13	1080 TO	1099	1089.5	0	0.00	6	0	0	18 90.00
12	1060 TO	1079	1069.5	0	0.00	5	0	0	18 90.00
11	1040 TO	1059	1049.5	1	5.00	4	4	16	18 90.00
10	1020 TO	1039	1029.5	2	10.00	3	6	18	17 85.00
9	1000 TO	1019	1009.5	1	5.00	2	2	4	15 75.00
8	980 TO	999	989.50	1	5.00	1	1	1	14 70.00
7	960 TO	979	969.50	1	5.00	0	0	0	13 65.00
6	940 TO	959	949.50	3	15.00	-1	-3	3	12 60.00
5	920 TO	939	929.50	1	5.00	-2	-2	4	9 45.00
4	900 TO	919	909.50	2	10.00	-3	-6	18	8 40.00
3	880 TO	899	889.50	3	15.00	-4	-12	48	6 30.00
2	860 TO	879	869.50	2	10.00	-5	-10	50	3 15.00
1	840 TO	859	849.50	1	5.00	-6	-6	36	1 5.00
						SUMS =	-5	423	

REGROUPED FOR CHISQ TESTS TO GIVE 3 INTERVALS WITHFREQUENCIES OF

6 6 8

CHISQ NORMAL = 0.10490 CHISQ UNIFORM = 0.40000

SEX	SUBJ. NO.	H.IN=LOG2(N)	H.OUT=IO	CYCLE	TIME
1	2	2	6	1	890.0
1	2	2	6	2	1215.0
1	2	2	6	3	898.0
1	2	2	6	4	946.0
1	2	2	6	5	1038.0
1	2	2	6	6	1056.0
1	2	2	6	7	946.0
1	2	2	6	8	1032.0
1	2	2	6	9	963.0
1	2	2	6	10	862.0
1	2	2	6	11	858.0
1	2	2	6	12	890.0
1	2	2	6	13	910.0
1	2	2	6	14	986.0
1	2	2	6	15	1142.0
1	2	2	6	16	868.0
1	2	2	6	17	1008.0
1	2	2	6	18	949.0
1	2	2	6	19	925.0
1	2	2	6	20	903.0

8

HISTOGRAM FOR HISTOGRAM OFPERFORMANCE TIMEFOR MAINSTUDY

```
15.00               $$$$           $$$$
13.93               $$$$           $$$$
12.86               $$$$           $$$$
11.79               $$$$           $$$$
10.71               $$$$           $$$$
 9.64          $$$$ $$$$ $$$$      $$$$                $$$$
 8.57          $$$$ $$$$ $$$$      $$$$                $$$$
 7.50          $$$$ $$$$ $$$$      $$$$                $$$$
 6.43          $$$$ $$$$ $$$$      $$$$                $$$$
 5.36     $$$$ $$$$ $$$$ $$$$ $$$$ $$$$ $$$$ $$$$ $$$$ $$$$ $$$$                     $$$$           $$$$
 4.29     $$$$ $$$$ $$$$ $$$$ $$$$ $$$$ $$$$ $$$$ $$$$ $$$$ $$$$                     $$$$           $$$$
 3.21     $$$$ $$$$ $$$$ $$$$ $$$$ $$$$ $$$$ $$$$ $$$$ $$$$ $$$$                     $$$$           $$$$
 2.14     $$$$ $$$$ $$$$ $$$$ $$$$ $$$$ $$$$ $$$$ $$$$ $$$$ $$$$                     $$$$           $$$$
 1.07     $$$$ $$$$ $$$$ $$$$ $$$$ $$$$ $$$$ $$$$ $$$$ $$$$ $$$$                     $$$$           $$$$
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 FREQ    849.50    909.50    969.50    1029.5    1089.5    1149.5    1209.5
              869.50    929.50    989.50    1049.5    1109.5    1169.5
                   889.50    949.50    1009.5    1069.5    1129.5    1189.5
```

9

STANDARD DEVIATION = 98. MEAN OF SAMPLE = 978.
FREQUENCY DISTRIBUTION FOR HISTOGRAM OFPERFORMANCE TIMESFOR MAINSTUDY

MAXIMUM = 1176 MINIMUM = 808 RANGE= 368 INTERVAL WIDTH = 20

MEAN = 977.65 IN INTERVAL 9. ST. DVN. = 98.317 MEDIAN = 964.00

INT. NO.	EXACT LIMITS		MID-POINT	F	FX	D	FD	F*D**2	CUM F	- X
19	1160 TO	1179	1169.5	1	5.00	10	10	100	20	100.00
18	1140 TO	1159	1149.5	1	5.00	9	9	81	19	95.00
17	1120 TO	1139	1129.5	0	0.00	8	0	0	18	90.00
16	1100 TO	1119	1109.5	0	0.00	7	0	0	18	90.00
15	1080 TO	1099	1089.5	1	5.00	6	6	36	18	90.00
14	1060 TO	1079	1069.5	3	15.00	5	15	75	17	85.00
13	1040 TO	1059	1049.5	0	0.00	4	0	0	14	70.00
12	1020 TO	1039	1029.5	0	0.00	3	0	0	14	70.00
11	1000 TO	1019	1009.5	1	5.00	2	2	4	14	70.00
10	980 TO	999	989.50	1	5.00	1	1	1	13	65.00
9	960 TO	979	969.50	3	15.00	0	0	0	12	60.00
8	940 TO	959	949.50	2	10.00	-1	-2	2	9	45.00
7	920 TO	939	929.50	0	0.00	-2	0	0	7	35.00
6	900 TO	919	909.50	3	15.00	-3	-9	27	7	35.00
5	880 TO	899	889.50	2	10.00	-4	-8	32	4	20.00
4	860 TO	879	869.50	0	0.00	-5	0	0	2	10.00
3	840 TO	859	849.50	1	5.00	-6	-6	36	2	10.00
2	820 TO	839	829.50	0	0.00	-7	0	0	1	5.00
1	800 TO	819	809.50	1	5.00	-8	-8	64	1	5.00
						SUMS =	10	458		

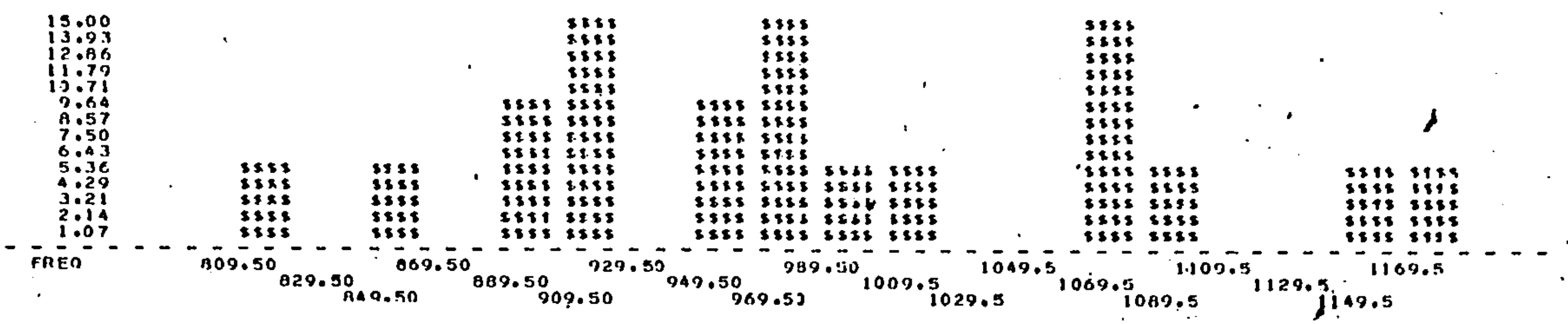
REGROUPED FOR CHISQ TESTS TO GIVE 3 INTERVALS WITHFREQUENCIES OF

7 7 6

CHISQ NORMAL = 0.24461 CHISQ UNIFORM = 0.10000E 00

SEX	SUBJ. NO.	H.IN=LOG2(N)	H.OUT=ID	CYCLF	TIME
1	2	3	1	1	1087.0
1	2	3	1	2	890.0
1	2	3	1	3	884.0
1	2	3	1	4	980.0
1	2	3	1	5	914.0
1	2	3	1	6	846.0
1	2	3	1	7	1176.0
1	2	3	1	8	911.0
1	2	3	1	9	1072.0
1	2	3	1	10	968.0
1	2	3	1	11	969.0
1	2	3	1	12	1064.0
1	2	3	1	13	1060.0
1	2	3	1	14	955.0
1	2	3	1	15	960.0
1	2	3	1	16	808.0
1	2	3	1	17	907.0
1	2	3	1	18	943.0
1	2	3	1	19	1008.0
1	2	3	1	20	1151.0

HISTOGRAM FOR HISTOGRAM OFPERFORMANCE TIMEFOR MAINSTUDY



FREQUENCY DISTRIBUTION FOR HISTOGRAM OFPERFORMANCE TIMEFOR MAINSTUDY

MAXIMUM = 1259 MINIMUM = 825 RANGE= 434 INTERVAL WIDTH = 30

MEAN = 966.85 IN INTERVAL 6, ST. DVN. = 112.65 MEDIAN = 947.00

INT. NO.	EXACT LIMITS			MID-POINT	F	FX	D	FD	F*D**2	CUM F	- %
15	1230	TO	1259	1244.5	1	5.00	9	9	81	20	100.00
14	1200	TO	1229	1214.5	0	0.00	8	0	0	19	95.00
13	1170	TO	1199	1184.5	1	5.00	7	7	49	19	95.00
12	1140	TO	1169	1154.5	0	0.00	6	0	0	18	90.00
11	1110	TO	1139	1124.5	0	0.00	5	0	0	18	90.00
10	1080	TO	1109	1094.5	0	0.00	4	0	0	18	90.00
9	1050	TO	1079	1064.5	2	10.00	3	6	18	18	90.00
8	1020	TO	1049	1034.5	1	5.00	2	2	4	16	80.00
7	990	TO	1019	1004.5	3	15.00	1	3	3	15	75.00
6	960	TO	989	974.50	1	5.00	0	0	0	12	60.00
5	930	TO	959	944.50	2	10.00	-1	-2	2	11	55.00
4	900	TO	929	914.50	3	15.00	-2	-6	12	9	45.00
3	870	TO	899	884.50	2	10.00	-3	-6	18	6	30.00
2	840	TO	869	854.50	3	15.00	-4	-12	48	4	20.00
1	810	TO	839	824.50	1	5.00	-5	-5	25	1	5.00
							SUMS =	-4	260		

REGROUPED FOR CHISQ TESTS TO GIVE 3 INTERVALS WITHFREQUENCIES OF

6 5 9

CHISQ NORMAL = 0.11543 CHISQ UNIFORM = 1.3000

**************SUBJECT NUMBER 2***********************

SEX	SUBJ. NO.H.IN=LOG2(N)	H.OUT=ID	CYCLE	TIME
1	2	3	4	1	922.0
1	2	3	4	2	908.0
1	2	3	4	3	1007.0
1	2	3	4	4	825.0
1	2	3	4	5	940.0
1	2	3	4	6	991.0
1	2	3	4	7	1051.0
1	2	3	4	8	907.0
1	2	3	4	9	840.0
1	2	3	4	10	954.0
1	2	3	4	11	862.0
1	2	3	4	12	964.0
1	2	3	4	13	1181.0
1	2	3	4	14	871.0
1	2	3	4	15	1044.0
1	2	3	4	16	1259.0
1	2	3	4	17	1010.0
1	2	3	4	18	896.0
1	2	3	4	19	850.0
1	2	3	4	20	1055.0

HISTOGRAM FOR HISTOGRAM OFPERFORMANCE TIMEFOR MAINSTUDY

```
15.00          $$$$       $$$$             $$$$
13.93          $$$$       $$$$             $$$$
12.86          $$$$       $$$$             $$$$
11.79          $$$$       $$$$             $$$$
10.71          $$$$       $$$$             $$$$
 9.64          $$$$ $$$$  $$$$ $$$$        $$$$      $$$$
 8.57          $$$$ $$$$  $$$$ $$$$        $$$$      $$$$
 7.50          $$$$ $$$$  $$$$ $$$$        $$$$      $$$$
 6.43          $$$$ $$$$  $$$$ $$$$        $$$$      $$$$
 5.36     $$$$ $$$$ $$$$  $$$$ $$$$ $$$$   $$$$ $$$$ $$$$                 $$$$      $$$$
 4.29     $$$$ $$$$ $$$$  $$$$ $$$$ $$$$   $$$$ $$$$ $$$$                 $$$$      $$$$
 3.21     $$$$ $$$$ $$$$  $$$$ $$$$ $$$$   $$$$ $$$$ $$$$                 $$$$      $$$$
 2.14     $$$$ $$$$ $$$$  $$$$ $$$$ $$$$   $$$$ $$$$ $$$$                 $$$$      $$$$
 1.07     $$$$ $$$$ $$$$  $$$$ $$$$ $$$$   $$$$ $$$$ $$$$                 $$$$      $$$$
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
 FREQ   824.50     914.50      1004.5     1094.5      1184.5
          854.50      944.50      1034.5     1124.5      1214.5
             884.50      974.50      1064.5     1154.5      1244.5
```

4. Mean Experimental Performance Times

```
DATA GENERAL ;
INPUT    DDNAME=FT10F001   SEX 1-2 SUBJECT 3-4 HIN 5-6 HOUT 7-8
         ANGLE 9-10 CYCLE 11-12 TIME 13-19 ;

28800 OBSERVATIONS IN DATA SET GENERAL          7  VARIABLES

DATA HCDA1 ;
SET GENERAL ; IF ANGLE=1 ;
IF HOUT=1 THEN CL=.25 ; IF HOUT=1 THEN D=7 ;
IF HOUT=2 THEN CL=.25 ; IF HOUT=2 THEN D=10 ;
IF HOUT=3 THEN CL=.25 ; IF HOUT=3 THEN D=13 ;
IF HOUT=4 THEN CL=.25 ; IF HOUT=4 THEN D=16 ;
IF HOUT=5 THEN CL=.0625 ; IF HOUT=5 THEN D=7 ;
IF HOUT=6 THEN CL=.0625 ; IF HOUT=6 THEN D=10 ;
IF HOUT=7 THEN CL=.0625 ; IF HOUT=7 THEN D=13 ;
IF HOUT=8 THEN CL=.0625 ; IF HOUT=8 THEN D=16 ;
IF HOUT=9 THEN CL=78125E-07 ; IF HCUT=9 THEN D=7 ;
IF HOUT=10 THEN CL=78125E-07 ; IF HOUT=10 THEN D=10 ;
IF HOUT=11 THEN CL=78125E-07 ; IF HOUT=11 THEN D=13 ;
IF HOUT=12 THEN CL=78125E-07 ; IF HOUT=12 THEN D=16 ;
DROP HOUT ;

14400 OBSERVATIONS IN DATA SET HCDA1          8  VARIABLES

PROC SORT ; BY HIN CL D ;
```



```
PROC MEANS OUT=AVER ; BY HIN CL D ;
```

STATISTICAL ANALYSIS SYSTEM

HIN=2 CL=0 D=7

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	1.000000	0.0	0.0	400.000000	0.0	1.000000	1.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	937.566250	161.709837	26150.071364	375026.500000	10433878.4744	651.000000	1952.000000	17.248

HIN=2 CL=0 D=10

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	1.000000	0.0	0.0	400.000000	0.0	1.000000	1.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1009.231750	163.499509	26732.089290	403692.700000	10666103.6268	711.000000	1747.000000	16.200

HIN=2 CL=0 D=13

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	1.000000	0.0	0.0	400.000000	0.0	1.000000	1.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1009.245250	159.560386	25459.516569	403698.100000	10158347.1510	695.000000	1785.000000	15.810

HIN=2 CL=0 D=16

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	1.000000	0.0	0.0	400.000000	0.0	1.000000	1.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1084.046000	165.128531	27267.431613	433618.400000	10879705.2136	790.000000	1929.000000	15.233

HIN=2 CL=0 D=7

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	1.000000	0.0	0.0	400.000000	0.0	1.000000	1.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	894.229500	162.933240	26547.240732	357691.800000	10592349.0519	536.000000	1824.000000	18.221

HIN=2 CL=0 D=10

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	1.000000	0.0	0.0	400.000000	0.0	1.000000	1.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	976.149750	165.160054	27277.843308	390459.900000	10883859.4800	690.000000	1640.000000	16.920

B

STATISTICAL ANALYSIS SYSTEM

MIN=3 CL=0 D=13

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.00000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.00000	1.000000	10.000000	52.289
ANGLE	400	1.000000	0.0	0.0	400.000000	0.0	1.000000	1.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.00000	1.000000	20.000000	54.986
TIME	400	1011.905000	142.244243	20233.424536	404762.000000	8073136.39000	689.000000	1733.000000	14.057

MIN=3 CL=0 D=16

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	1.000000	0.0	0.0	400.000000	0.0	1.000000	1.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1091.712500	181.271905	32859.503603	436685.000000	13110941.9375	737.000000	1932.000000	16.604

MIN=3 CL=0 D=7

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.00000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.00000	1.000000	10.000000	52.289
ANGLE	400	1.000000	0.0	0.0	400.000000	0.0	1.000000	1.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.00000	1.000000	20.000000	54.986
TIME	400	903.067500	144.963198	21014.328766	361227.000000	8304717.17750	577.000000	1644.000000	16.052

MIN=3 CL=0 D=10

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.00000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.00000	1.000000	10.000000	52.289
ANGLE	400	1.000000	0.0	0.0	400.000000	0.0	1.000000	1.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.00000	1.000000	20.000000	54.986
TIME	400	997.076500	140.117410	19632.888619	398830.600000	7833522.55910	709.000000	1521.000000	14.053

MIN=3 CL=0 D=13

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.00000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.00000	1.000000	10.000000	52.289
ANGLE	400	1.000000	0.0	0.0	400.000000	0.0	1.000000	1.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.00000	1.000000	20.000000	54.986
TIME	400	964.279500	139.124906	19355.739529	385711.800000	7722940.07190	703.000000	1728.000000	14.428

MIN=3 CL=0 D=16

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.00000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.00000	1.000000	10.000000	52.289
ANGLE	400	1.000000	0.0	0.0	400.000000	0.0	1.000000	1.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.00000	1.000000	20.000000	54.986
TIME	400	1034.557500	152.842529	23360.838791	413823.000000	9320974.67750	730.000000	1831.000000	14.774

STATISTICAL ANALYSIS SYSTEM

MIN=4 CL=0 D=7

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	1.000000	0.0	0.0	400.000000	0.0	1.000000	1.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1144.990000	222.086641	49322.476090	457996.000000	19679667.9600	782.000000	1976.000000	19.396

MIN=4 CL=0 D=10

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	1.000000	0.0	0.0	400.000000	0.0	1.000000	1.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1167.001000	185.710774	34488.491628	466800.400000	13760908.1596	798.000000	1926.000000	15.914

MIN=4 CL=0 D=13

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	1.000000	0.0	0.0	400.000000	0.0	1.000000	1.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1224.987000	184.193413	33927.213465	489994.800000	13536958.1724	832.000000	1940.000000	15.036

MIN=4 CL=0 D=16

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	1.000000	0.0	0.0	400.000000	0.0	1.000000	1.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1296.375000	208.494675	43470.029449	518550.000000	17344541.7500	860.000000	1982.000000	16.083

MIN=4 CL=0 D=7

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	1.000000	0.0	0.0	400.000000	0.0	1.000000	1.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1082.804250	212.754475	45264.466473	433121.700000	18060522.1228	628.000000	1995.000000	19.648

MIN=4 CL=0 D=10

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	1.000000	0.0	0.0	400.000000	0.0	1.000000	1.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1150.345750	191.271865	36584.926398	460138.300000	14597385.6328	724.000000	1900.000000	16.627

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

MIN=4 CL=0 D=13

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875870	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	1.000000	0.0	0.0	400.000000	0.0	1.000000	1.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1187.990000	194.118287	37681.909373	475192.000000	15035081.8400	811.000000	1923.000000	16.340

MIN=4 CL=0 D=16

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270577	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	1.000000	0.0	0.0	400.000000	0.0	1.000000	1.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1259.682500	210.303496	44227.550595	503873.000000	17646796.6775	802.000000	1990.000000	16.695

MIN=4 CL=0 D=7

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	1.000000	0.0	0.0	400.000000	0.0	1.000000	1.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1000.794000	180.720733	32659.983222	400317.600000	13031333.3056	688.000000	1828.000000	18.058

MIN=4 CL=0 D=10

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270577	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	1.000000	0.0	0.0	400.000000	0.0	1.000000	1.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1094.677250	171.899929	29549.585421	437930.900000	11790284.5830	813.000000	1953.000000	15.700

MIN=4 CL=0 D=13

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	1.000000	0.0	0.0	400.000000	0.0	1.000000	1.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1130.102500	168.224629	29299.525808	452041.000000	11291510.7975	838.000000	1905.000000	14.886

MIN=4 CL=0 D=16

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	1.000000	0.0	0.0	400.000000	0.0	1.000000	1.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1206.540000	198.913385	39566.534737	482615.000000	15787047.3600	880.000000	1969.000000	16.486

```
DATA GENERAL ;
INPUT   DDNAME=FT10F001  SEX 1-2 SUBJECT 3-4 HIN 5-6 HOUT 7-8
        ANGLE 9-10 CYCLE 11-12 TIME 13-19 ;

28800 OBSERVATIONS IN DATA SET GENERAL          7  VARIABLES

DATA CDH1 ;
SET GENERAL ; IF ANGLE=2 ;
IF HOUT=1 THEN CL=.25 ; IF HOUT=1 THEN D=7 ;
IF HOUT=2 THEN CL=.25 ; IF HOUT=2 THEN D=10 ;
IF HOUT=3 THEN CL=.25 ; IF HOUT=3 THEN D=13 ;
IF HOUT=4 THEN CL=.25 ; IF HOUT=4 THEN D=16 ;
IF HOUT=5 THEN CL=.0625 ; IF HOUT=5 THEN D=7 ;
IF HOUT=6 THEN CL=.0625 ; IF HOUT=6 THEN D=10 ;
IF HOUT=7 THEN CL=.0625 ; IF HOUT=7 THEN D=13 ;
IF HOUT=8 THEN CL=.0625 ; IF HOUT=8 THEN D=16 ;
IF HOUT=9 THEN CL=78125E-07 ; IF HOUT=9 THEN D=7 ;
IF HOUT=10 THEN CL=78125E-07 ; IF HOUT=10 THEN D=10 ;
IF HOUT=11 THEN CL=78125E-07 ; IF HOUT=11 THEN D=13 ;
IF HOUT=12 THEN CL=78125E-07 ; IF HOUT=12 THEN D=16 ;
DROP HOUT ;

14400 OBSERVATIONS IN DATA SET CDH1          8  VARIABLES

PROC SORT ; BY HIN CL D ;

PROC MEANS OUT=AVERAGES ; BY HIN CL D ;
```

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

HIN=2 CL=0 D=7

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1028.927500	169.692140	28795.422400	411571.000000	11489373.5375	686.000000	1825.000000	16.492
HIN=2 CL=0 D=10									
SEX	400	1.500000	0.500626	0.250627	600.000000	100.00000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.00000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.00000	1.000000	20.000000	54.986
TIME	400	1077.319000	155.170963	24078.027658	430927.600000	9607133.03560	763.000000	1645.000000	14.403
HIN=2 CL=0 D=13									
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1048.664750	160.232043	25674.307752	419465.900000	10244048.7930	667.000000	1721.000000	15.280
HIN=2 CL=0 D=16									
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1110.905000	170.125467	28942.674662	444362.000000	11548127.1900	790.000000	1964.000000	15.314
HIN=2 CL=0 D=7									
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	967.130000	173.028808	29938.968471	386852.000000	11945648.4200	563.900000	1905.000000	17.891
HIN=2 CL=0 D=10									
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1040.982250	179.623144	32264.473845	416392.900000	12873525.0640	661.000000	1891.000000	17.255

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

MIN=2 CL=0 D=13

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.00000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.00000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.00000	1.000000	20.000000	54.986
TIME	400	975.990500	152.208656	23167.474897	390396.200000	9243822.48390	652.000000	1867.000000	15.598

MIN=2 CL=0 D=16

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.00000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.00000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.00000	1.000000	20.000000	54.986
TIME	400	1041.868250	154.416352	23844.409741	416747.300000	9513919.48677	721.000000	1998.000000	14.821

MIN=2 CL=0 D=7

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.00000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.00000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.00000	1.000000	20.000000	54.986
TIME	400	910.233250	158.135816	25006.936310	364093.300000	9977767.58778	604.000000	1960.000000	17.373

MIN=2 CL=0 D=10

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.00000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.00000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.00000	1.000000	20.000000	54.986
TIME	400	999.470250	146.215002	21378.826057	399788.100000	8530151.91598	751.000000	1788.000000	14.629

MIN=2 CL=0 D=13

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.00000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.00000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.00000	1.000000	20.000000	54.986
TIME	400	928.919000	140.000637	19600.178485	371567.600000	7820471.21560	630.000000	1975.000000	15.071

MIN=2 CL=0 D=16

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.00000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.00000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.00000	1.000000	20.000000	54.986
TIME	400	976.594500	122.224182	14938.750546	390637.800000	5960561.46790	699.000000	1674.000000	12.515

STATISTICAL ANALYSIS SYSTEM

MIN=3 CL=0 D=7

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.209
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1093.655000	172.572591	29781.299223	437462.000000	11882738.3900	730.000000	1843.000000	15.779

MIN=3 CL=0 D=10

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1186.775000	197.324255	38936.861529	474710.000000	15535807.7500	809.000000	1896.000000	16.627

MIN=3 CL=0 D=13

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1134.918750	164.300153	26994.540174	453967.500000	10770821.5294	800.000000	1821.000000	14.477

MIN=3 CL=0 D=16

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1175.133750	167.187277	27951.585500	470053.500000	11152682.6144	874.000000	1935.000000	14.227

MIN=3 CL=0 D=7

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1042.799500	185.554181	34430.354185	417119.800000	13737711.3199	716.000000	1927.000000	17.794

MIN=3 CL=0 D=10

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1138.558000	181.640164	32993.149259	455423.200000	13164266.5544	754.000000	1935.000000	15.954

STATISTICAL ANALYSIS SYSTEM

HIN=3 CL=0 D=13

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.00000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.00000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.00000	1.000000	20.000000	54.986
TIME	400	1069.058000	153.252994	23486.480136	427623.200000	9371105.57440	756.000000	1861.000000	14.335

HIN=3 CL=0 D=16

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1101.376750	161.935502	26223.106902	440550.700000	10463019.6538	743.000000	1781.000000	14.703

HIN=3 CL=0 D=7

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	982.007750	170.835265	29184.687684	392803.100000	11644690.3860	666.000000	1749.000000	17.397

HIN=3 CL=0 D=10

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1075.215000	172.182085	29646.670451	430086.000000	11829021.5100	728.000000	1942.000000	16.014

HIN=3 CL=0 D=13

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1024.789000	164.758614	27145.400931	409915.600000	10831014.9716	721.000000	1968.000000	16.077

HIN=3 CL=0 D=16

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1057.060750	160.506039	25762.195122	422824.300000	10279115.8538	749.000000	1870.000000	15.184

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

MIN=4 CL=0 D=7

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1247.114000	203.132412	41262.776746	498845.600000	16463047.9216	893.000000	1957.000000	16.288

MIN=4 CL=0 D=10

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1224.550000	200.152968	40061.210526	489820.000000	15984423.0000	880.000000	1995.000000	16.345

MIN=4 CL=0 D=13

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1292.371000	197.704946	39087.245723	516948.400000	15595811.0436	850.000000	1990.000000	15.298

MIN=4 CL=0 D=16

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1285.596250	194.982228	38018.069234	514238.500000	15169209.6244	908.000000	1988.000000	15.167

MIN=4 CL=0 D=7

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	[illegible]	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	[illegible]	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1226.336000	235.483010	55452.247924	490534.400000	22125446.9216	737.000000	1981.000000	19.202

MIN=4 CL=0 D=10

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1189.955000	208.959633	43664.128296	475982.000000	17421987.1900	722.000000	1944.000000	17.560

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

HIN=4 CL=0 D=13

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1283.613250	198.270389	39311.147318	513445.300000	15685147.7798	813.000000	1952.000000	15.446

HIN=4 CL=0 D=16

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1258.003750	199.328896	39732.008582	503201.500000	15853071.4244	829.000000	1902.000000	15.845

HIN=4 CL=0 D=7

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1153.699250	216.815407	47008.920877	461359.700000	18756559.4298	764.000000	1997.000000	18.790

HIN=4 CL=0 D=10

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1109.172500	173.335096	300[illegible]5.055382	443669.000000	11987977.0975	778.000000	1913.000000	15.627

HIN=4 CL=0 D=13

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1203.992250	180.260924	32494.000817	481596.900000	12965106.3260	932.000000	1874.000000	14.972

HIN=4 CL=0 D=16

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
SEX	400	1.500000	0.500626	0.250627	600.000000	100.0000	1.000000	2.000000	33.375
SUBJECT	400	5.500000	2.875878	8.270677	2200.000000	3300.0000	1.000000	10.000000	52.289
ANGLE	400	2.000000	0.0	0.0	800.000000	0.0	2.000000	2.000000	0.0
CYCLE	400	10.500000	5.773503	33.333333	4200.000000	13300.0000	1.000000	20.000000	54.986
TIME	400	1173.882000	162.424362	26391.673259	469552.800000	10526287.6304	893.000000	1873.000000	13.837

5. SAS Linear Regression Procedure Printout

Performance Time versus Hin, C, D for

Right-sided Movement

```
PROC REGR   :  S T A T I S T I C A L   A N A L Y S I S   S Y S T E M
DATA SET    :  AVER        NUMBER OF VARIABLES =  4      NUMBER OF CLASSES =  2
VARIABLES   :  MIN TIME CL D

CLASSES        LEVELS     VALUES
SEX               1         1
SUBJECT           1         5
```

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

SIMPLE STATISTICS

N = 36

VARIABLE	SUM	MEAN	UNCORRECTED SS	CORRECTED SS	VARIANCE	STANDARD DEV
MIN	108.00000000	3.00000000	348.00000000	24.00000000	0.68571429	0.82807867
TIME	37872.32250000	1052.00895833	40282823.05973600	440800.51684706	12594.30048134	112.22433106
CL	3.84375000	0.10677093	0.79760742	0.38720703	0.01106306	0.10518107
D	414.00000000	11.50000000	5166.00000000	405.00000000	11.57142857	3.40168026

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

ANALYSIS OF VARIANCE TABLE , REGRESSION COEFFICIENTS , AND STATISTICS OF FIT FOR DEPENDENT VARIABLE TIME

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB > F	R-SQUARE	C.V.
REGRESSION	3	401290.81428114	133763.60476038	108.33884	0.0001	0.91036829	3.34008 %
ERROR	32	39539.70256592	1234.67820519				
CORRECTED TOTAL	35	440800.51684706				STD DEV	TIME MEAN
						35.13798806	1052.00896

SOURCE	DF	SEQUENTIAL SS	F VALUE	PROB > F	PARTIAL SS	F VALUE	PROB > F
HIN	1	252552.34620106	204.63012	0.0001	252652.34620106	204.63012	0.0001
CL	1	65471.26078764	53.02698	0.0001	65471.26078764	53.02698	0.0001
D	1	83167.20729245	67.35942	0.0001	83167.20729245	67.35942	0.0001

SOURCE	B VALUES	T FOR H0:B=0	PROB > |T|	STD ERR B	STD B VALUES
INTERCEPT	623.31113786	20.36456	0.0001	30.60764091	0.0
HIN	102.60205208	14.30490	0.0001	7.17251178	0.75707799
CL	-411.20059521	-7.28196	0.0001	56.46837283	-0.38539343
D	14.33007778	8.20728	0.0001	1.74602066	0.43436519

OBS NUMBER	OBSERVED VALUE	PREDICTED VALUE	RESIDUAL	LOWER 95% CL FOR MEAN	UPPER 95% CL FOR MEAN
1	937.56625000	925.61328182	11.95296818	898.38390852	952.84265512
2	1009.23175000	963.60351515	40.62823485	945.93719580	991.26983450
3	1009.24525000	1011.59374848	-2.34849848	988.92742914	1034.26006783
4	1084.04600000	1054.58398182	29.46201810	1027.35460852	1081.81335512
5	894.22550000	903.12574927	-8.89624927	877.97083521	928.38066332
6	976.14975000	946.11598260	30.03376740	925.86421857	966.36774663
7	926.07100000	989.10621593	-63.03521593	968.95445190	1009.35797997
8	1020.59025000	1032.09644927	-11.50619927	1006.84153521	1057.35136332
9	835.79775000	826.02563767	9.77211233	796.30547406	855.74580127
10	932.12500000	869.01587100	63.10912900	843.41096156	894.62078044
11	897.80750000	912.00610433	-14.19860433	886.40119489	937.61101377
12	961.17000000	954.99633767	6.17366233	925.27617406	984.71650127
13	1023.38000000	1028.21533390	-4.83533390	1005.23726112	1051.19340669
14	1121.98050000	1071.20556723	50.77493277	1053.87396564	1089.53516883
15	1070.44325000	1114.19580057	-43.75255057	1096.66619897	1131.52540216
16	1163.18000000	1157.18603390	5.99396610	1134.20796112	1180.16410669
17	965.17750000	1005.72780135	-40.55030135	985.12771051	1026.32789219
18	1095.05350000	1048.71803468	46.33546532	1034.69352025	1062.74254912
19	1011.90500000	1091.70826802	-79.80326802	1077.68375358	1105.73278245
20	1091.71250000	1134.69851135	-42.98601135	1114.09841051	1155.29859219
21	903.06750000	928.62768975	-25.56018975	902.74639953	954.50897997
22	997.07650000	971.61792308	25.45857692	950.59021646	992.64562971
23	964.27950000	1014.60815642	-50.22865642	993.58044579	1035.63586304
24	1034.55750000	1057.59830975	-23.04088975	1031.71709953	1081.47967997
25	1144.99000000	1130.81739581	14.17701432	1103.58801258	1150.04675928
26	1167.00100000	1173.83761932	-6.83761932	1151.14129597	1196.47391867
27	1224.98760000	1216.79785265	8.18914735	1194.13153330	1239.46417200
28	1296.37500000	1259.78808598	36.58691402	1232.55871268	1287.01745928
29	1082.80425000	1108.32985343	-25.52560343	1083.07493538	1133.58476749
30	1150.34575000	1151.32008677	-0.97433677	1131.06832273	1171.57185080
31	1187.98000000	1194.31032010	-6.33032010	1174.05955607	1214.56209413
32	1259.68250000	1237.30055343	22.38194657	1212.04563938	1262.55546749
33	1000.79400000	1031.22974183	-30.43574183	1001.50937822	1060.94990544
34	1094.87725000	1074.21997517	20.65727483	1048.61506573	1099.82488460
35	1130.10250000	1117.21020850	12.89229150	1091.60529906	1142.81511794
36	1206.54000000	1160.20044183	46.33955817	1130.48027822	1189.92060544

SUM OF RESIDUALS	=	0.00000000
SUM OF SQUARED RESIDUALS	=	39509.70256591
SUM OF SQUARED RESIDUALS - ERROR SS	=	-0.00000001
FIRST ORDER AUTOCORRELATION OF RESIDUALS	=	-0.21765951
DURBIN-WATSON D	=	2.36459241

ANGLE = 1

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

ANALYSIS OF VARIANCE TABLE , REGRESSION COEFFICIENTS , AND STATISTICS OF FIT FOR DEPENDENT VARIABLE TIME

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB > F	R-SQUARE	C.V.
REGRESSION	2	352732.94015648	176366.47007824	66.08668	0.0001	0.80020991	4.91057 %
ERROR	33	88067.57669057	2668.71444517			STD DEV	TIME MEAN
CORRECTED TOTAL	35	440800.51684705				51.65960167	1052.00896

SOURCE	DF	SEQUENTIAL SS	F VALUE	PROB > F	PARTIAL SS	F VALUE	PROB > F
HIN	1	252652.34620105	94.67193	0.0001	252652.34620105	94.67193	0.0001
INDEXD	1	100080.59395543	37.50142	0.0001	100080.59395543	37.50142	0.0001

SOURCE	B VALUES	T FOR H0:B=0	PROB > |T|	STD ERR B	STD B VALUES
INTERCEPT	523.71702574	10.75500	0.0001	48.69519850	0.0
HIN	102.60205208	9.72995	0.0001	10.54497203	0.75707799
INDEXD	25.08037724	6.12384	0.0001	4.09553065	0.47649011

OBS	OBSERVED	PREDICTED	RESIDUAL	LOWER 95% CL	UPPER 95% CL

6. SAS Linear Regression Procedure Printout

Performance Time versus Hin, C, D for
Left-sided Movement

```
PROC REGR S DATA=AVERAGES ;
CLASSES SEX SUBJECT ;
MODEL TIME=MIN CL D / P CLM ;
TITLE ' LIN.REG. TIME VS MIN CL D ' ;
```

```
PROC REGR  :  LIN.REG. TIME VS MIN CL D
DATA SET   :  AVERAGES      NUMBER OF VARIABLES =  4      NUMBER OF CLASSES =  2
VARIABLES  :  MIN TIME CL D

CLASSES        LEVELS     VALUES
SEX               1         1
SUBJECT           1         5
```

LIN.REG. TIME VS MIN CL D

SIMPLE STATISTICS

N = 36

VARIABLE	SUM	MEAN	UNCORRECTED SS	CORRECTED SS	VARIANCE	STANDARD DEV
MIN	108.00000000	3.00000000	348.00000000	24.00000000	0.68571429	0.82807867
TIME	39836.83675000	1106.57879861	44472662.38910063	390063.43790672	11144.66565448	105.56831747
CL	3.84375000	0.10677083	0.79760742	0.38720703	0.01106306	0.10518107
D	414.00000000	11.50000000	5166.00000000	405.00000000	11.57142857	3.40168026

LIN.REG. TIME VS MIN CL D

ANALYSIS OF VARIANCE TABLE , REGRESSION COEFFICIENTS , AND STATISTICS OF FIT FOR DEPENDENT VARIABLE TIME

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB > F	R-SQUARE	C.V.
REGRESSION	3	349901.48752766	116633.82917589	92.93081	0.0001	0.89703739	3.20147 %
ERROR	32	40161.95037906	1255.06094935			STD DEV	TIME MEAN
CORRECTED TOTAL	35	390063.43790672				35.42683939	1106.57880

SOURCE	DF	SEQUENTIAL SS	F VALUE	PROB > F	PARTIAL SS	F VALUE	PROB > F
MIN	1	269130.23639004	214.43599	0.0001	269130.23639004	214.43599	0.0001
CL	1	68183.16734019	54.32658	0.0001	68183.16734019	54.32658	0.0001
D	1	12588.08379743	10.02986	0.0036	12588.08379743	10.02986	0.0036

SOURCE	B VALUES	T FOR H0:B=0	PROB > |T|	STD ERR B	STD B VALUES
INTERCEPT	769.58436697	24.93853	0.0001	30.85925058	0.0
MIN	105.89504167	14.64353	0.0001	7.23147331	0.83064150
CL	-419.63042455	-7.37066	0.0001	56.93257028	-0.41809114
D	5.57509537	3.16700	0.0036	1.76037380	0.17964378

OBS NUMBER	OBSERVED VALUE	PREDICTED VALUE	RESIDUAL	LOWER 95% CL FOR MEAN	UPPER 95% CL FOR MEAN
1	1028.92750000	1017.12175521	11.80574479	989.66854323	1044.57496718
2	1077.31900000	1033.84704132	43.47195868	1010.99439382	1056.69968882
3	1048.66475000	1050.57232743	-1.90757743	1027.71967593	1073.42497893
4	1110.90500000	1067.29761354	43.60738646	1039.84440157	1094.75082552
5	967.13000000	994.17321636	-27.04321636	968.71069465	1019.63573808
6	1040.98225000	1010.89850248	30.08374752	990.48025910	1031.31674585
7	975.99050000	1027.62378859	-51.63328859	1007.20554522	1048.04203196
8	1041.86025000	1044.34907470	-2.48882470	1018.88655298	1069.81159641
9	910.23325000	915.49251176	-5.25926176	885.52607397	945.45699955
10	999.47025000	932.21779787	67.25245213	906.40240364	958.03319210
11	928.91900000	948.94308398	-20.02408398	923.12768575	974.75847821
12	976.59450000	965.66837010	10.92612990	935.70389231	995.63284788
13	1093.65500000	1123.01679687	-29.36179687	1099.84983317	1146.18376058
14	1186.77300000	1139.74208298	47.03291702	1122.27002365	1157.21414232
15	1134.91875000	1156.46736910	-21.54861910	1138.99530976	1173.93942843
16	1175.13375000	1173.19265521	1.94109479	1150.02569150	1196.35961891
17	1042.79950000	1100.06825803	-57.26875803	1079.29882444	1120.83769162
18	1138.55800000	1116.79354414	21.76445586	1102.65374179	1130.93334689
19	1069.05800000	1133.51883025	-64.46083025	1119.37902750	1147.65863301
20	1101.37675000	1150.24411636	-48.86736636	1129.47468277	1171.01354996
21	982.00775000	1021.38755343	-39.37980343	995.29350643	1047.48160042
22	1075.21500000	1038.11283954	37.10216046	1016.91227495	1059.31340413
23	1024.78900000	1054.83812565	-30.04912565	1033.63756106	1076.03869024
24	1057.06075000	1071.56341176	-14.50266176	1045.46936477	1097.65745876
25	1247.11400000	1229.91183854	18.20216146	1201.45862657	1256.36505052
26	1224.55000000	1245.63712465	-21.08712465	1222.78447715	1268.48977215
27	1292.37100000	1262.36241076	30.00858924	1239.50976326	1285.21505827
28	1285.59625000	1279.08769687	6.50855313	1251.63448490	1306.54090885
29	1226.33600000	1205.96329970	20.37270030	1180.50077798	1231.42582141
30	1189.95500000	1222.68858581	-32.73358581	1202.27034244	1243.10682918
31	1283.61325000	1239.41387192	44.19937808	1218.99562855	1259.83211529
32	1258.00375000	1256.13915803	1.86459197	1230.67663631	1281.60167975
33	1153.89925000	1127.28259510	26.61665490	1097.31811731	1157.24707288
34	1109.17250000	1144.00708121	-34.83538121	1118.19248698	1169.82327544
35	1203.99225000	1160.73316732	43.25908268	1134.91777309	1186.54856155
36	1173.88200000	1177.45845343	-3.57645343	1147.49397564	1207.42293122

OBS NUMBER	OBSERVED VALUE	PREDICTED VALUE	RESIDUAL	LOWER 95% CL FOR MEAN	UPPER 95% CL FOR MEAN
1	1028.92750000	1017.12175521	11.80574479	989.68854323	1044.57496718
2	1077.31900000	1033.84704132	43.47195868	1010.99439382	1056.69959882
3	1048.66475000	1050.57232743	-1.90757743	1027.71567593	1073.42497493
4	1110.90500000	1067.29761354	43.60738646	1039.84440157	1094.75082552
5	967.13300000	994.17321636	-27.04321636	968.71069465	1019.63573808
6	1040.98225000	1010.83850248	30.08374752	990.48025910	1031.31674585
7	973.99050000	1027.62378859	-51.63328859	1007.20554522	1048.04203196
8	1041.86025000	1044.34907470	-2.48882470	1018.88655298	1069.81159641
9	910.23325000	915.49251176	-5.25926176	885.52803397	945.45699755
10	999.47025000	932.21779787	67.25245213	906.40240364	958.03319210
11	925.91900000	948.94309398	-23.02409398	923.12769575	974.75847821
12	976.39450000	965.66837010	10.92612990	935.70389231	995.63284788
13	1093.65500000	1123.01679687	-29.36179687	1099.84983317	1146.18376058
14	1186.77300000	1139.74208298	47.03291702	1122.27002365	1157.21414232
15	1134.91875000	1156.46736910	-21.54861910	1138.99530976	1173.93942843
16	1175.13375000	1173.19265521	1.94109479	1150.02569150	1196.35961891
17	1042.79950000	1100.06825803	-57.26875803	1079.29887444	1120.83769162
18	1138.55800000	1116.79354414	21.76445586	1102.65374179	1130.93334689
19	1069.05800000	1133.51883025	-64.46083025	1119.37932750	1147.65983301
20	1101.37675000	1150.24411636	-48.86736636	1129.47468277	1171.01354996
21	982.00775000	1021.38755343	-39.37980343	995.29350643	1047.48160042
22	1075.21500000	1038.11283954	37.10216046	1016.91227495	1059.31340413
23	1024.78900000	1054.83812565	-30.04912565	1033.63756106	1076.03869024
24	1057.06675000	1071.56341176	-14.50276176	1045.46936477	1097.65745876
25	1247.111[illegible]	1229.91183854	18.20216146	1201.45842657	1256.36635052
26	1224.65000000	1245.63712465	-21.08712465	1222.78447715	1268.46977215
27	1292.37100000	1262.36241076	30.00858924	1239.50576326	1285.21505927
28	1285.59625000	1279.08769687	6.50856313	1251.63448490	1306.54090885
29	1226.33600000	1205.96329970	20.37270030	1180.50077798	1231.42582141
30	1189.95500000	1222.68859581	-32.73358581	1202.27034244	1243.10692918
31	1283.61325000	1239.41387192	44.19937808	1218.99562855	1259.83211529
32	1258.00375000	1256.13915803	1.86459197	1230.67663631	1281.60167975
33	1153.89925000	1127.28259510	26.61665490	1097.31811731	1157.24707288
34	1109.17250000	1144.00708121	-34.83538121	1118.19249658	1169.82327544
35	1203.99223000	1160.73316732	43.25908268	1134.91777309	1186.54856155
36	1173.88200000	1177.45845343	-3.57645343	1147.49397564	1207.42293122

SUM OF RESIDUALS = 0.00000000
SUM OF SQUARED RESIDUALS = 40161.55037906
SUM OF SQUARED RESIDUALS - ERROR SS = 0.00000000
FIRST ORDER AUTOCORRELATION OF RESIDUALS = -0.32635131
DURBIN-WATSON D. = 2.64775635

LIN.REG. FOR ALL SUBJECTS HIN INDEXO , ANGLE=2

ANALYSIS OF VARIANCE TABLE , REGRESSION COEFFICIENTS , AND STATISTICS OF FIT FOR DEPENDENT VARIABLE TIME

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB > F	R-SQUARE	C.V.
REGRESSION	2	348665.99275870	174332.99637935	138.96966	0.0001	0.89336997	3.20072 %
ERROR	33	41397.44514831	1254.46803473			STD DEV	TIME MEAN
CORRECTED TOTAL	35	390063.43790672				35.41847025	1106.57880

SOURCE	DF	SEQUENTIAL SS	F VALUE	PROB > F	PARTIAL SS	F VALUE	PROB > F
HIN	1	269130.23639004	214.53734	0.0001	269130.23639004	214.53734	0.0001
INDEXO	1	79535.75636866	63.40198	0.0001	79535.75636866	63.40198	0.0001

SOURCE	B VALUES	T FOR H0:B=0	PROB > |T|	STD ERR B	STD B VALUES
INTERCEPT	392.33742771	11.74207	0.0001	33.38603829	0.0
HIN	105.89564167	14.64709	0.0001	7.22976497	0.83064150
INDEXO	22.35030011	7.96274	0.0001	2.80794714	0.45155805

7. SAS ANOVA Procedure

and

ANOVA Printout

for

Left-sided Movement

(Sample, Model 4 of Part 2)

```
DATA GENERAL ;
INPUT DDNAME=FT10F001 SEX 1-2 SUBJECT 3-4 HIN 5-6 HOUT 7-8
      ANGLE 9-10 CYCLE 11-12 TIME 13-19 ;

28800 OBSERVATIONS IN DATA SET GENERAL          7 VARIABLES

DATA ALLSUB ;
SET GENERAL ; IF ANGLE=2 ;
IF HOUT=1 THEN INDEXD=1 ;
IF HOUT=2 THEN INDEXD=2 ;
IF HOUT=3 THEN INDEXD=3 ;
IF HOUT=4 THEN INDEXD=4 ;
IF HOUT=5 THEN INDEXD=5 ;
IF HOUT=6 THEN INDEXD=6 ;
IF HOUT=7 THEN INDEXD=7 ;
IF HOUT=8 THEN INDEXD=8 ;
IF HOUT=9 THEN INDEXD=9 ;
IF HOUT=10 THEN INDEXD=10 ;
IF HOUT=11 THEN INDEXD=11 ;
IF HOUT=12 THEN INDEXD=12 ;
DROP HOUT ;

14400 OBSERVATIONS IN DATA SET ALLSUB          7 VARIABLES

PROC SORT ; BY SEX SUBJECT HIN INDEXD ;

PROC ANOVA SORT=2 ;
CLASSES SEX SUBJECT HIN INDEXD ;
MEANS SEX SUBJECT HIN INDEXD ;
MODEL TIME=SEX SUBJECT(SEX) HIN INDEXD HIN*INDEXD HIN*SUBJECT(SEX)
      INDEXD*SUBJECT(SEX) HIN*INDEXD*SUBJECT(SEX) SEX*HIN SEX*INDEXD ;
TEST HIN BY SUBJECT(SEX) ;
TEST INDEXD BY INDEXD*SUBJECT(SEX) ;
TEST SUBJECT(SEX) HIN*SUBJECT(SEX) INDEXD*SUBJECT(SEX) BY RESIDUAL ;
TEST HIN*INDEXD BY HIN*INDEXD*SUBJECT(SEX) ;
TEST SEX BY SUBJECT(SEX) ;
TEST SEX*HIN BY HIN*SUBJECT(SEX) ;
TEST SEX*INDEXD BY INDEXD*SUBJECT(SEX) ;
TITLE ' ANOVA FOR ALL SUBJECTS ANGLE=2 ' ;
```

ANOVA FOR ALL SUBJECTS ANGLE=2

DATA SET ALLSUB

CLASSES	VALUES
SEX	1 2
SUBJECT	1 2 3 4 5 6 7 8 9 10
HIN	2 3 4
INDEXD	1 2 3 4 5 6 7 8 9 10 11 12

ANOVA FOR ALL SUBJECTS ANGLE=2

MEANS

INDEXD	N	TIME
1	1200	1015.38008
2	1200	1061.28592
3	1200	1052.56675
4	1200	1069.17908
5	1200	1078.75517
6	1200	1123.16508
7	1200	1109.55392
8	1200	1133.74958
9	1200	1123.23217
10	1200	1162.88133
11	1200	1158.65150
12	1200	1190.54500

HIN		
2	4800	1008.91702
3	4800	1090.11227
4	4800	1220.70710

SUBJECT		
1	1440	1024.37292
2	1440	1033.93139
3	1440	1179.70996
4	1440	1174.45167
5	1440	1092.08389
6	1440	1186.59049
7	1440	1167.10972
8	1440	1145.07042
9	1440	1026.33292
10	1440	1026.13562

SEX		
1	7200	1123.81131
2	7200	1089.34629

OVERALL MEANS 14400 1106.57880

ANOVA FOR ALL SUBJECTS ANGLE=2

ANALYSIS OF VARIANCE FOR VARIABLE TIME   MEAN 1106.57880   C.V. 13.4565715 %

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
SEX	1	4276214	4276213.9
SUBJECT(SEX)	18	81049751	4502763.9
HIN	2	109604350	54802174.8
INDEXD	11	35628303	3238936.6
HIN*INDEXD	22	10792723	490578.3
SUBJECT*HIN(SEX)	36	6802282	188952.3
SUBJECT*INDEXD(SEX)	198	18778088	94839.8
SUBJECT*HIN*INDEXD(SEX)	396	32431670	81898.2
SEX*HIN	2	133792	66895.8
SEX*INDEXD	11	658827	59893.4
RESIDUAL	13702	303820798	22173.5
CORRECTED TOTAL	14399	603976797	41945.7

TESTS	SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB > F
NUMERATOR:	HIN	2	109604350	54802174.8	12.17079	0.0007
DENOMINATOR:	SUBJECT(SEX)	18	81049751	4502763.9		
NUMERATOR:	INDEXD	11	35628303	3238936.6	34.15201	0.0001
DENOMINATOR:	SUBJECT*INDEXD(SEX)	198	18778088	94838.8		
NUMERATOR:	SUBJECT(SEX)	18	81049751	4502763.9	203.06994	0.0001
DENOMINATOR:	RESIDUAL	13702	303820798	22173.5		
NUMERATOR:	SUBJECT*HIN(SEX)	36	6802282	188952.3	8.52155	0.0001
DENOMINATOR:	RESIDUAL	13702	303820798	22173.5		

ANOVA FOR ALL SUBJECTS ANGLE=2

TESTS	SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB > F
NUMERATOR:	SUBJECT*INDEXD(SEX)	198	18778088	94838.8	4.27713	0.0001
DENOMINATOR:	RESIDUAL	13702	303820758	22173.5		
NUMERATOR:	MIN*INDEXD	22	10792723	490578.3	5.99010	0.0001
DENOMINATOR:	SUBJECT*MIN*INDEXD(SEX)	396	32431670	81898.2		
NUMERATOR:	SEX	1	4276214	4276213.9	0.94969	0.6595
DENOMINATOR:	SUBJECT(SEX)	18	81049751	4502763.9		
NUMERATOR:	SEX*MIN	2	133792	66895.8	0.35404	0.7002
DENOMINATOR:	SUBJECT*MIN(SEX)	36	6802282	188952.3		
NUMERATOR:	SEX*INDEXD	11	658827	59893.4	0.63153	0.8014
DENOMINATOR:	SUBJECT*INDEXD(SEX)	198	18778088	94838.8		

STATISTICAL ANALYSIS SYSTEM

DESIGNED AND IMPLEMENTED BY

ANTHONY JAMES BARR
JAMES HOWARD GOODNIGHT

DEPARTMENT OF STATISTICS
NORTH CAROLINA STATE UNIVERSITY
RALEIGH, NORTH CAROLINA
AUGUST, 1972

A USER'S GUIDE TO THE STATISTICAL ANALYSIS SYSTEM
IS AVAILABLE THROUGH

STUDENTS SUPPLY STORES
NORTH CAROLINA STATE UNIVERSITY
RALEIGH, NORTH CAROLINA 27607

AT A COST OF $7.95 PLUS POSTAGE AND HANDLING

8. SAS ANOVA Procedure

and

ANOVA Printout

for

Right-sided Movement

(Sample, Model 4 of Part 2)

```
DATA GENERAL ;
INPUT  DDNAME=FT10F001   SEX 1-2 SUBJECT 3-4 HIN 5-6 HOUT 7-8 ANGLE 9-10
                  CYCLE 11-12 TIME 13-19 ;

28800 OBSERVATIONS IN DATA SET GENERAL          7  VARIABLES

DATA ALLSUB ;
SET GENERAL ; IF ANGLE=1 ;
IF HOUT=1 THEN INDEXD=1 ;
IF HOUT=2 THEN INDEXD=2 ;
IF HOUT=3 THEN INDEXD=3 ;
IF HOUT=4 THEN INDEXD=4 ;
IF HOUT=5 THEN INDEXD=5 ;
IF HOUT=6 THEN INDEXD=6 ;
IF HOUT=7 THEN INDEXD=7 ;
IF HOUT=8 THEN INDEXD=8 ;
IF HOUT=9 THEN INDEXD=9 ;
IF HOUT=10 THEN INDEXD=10 ;
IF HOUT=11 THEN INDEXD=11 ;
IF HOUT=12 THEN INDEXD=12 ;
DROP HOUT ;

14400 OBSERVATIONS IN DATA SET ALLSUB           7  VARIABLES

PROC SORT ; BY SEX SUBJECT HIN INDEXD ;
```

AL ANALYSIS SYSTEM 21:3A

```
PROC ANOVA SORT=2 ;
CLASSES SEX SUBJECT HIN INDEXD ;
MEANS SEX SUBJECT HIN INDEXD ;
MODEL TIME=SEX SUBJECT(SEX) HIN INDEXD HIN*INDEXD HIN*SUBJECT(SEX)
        INDEXD*SUBJECT(SEX) HIN*INDEXD*SUBJECT(SEX) SEX*HIN SEX*INDEXD ;
TEST HIN BY SUBJECT(SEX) ;
TEST INDEXD BY INDEXD*SUBJECT(SEX) ;
TEST SUBJECT(SEX) HIN*SUBJECT(SEX) INDEXD*SUBJECT(SEX) BY RESIDUAL ;
TEST HIN*INDEXD BY HIN*INDEXD*SUBJECT(SEX) ;
TEST SEX BY SUBJECT(SEX) ;
TEST SEX*HIN BY HIN*SUBJECT(SEX) ;
TEST SEX*INDEXD BY INDEXD*SUBJECT(SEX) ;
TITLE ' ANOVA FOR ALL SUBJECTS ANGLE=1 ' ;
```

ANOVA FOR ALL SUBJECTS ANGLE=1

DATA SET ALLSUB

CLASSES	VALUES
SEX	1 2
SUBJECT	1 2 3 4 5 6 7 8 9 10
HIN	2 3 4
INDEXD	1 2 3 4 5 6 7 8 9 10 11 12

ANOVA FOR ALL SUBJECTS ANGLE=1

MEANS

INDEXD	N	TIME
1	1200	913.21975
2	1200	1008.02625
3	1200	997.39650
4	1200	1067.42250
5	1200	980.73708
6	1200	1073.84967
7	1200	1041.98533
8	1200	1123.99508
9	1200	1035.31208
10	1200	1099.40442
11	1200	1101.55850
12	1200	1181.20033
HIN		
2	4800	957.00250
3	4800	1036.81777
4	4800	1162.20660
SUBJECT		
1	1440	983.58924
2	1440	995.82181
3	1440	1106.95847
4	1440	1094.44076
5	1440	1042.43382
6	1440	1149.97264
7	1440	1114.24597
8	1440	1089.35597
9	1440	971.27410
10	1440	966.99681
SEX		
1	7200	1063.35560
2	7200	1040.66232
OVERALL MEANS	14400	1052.00896

ANOVA FOR ALL SUBJECTS ANGLE=1

ANALYSIS OF VARIANCE FOR VARIABLE TIME   MEAN 1052.06696   C.V. 14.0752936 %

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
SEX	1	1853945	1853945.5
SUBJECT(SEX)	18	70460778	3914487.7
HIN	2	102722498	51361249.1
INDEXO	11	68312252	6210204.7
HIN*INDEXO	22	5285457	240248.0
SUBJECT*HIN(SEX)	36	6931811	192550.3
SUBJECT*INDEXO(SEX)	198	17808106	89939.9
SUBJECT*HIN*INDEXO(SEX)	396	27382763	69148.1
SEX*HIN	2	1692	845.9
SEX*INDEXO	11	720234	65475.8
RESIDUAL	13702	300426173	21925.7
CORRECTED TOTAL	14399	601905609	41801.9

TESTS	SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB > F
NUMERATOR:	HIN	2	102722498	51361249.1	13.12081	0.0005
DENOMINATOR:	SUBJECT(SEX)	18	70460778	3914487.7		
NUMERATOR:	INDEXO	11	68312252	6210204.7	69.04836	0.0001
DENOMINATOR:	SUBJECT*INDEXO(SEX)	198	17808106	89939.9		
NUMERATOR:	SUBJECT(SEX)	18	70460778	3914487.7	178.53409	0.0001
DENOMINATOR:	RESIDUAL	13702	300426173	21925.7		
NUMERATOR:	SUBJECT*HIN(SEX)	36	6931811	192550.3	8.78194	0.0001
DENOMINATOR:	RESIDUAL	13702	300426173	21925.7		

ANOVA FOR ALL SUBJECTS ANGLE=1

TESTS	SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB > F
NUMERATOR:	SUBJECT*INDEXD(SEX)	198	17808106	89939.9	4.10203	0.0001
DENOMINATOR:	RESIDUAL	13702	300426173	21925.7		
NUMERATOR:	HIN*INDEXD	22	5285457	240248.0	3.47440	0.0001
DENOMINATOR:	SUBJECT*HIN*INDEXD(SEX)	396	27382663	69148.1		
NUMERATOR:	SEX	1	1853945	1853945.5	0.47361	0.5065
DENOMINATOR:	SUBJECT(SEX)	18	70460778	3914487.7		
NUMERATOR:	SEX*HIN	2	1692	845.9	0.00439	0.9960
DENOMINATOR:	SUBJECT*HIN(SEX)	36	6931811	192550.3		
NUMERATOR:	SEX*INDEXD	11	720234	65475.8	0.72799	0.7121
DENOMINATOR:	SUBJECT*INDEXD(SEX)	198	17808106	89939.9		

BIBLIOGRAPHY

1. Barr, A.J., Goodnight, J.H., 1973, Statistical Analysis System. Department of Statistics, North Carolina State University.

2. Bayha, F.H., Hancock, W.M., Application Guidelines on Decide Action Research. Department of Industrial Engineering, University of Michigan, Ann Arbor, Michigan.

3. Bowker A.H. and Lieberman G.J., 1972. Engineering Statistics Prentice-Hall Inc., Englewood Cliffs, New Jersey.

4. Draper and Smith, "Applied Regression Analysis" second edition. John Wiley and Sons Inc.

5 Draper and Smith, 1966, " Applied Regression Analysis ", Second Edition. John Wiley and Sons.Inc.

6. Fitts P.M., 1954, The Information Capacity of the Human Motor System in Controlling the Amplitude of Movement. Journal of Experimental Psychology, Vol. 47, #6.

7. Fitts P.M. and Peterson J.R., 1964, Information Capacity of Discrete Motor Responses. Journal of Experimental Psychology, Vol. 67, #2.

8. Fitts P.M. and Radford B.K., 1966, Information Capacity of Discrete Motor Responses Under Different Cognitive Sets. Journal of Experimental Psychology, Vol. 71, #4.

9. Hancock, W.M. and Foulke, J.A., 1963, Learning Curve Research on Short-Cycle Operations, Res. Report #112, M.T.M. Association, New Jersey.

10. Hicks, C.R., 'Fundamental Concepts in the Design of Experiments', second edition. Holt, Rinehart and Winston.

11. Hicks, R.C., 1973, Fundamental Concepts in the Design of Experiments, (New York : Holt, Rinehart and Winston, Inc.).

12. Keele, S.W., 1968, Movement Control in Skilled Motor Performance, Psychological Bulletin Vol. 70, #6, Part 1.

13. Posner, M.I., 1962, An Information Approach to Thinking. University of Michigan, Technical Report #02814.

14. Raouf, A., 1973, Information Processing Rate and Prediction of Decision Times, J.M.T.M., xviii.

15. Raouf, A., and El-Sayed, E.A., 1975, Effect of Informational Load and Angle of Moves on Performance Time in a Combined Manual and Decision Task, Proceedings, A.I.I.E. 1975 Spring Annual Conference.

16. Raouf, A., and Khare, S., 1975, Effect of Informational Load on Human Performance in a Combined Manual and Decision Task, American Industrial Hygiene Association Journal, 36. 1.

17. Raouf, A., and Mehra, M.L., 1974, Experimental Investigations Related to Combined Manual and Decision Tasks, Int. J. Prod. Res., Vol. 12, #2, 151-157.

18. Sadosky, T.L., 1969, Prediction of Cycle Times for Combined Manual and Decision Tasks, Research Report #116, M.T.M. Association, New Jersey.

19. Scholes, E.E., 1970, Information Capacity of Manual Discrete Motor Responses Compared for Different Directions and Amplitudes of Movement, Master Thesis, Naval Postgraduate School, 1970.

20. Shannon, C.E., and Weaver, W., 1949, The Mathematical Theory of Communication, Urbana: University of Illinois Press.

21. Thomas, M.U., 1971, "Some Probabilistic Aspects of Performance Times for a Combined Manual and Decision Task", a Ph.D. Dissertation, Industrial Engineering, University of Michigan.

22. Thomas, M.U., Hancock, W.M., and Chaffin, D.B., 1974, Performance of a Combined Manual and Decision Task With Discrete Uncertainty, Int. J. Prod. Research 12, 3.

23. Welford A.T., 1960, The Measurement of Sensory-Motor Performance: Survey and Reappraisal of Twelve Years' Progress Ergonomics, 1960, Page 189-230.

24. Bailey and Presgrave, 1958, 'Basic Motion Time Study' McGraw Hill, New York.

25. Crossman and Goodeve, 1963, 'Feedback Control of Hand Movement and Fitts' Law'. Communication to The Experimental Phychology Society.

26. Handcock, Langolf and Clark, June 1973. Development of Standard Data for Sterioscopic Microscopic Work, A.I.I.E. Transaction, Volume 5, #2.

27. Welford A.T., 1975. Effect of Informational Load and Angle of Move on Performance Time in a Combined Manual and Decision Task. Proceedings, A.I.I.E. 1975 Spring Annual Conference.

28. Sethi, H.S. 1975. Effect of Information Reduction on Certain Aspects of Operator's Performance in a Decision Task. A.M.A.Sc. Thesis, Industrial Engineering, University of Windsor.

Vita Auctoris

1948	Born in Hong Kong.
1966	Graduated from Form V at St. Louis School.
1968	Senior Matriculation at New Method College.
1972	Graduated at University of Windsor with B.A. Sc. in Chemical Engineering.
1975	Graduated at University of Windsor with Business Communication.
1976	Employed in Industrial Engineering functions with the Northern Telecom Limited.
1977	Candidate for the degree of Master of Applied Science.