1982

A study of unequal task difficulty and unequal angles for simultaneous hand motion an a horizontal plane[microform].

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A STUDY OF UNEQUAL TASK DIFFICULTY AND UNEQUAL ANGLES FOR SIMULTANEOUS HAND MOTION ON A HORIZONTAL PLANE

by

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A Thesis
Submitted to the Faculty of Graduate Studies
through the Department of Industrial Engineering
in Partial Fulfillment for the
Degree of Master of Applied Science
at the University of Windsor

Faculty of Graduate Studies

University of Windsor

August, 1982

I wish to dedicate this work

to my parents and sister.

ABSTRACT

It has been recognized that the amount of work done by workers using two hands simultaneously is greater than that of workers using one hand alone. However, it has also been reported that when a task is simultaneously performed the cycle time of such task is higher than when it is performed single-handedly. Many attempts have been made to set the standard time for such tasks, but these motions are still handled differently in all available predetermined Motion Time Systems.

Simultaneous hand motions have been generally defined as the motions begun and completed by two hands in the same period of time either in a symmetrical or an asymmetrical way. Symmetrical simultaneous hand motions are those motions with identical angles and equal degrees of task difficulty; others are asymmetrical simultaneous motions. The task difficulty of manual tasks where "move" and "position" are involved has often been defined by the following relationship, $TD = \log_2(2D/C)$ bits, where D is the distance moved and C is the target diameter. Therefore, it seems that the task difficulty of simultaneous hand motion may also be defined by the above - mentioned relationship for given angles of hand motions.

The heart rate of workers performing a task have sometimes been used as a physiological measure to predict work-load and to rate worker performance and has proven to be

highly correlated with the physical load of various tasks. On the other hand, it has been found that the mental load of tasks may be measured by the amount of the fluctuations of Heart rate (Heart Rate Variability or HRV).

The effects of the task difficulty and the angle of hand movements along with the physical and the mental loads on simultaneous motions do not seem to have been adaquately investigated. In this study, the simultaneity of a task involving "move" and "position" was investigated under three conditions, 1) symmetrical angles and symmetrical task difficulties, 2) symmetrical angles and asymmetrical task difficulties and 3) asymmetrical angles and symmetrical task difficulties.

The results for the first condition (symmetrical angles and symmetrical task difficulty) show that the effects of task difficulty and angle of move were significant on the performance time. However, heart rate was not significantly affected by both the above factors. Statistical tests for the entire study used a significance level of $\alpha=0.05$. The results for the second condition (symmetrical angles and asymmetrical task difficulty) show that performance time once again was significantly affected by the task difficulty as well as the angle of move. However, neither of the above factors do not affect the heart rate significantly. The results for the third condition (asymmetrical angles and symmetrical task difficulty) show that the effects of task difficulty , the angle of move of left hand (AL), the angle of move of right hand (RH), and the interaction between the angle of move of left and right hand (AL*AR) significantly affected the performance time. Further, task difficulty significantly affected the heart rate while angle of move of left hand and angle of move of right hand had no effect on it. Within task difficulty it was seen that only distance of move had a significant effect on the heart rate while the lateral clearance of fit had no effect. It was also seen that task difficulty, angle of move of left hand, and angle of move of right hand have significant effects on the Heart Rate Variability Index. From these results it was concluded that as angle was seen to be a significant factor, PMTS's that do not incorporate angle effects (most of the available PMTS's do not) do not aid the design of such tasks in choosing the optimal direction of moves of simultaneous motion. Further, task difficulty was not found to be a preferable measure of physical load. Distance of move was found to be the better measure.

ACKNOWLEDGMENTS

The author is sincerely grateful to his advisor Professor A. Raouf, for his guidance during the years of graduate study and his helpful suggestions during the course of research

Special appreciation is extended to Professor N. N. Shklov, and to Professor K. Morooka, Dr. A. Yuceer and Dr. Galwey for their inspiration, encouragement and helpful comments.

The author wishes to express his sincere thanks to Dr. M. A. Rahim for the statistical interpretation of the results of this study and to Dr. R. S. Lashkari, Head of the Department of Industrial Engineering, for encouragement.

Special thanks are extended to Ms. Marion Sherwood who typed the first draft of this thesis and Mr. Cory and his staff who designed and built the experimental units for this study.

Finally, the author gratefully acknowledges the inspiration and encouragement of his graduate student fellows, Thomas Joseph, Sasan Hatami, Daman Luthra, Iiji Ogawa and Hirofumi Imanishi.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

GENERAL INTRODUCTION

In industry it has been recognized that there are some situations where tasks are performed simultaneously by a worker using two hands (Raphael et al., 1952). For such tasks the amount of work done by the worker using two hands is greater than that of the worker using one hand alone (Barnes and Mackenzie, 1940). The idea of using two hands simultaneously to increase the productivity of such tasks was first documented in the 'Fundamental of Laws of Motion Economy' by Gilbreth (1923).

Simultaneous hand motions have been generally defined as the motions begun and completed by two hands in the same period of time either in a symmetrical or an asymmetrical way. Symmetrical simultaneous hand motions are those motions with identical angles and equal degrees of task difficulty; others are asymmetrical simultaneous motions. Although simultaneous motions have been studied by many researchers, these motions are still handled differently in all available Predetermined Motion Time Systems (PMTS's). In Method Time Measurement (MTM), for instance, there is no allowance in performance time for simultaneous motions unless the two motions are considered to be difficult to perform simultaneously. The time values for both motions are assigned to complete the simultaneous motions (i.e., twice the time value for an equivalent single handed motion in the symmetrical case).

Simultaneous symmetrical and asymmetrical "reach" motion experiments were conducted recently (Raouf et al., 1978, Ito, 1979, Mak, 1978). Findings in these experiments confirmed that simultaneous motions require more time than single-handed motions for element reach. Although the mean performance times for single-handed motions generally agree with the values assigned by PMTS's, in the same experimental conditions, it was found that the time values for simultaneous two handed reach motions are always higher than those of PMTS's. For the motion employed in the previously cited experiments, PMTS's do not allow any extra time for simultaneously performed tasks. However, none of the motions required twice the time values which one PMTS assigns in some other cases. The largest percentage increase in performance time for symmetrical simultaneous motions over single-handed motions, in the same experimental conditions, was calculated to be 66.0%.

Another important result in these experiments is that the angle of the moves was found to be a significant factor (Raouf et al., 1978, Ito, 1979). In industry not only "reach" but also motion "move" and "position" are often performed simultaneously (Raphael et al., 1952). The time necessary to complete a task depends on its difficulty. This difficulty normally consists of more than one factor. Fitts (1954, 1964) introduced information theory, index of difficulty (task difficulty), in prediction of work performance of certain types of task, and found that performance time was well predicted by the following relationship.

Task difficulty (TD) = $\log_2$ (2D/C) bits,

where D is the distance of the hand movements and C is the tolerance range. Raouf et al., (1977) reported that many researchers have obtained high correlations between TD and the performance time of manual tasks.

It has been reported that when a task is performed simultaneously it requires somewhat more attention than when it is performed single-handedly. The results of symmetrical simultaneous reach experiments (Ito, 1979) show that the mean heart rate differences of subjects performing two-handed simultaneous tasks were higher than those performing single-handed tasks. It was also shown as the angle of hand motion from a central reference plane (12 o'clock) increased, performance time also increased and subject heart rate difference decreased. Since it is obvious that as the angle increases visual requirement to complete the task is increased, it may be said that the degree of difficulty of the task at a larger angle was somewhat greater than that at zero degrees (12 o'clock). Although the subjects were asked to perform the tasks as quickly as they could, it was not possible to perform the tasks at the larger angle as quickly as at zero degrees. Furthermore, the physical load of the task per hour was reduced because of lower performance; consequently heart rate differences were observed to be lower at larger angles than at zero degrees. From the above discussion one may feel that it is necessary to investigate this nonphysical load of the task, which can not be measured by Heart Rate (HR) alone and which may have an important influence on simultaneous hand motion. As Macormick (1976) described, every kind of human activity is considered to involve physical acts and mental work.

The relationship between Heart Rate Variability (HRV) and Mental Load has been studied by many and proved to be highly correlated in some cases (Kalsbeek, 1973; Rohmert et al., 1973; Zwaga, 1973). In the area of mental load study, bits of information have been used as a unit to express mental load or the rate of information processing. The difficulty of manual tasks such as "move" task and "position" task can also be expressed by the use of bits of information as discussed earlier. However, the relationship between such task difficulty of simultaneous motions (expressed in bits) and HRV does not seem to have been investigated in the past. In this study a task consisting of motions "move" and "position" is used to investigate the simultaneity under laboratory conditions. Independent variables to be included in the experiment are angle and task difficulty.

CHAPTER II

LITERATURE SURVEY

2.1 INTRODUCTION

The related literature on simultaneous hand motions and physiological measures is documented in this Chapter.

2.2 CHARACTERISTICS OF SIMULTANEOUS MOTIONS

Simultaneous motions are generally defined as motions begun and completed at the same time, in either a symmetrical or an asymmetrical way.

It was observed through a film analysis that when tasks are performed simultaneously, there is a tendency for one of the hands to limit the other. When two hands travel different distances, the hand which travels the shorter distance slows down and the other hand which travels the longer distance speeds up such that their time of travel is almost equivalent. Raphael et al., (1952) concluded that, in general, motions requiring more control will limit motions which need the same or a lesser amount of control. Later, Barnes (1968) found that symmetrical movement of arms tends to balance both arms, reducing the shock and jar on the body, thus allowing the worker to be able to perform the tasks with less mental and physical effort.

It has also been recognized that as the amount of control of one hand increases, the performance time of the other hand also increases. The amount of control required to perform such simultaneous motions is considered to depend upon a worker's biomechanical and visual controls. Furthermore, each type of control depends upon the type and degree of the difficulty of the task. The factors considered to be influencing the difficulty of the tasks involving simultaneous motions are the angle of movements, the separation distance of the two hands at starting points, and the distance moved, and if a "position" task is to be executed with width of the target or clearance of fit.

The effects of angle on symmetrical simultaneous (SYMT SIMO) motions were investigated by Barnes and Mundel (1953). The results of a series of experiments indicate that although minimum performance time occurred at 30 degrees from the central reference plane the least number of mistakes was recorded at zero degrees. They also indicate that as the angle of the motions decreased, the number of errors decreased. Hassan and Block (1967) investigated the effects of separation distance and class of fit in positioning tasks. The results show that there is a linear relationship between performance time and separation distance in each class of fit. The results also indicate that the performance times for simultaneous positioning are greater than that for one-hand positioning. However, the results of simultaneous symmetrical positioning experiments using pegs and pegboards by Niebel, Kassab and Noll (1972) show the existence of an exponential relationship between performance time and separation distance.

Ito (1979) compared the performance times of SYMT SIMO's with single handed motions under various conditions. His results show that minimum performance times for single handed motions occur between 30 degrees and 60 degrees from the central reference plane in most cases. However, minimum performance times for SYMT SIMO's occur at 0 degrees in most cases. Single hand motions require less visual control than SYMT SIMO's. These results indicate that when the visual requirements of a task are minimal, the most efficient direction of arm movements is determined by biomechanical factors, but when SYMT SIMO's are performed visual requirements are the predominant factors determining optimum conditions. Therefore it can be said that in this latter case there is a trade-off between the speed of moves and the accuracy of the moves.

2.3 HEART RATE AND HEART RATE VARIABILITY

Heart Rate (HR) and Heart Rate Variability (HRV) are often used to measure the workload of a task. MaCormick (1976) proposed that every kind of human activity involves some combination of physiological processes involving not only with physical acts but also with mental work and nonphysical acts.

The Heart Rate differences of a worker at rest and at work, or when he performs different types of work, have been used to measure physical workload (Brouha, 1954). Since high correlations have been obtained between the intensity of paced physical work and Heart Rate, it was suggested that Heart Rate may be used to rate operator performance (Young, 1956).

Kalsbeek, et al., (1964) reported that when the Heart Rate of a man sitting at rest was measured continuously, it was observed that Heart Rate was irregular (sinus arrythmia) and the fluctuations could be up to 20 beats per minute. On the other hand when the subjects were performing a binary choice-reaction task, Heart Rate rose to a certain level and the irregularity diminished. They also found that when subjects were performing this type of task, sinus arrythmia was gradually supressed as the rate of information processing was increased.

Many workers looked at the relationship between mental load and sinus arrythmia under various conditions (Sayers, 1973; Rohmert et al., 1973; Zwaga, 1973; Mulder et al., 1973; Luczak et al., 1973; Kalsbeek, 1973; Opmeer, 1973). However, there is more than one method of expressing sinus arrythmia in the literature. Kalsbeek (1973) mentioned that there are at least 30 different methods of scoring sinus arrythmia and obtaining so-called Heart Rate Variability in the literature. As a result of the diversity of approaches, he was able to discern that "different scoring methods lead to different values calculated from the same heart rate data".

Luczak (1973) compared 8 different formulae of scoring HRV from the same HR of 12 subjects performing binary choice tasks. Some of the commonly used HRV scoring methods did not show consistent changes in the scored values with the changes in the difficulty of the task. One computational method of HRV which is the combination of 2 measures (those being the amplitude information of HR in the numerator and the frequency information of HR in the denominator) was proposed earlier by Laurig in 1971. In Luczak's study both terms, numerator and denominator, were found to be significant at $\alpha = .05$ on "mental load" and HRV score itself was significant at $\alpha = .05$. The formula to obtain HRV is given below.

$$HRV = \frac{\sum(HR_i - HR_{i+1}) \quad \text{for } (HR_i - HR_{i+1}) > 0}{\text{Freq.}(((HR_{i-1} > HR_i)\wedge(HR_i < HR_{i+1}))\vee((HR_{i-1} < HR_i)\wedge(HR_i > HR_{i+1})))}$$

The numerator is the sum of difference of two successive beats when HR is decreasing. The denominator is the frequency of relative maxima and minima.

The effects of "mental load" under different physical load were studied by Boyce (1974). Ten subjects were used in mental arithmetic experiments and their HR's and standard deviations of HR's to score HRV were measured. It was reported that HR increased when both physical and mental load were increased. HRV was determined by using standard deviation and found to decrease when "mental load" increased; however, an increase in HRV (which does not agree with the results from others' studies) was observed when physical load increased. Because the standard deviation was used to score HRV, together with the fact that a steady increase in HR during the experiment due to the nature of the task was expected, seem to explain the above mentioned disagreement.

In 1979, Luczak carried out a series or 2 experiments using the previously mentioned HRV scoring method. In the first experiment 48 male subjects worked on a binary choice task. The results show that the correlations between HR and HRV, physical stress and HR, and mental stress on HRV are significant. In the second experiment, 20 female subjects performed a multiple choice-reaction task with 5 levels of task difficulty. The task difficulty levels were defined by the number of alternatives to the subjects, i.e., 2,4,6,8,10. Subjects were asked to perform the task in a 5-minute rest-work-schedule. The levels of the task difficulty were intentionally not randomized, but were increased gradually from session to session. It was observed that HR decreased significantly in dependence on the duration of the experiment and is independent of task difficulty. In other words it was found that HR decreased as the experiment progressed, although task difficulty was increased from session to session as planned. HRV decreased when task difficulty was increased. It was also found that HRV in the rest periods increased with the duration of the experiment.

Wierwille (1979) carried out an extensive research on "Physiological Measures of Aircrew Mental Workload" and found out that some researchers have found "no systematic relationship between heart rate and task difficulty. ... no relationship between heart rate variability and task difficulty". Mulder (1973) and Sayers (1973) used the variance of inter-beat-interval and HR, respectively, to score HRV in their research and found out that HRV is not significant on "mental load". However, through a different approach than that used by previous studies, they found by the use of spectrum analysis that respiration affected

HR and suggested the use of respiration as a measure of "mental load". Other researchers also found that HRV is affected by changes in respiration rate (Hichen et al., 1980; Hyndman et al, 1974). It seems that there is evidence that HRV is affected by changes in respiration rate caused by "mental load". However, Kalsbeek (1973) has already reported "sinus arrythmia occurs during rest, whereas recorded breathing pattern does not show marked abnormality".

The definition of "mental load" or the effect being measured by HR and HRV is somewhat different among researchers. Zwaga (1973) found a decrease in HR during mental arithmetic tasks over time. He concluded that this is because of a decrease in "mental effort" over time. Hyndman (1974) agreed with the suggestion made by Kalsbeek (1964) that sinus arrythmia is a measure of "total mental load" rather than just the load resulting from the task. Later Kalsbeek (1973) defined sinus arrythmia as "an indicator of the proportional occupation of an individual's single channel capacity during rest and work".

As one can see there are several interpretations on sinus arrythmia or HRV. However, one may conclude that sinus arrythmia does decrease when the mental load which may be demanded by the task an individual is performing increase. External stimuli and other factors in the environment may cause an increase in mental load during performance of the task. Therefore, it seems important to analyze the task and isolate undesired influences from other sources than the task (Kalsbeek, 1973). In this sense the use of HRV as a measure of mental load on a task under laboratory conditions may be validated.

As a final note it is important to stress that the task in which the effects of mental load are to be measured should not involve heavy physical load. Excessive physical load would provoke unwanted increase in HR during the experiment and would invalidate the meaning of the data (Luczak, 1979).

CHAPTER III

EXPERIMENTAL SET UP

3.1 INTRODUCTION

Special simultaneous two-handed motion experimental equipment and performance time recording equipment, as well as physiological study equipment are used in the study. In this Chapter these experimental apparati are described and corresponding procedures for processing performance time and physiological measures are explained.

3.2 SIMULTANEOUS TWO-HANDED MOTION EXPERIMENTAL EQUIPMENT

The simultaneous two-handed motion experimental apparatus was designed and built for this study. The equipment consisted of three units: (1) a SIMO-PIN unit; (2) a time-measuring unit and (3) a recording unit (paper tape punch). A layout of the SIMO-PIN unit is shown in Figure 3.1.

The SIMO-PIN unit consists of a wooden box 1580 mm long, 760 mm wide, 180 mm high, and the top of the box being 720 mm from the floor. Two 550 mm long x 45 mm wide mechanical units are located in the box. These mechanical units have two pin sockets each 7 mm in diameter. These sockets on the near side of the mechanical unit are fixed and the other two can be moved at any desired distance from the fixed pin sockets in the range of 50 mm to 450 mm. The distances between the

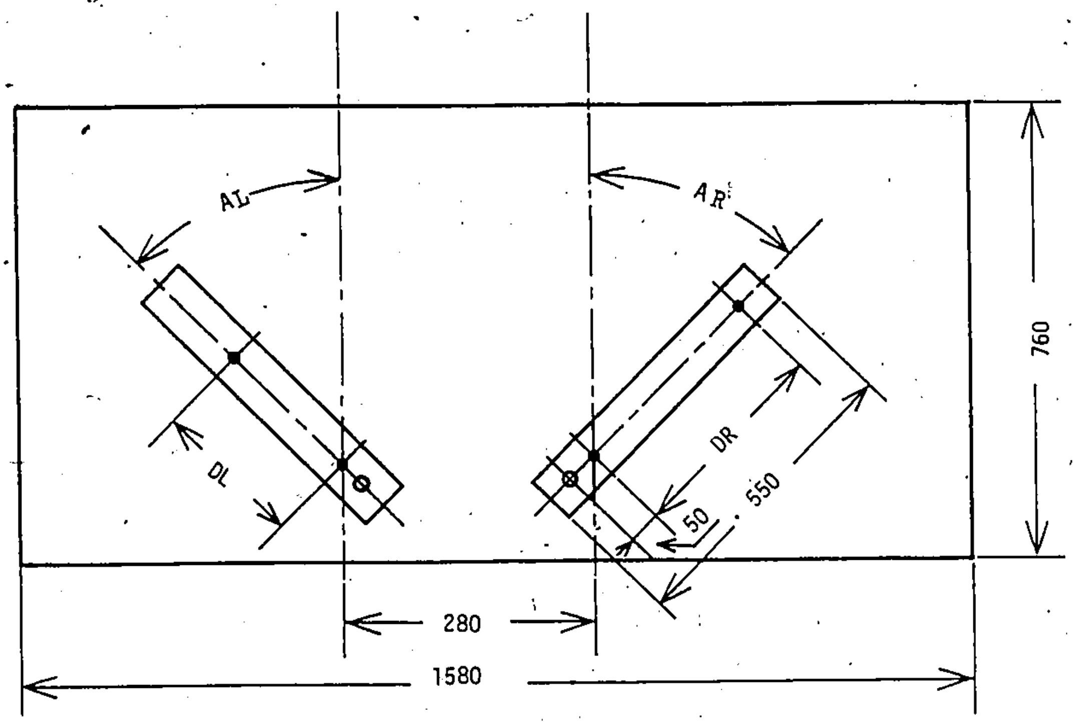

Figure 3.1
Experimental Layout

fixed pin sockets and movable pin sockets can be varied independently so that symmetrical (SYMT) and asymmetrical (ASYM) conditions are obtained. Each pin socket has a photoelectric sensor to activate the time measuring device. There are two switches 25 mm in diameter, 50 mm away from the fixed pin sockets. On pressing these switches two pins each 32 mm long, 6.35 mm in diameter and weighing 8 grams apiece are pre-positioned in the fixed pin sockets.

The time-measuring unit measures the elapsed time between the removal of the pins from the fixed pin sockets and the insertion (positioning) of each pin in the movable pin sockets. For changing the clearance between the pins and the pin sockets, top covers having different size holes are used. The time taken by the left hand and the right hand is measured simultaneously and punched onto a paper tape.

3.3 THE PERFORMANCE TIME DATA PROCESSING PROCEDURES

The performance times for the left hand and the right hand are measured in milliseconds and these data are sent to the paper tape punch through a specially built interface. Then the data is punched onto a paper tape in IBM 8-digit code. The data on the paper can be transferred onto computer cards later and analyzed on an IBM 370/3031 computer. Graphical representation of the data processing procedures is shown in Figure 3.2

3.4 THE PHYSIOLOGICAL MEASURES PROCESSING PROCEDURES

The subject heart beats are monitored by a Polygraph (Grass Instrument, Model 7) which equips an EKG Tachograph Pre-Amplifier

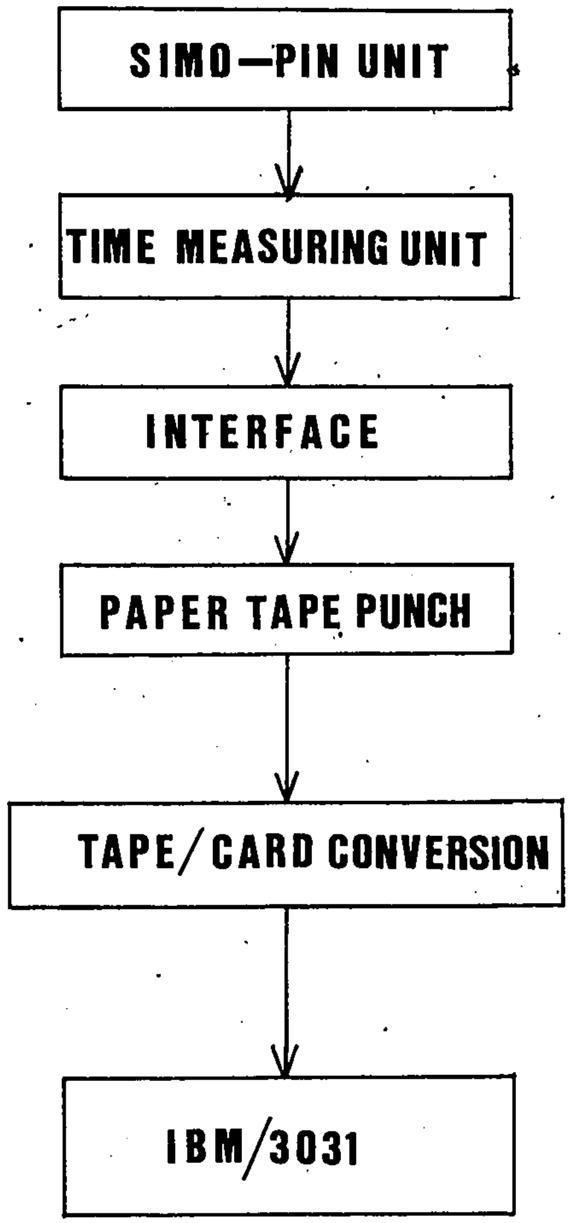

Figure 3.2

Graphical Representation Of Preformance Time Data Processing Procedures

(Model 7P4F), four DC Pen Drive Amplifiers (Two being used for this study, Model 7DAF), and a 4-channel chart recorder. Three Beckman electrodes are attached to the subject's skin surface and leads are connected to the EKG preamplifier. The potential differences between pairs of points on the skin surface due to cardiac activity are amplified by the EKG preamplifier. Then beat-to-beat (inter-beat) Heart Rate (beats/minute) is computed by the tachograph. This HR data is recorded by the chart recorder in analog form and is simultaneously supplied to a PDP-11/03 digital computer. The PDP-11/03 has a 16-channel Analog-to-Digital (A/D) converter, and is capable of real-time processing the HR data at desired intervals up to 60 times/second. The HR data input to the PDP-11/03 is then digitaized and each beat-to-beat HR is determined by a computer program and recorded on a magnetic disk. An average HR and a scored HRV are computed for each experimental condition for each subject upon completion of each experimental condition. The HR data recorded on the disk was subsequently transferred to the IBM/3031 through the WYLBUR (text editing system) by a specially written program on PDP-11/03. The diagramatical representation of the procedures are shown in Figure 3.3.

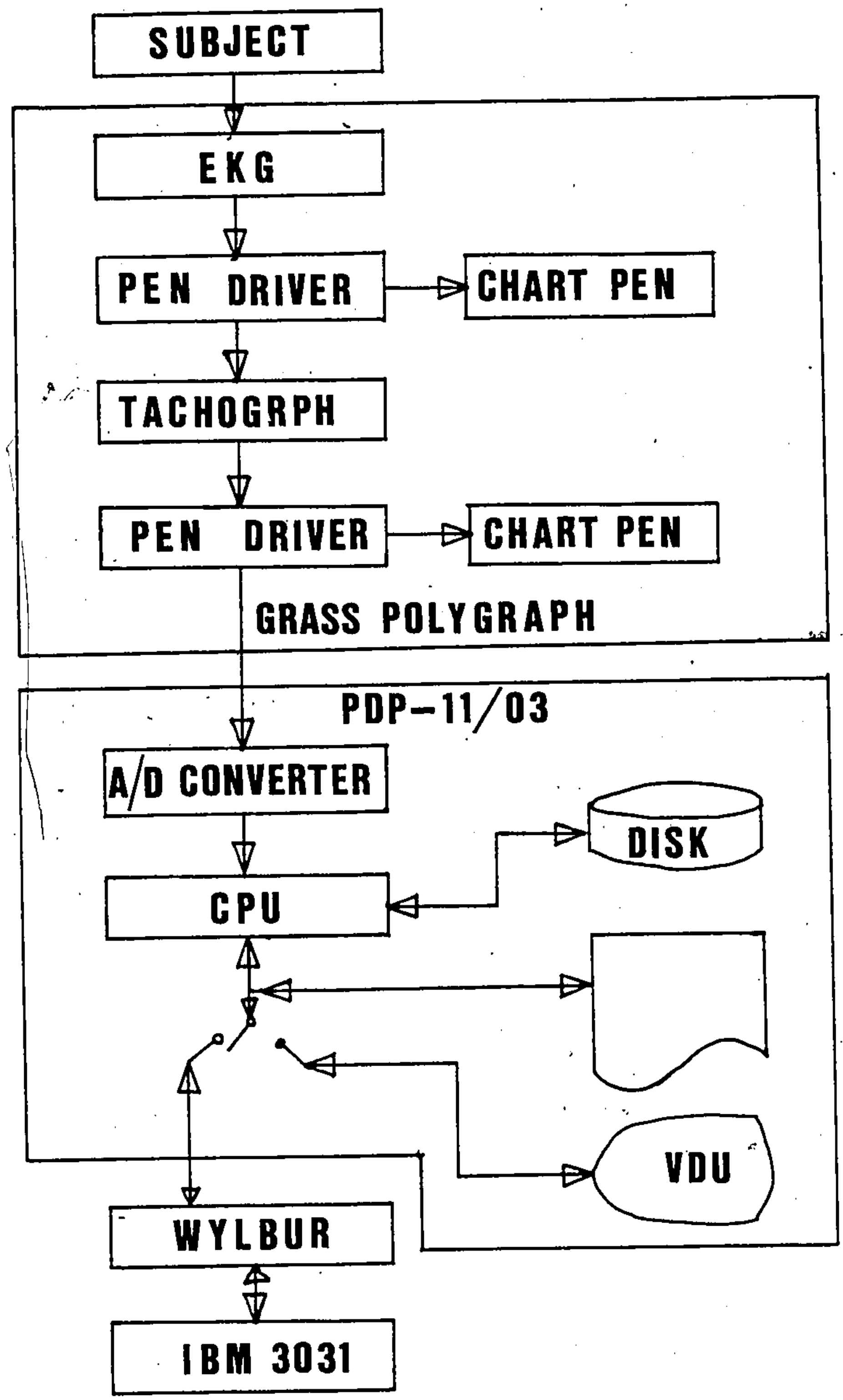

Figure 3.3

Graphical Representation Of Physiological Data Processing Procedures

CHAPTER IV

THE DESIGN OF THE EXPERIMENT

4.1 INTRODUCTION

The task employed in this study, the objectives of the study, the experimental conditions, the statistical models developed and the results of pilot studies are described in this Chapter.

4.2 EXPERIMENTAL TASK

In this study each subject is asked to perform a simultaneous two-handed task under various conditions. The subject is asked to sit at the SIMO-PIN unit and not to shift his body or speak during the experiment. The task to be performed by the subject is shown diagramatically in Figure 4.1. On hearing an audio signal, the subject is required to press simultaneously two switches located near the end of the experimental units using his index fingers. This results in activation of the mechanical units that push up two pins in the fixed pin sockets. The subject is required to grasp the pins and move these pins to the movable-pin sockets and to position (insert) them in the respective holes of the pin sockets. Approximately two seconds after completion of the task, the audio signal is given again and the subject performs the next cycle of the task.

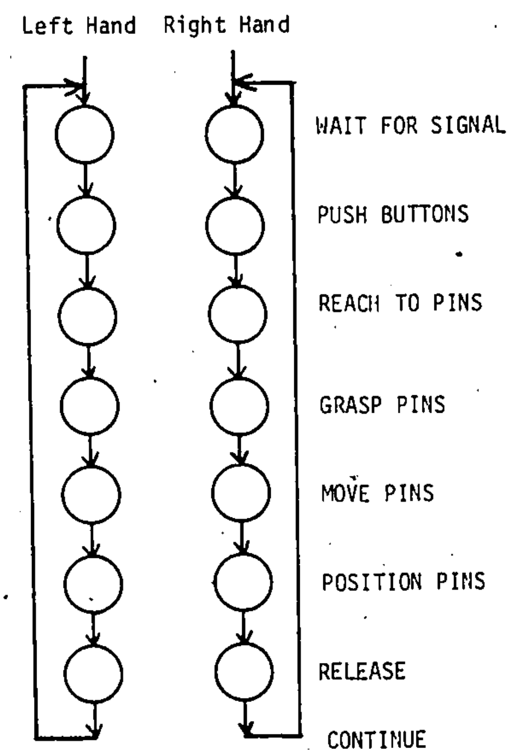

Figure 4.1 Diagramatic Layout of Subject's Task.

4.3 THE OBJECTIVES OF THIS STUDY

The following are the objectives of this study.

(1) To see if there is any systematic relationship between the performance time and the factors constituting the task, i.e., the angle of hand movements, the distance of hand movements and lateral clearance, on a horizontal plane.

(2) To see if there is any systematic relationship between the factors constituting the task and the physiological measures of subjects.

4.4 THE RESULTS OF PILOT STUDIES

Two pilot studies were carried out. The first pilot study was designed to determine appropriate levels of the factors. The second pilot study was designed to discover the relationship between the factors and the performance time under (1) symmetrical conditions and (2) a type of asymmetrical condition (symmetrical angle and asymmetrical TD). HR of subjects was monitored during the experiments in the second pilot study.

4.4.1 The First Pilot Study

Four right-handed male subjects between the age of 21-27 were used in the first study. The factors investigated in this study were:

(1) Subject S_i i=1,2,3,4

(2) Distance D_k k=100,150,200,250,300 (mm)

(3) Clearance C_l l=0.65,2.65,4.65,6.65,8.65,10.65,12.65 (mm)

(4) Hand H_m m="right","left".

(5) Angle A_j j=0,15,30,45,60 (degrees)

4.4.1.1 Statistical Model

Three statistical models using a 3-way classification were used. Each model involved S and H, and A, D or C. The models are shown below.

$$PT_{ijmn} = + S_i + A_j + H_m + (S.A)_{ij} + (S.H)_{im} + (A.H)_{jm}$$
$$(S.A.H)_{ijm} + E_{ijmn}$$

$$PT_{ikmn} = + S_i + D_k + H_m + (S.D)_{ik} + (S.H)_{im} + (D.H)_{km}$$
$$(S.D.H)_{ikm} + E_{ikmn}$$

$$PT_{ilmn} = + S_i + C_l + H_m + (S.C)_{il} + (S.H)_{im} + (C.H)_{lm}$$
$$(S.C.H)_{ilm} + E_{ilmn}$$

4.4.1.2 Results

The factors, A, D, C were found to be significant at $\alpha = .05$. The results of ANOVA's are shown in Appendix A. A Duncan's Multiple Range Test was carried out for each factor. The results are summarized below.

DUNCAN'S MULTIPLE RANGE TEST

Variable	A					(degrees)		
Levels	0	15	30	45	60			
Grouping	—	———	———	———	———			
Variable	C							
Levels	.65	2.65	4.65	6.65	10.65	12.65	8.65	(mm)
Grouping	——	——	———	———	———	———	———	
				———	———			

Variable	D					
Levels	100	150	200	250	300	(mm)
Grouping	———	—————	—————	———	———	

The results of Duncan's Multiple Range Test show that for the factor A, there is a significant difference between the mean performance time at 0 degrees and at the other angles. The mean performance times were significantly different from each other at all levels except 150 mm and 250 mm for the factor D. The significance of the mean performance times, when lateral clearance was varied, was tested at seven levels. At the higher levels of hole size, results did not show a significant difference, but when the hole size was relatively smaller the factor showed a significant difference in performance.

4.4.2 The Second Pilot Study

By making use of the results of the first pilot study, appropriate levels of the factors were chosen. The second pilot study involved varying both factors A and TD. In this study an interaction between A and TD was also tested. The study was carried out in two parts. In part I subjects performed the task simultaneously under symmetrical conditions and in part II under asymmetrical conditions, those being the asymmetrical distance of move and lateral clearance, and the symmetrical angle. Eight right-handed male subjects participated in these studies. All of them were university students between the age of 20-24 and were paid a minimum wage rate. The only dependent variable used in these studies was performance time for the limiting hand (greater of two time values). For part I the following independent variables were studied:

Variables		Levels	
Distance	(D)	150, 250, 300	(mm)
Lateral Clearance	(C)	0.65, 4.65, 8.65	(mm)
Angle	(A)	0, 30, 60	(degrees)

The variables used in part II are:

Variables		Levels	
Distance moved by:			
right hand	(DR)	250, 350, 150, 150	(mm)
left hand	(DL)	150, 150, 250, 350	(mm)
Lateral Clearance	(C)	0.65, 4.65, 8.65	(mm)
Angle of Moves	(A)	0, 30, 60	(degrees)

For both studies subjects performed the task 35 times in each condition.

4.4.2.1 Statistical Model

A statistical model was developed for each study. TD's were calculated for each of the combinations using the following relationship, $TD = \log_2 (2D/C)$ bits. For analyzing the results of part I the following statistical model was used.

$$PT_{ijkn} = \mu + S_i + A_j + TD_k + (S.A)_{ij} + (S.TD)_{ij} + (A.TD)_{jk} + (S.A.TD)_{ijk} + E_{ijkn}$$

where

PT_{ijkn} = MAX $[PTR_{ijkn}, PTL_{ijkn}]$

PTR = PT for right hand

PTL = PT for left hand

μ = average PT

S_i = ith subject

A_j = jth level of angle effect

TD_k = kth level of task difficulty

n = nth observation

E_{ijkn} = experimental error.

The statistical model used in part II is:

$$PT_{ijln} = \mu + S_i + A_j + TDLTG_l + (S.A)_{ij} + (S.TDLTG)_{il} + (A.TDLTG)_{il} + (S.A.TDLTG)_{ijl} + E_{ijln}$$

where

TDLTG = MAX [TDR, TDL]

TDR = TD for right hand

TDL = TD for left hand.

4.4.2.2 Results

Analysis of collected data indicated that a logarithmic transformation was required before the analysis of variance could be carried out. ANOVA for part I and part II are shown in Appendix B. It is observed that the following variables had significant effects upon performance time at ,05 level.

Part I	Part II
TD, A and S	TDLTG, A and S.

Duncan's Multiple Range Test was carried out for each of the above variables. The results are shown below.

DUNCAN'S MULTIPLE RANGE TEST

PART I SYMMETRICAL SIMO

Variable	A									
Levels	0	30	60	(degrees)						
Grouping	—	—	—							

Variable	TD									
Levels	5.11	6.01	5.85	6.33	6.74	8.65	9.58	7.23	10.07	(Ibits)
Grouping	———	———	———	————	————	———	————	————	———	

DUNCAN'S MULTIPLE RANGE TEST

PART II ASYMMETRICAL SIMO

Variable	A			
Levels	0	30	60	(degrees)
Grouping	—	—	—	

Variable	TD						
Levels	5.85	6.33	6.74	7.23	9.58	10.07	(Ibits)
Grouping	———	———	———	———	———	———	

It was observed that as the angle increased mean performance time at each level increased significantly in both symmetrical and asymmetrical cases. For the factor TD in the symmetrical case, it seems that, as the task difficulty increased, PT increased and in the asymmetrical case it is clear that all mean PT's are significantly different from each other and that PT increased when TD was increased.

4.5 HEART RATE

During the experiments the HR of each subject was monitored. For part I, the significance level of factor A was found to be .0542, and that of TD was .0893. Furthermore, a statistical model with A, C and D was developed and the effects of factors C and D were tested. The results of the ANOVA indicated that the factor C was not significant but the factor D was significant at $\alpha = .05$. A mean HR was computed for each level of factors. It was observed that the mean of HR at each level was significantly different from all others for both the factors A and D. It was also found that HR increased when the distance of moves was increased and HR decreased when the angle was increased. These results agree with the ones in the literature and seem to indicate that HR may be used as a measure of the physiological cost of such tasks. For part II both factors A and TDLTG were insignificant, but the mean HR's showed similar trends as the results in part I did. The results of ANOVA and Duncan's Multiple Range Test for part I and part II are found in Appendix B.

4.6 SIMULTANEOUS MOTION WITH ASYMMETRICAL ANGLE OF MOVES

In pilot study #2, the task difficulties were defined for given angles of 0, 30 and 60 (degrees), and, in each case the angle of moves was kept symmetrical. However, simultaneous motion with an asymmetrical angle of moves has not been investigated. What was intended was a measure of the physiological load on TD by use of HR. However, results showed that the relationship between physiological load on TD and HR was not significant. It was therefore necessary to design a new set of experiments to find a better method of measuring physiological load on TD. The outline of this new set of experiments is found in section 4.6.1.

4.6.1 Experimental Conditions

The following conditions were used:

ANGLE (A) for Right Hand	AR	0	0	0	30	30	30	60	60	60	(degrees)
ANGLE (A) for Left Hand	AL	0	30	60	0	30	60	0	30	60	(degrees)

Resulting TD 5.11, 6.34, 8.85 and 10.07 (Ibits)

D 150 350 (mm)

C .65 8.65 (mm).

The study was carried out in two parts, performance time study and physiological study.

4.6.2 Performance Time Study

Performance time was investigated under the experimental conditions. The statistical model used in this study was:

$$PT_{ijkln} = \mu + S_i + AR_j + AL_k + TD_l$$
$$+ (S.AR)_{ij} + (S.AL)_{ik} + (S.TD)_{il}$$
$$+ (AR.AL)_{jk} + (AR.TD)_{jl} + (AL.TD)_{kl}$$
$$+ (S.AR.AL)_{ijk} + (S.AR.TD)_{ijl} + (S.AL.TD)_{ikl}$$
$$+ (AR.AL.TD)_{jkl} + (S.AR.AL.TD)_{ijkl} + E_{ijkln}$$

where

PT_{ijkln}	=	Max $[PTR_{ijkln}, PTL_{ijkln}]$	
PTR	=	PT for right hand	
PTL	=	PT for left hand	
μ	=	average PT	
S_i	=	ith level of subject	i=1,9
AR_j	=	jth level of AR	j=1,3
AL_k	=	kth level of AL	k=1,3
TD_l	=	lth level of TD	l=1,4
E_{ijkln}	=	experimental error	n=1,30.

The task was replicated 15 times for each condition. The model can be expressed as 9 x 3x 3 x 4 factorial with 15 replications.

4.6.3 Physiolocial Study

HR and HRV are used to measure physiological load of the task. To eliminate individual differences in HR and HRV, a "range correction" technique proposed by Luczak (1979) was used. The formulae are given below.

$$SHR = (HR - HRmin)/(HRmax - HRmin)$$

where

SHR = standardized mean HR

HR = the mean HR in the experimental condition

HRmin = min. HR for the subject during the experiments

HRmax = max. HR for the subject during the experiments.

$$SHRV = (HRV - HRVmin)/(HRVmax - HRVmin)$$

where

SHRV = standardized scored HRV

HRV = scored HRV in the experimental condition

HRVmin = min HRV for the subject during the experiments

HRVmax = max HRV for the subject during the experiments.

The SHRV values were then divided by the subject's mean PT for the experimental condition and a new measure of heart rate variability, Heart Rate Variability Index (HRVI) was developed. The definition of the HRVI is given below.

$$HRVI_{ijkl} \text{ (per unit time)} = \frac{SHRV_{ijkl} \text{ (\%)}}{\text{mean } PT_{ijkl} \text{ (sec)}}$$

where

i = ith subject

j = jth AL

k = kth AR

l = lth TD.

This new measure of HRV, HRVI provides that relative HRV for the subject per unit time. The same experimental conditions in the performance time study were used since HR and HRVI are measured throughout the experiments. The statistical models for this study are shown below.

$$\begin{aligned} HR_{ijkl} = \mu &+ S_i + AR_j + AL_k + TD_l \\ &+ (S.AR)_{ij} + (S.AL)_{ik} + (S.TD)_{il} \\ &+ (AR.AL)_{jk} + (AR.TD)_{jl} + (AL.TD)_{kl} \\ &+ (S.AR.AL)_{ijk} + (S.AR.TD)_{ijl} + (S.AL.TD)_{ikl} \\ &+ (AR.AL.TD)_{jkl} + (S.AR.AL.TD)_{ijkl} + E_{ijkl} \end{aligned}$$

where

HR_{ijkl}	= standardized mean HR	
μ	= constant	
S_i	= ith level of subject	i=1,9
AR_j	= jth level of AAR	j=1,3
AL_k	= kth level of AAL	k=1,3
TD_l	= lth level of TD	l=1,4
E_{ijkl}	= experimental error.	

$$\begin{aligned} HRVI_{ijkl} = \mu &+ S_i + AR_j + AL_k + TD_l \\ &+ (S.AR)_{ij} + (S.AL)_{ik} + (S.TD)_{il} \\ &+ (AR.AL)_{jk} + (AR.TD)_{jl} + (AL.TD)_{kl} \\ &+ (S.AR.AL)_{ijk} + (S.AR.TD)_{ijl} + (S.AL.TD)_{ikl} \\ &+ (AR.AL.TD)_{jkl} + (S.AR.AL.TD)_{ijkl} + E_{ijkl} \end{aligned}$$

where

$HRVI_{ijkl}$	=	heart rate variability index	
μ	=	constant	
S_i	=	ith level of subject	i=1,9
AR_j	=	jth level of AR	j=1,3
AL_k	=	kth level of AL	k=1,3
TD_l	=	lth level of TD	l=1,4
E_{ijkl}	=	experimental error	

The statistical models have one observation per cell. The test statistics for ANOVA were chosen upon determination of the expected mean squares.

4.7 THE SUBJECTS

Nine subjects - volunteers for this study are chosen from among the students of the University of Windsor at the time that the experiments are carried out.

To be eligible to participate in the experiments, each subject must satisfy the following conditions;

(1) to be a Canadian citizen or Landed Immigrant

(2) to be a right-handed male between the age of 20-26

(3) to have no physical disability

(4) to have good vision (20/20)

(5) to have knowledge about neither the characteristics of simultaneous motions nor the physiological load of the task.

It is estimated that the experiments take approximately five hours for a subject. The subjects are paid for participating in the experiments. The basic payment is $25.00, 70 cents per the experiment condition. This amount is equivalent to an hourly wage rate of $5.00. However, there was a penalty for making errors. If the subject fumbled the pin, he is penalized ten cents each time. After the experiments, a mean performance time for each condition is computed and if the time value exceeded 150% of what PMTS's assign, the subject is penalized 20 cents for the experimental condition.

To confirm these agreements with the subjects, they are asked to fill out a questionnaire. The form is given in Appendix C.

4.7.1 The Randomization of the Experimental Conditions

To eliminate or balance undesired influences to the experiments, such as boredom, fatigue and the effects of circardian rhythm, the sequence of the experiments is randomized for each subject. One set of random numbers, 1 to 36, has been generated by a computer. These numbers are divided into 9 groups, 4 numbers in one group. These 9 groups are rotated and randomized by Latin-Square-like randomization while 4 numbers in each group are randomized for each group and each subject. The results are given in Appendix C.

CHAPTER V

ANALYSIS, RESULTS AND DISCUSSION

5.1 INTRODUCTION

This chapter describes the analysis of the performance time and physiological measures.

5.2 PERFORMANCE TIME ANALYSIS

5.2.1 Data Analysis

Nine subjects, each of them performed the task, using both hands, twenty times under 36 experimental conditions so that a total of 12960 data points of performance times was obtained. The highest performance time, either of, right hand or left hand was considered as a simultaneous two-handed performance time. After filtering out the errouneous data due to machine error, in order to obtain a balanced design, 15 observations per condition for each subject were used for statistical analysis. Thus, out of the total number of observations only 4860 were used in the study. The normality of the performance time data was tested before the analysis of variance was carried out. The data showed a pattern of log-normal distribution. As such a logarithmic transformation was made on the original data.

5.2.2 Results of Performance Time Analysis

The mean performance times of the fifteen cycles of all the experimental conditions for all the subjects are shown in Table D.1 of Appendix D.1. The results of the analysis of variance of the performance time (PT) and Duncan's Multiple Range Test are shown in Appendix D.2.

The analysis of variance considering all the main effects and the interactions of the model (see 4.6.1) was carried out first. The model consisted of four main effects, six second order interactions, four third order interactions and one fourth order interaction. Three insignificant interaction terms were determined by the above anlysis of variance: these were pooled and a new model was developed. This model consisted of four main effects, four second order interactions, three third order interactions and a fourth order interaction.

The analysis of variance (ANOVA) using the new model indicated that all the main effects (i.e. S, TD, AL and AR) had significant effects upon PT. An interaction term AL*AR was also found to be significant. The proposed ANOVA model involves both fixed effects and random effects. The Expected Mean Square (EMS) for all the terms in the model was determined and is shown in Appendix D.3.

The percentage contribution of variance component to the model was calculated for all the terms and is shown in Appendix D.6, and that for the significant effects are summarized in Table 5.1.

As shown in Table 5.1, the highest percentage contribution of variance component to the model was made by the effect TD followed by the effect S. However, the contribution made by

Effect	% of variance
S	7.29
TD	52.65
AL	1.15
AR	1.64
AL*AR	0.35

Table 5.1

Percentages of Variance Component of Significant Effects.

effects AL, AR and the interaction AL*AR to the model were found to be relatively small.

The results of the Duncan's Multiple Range Test for the mean performance times (MPT's) of each main effect are summarized in Table 5.2. The MPT's are then re-transformed and shown in milliseconds. The table shows that the MPT's were not significantly different when TD was equal to 8.85 and 6.33. However, MPT's at other levels were significantly different from each other, and it seems that there is a trend that the MPT was increased when the TD increased. The minimum MPT occured when the TD was smallest (i.e. 5.116). For AL and AR, the MPT's were significantly different from each other at each level. The Maximum MPT's were observed at 60 degrees for both AL and AR. The minimum MPT's occured at 0 degrees for both effects. It is clear that when the angle was widened more time was needed to complete the task.

5.2.3 Prediction Model

In order to predict the simuultaneous performance time for the task used in this study, a regression analysis was carried out. The model used in the regression analysis consisted of three main effects, TD, AL and AR, and a first-order interaction AL*AR. The results are given in Appendix D.4 The results show that the model had a significant level of fit (prob.>F = 0.01) and a correlation coefficient of 0.66. Table 5.3 shows a comparison between the predicted values calculated by the above mentioned model and the actual mean performance time (MPT). An upper confidence limit and a lower confidence limit (both at $\alpha = 0.05$) are calculated for each experimental condition and are shown in the Table as well.

A series of plots were drawn to compare the predicted time values in this study and those given by some of the available Predetermined Motion Time systems (PMTS's). The graphs are given in Figure D.1 to D.9 in Appendix D.5. From the graphs it is observed that the values obtained from PMTS's are, in most cases, higher than those obtained by the prediction model developed in this study. It is also observed that time values for all the PMTS's do not follow a consistent trend of increasing as the TD increases.

DUNCAN'S MULTIPLE RANGE TEST

Dependent Variable PT

Variable TD

Levels	5.12	6.34	8.85	10.07	(Ibits)
Grouping	----	-----	-----	----	

Variable AL

Levels	0	30	60	(degrees)
Grouping	---	---	---	

Variable AR

Levels	0	30	60	(degrees)
Grouping	---	---	---	

Table 5.2

Duncan's Multiple Range Test For
Performance Time Data

TD	AR	AL	MPT	PREDICTED VALUE	UPPER LIMIT	LOWER LIMIT
5.116	0.	0.	744.	782.	767.	797.
5.116	0.	30.	769.	821.	801.	841.
5.116	0.	60.	793.	862.	837.	887.
5.116	30.	0.	795.	825.	806.	846.
5.116	30.	30.	830.	851.	823.	880.
5.116	30.	60.	860.	878.	841.	916.
5.116	60.	0.	829.	871.	846.	897.
5.116	60.	30.	854.	883.	846.	921.
5.116	60.	60.	818.	894.	846.	945.
6.339	0.	0.	959.	862.	845.	880.
6.339	0.	30.	1034.	905.	882.	929.
6.339	0.	60.	1093.	950.	921.	980.
6.339	30.	0.	1014.	910.	887.	934.
6.339	30.	30.	1116.	939.	906.	972.
6.339	30.	60.	1103.	968.	926.	1011.
6.339	60.	0.	1030.	961.	932.	991.
6.339	60.	30.	1130.	973.	931.	1017.
6.339	60.	60.	1122.	986.	931.	1044.
8.850	0.	0.	978.	1054.	1029.	1080.
8.850	0.	30.	1027.	1106.	1075.	1139.
8.850	0.	60.	1117.	1161.	1122.	1202.
8.850	30.	0.	1060.	1113.	1081.	1146.
8.850	30.	30.	1102.	1147.	1104.	1192.
8.850	30.	60.	1083.	1183.	1128.	1241.
8.850	60.	0.	1101.	1175.	1135.	1216.
8.850	60.	30.	1102.	1190.	1135.	1248.
8.850	60.	60.	1089.	1205.	1135.	1280.
10.073	0.	0.	1241.	1162.	1133.	1193.
10.073	0.	30.	1241.	1220.	1183.	1258.
10.073	0.	60.	1336.	1281.	1235.	1328.
10.073	30.	0.	1321.	1227.	1190.	1265.
10.073	30.	30.	1264.	1265.	1216.	1317.
10.073	30.	60.	1344.	1305.	1242.	1370.
10.073	60.	0.	1377.	1295.	1249.	1343.
10.073	60.	30.	1361.	1312.	1249.	1378.
10.073	60.	60.	1456.	1329.	1249.	1414.

Table 5.3

A Comparison Between The Predicted Values
And The Actual Mean Performance Times

5.3 HEART RATE ANALYSIS

5.3.1 Data Analysis

Subject's Heart Rate(HR) was measured by using the Polygraph throughout the experiment and was recorded on a magnetic disk. The computer program to collect HR data, to store it on the disk and to compute the Heart Rate Variabilty (described in later section) is listed in Appendix E.1. Another computer program which lets the PDP 11/03 computer to communicate with WYLBUR is given in Appendix E.2. The Mean Heart Rate (MHR) was then computed for each experimental condition for each subject. In order to eliminate the variation among the subjects, 'range correction' (described in section 4.6.3) was performed on the MHR. From this the standardised HR (SHR) was calculated. The results of the collection are given in Table F.1 in Appendix F.

The results of the analysis of variance using the model described before (4.6.3) are shown in Table F.2. in Appendix F.

The results indicate that two of the main effects, SUB and TD were significant factors upon SHR at $\alpha = 0.05$. The insignificant terms inculding AL and AR were then pooled into the error term and a new model considering only two of the main effects, SUB and TD was developed. The new model is defined below:-

$$SHR_{ij} = S_i + TD_J + E_{ij}.$$

The results of the anlaysis of variance and Duncan's Multiple Range Test for the SHR using the new model are given in Table F.3 in Appendix F. The results of the analysis of variance indicate that the effects SUB and TD were significant at α=0.05 level. However, the Duncan's test of means shows the mean SHR and TD's are not consistent.

The mean SHR's for TD=6.34 and TD=10.07 were found to be not significantly different and those for TD=5.12 and TD=8.85 were also found to be not significantly different from each other. Therefore it was considered necessary to use some other measure to investigate the characteristics of the SHR. Since the TD was calculated from two measures, namely the Distance of move (DIS) and Clearance of fit (CLE), it was decided to use these measures in place of TD in the analysis of variance. The statistical model employed using DIS and CLE is defined below:-

$$\begin{aligned} SHR_{iop} &= SUB_i + DIS_o + CLE_p \\ &+ SUB.DIS_{io} + SUB.CLE_{ip} + DIS.CLE_{op} \\ &+ SUB.DIS.CLE_{iop} + E_{iop} \end{aligned}$$

where

SUB_i = i th subject

DIS_o = o th level of DIS. o=1,2

CLE = p th level of CLE. p=1,2.

E_{iop} = Experimental ERROR.

DIS1= 150 mm

DIS2= 350 mm

CLE1= 0.65 mm

CLE2= 8.65 mm

The results of the analysis of the above model are given in Table F.4. The results show that the effects SUB and DIS were significant at α=0.05. The insignificant terms found in the analysis of variance was then pooled and a model considering only the SUB and DIS was developed. The new model includes only SUB and DIS and is shown below:-

$$SHR_{io} = SUB_i + DIS_o + E_{io}.$$

The results of the analysis of variance and Duncan's test are given in Table F.5.

The results show that the effect DIS was significant at α=0.05 and the Duncan's test indicate that when the DIS was increased from 150 mm to 350 mm, the subject HR increased over 10% on the average.

5.4 HEART RATE VARIABILITY INDEX ANALYSIS

5.4.1 Data analysis

The Heart Rate Variability Index (HRVI) was computed from the HR data stored on the magnetic disk (described in 5.3.1). The analysis of variance for the HRVI using the full factorial model was carried out. The results are given in Appendix G.1. From the above analysis some insignificant terms were found. These insignificant terms were then pooled and a new analysis of variance model was developed. The new model is defined below:-

$$HRVI_{ijkl} = SUB_i + TD_j + AL_k + AR_l + SUB.TD_{ij} + SUB.AL_{ik} + SUB.AR_{il} + E_{ijkl}.$$

The results of the analysis of variance for HRVI using the new model are given in Appendix G.2. The results show that the significant variables, at $\alpha = 0.05$ level were SUB, TD, AL and AR. The Duncan's Multiple Range Test was also performed on the HRVI data. The results are summarised below.

Duncan's Multiple Range Test for Dependent Variable HRVI

Variable TD

Levels	5.12	6.34	8.85	10.07
Grouping	-----------	-----------	------------	------------

Variable AL

Levels	0	30	60	(degrees)
Grouping	--------	--------	--	

Variable AR

Levels	0	30	60	(degrees)
Grouping	---------------	---------------	---------------	

For the variable TD, the results show that the mean HRVI's for TD=5.12 (Ibits) and TD=6.34 are not signficantly different, and also those for TD=8.85 and TD=10.07 do not differ significantly from each other.
It was also found that the mean HRVI's for the variables AL are not significantly different when AL=0° and AL=30°. For AR, the results indicate that mean HRVI's are not significantly different from each other. All of the above Duncan's tests were performed with the significant level of α=0.05.
A series of plots for the HRVI's was drawn and is shown in Figure 5.1. The plots show that as AL increased from 30° to 60°, the HRVI decreased. Figure 5.1 shows that the HRVI values for AL=0° are somewhat higher than those for AL=30°, but Duncan's test has proved that these values are not significantly diferent.

5.5 DISCUSSION

From the results of the analysis, some considerations on the design of the task which involves simultaneous motions are disscussed here.

5.5.1 The Effects of the Angle

As it was shown that when the task is simultaneously performed by both the hands, the angles (i.e. AL and AR) affect the performance time (PT) significantly. A comparision of the mean performance times for the task in this study and predicted values in

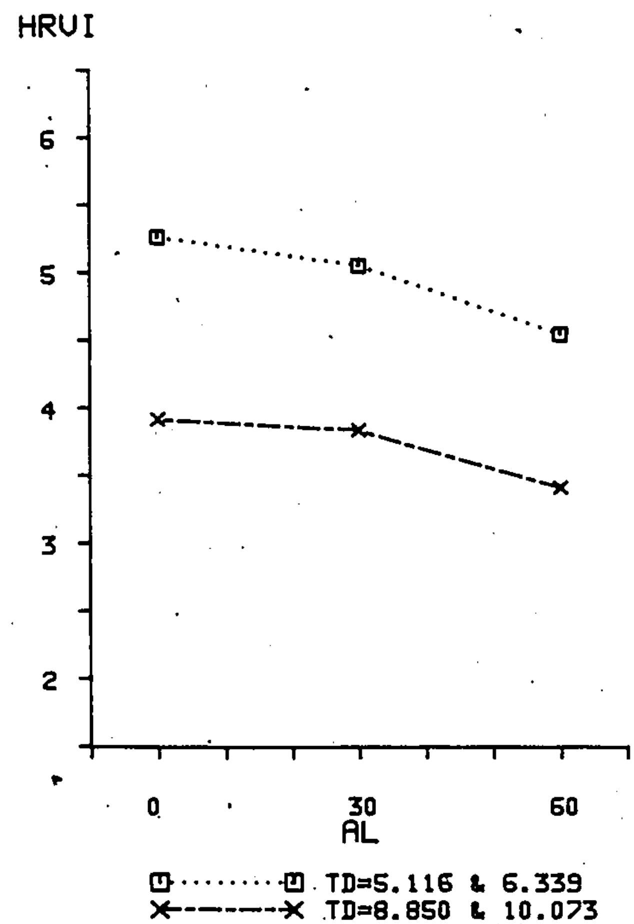

Figure 5.1

A Series of Plots for HRVI vs. AL

PMTS's is shown in Figure 5.2. The figure shows that although most of the PMTS's (e.g. MTM and BMTS) allow sufficient time for the task, the time values are equal for all the angles. This means that PMTS's do not aid the designer of such tasks in choosing the optimal direction of moves of simultaneous motion.

Another important finding concerning the direction of moves was indicated by the HRVI analysis i.e. as the angle of move (AL) increased from 30° to 60° the HRVI decreased significantly. It seems that when the angle of move becomes wider, the increase in visual requirement caused an increase in the mental load of the task.

5.5.2 The effects of the Task Difficulty

From the results of the analysis we have learnt that an increase in the TD of the task yields longer performance time and greater mental load. However, TD was not found to be a preferable measure for the physical load (expressed in subject's heart rate). The distance of move was found to be the better measure for the physical load. Further, in designing such tasks, care must be taken to incorporate an appropriate level of mental load. If the mental load is too low, the subject's attention is liable to be distracted from the task, resulting in an error. On the other hand if the mental load is set too high, then the subject is liable to be more error-prone due to high task difficulty and could be fatigued needlessly. Further, this would result in an unnecessary increase in performance time.

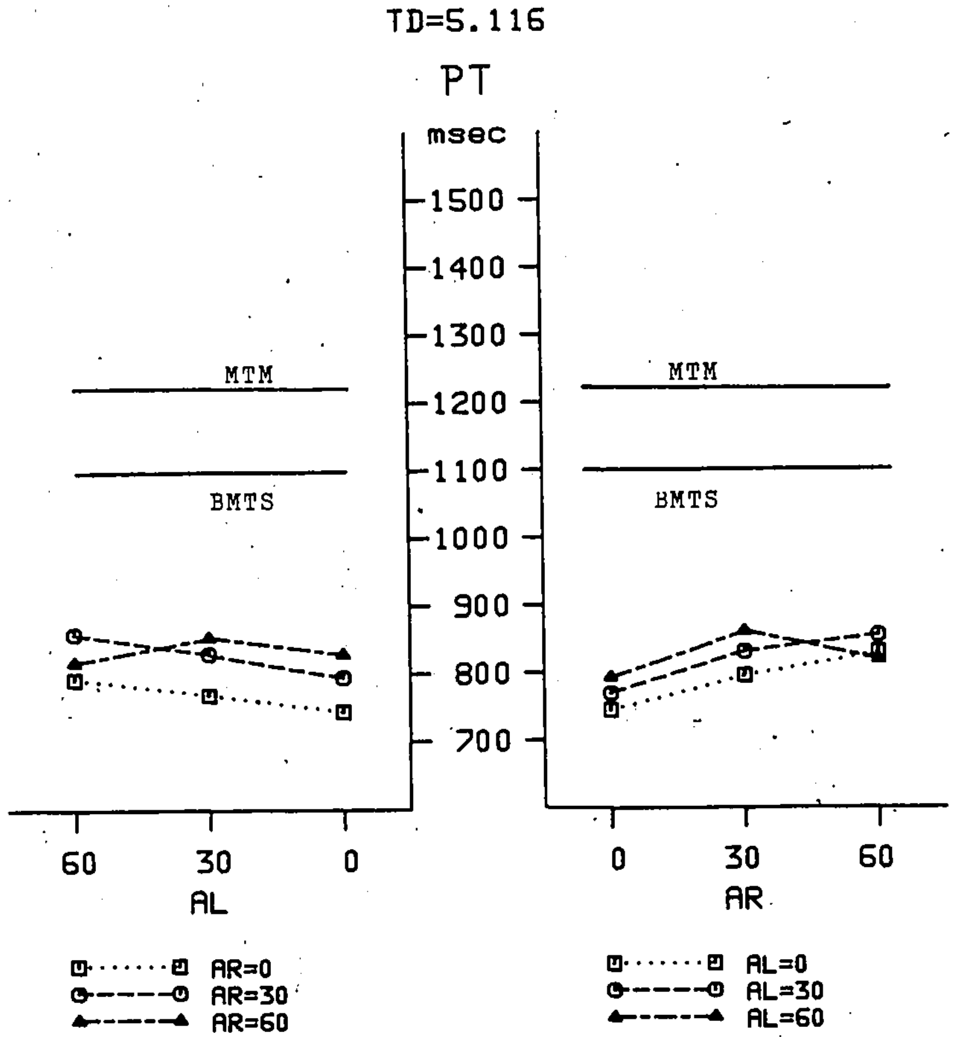

Figure 5.2

A Comparison of The Mean Performance Times and Predicted Time Values By Some of PMTS's

Figure 5.3 shows the super-imposition of percentage increase in PT with TD and the percentage decrease in HRVI(increase in mental load) with TD. The intersection of the two lines seems to suggest the value of TD which corresponds to an appropiate level of mental load.

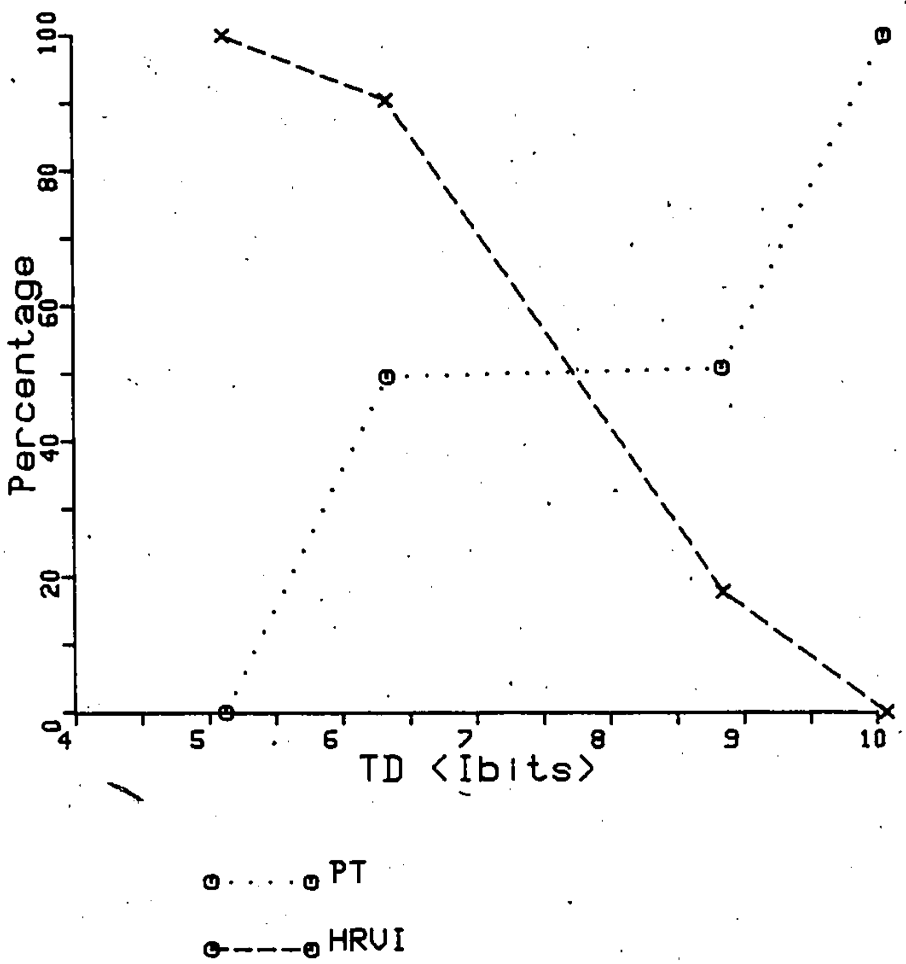

Figure 5.3

Super-imposition of Percentage Increase in PT with TD and The Percentage Decrease in HRVI (increase in mental load) with TD

CHAPTER VI

CONCLUSIONS AND SUGGESTIONS FOR FURTHER STUDIES

6.1 Performance Time

a) Performance Time (PT) is shown to increase significantly with task difficulty. This conclusion is based on studies involving both distance and hole size variations.

b) Performance Time also increases significantly with the angle of motion in the range of 0 to 60 degrees. It is futher shown that the performance time increases if asymmetry is introduced in the angle motion. It is futher shown that the interaction effect between the left side angle and also the right side angle is significant.

c) The performance time is shown to increase if asymmetry is introduced in the task difficulty.

6.2 Heart Rate and Heart Rate Index

a) The heart rate (HR) and heart rate variability index (HRVI) are shown to be functions of the task difficulty both for the symmetrical and the asymmetrical cases. However, the relationship is found to be non-linear in general.

b) On the basis of the experimental observations, it is felt that distance rather than task difficulty is a better measure of physical load and hence heart rate will be affected more by the distance involved than the hole size. This could explain the non-linear effects observed.

c) In general, it was found that angle (symmetrical or asymmetrical) did not have any significant effect on the heart rate.

d) However, HRVI was found to be significantly affected by the asymmetrical angle for left hand (AL)

Insummary it is concluded that an appropriate level of mental load may be obtained on the intersection of PT-TD and HRVI-TD curves (Figure 5.3).

6.3 SUGGESTIONS FOR FURTHER STUDIES

In order to make study more general and applicable to practical situations, the following are the suggestions for further studies.

1. The effect of sex and age on the performance of the same task needs to be studied.
2. The same experiment, under similar conditions should be conducted with tasks involving inward hand movements.
3. The same experiment should be repeated with different weight of pins.
4. The effect of different plane angles on the performance of such types of tasks needs to be investigated.

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VITA AUCTORIS

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1972 Completed Secondary education from Takanawa High School, Tokyo, Japan.

1977 Graduated with a Bachelor of Engineering from Tokai University, Kanagawa, Japan.

1977 Joined the Graduate School at the University of Windsor, Ontario, Canada.

1982 Currently a Candidate for the degree of M.A.Sc. in Industrial Engineering.

APPENDIX A

The Results of ANOVA for The Pilot Study #1

ANOVA for Pilot study 1

Variable : Angle

Source	df	SS	MS	F	
A	4	6204.96	1151.24	3.41	**
HAND	1	4462.24	4462.24	13.21	**
A*HAND	4	4788.74	1197.19	14.18	**
ERROR	890	300508.04	337.65		
TOTAL	899	315947.98			

Variable : Distance

Source	df	SS	MS	F	
S	2	38070.15	190035.08	87.67	**
DISTANCE	4	98028.09	24507.02	6.48	*
S*DISTANCE	8	30247.71	3780.96	17.41	**
HAND	1	15491.95	15491.95	13.19	
S*HAND	2	2349.62	1147.81	5.41	**
DISTANCE*HAND	4	3908.63	977.16	.42	
S*DIST*HAND	8	18820.91	2352.61	10.84	**
ERROR	870	188896.38	217.12		
TOTAL	899	395813.38			

Variable : Clearance

Source	df	SS	MS	F	
S	2	11954.91	5977.46	5.88	**
CLEARANCE	6	132565.40	22094.23	3.49	*
S*CLEARANCE	12	75947.62	6328.97	6.23	**
HAND	1	38600.54	38600.54	37.96	**
ERROR	1238	1260021.59	1017.78		
TOTAL	1259	1519090.06			

** Significance level .01

** Significance level .05

APPENDIX B

The Results of ANOVA and Duncan's Multiple Range Test for The Pilot Study #2

SOURCE	DF	SS	F VALUE	PR > F
SUB	3	19.36683325	200.01	0.0001
A	2	7.03467378	7.51	0.0233
SUB * A	6	2.81057251	14.51	0.0001
TD	8	36.39196008	18.10	0.0001
SUB * TD	24	6.03040508	7.78	0.0001
A * TD	4	2.19506495	2.13	0.1395
SUB * A * TD	12	3.08993948	7.98	0.0001
ERROR	1740	56.16010099		
CORRECTED TOTAL	1799	133.07955011		

ANOVA Table for The Pilot Study #2 Part II

SOURCE	DF	SS	F VALUE	PR > F
SUB	3	17.67770230	307.65	0.0001
A	2	8.50915786	40.94	0.0003
SUB * A	6	0.62358108	5.43	0.0001
TDLTG	5	18.74605595	24.58	0.0001
SUB * TDLTG	15	2.28790865	7.96	0.0001
A * TDLTG	10	0.94988058	0.87	0.5712
SUB * A * TDLTG	30	3.28163933	5.71	0.0001
ERROR	2328	44.58982446		
CORRECTED TOTAL	2399	96.66575022		

ANOVA Table for The Pilot Study #2 Part I

1. SYMT SIMO	2. ASYMT SIMO
Variable: Angle (A) Levels: 1 2 3 Grouping: — — — Variable: Task Difficulty (TD) Levels: 1 2 3 4 5-7 8 6 9 Grouping: — — — —— — —— —	Variable: Angle (A) Levels: 1 2 3 Grouping: — — — Variable: Task Difficulty for the limiting hand (TDLTG) Levels: 1 4 6 5 8 9 Grouping: — — — — — —

The Results of Duncan's Multiple Range Test
for The Pilot Study #2 Part I and Part II

APPENDIX C

The Questionnaire Form

University of Windsor

Department of Industrial Engineering

Simultaneous Motions Experiment
Questionnaire

Page 1 of 2 (Preliminary Questions)

Circle or fill in your answers.

1. Are you a canadian citizen or a landed immigrant ? Yes. No.

2. Are you right-handed ? Yes. No.

3. How old are you ? ________ years old.

4. Do you have any physical disability ? Yes. No.

5. Do you have 20/20 vision ? Yes. No.

6. Are you a student of the University of Windsor ? Yes. No.

   If Yes, please write faculty and year. _________. __________.

7. Are you on any medical treatment now ? Yes. No.
   If Yes, are you taking any of followings ?
   (1) antibiotics,
   (2) tranquilizer,
   (3) stimulants,
   (4) anodynes (pain killer). Yes. No.

8. Have you ever had any of following problems or seen a doctor because of the problem(s) ?
   (1) high blood pressure,
   (2) respiratory problems,
   (3) heart problems,
   (4) circulatory problems,
   (5) diabetes,
   (6) epilepsy,
   (7) psycological problems,
   (8) allergic to adhesive tape. Yes. No.

Please, read the following and sign.

To the best of my knoledge, above answers are all true.

X____________________

Date________________.

Please hand this sheet to the interviewer once.

Please, read the following and sign.

The experiment consists of 36 conditions (sessions) and takes about 5 (five) hours. There will be a short break in between the sessions and two 15-minute breaks during the experiment.

I During the experiment you are asked to performed two simple and almost identical tasks by both the right and the left hands simultaneously. Each task involves moving a light metal pin from one place to another and dropping it in a hole. The direction of moving the pin and the size of the hole will be changed from session to session. Your performance will be measured and recorded for each cycle in each session.

II In addition to the performance time, your Heart Rate (Pulse rate) will also be observed throughout the experiment. For this purpose, three "electrodes" will be attached on your chest. When these electrodes are attached, it is necessary to remove a part of or all of your shirt(s) when you are asked to do so.

III When you have completed all 36 (thirty-six) sessions, you will be paid 7 (seventy) cents for a session or $25.2 for 36 sessions. However, there will be two types of penalty, 1) 1 (ten) cents for dropping the pin outside the hole and 2) 2 centss for taking too long for the session. The penalty for dropping the pin will be applied for each hand each time.

IV Since the experiment lasts for 5 (five) hours, you have to choose your "pace" so that you are able to maintain the accuracy and the speed of performing the tasks through out the experiment. A practice session is provided at the begining of the experiment and also, at the begining of each session, there will be a practice period.

V Lastly, you may drop out from the experiment anytime, but you will be paid at rate of $3.3 /hr. but the total will not be more than $5.

X____________________

Date____________________

NAME____________________ PHONE #____________________

ID____________________ S.I.N.____________________

MAILING ADDRESS____

SEQUENCE	SUBJECT 1	2	3	4	5	6	7	8	9
1	36	34	9	29	20	28	17	32	3
2	27	17	26	9	3	29	7	30	21
3	7	22	19	18	30	26	5	21	13
4	21	10	27	11	16	17	3	8	25
5	12	35	22	36	26	2	23	9	14
6	10	13	17	27	18	7	21	15	8
7	6	32	4	17	9	27	20	29	26
8	8	26	35	31	24	13	25	22	7
9	22	5	28	19	23	25	11	20	32
10	13	21	36	5	19	22	10	25	28
11	35	3	5	22	29	11	32	16	33
12	19	28	30	12	2	3	14	34	36
13	23	12	7	24	8	1	30	18	16
14	34	2	15	33	6	14	36	10	12
15	25	33	31	13	34	30	28	36	24
16	14	9	12	3	1	20	26	7	2
17	17	4	25	28	32	9	1	6	35
18	29	19	32	6	22	35	15	11	5
19	20	6	24	1	14	4	31	26	9
20	31	30	34	7	28	24	6	19	18
21	30	23	2	34	25	36	12	28	19
22	18	8	21	23	27	10	16	4	17
23	5	11	14	26	21	33	27	13	30
24	26	18	13	30	36	21	8	17	1
25	3	31	11	2	33	34	35	14	15
26	11	1	8	25	10	16	2	31	23
27	32	20	1	4	15	5	13	33	29
28	16	29	3	20	11	31	9	24	27
29	24	36	18	15	12	19	22	3	20
30	4	27	33	14	35	15	24	12	6
31	28	14	6	35	4	32	19	5	34
32	33	16	20	32	5	23	18	1	11
33	9	15	10	21	17	6	29	27	4
34	2	7	29	16	31	8	34	23	10
35	15	25	23	10	7	12	33	2	22
36	1	24	16	8	13	18	4	35	31

APPENDIX D.1

Table D.1 for The Performance Time Study

TD	AL	AR	SUB1	SUB2	SUB3	SUB4	SUB5	SUB6	SUB7	SUB8	SUB9
5.116	0	0	786.	853.	666.	733.	733.	833.	640.	793.	653.
5.116	0	30	880.	926.	753.	780.	673.	886.	666.	866.	720.
5.116	0	60	886.	920.	800.	766.	733.	960.	853.	840.	700.
5.116	30	0	966.	920.	720.	713.	626.	853.	686.	740.	693.
5.116	30	30	1053.	833.	913.	793.	693.	820.	806.	786.	766.
5.116	30	60	1080.	980.	880.	693.	873.	973.	720.	813.	673.
5.116	60	0	853.	933.	726.	766.	706.	926.	746.	766.	713.
5.116	60	30	1100.	946.	820.	713.	753.	980.	773.	893.	760.
5.116	60	60	893.	840.	766.	760.	720.	1033.	773.	826.	746.
6.338	0	0	913.	1120.	893.	973.	840.	1006.	886.	1113.	880.
6.338	0	30	1066.	1133.	886.	1000.	1113.	1020.	1040.	1013.	853.
6.338	0	60	1126.	1153.	1080.	966.	1093.	1053.	966.	1100.	726.
6.338	30	0	1213.	1080.	940.	1040.	1020.	1033.	946.	1093.	940.
6.338	30	30	1380.	1220.	980.	1040.	1040.	1473.	920.	1120.	866.
6.338	30	60	1500.	1120.	1120.	1040.	1186.	1146.	1026.	1033.	993.
6.338	60	0	1120.	1173.	1206.	1033.	1053.	1160.	1020.	1093.	973.
6.338	60	30	1166.	1213.	1086.	1033.	1066.	1186.	1073.	1120.	980.
6.338	60	60	1066.	1226.	1106.	1033.	1166.	1173.	1106.	1186.	1033.
8.850	0	0	900.	1013.	893.	1073.	913.	1126.	920.	1006.	953.
8.850	0	30	966.	1080.	1166.	1026.	960.	1246.	966.	1160.	966.
8.850	0	60	1133.	1213.	1006.	1133.	973.	1306.	1013.	1060.	1066.
8.850	30	0	1060.	1060.	920.	1100.	986.	1153.	946.	1033.	986.
8.850	30	30	1046.	1440.	1006.	1053.	960.	1266.	1080.	1066.	1000.
8.850	30	60	1053.	1233.	1140.	1113.	1073.	1240.	980.	1086.	1000.
8.850	60	0	1160.	1186.	1160.	1086.	1013.	1273.	960.	1100.	1113.
8.850	60	30	806.	1340.	1006.	1086.	1006.	1253.	1113.	1120.	1013.
8.850	60	60	1113.	1300.	960.	1046.	1000.	1193.	986.	1180.	1020.
10.072	0	0	1160.	1433.	1006.	1200.	1413.	1360.	1046.	1333.	1213.
10.072	0	30	1446.	1420.	1180.	1340.	1340.	1406.	1233.	1473.	1053.
10.072	0	60	1246.	1533.	1366.	1460.	1433.	1553.	1260.	1340.	1200.
10.072	30	0	1053.	1293.	1246.	1306.	1173.	1393.	1193.	1246.	1266.
10.072	30	30	880.	1646.	1233.	1266.	1286.	1400.	1233.	1286.	1146.
10.072	30	60	1126.	1486.	1233.	1266.	1526.	1506.	1540.	1366.	1200.
10.072	60	0	1253.	1493.	1053.	1366.	1280.	1673.	1273.	1426.	1200.
10.072	60	30	1420.	1566.	1353.	1326.	1313.	1420.	1266.	1273.	1160.
10.072	60	60	1466.	1486.	1526.	1360.	1466.	1640.	1286.	1433.	1433.

Table D.1

The Mean Performance Times of The Fifteen Cycles of All The Experimental Conditions for All The Subject

APPENDIX D.2

The results of The Analysis of Variance of The Performance Time and Duncan's Multiple Range Test

```
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
                                  5:50 WEDNESDAY, JUNE 30, 1982

NOTE: THE JOB PT HAS BEEN RUN UNDER RELEASE 79.5 OF SAS
      AT THE UNIVERSITY OF WINDSOR (00666).

NOTE: SAS OPTIONS SPECIFIED ARE:
      LS=65


           DATA;
           INPUT CNDTN SUB AL AR DIS CLE;
                X=2.*DIS/CLE;
                TD=LOG2(X);
           IF SUB EQ 1 THEN OHTS=LOG(801.);
           IF SUB EQ 2 THEN OHTS=LOG(902.);
           IF SUB EQ 3 THEN OHTS=LOG(1016.);
           IF SUB EQ 4 THEN OHTS=LOG(1168.);
           IF SUB EQ 5 THEN OHTS=LOG(970.);
           IF SUB EQ 6 THEN OHTS=LOG(906.);
           IF SUB EQ 7 THEN OHTS=LOG(914.);
           IF SUB EQ 8 THEN OHTS=LOG(877.);
           IF SUB EQ 9 THEN OHTS=LOG(832.);
                RETAIN SUB AL AR DIS CLE TD OHTS;
             DO I=1 TO 15;
                INPUT R L @@;
                R=R*100.0;
                L=L*100.0;
                IF L GE R THEN PT=L;
                IF L LT R THEN PT=R;
                PT=LOG(PT);
                OUTPUT;
             END;
           DROP I X L R;
           CARDS;

NOTE: SAS WENT TO A NEW LINE WHEN INPUT STATEMENT
      REACHED PAST THE END OF A LINE.
NOTE: DATA SET WORK.DATA1 HAS 4860 OBSERVATIONS AND 9 VARIABLES.
171 OBS/TRK
NOTE: THE DATA STATEMENT USED 5.31 SECONDS AND 160K.

           PROC ANOVA;
           CLASSES SUB TD AL AR;
           MODEL PT=SUB¶TD¶AL¶AR;
           TEST H=TD E=SUB*TD;
           TEST H=AL E=SUB*AL;
           TEST H=AR E=SUB*AR;
           TEST H=TD*AL E=SUB*TD*AL;
           TEST H=TD*AR E=SUB*TD*AR;
           TEST H=AL*AR E=SUB*AL*AR;
           TEST H=TD*AL*AR E=SUB*TD*AL*AR;
           MEANS TD AL AR/DUNCAN;

NOTE: THE PROCEDURE ANOVA USED 30.72 SECONDS AND 204K
      AND PRINTED PAGES 1 TO 6.

           PROC SORT;
           BY SUB;

NOTE: DATA SET WORK.DATA1 HAS 4860 OBSERVATIONS AND 9 VARIABLES.
171 OBS/TRK
NOTE: THE PROCEDURE SORT USED 3.29 SECONDS AND 282K.

           PROC ANOVA;
           CLASSES TD AL AR;
           MODEL PT=TD¶AL¶AR;
           MEANS TD AL AR/DUNCAN;
```

ANALYSIS OF VARIANCE PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
SUB	9	1 2 3 4 5 6 7 8 9
TD	4	10.0727 5.116119 6.338511 8.850307
AL	3	0 30 60
AR	3	0 30 60

NUMBER OF OBSERVATIONS IN DATA SET = 4860

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: PT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	323	217.75549572	0.67416562
ERROR	4536	75.23522660	0.01658625
CORRECTED TOTAL	4859	292.99072232	

MODEL F = 40.65 PR > F = 0.0001

R-SQUARE	C.V.	STD DEV	PT MEAN
0.743216	1.8544	0.12878761	6.94481240

SOURCE	DF	ANOVA SS	F VALUE	PR > F
SUB	8	24.79887361	186.89	0.0001
TD	3	151.39362623	3042.55	0.0001
SUB*TD	24	8.94088717	22.46	0.0001
AL	2	3.05711720	92.16	0.0001
SUB*AL	16	1.15561770	4.35	0.0001
TD*AL	6	1.34813821	13.55	0.0001
SUB*TD*AL	48	5.73375658	7.20	0.0001
AR	2	4.36165871	131.48	0.0001
SUB*AR	16	1.70877348	6.44	0.0001
TD*AR	6	0.63095243	6.34	0.0001
SUB*TD*AR	48	3.29935723	4.14	0.0001
AL*AR	4	0.82208812	12.39	0.0001
SUB*AL*AR	32	1.77049006	3.34	0.0001
TD*AL*AR	12	0.76353835	3.84	0.0001
SUB*TD*AL*AR	96	7.97062065	5.01	0.0001

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*TD AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
TD	3	151.39362623	135.46	0.0001

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*AL AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
AL	2	3.05711720	21.16	0.0001

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*AR AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
AR	2	4.36165871	20.42	0.0001

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*TD*AL AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
TD*AL	6	1.34813821	1.88	0.1035

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: PT

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*TD*AR AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
TD*AR	6	0.63095243	1.53	0.1888

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*AL*AR AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
AL*AR	4	0.82208812	3.71	0.0136

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*TD*AL*AR AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
TD*AL*AR	12	0.76353835	0.77	0.6831

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE PT

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=4536 MS=.0165862

GROUPING	MEAN	N	TD
A	7.177243	1215	10.0727
B	6.961866	1215	8.850307
B			
B	6.960014	1215	6.338511
C	6.680127	1215	5.116119

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE PT

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=4536 MS=.0165862

GROUPING	MEAN	N	AL
A	6.974861	1620	60
B	6.946108	1620	30
C	6.913468	1620	0

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE PT

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05   DF=4536   MS=.0165862

GROUPING	MEAN	N	AR
A	6.977958	1620	60
B	6.951092	1620	30
C	6.905387	1620	0

SUB=1

ANALYSIS OF VARIANCE PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
TD	4	10.0727 5.116119 6.338511 8.850307
AL	3	0 30 60
AR	3	0 30 60

NUMBER OF OBSERVATIONS IN BY GROUP = 540

```
NOTE: THE JOB PT HAS BEEN RUN UNDER RELEASE 79.5 OF SAS
      AT THE UNIVERSITY OF WINDSOR (00666).

NOTE: SAS OPTIONS SPECIFIED ARE:
      LS=65

           DATA;
           INPUT CNDTN SUB AL AR DIS CLE;
                X=2.*DIS/CLE;
                TD=LOG2(X);
             DO I=1 TO 15;
                INPUT R L @@;
                R=R*100.0;
                L=L*100.0;
                IF L GE R THEN PT=L;
                IF L LT R THEN PT=R;
                PT=LOG(PT);
                OUTPUT;
              END;
           DROP I X L R;
           CARDS;

NOTE: SAS WENT TO A NEW LINE WHEN INPUT STATEMENT
      REACHED PAST THE END OF A LINE.
NOTE: DATA SET WORK.DATA1 HAS 4860 OBSERVATIONS AND 8 VARIABLES.
 191 OBS/TRK
NOTE: THE DATA STATEMENT USED 5.24 SECONDS AND 160K.

           PROC ANOVA;
           CLASSES SUB TD AL AR;
           MODEL PT = SUB TD AL AR
                      SUB*TD SUB*AL SUB*AR AL*AR
                      SUB*AL*AR
                      SUB*TD*AL
                      SUB*TD*AR
                      SUB*TD*AL*AR;
           TEST H=TD E=SUB*TD;
           TEST H=AL E=SUB*AL;
           TEST H=AR E=SUB*AR;
           TEST H=AL*AR E=SUB*AL*AR;
           MEANS TD AL AR AL*AR / DUNCAN;

NOTE: THE PROCEDURE ANOVA USED 31.63 SECONDS AND 200K
      AND PRINTED PAGES 1 TO 6.

NOTE: SAS INSTITUTE INC.
      SAS CIRCLE
      BOX 8000
      CARY, N.C. 27511
```

ANALYSIS OF VARIANCE PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
SUB	9	1 2 3 4 5 6 7 8 9
TD	4	10.0727 5.116119 6.338511 8.850307
AL	3	0 30 60
AR	3	0 30 60

NUMBER OF OBSERVATIONS IN DATA SET = 4860

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: PT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	323	217.75549572	0.67416562
ERROR	4536	75.23522660	0.01658625
CORRECTED TOTAL	4859	292.99072232	

MODEL F = 40.65 PR > F = 0.0001

R-SQUARE	C.V.	STD DEV	PT MEAN
0.743216	1.8544	0.12878761	6.94481240

SOURCE	DF	ANOVA SS	F VALUE	PR > F
SUB	8	24.79887361	186.89	0.0001
TD	3	151.39362623	3042.55	0.0001
AL	2	3.05711720	92.16	0.0001
AR	2	4.36165871	131.48	0.0001
SUB*TD	24	8.94088717	22.46	0.0001
SUB*AL	16	1.15561770	4.35	0.0001
SUB*AR	16	1.70877348	6.44	0.0001
AL*AR	4	0.82208812	12.39	0.0001
SUB*AL*AR	32	1.77049006	3.34	0.0001
SUB*TD*AL	54	7.08189480	7.91	0.0001
SUB*TD*AR	54	3.93030966	4.39	0.0001
SUB*TD*AL*AR	108	8.73415900	4.88	0.0001

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*TD AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
TD	3	151.39362623	135.46	0.0001

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*AL AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
AL	2	3.05711720	21.16	0.0001

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*AR AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
AR	2	4.36165871	20.42	0.0001

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*AL*AR AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
AL*AR	4	0.82208812	3.71	0.0136

```
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    3
                                   6:16 TUESDAY, JULY 20, 1982

              ANALYSIS OF VARIANCE PROCEDURE

        DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE PT

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.
        ALPHA LEVEL=.05        DF=4536      MS=.0165862

         GROUPING              MEAN        N       TD

                A          7.177243     1215    10.0727

                B          6.961866     1215    8.850307
                B
                B          6.960014     1215    6.338511

                C          6.680127     1215    5.116119
```

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE PT

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05   DF=4536   MS=.0165862

GROUPING	MEAN	N	AL
A	6.974861	1620	60
B	6.946108	1620	30
C	6.913468	1620	0

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE PT

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05   DF=4536   MS=.0165862

GROUPING	MEAN	N	AR
A	6.977958	1620	60
B	6.951092	1620	30
C	6.905387	1620	0

ANALYSIS OF VARIANCE PROCEDURE

MEANS

AL	AR	N	PT
0	0	540	6.85738078
0	30	540	6.92476745
0	60	540	6.95825445
30	0	540	6.89883784
30	30	540	6.95349839
30	60	540	6.98598905
60	0	540	6.95994327
60	30	540	6.97501095
60	60	540	6.98962939

APPENDIX D.3

The Expected Mean Square for The Analysis of Variance Model with All The Interaction Termes.

SOURCE	SUB 9 R i	TD 4 F j	AL 3 F k	AR 3 F l	E 15 R m	EMS
(SUB)i	1	4	3	3	15	$\sigma_\varepsilon^2+540\,\sigma^2_{SUB}$
(TD)j	9		3	3	15	$\sigma_\varepsilon^2+135\,\sigma^2_{TD.SUB}+1215\,\phi_{TD}$
(SUB.TD)ij	1		3	3	15	$\sigma_\varepsilon^2+135\,\sigma^2_{SUB.TD}$
(AL)k	9	4		3	15	$\sigma_\varepsilon^2+180\,\sigma^2_{AL.SUB}+1620\,\phi_{AL}$
(SUB.AL)ik	1	4		3	15	$\sigma_\varepsilon^2+180\,\sigma^2_{SUB.AL}$
(AR)l	9	4	3		15	$\sigma_\varepsilon^2+180\,\sigma^2_{SUB.AR}+1620\,\phi_{AR}$
(SUB.AR)il	1	4	3		15	$\sigma_\varepsilon^2+180\,\sigma^2_{SUB.AR}$
(TD.AL)jk	9			3	15	$\sigma_\varepsilon^2+45\,\sigma^2_{SUB.TD.AL}+405\,\phi_{TD.AL}$
(SUB.TD.AL)ijk	1			3	15	$\sigma_\varepsilon^2+45\,\sigma^2_{SUB.TD.AL}$
(TD.AR)jl	9		3		15	$\sigma_\varepsilon^2+45\,\sigma^2_{SUB.TD.AR}+405\,\phi_{TD.AR}$
(SUB.TD.AR)ijl	1		3		15	$\sigma_\varepsilon^2+45\,\sigma^2_{SUB.TD.AR}$
(AL.AR)kl	9	4			15	$\sigma_\varepsilon^2+60\,\sigma^2_{SUB.TD.AR}+540\,\phi_{TD.AR}$
(SUB.AL.AR)ikl	1	4			15	$\sigma_\varepsilon^2+60\,\sigma^2_{SUB.AL.AR}$
(TD.AL.AR)jkl	9				15	$\sigma_\varepsilon^2+15\,\sigma^2_{SUB.TD.AL.AR}+135\,\phi_{TD.AL.AR}$
(SUB.TD.AL.AR)ijkl	1				15	$\sigma_\varepsilon^2+15\,\sigma^2_{SUB.TD.AL.AR}$
(Em(ijkl))	1	1	1	1	1	σ_ε^2

APPENDIX D.4

The Results of Thr regression Analisis for The Simultaneous Performance Time When The Task Difficulty Is Symmetrical and The Angle is Asymmetrical

```
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
                                          0:18 TUESDAY, JULY 27, 1982

NOTE: THE JOB PTB HAS BEEN RUN UNDER RELEASE 79.5 OF SAS
      AT THE UNIVERSITY OF WINDSOR (00666).

NOTE: SAS OPTIONS SPECIFIED ARE:
      LS=65

          DATA;
          INPUT CNDTN SUB AL AR DIS CLE;
               X=2.*DIS/CLE;
               TD=LOG2(X);
               RETAIN SUB AL AR DIS CLE TD;
            DO I=1 TO 15;
               INPUT R L @@;
               R=R*100.0;
               L=L*100.0;
               IF L GE R THEN PT=L;
               IF L LT R THEN PT=R;
          PT=LOG(PT) ;
               OUTPUT;
            END;
          DROP I X L R;
          CARDS;

NOTE: SAS WENT TO A NEW LINE WHEN INPUT STATEMENT
      REACHED PAST THE END OF A LINE.
NOTE: DATA SET WORK.DATA1 HAS 4860 OBSERVATIONS AND 8 VARIABLES.
191 OBS/TRK
NOTE: THE DATA STATEMENT USED 5.86 SECONDS AND 160K.

          PROC GLM;
          MODEL PT = TD AL AR AL*AR;

NOTE: THE PROCEDURE GLM USED 11.68 SECONDS AND 182K
      AND PRINTED PAGE 1.

NOTE: SAS INSTITUTE INC.
      SAS CIRCLE
      BOX 8000
      CARY, N.C. 27511
```

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: PT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	4	127.90619797	31.97654949
ERROR	4855	165.08452435	0.03400299
CORRECTED TOTAL	4859	292.99072232	

MODEL F = 940.40 PR > F = 0.0001

R-SQUARE	C.V.	STD DEV	PT MEAN
0.436554	2.6552	0.18439900	6.94481240

SOURCE	DF	TYPE I SS	F VALUE	PR > F
TD	1	119.90319971	3526.25	0.0001
AL	1	3.05303555	89.79	0.0001
AR	1	4.26582755	125.45	0.0001
AL*AR	1	0.68413517	20.12	0.0001

SOURCE	DF	TYPE IV SS	F VALUE	PR > F
TD	1	119.90319971	3526.25	0.0001
AL	1	3.04772548	89.63	0.0001
AR	1	3.79063007	111.48	0.0001
AL*AR	1	0.68413517	20.12	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > ¶T¶	STD ERROR OF ESTIMATE
INTERCEPT	6.25284998	513.50	0.0001	0.01217697
TD	0.07995139	59.38	0.0001	0.00134638
AL	0.00161646	9.47	0.0001	0.00017074
AR	0.00180274	10.56	0.0001	0.00017074
AL*AR	-1.9774321E-05	-4.49	0.0001	0.00000441

APPENDIX D.5

Figures for Comparing The Predicted Values in this Study and Those Given by PMTS's

Figure	AL	AR (degrees)
D.1	0	0
D.2	30	30
D.3	60	60
D.4	30	0
D.5	0	30
D.6	0	30
D.7	60	30
D.8	0	60
D.9	30	60

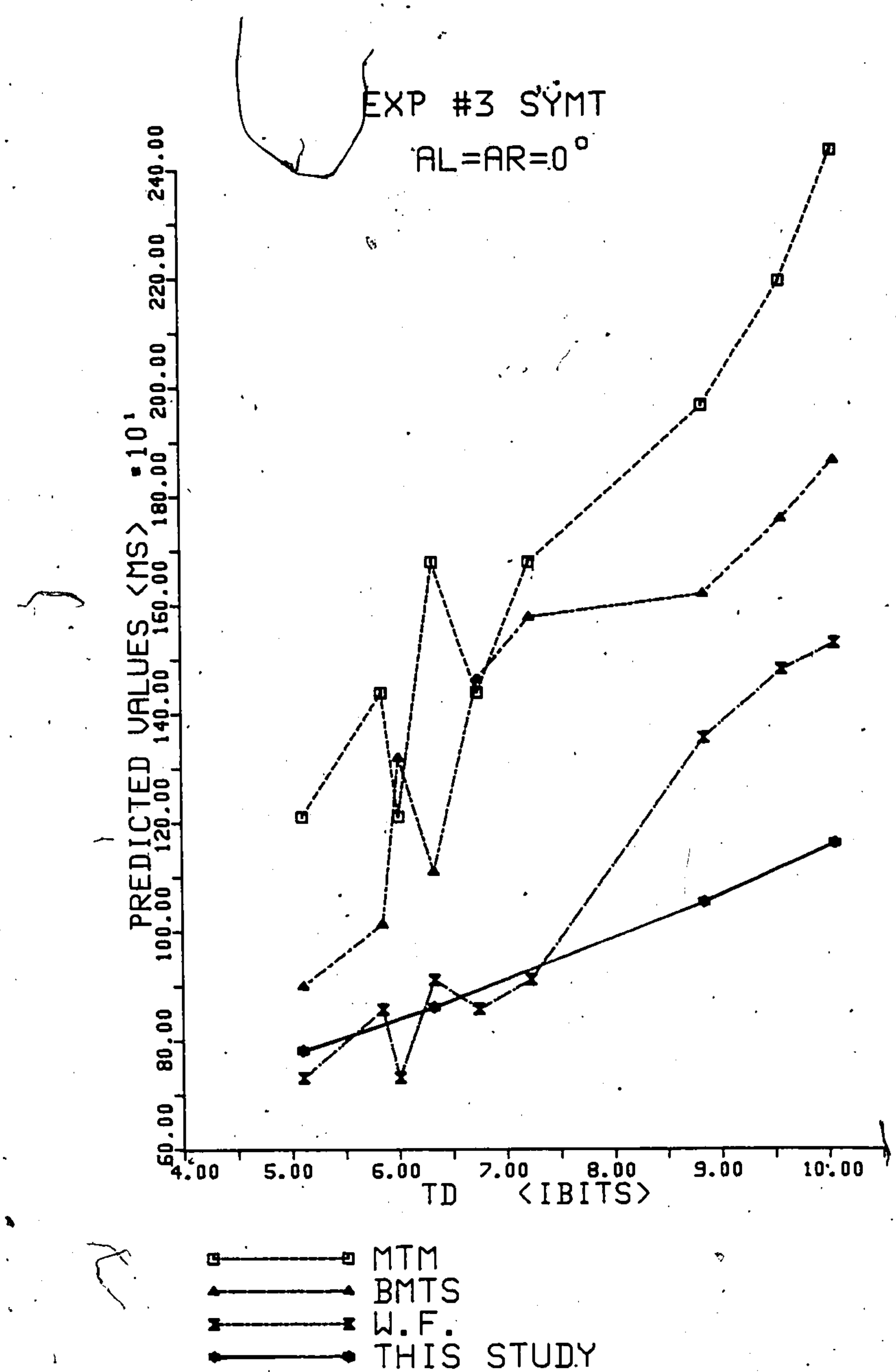
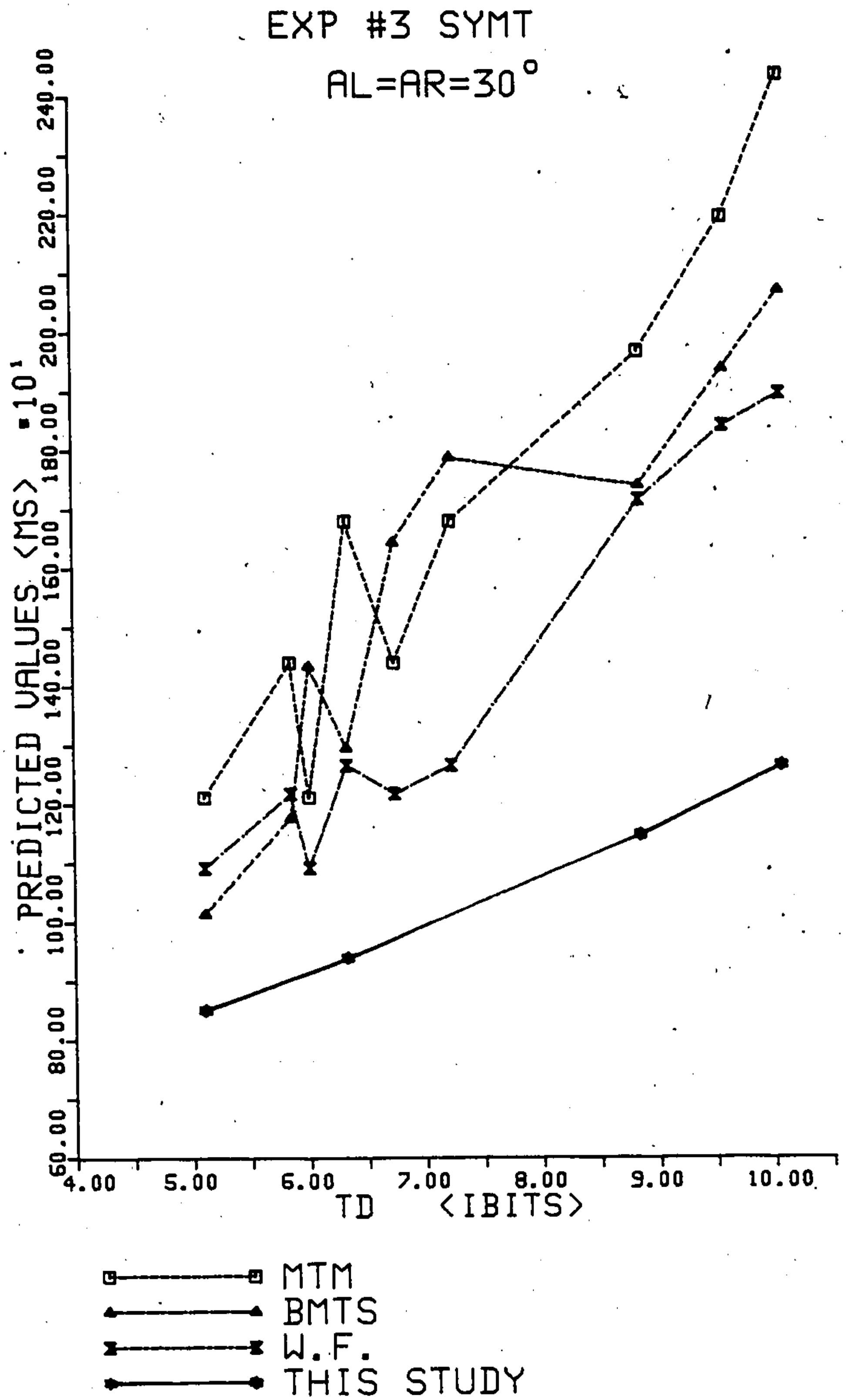

EXP #3 SYMT
AL=AR=0°
PREDICTED VALUES <MS> *10¹
240.00
220.00
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
TD <IBITS>
MTM
BMTS
W.F.
THIS STUDY

Figure D.1



EXP #3 SYMT
AL=AR=30°
PREDICTED VALUES <MS> *10¹
240.00
220.00
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
TD <IBITS>
MTM
BMTS
W.F.
THIS STUDY

Figure D.2

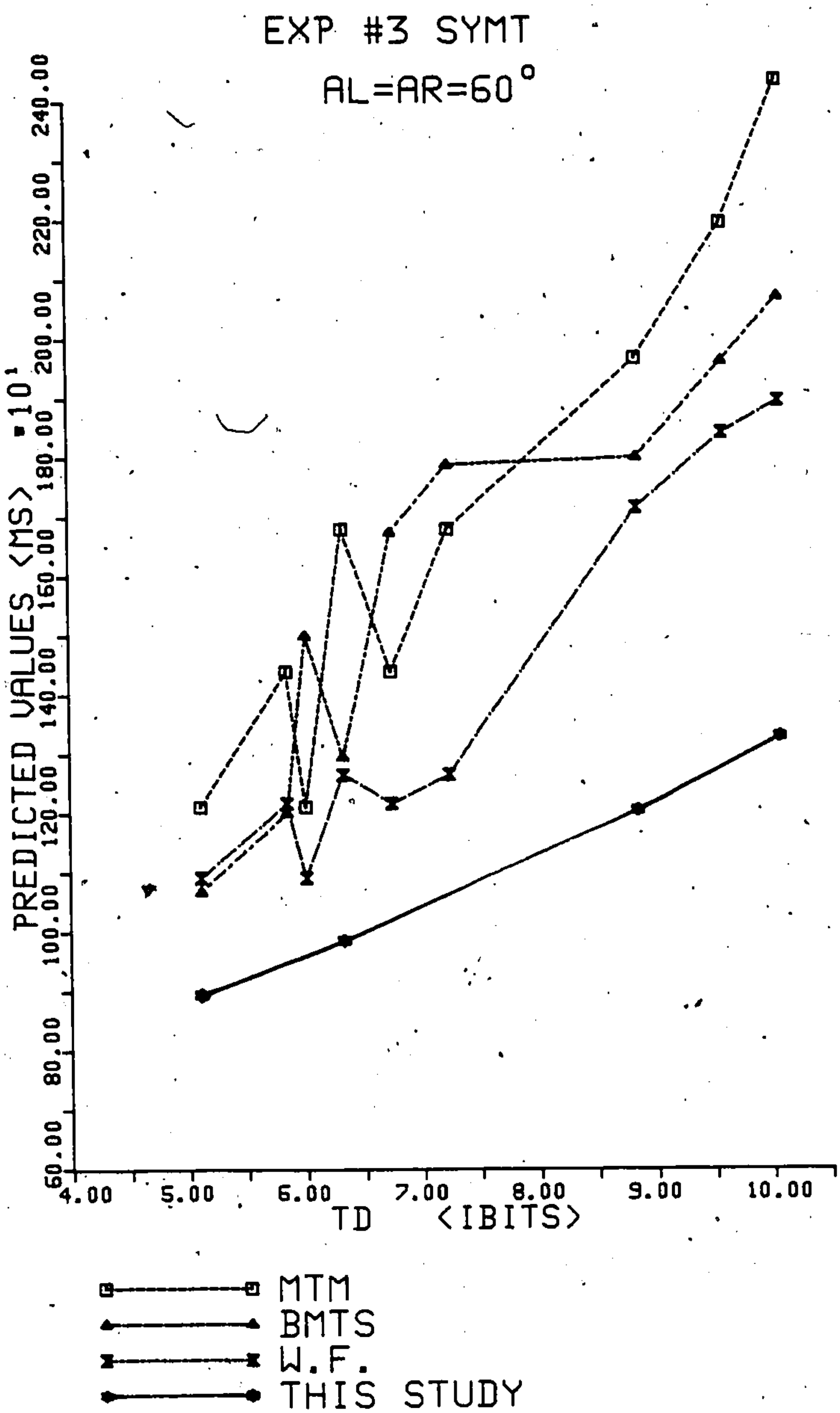

EXP #3 SYMT
AL=AR=60°
PREDICTED VALUES <MS> *10¹
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
220.00
240.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
TD <IBITS>
MTM
BMTS
W.F.
THIS STUDY

Figure D.3

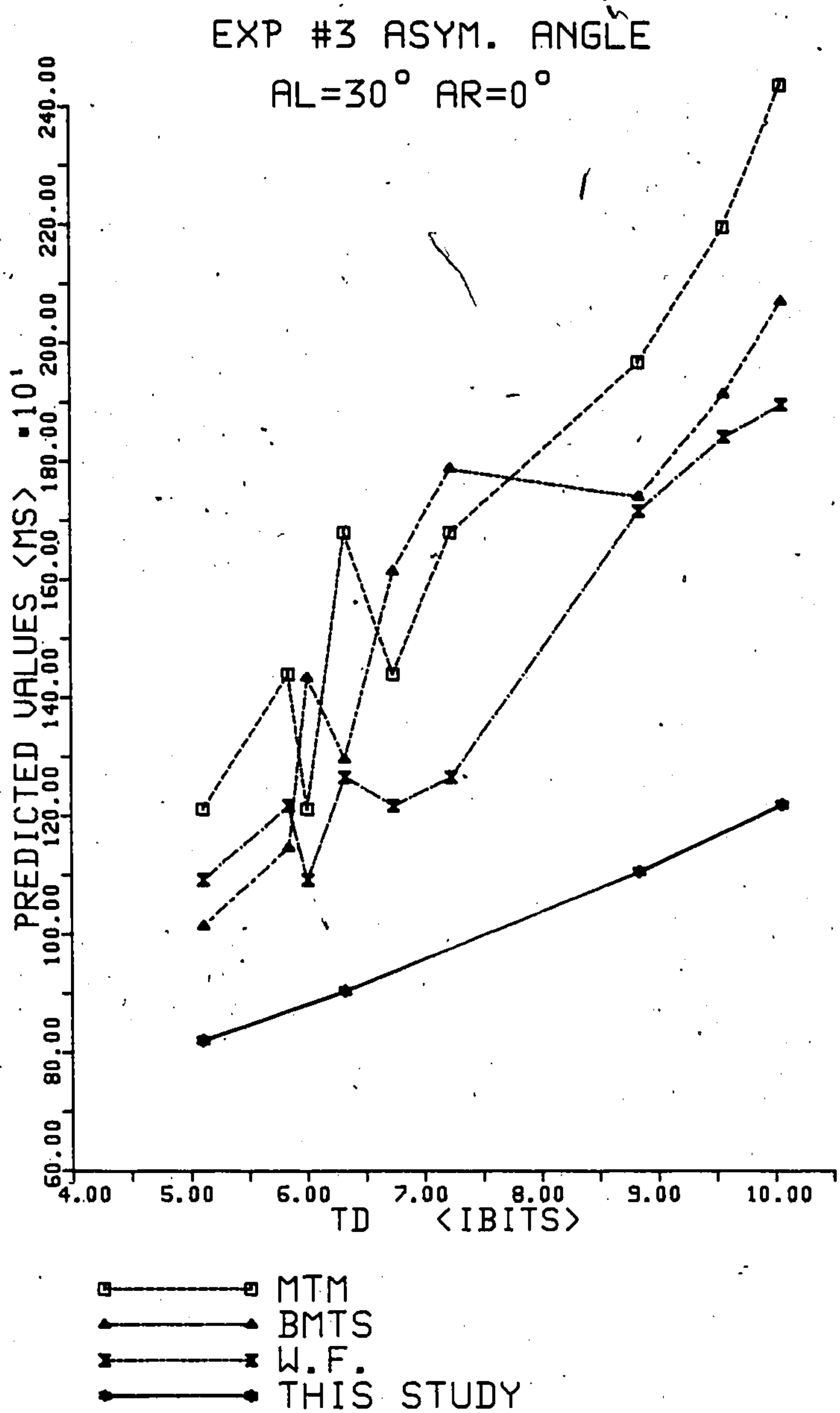

EXP #3 ASYM. ANGLE
AL=30° AR=0°
PREDICTED VALUES <MS> *10¹
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
220.00
240.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
TD <IBITS>
MTM
BMTS
W.F.
THIS STUDY

Figure D.4

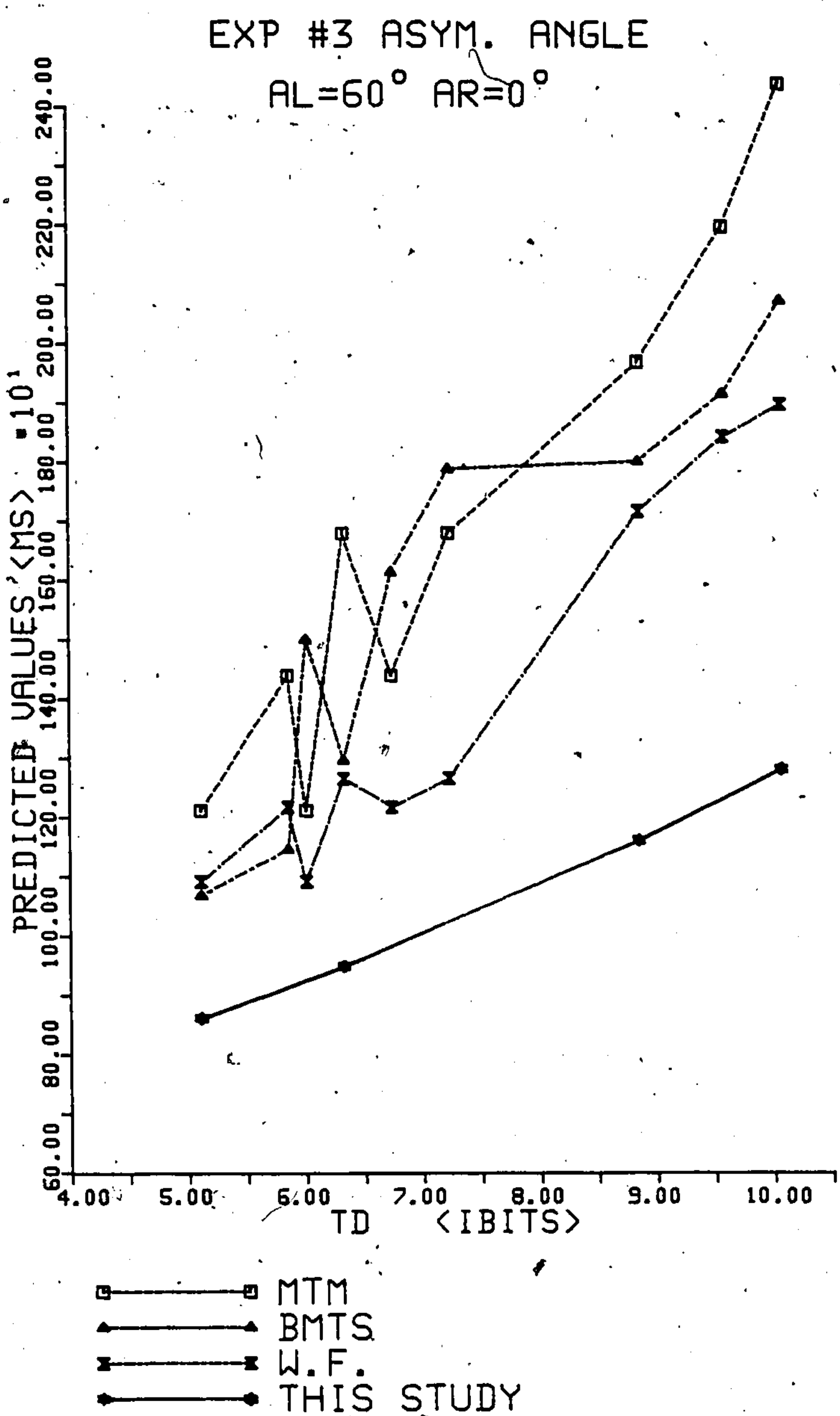

EXP #3 ASYM. ANGLE
AL=60° AR=0°
PREDICTED VALUES <MS> *10[1]
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
220.00
240.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
TD <IBITS>
MTM
BMTS
W.F.
THIS STUDY

Figure D.5

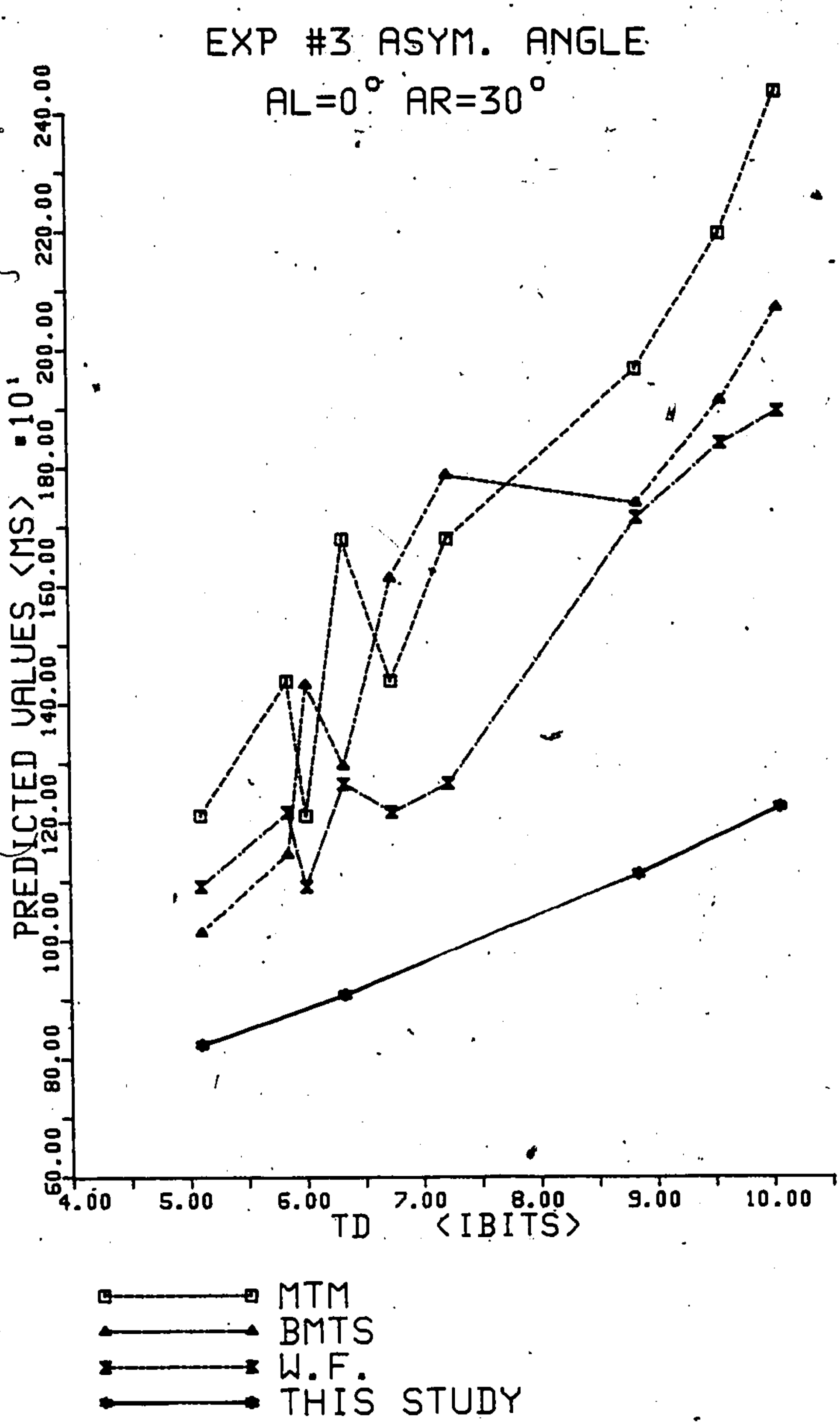

EXP #3 ASYM. ANGLE
AL=0° AR=30°
PREDICTED VALUES <MS> *10¹
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
220.00
240.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
TD <IBITS>
MTM
BMTS
W.F.
THIS STUDY

Figure D.6

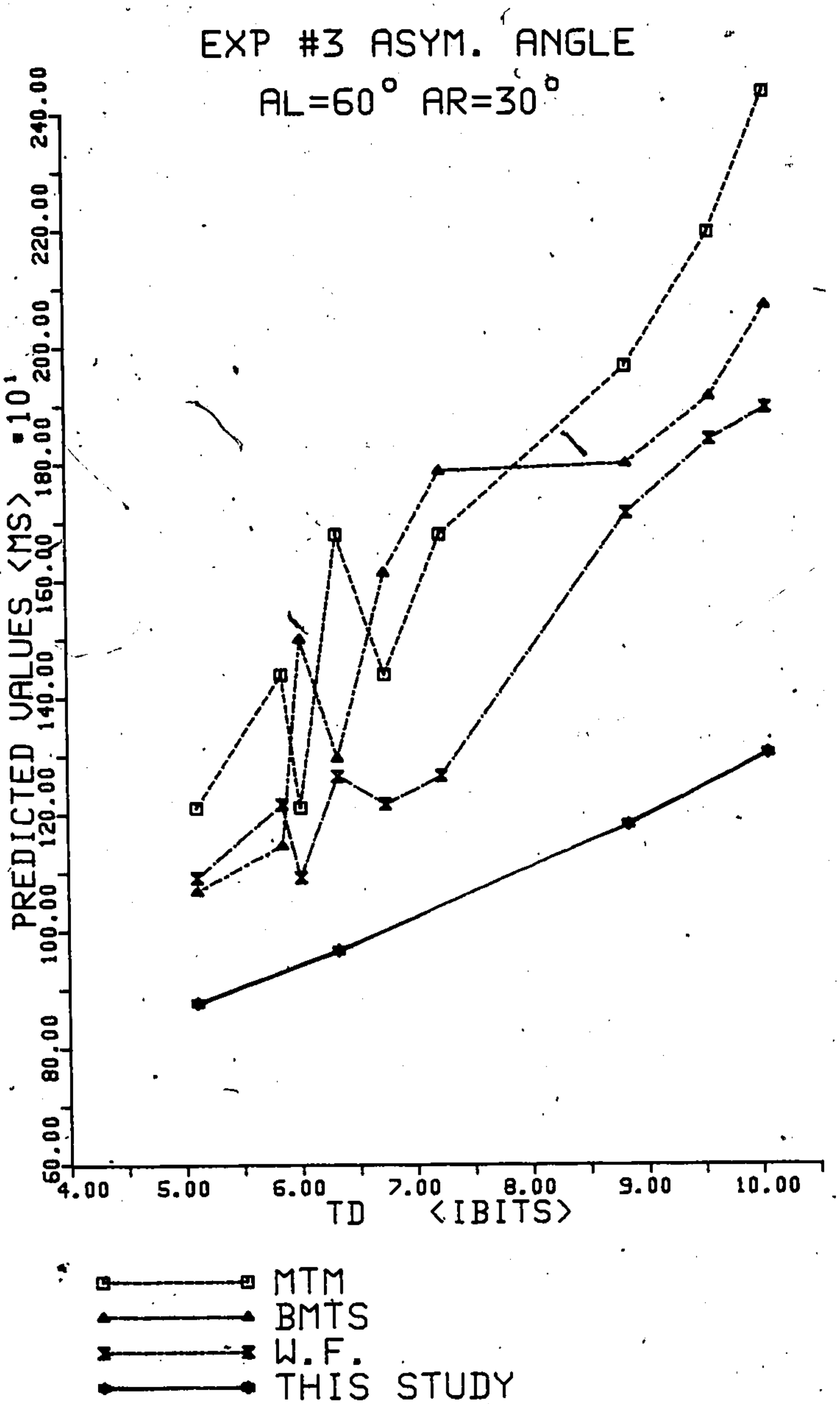

EXP #3 ASYM. ANGLE
AL=60° AR=30°
PREDICTED VALUES <MS> *10¹
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
220.00
240.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
TD <IBITS>
MTM
BMTS
W.F.
THIS STUDY

Figure D.7

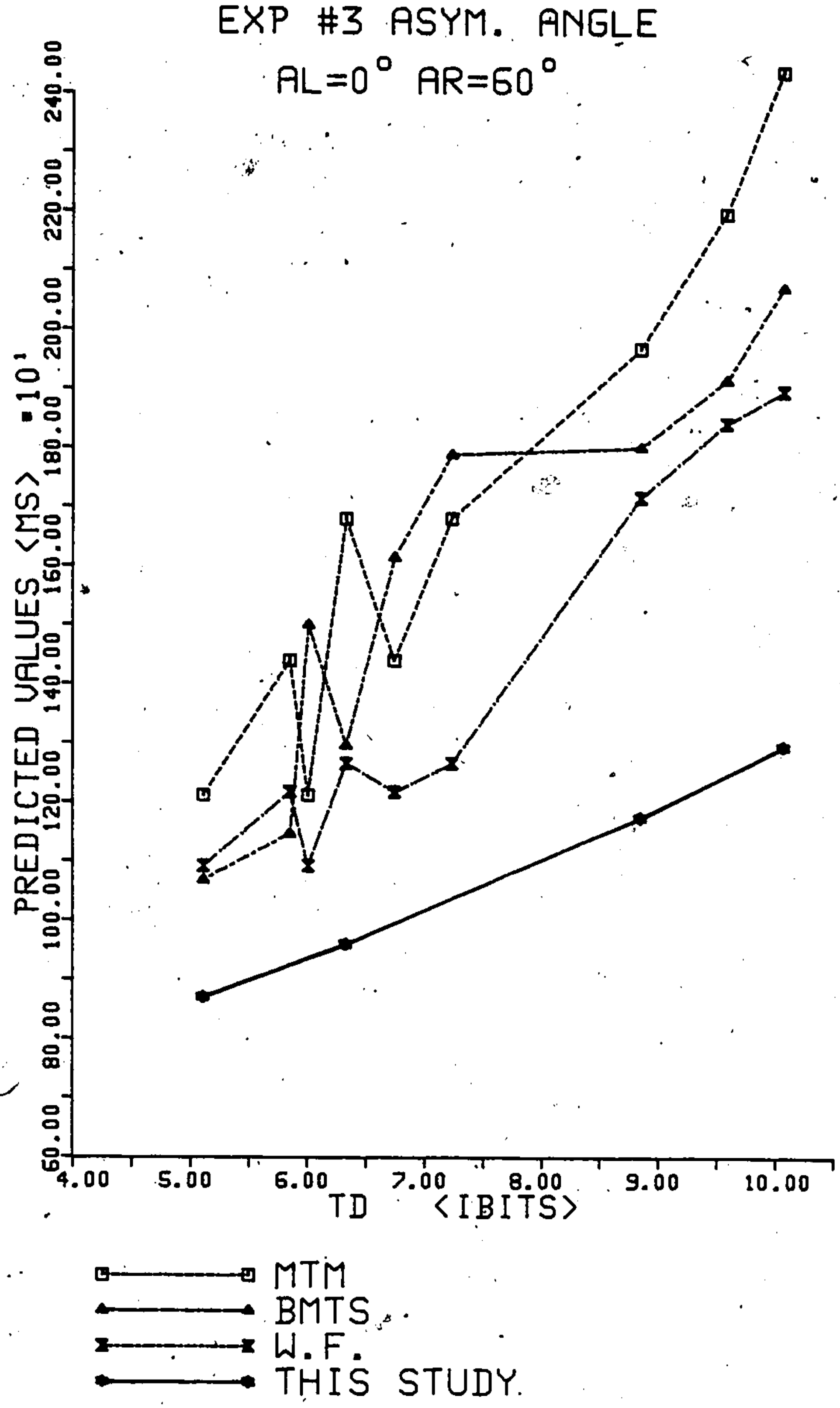

EXP #3 ASYM. ANGLE
AL=0° AR=60°
PREDICTED VALUES <MS> *10¹
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
220.00
240.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
TD <IBITS>
MTM
BMTS
W.F.
THIS STUDY

Figure D.8

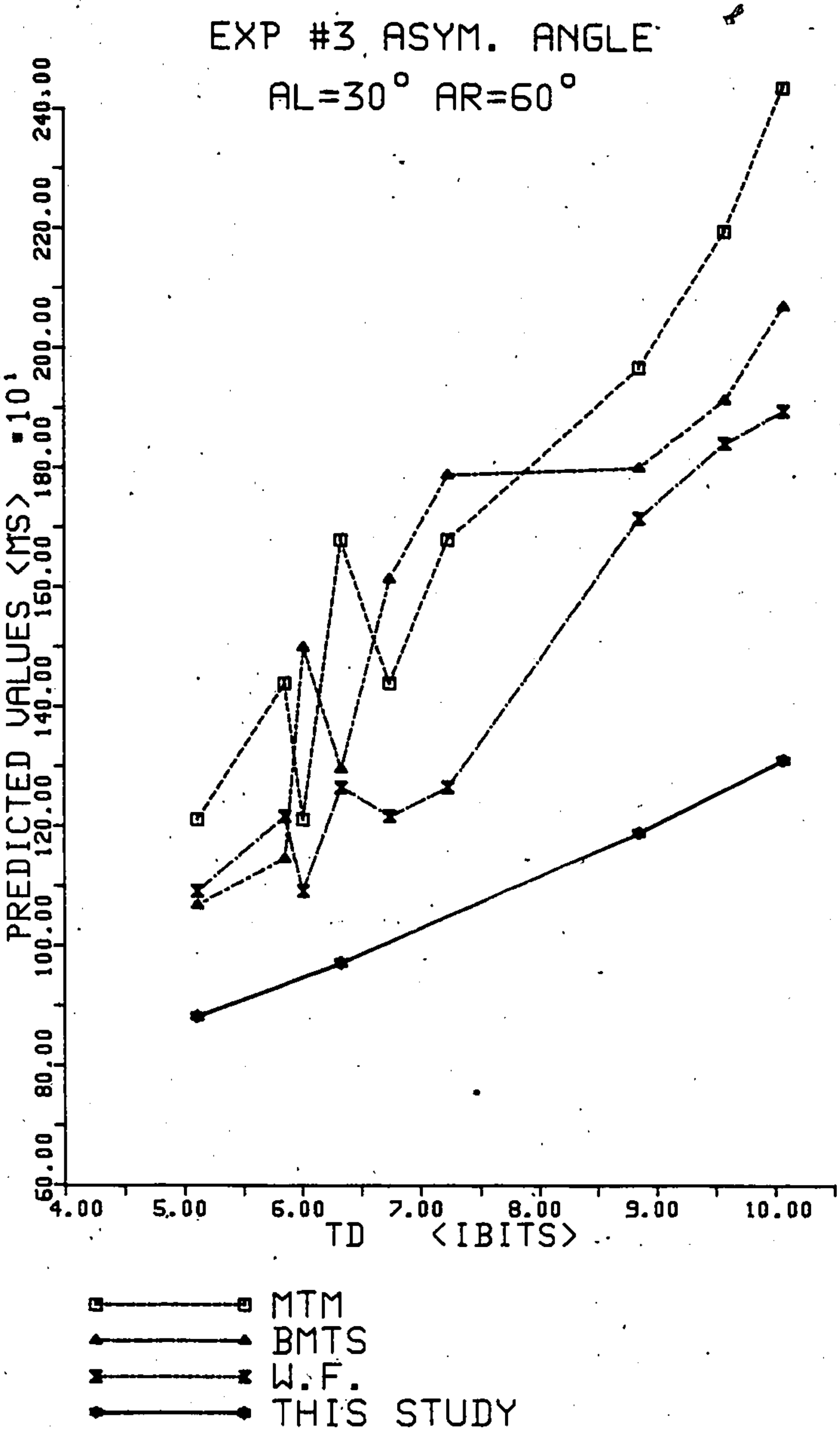

EXP #3 ASYM. ANGLE
AL=30° AR=60°
PREDICTED VALUES <MS> *10¹
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
220.00
240.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
TD <IBITS>
MTM
BMTS
W.F.
THIS STUDY

Figure D.9

APPENDIX D.6

The Percentage Contribution of Variance Component to the Model

Percentage Variance

Main Effects

SUB	7.29
TD	52.65
AL	1.14
AR	1.64
Subtotal	62.72

Second Order Interactions

TD.AL	0.33
TD.AR	0.11
AL.AR	0.36
SUB.AL	0.39
SUB.AR	0.64
SUB.TD	3.37
Subtotal	5.20

Third Order Interactins

SUB.TD.AL	1.48
SUB.TD.AR	2.92
SUB.AL.AR	0.82
TD.AL.AR	0.01
Subtotal	5.23

Fourth Order interaction and error term

SUB.TD.AL.AR	5.66
ERROR	21.19
Subtotal	26.85
TOTAL	100.00

APPENDIX E.1

The Computer Program to Collect HR Data, To Store It on The Magnetic Disk and To compute The HRV

```
0001          INTEGER*2 IHR(2,1000),ITEMS(13)
0002          LOGICAL*1 COND(6)
0003          REAL*4 LHR,LVOLT,MHR,MVOLT,LS,HRV(4,99)
0004          COMMON UHR,UVOLT,LHR,LVOLT,MHR,MVOLT,IHR,COND,
             *ITICK,IREP,ICOND,IFLAG1,LS,US,ZERO,ITEMS,HRV,
             *ICHHR,ICHSE,ICHST,ICHPR,ICHRE,ICHED,LUNCRT,LUNPRN
0005          DATA COND/'S',' ',' ',' ',' ',' '/
0006          CALL START
0007     1    CALL LOOP(IBEAT)
0008          CALL OUTPUT(IBEAT)
0009          GO TO 1
0010          END
```

```
0001          SUBROUTINE OUTPUT(IBEAT)
0002          INTEGER*2 IHR(2,1000),ITEMS(13),YESNO2
0003          LOGICAL*1 COND(6)
0004          REAL*4 LHR,LVOLT,MHR,MVOLT,LS,HRV(4,99)
0005          COMMON UHR,UVOLT,LHR,LVOLT,MHR,MVOLT,IHR,COND,
             *ITICK,IREP,ICOND,IFLAG1,LS,US,ZERO,ITEMS,HRV,
             *ICHHR,ICHSE,ICHST,ICHPR,ICHRE,ICHED,LUNCRT,LUNPRN
0006          CALL IEXAM(IBEAT)
0007          CALL ISTORE(IBEAT)
0008          CALL IEXAM2(IBEAT)
0009    828   WRITE(LUNCRT,830)
0010    830   FORMAT(' '/' ARE THERE ANY CHANGES IN INPUT-DATA SPEC ?',
             *'    <YES NO>'/)
0011          IF(YESNO2(LUNCRT)) 828,690,840
0012    840   CALL ISPEC2
0013    841   CALL ISPEC3(ICONT,K)
0014          IF(ICONT.EQ.0) GO TO 842
0016          CALL ISPEC4(K)
0017          GO TO 840
0018    842   WRITE(LUNCRT,832)
0019    832   FORMAT(' '/' IS RECALIBRATION NECESARRY ? <YES NO>'/)
0020          IF(YESNO2(LUNCRT)) 842,690,844
0021    844   CALL CALSEC
0022    690   RETURN
0023          END
```

```
      SUBROUTINE START
      INTEGER*2 IHR(2,1000),ITEMS(13),YESNO2,ANS,YESNO
      LOGICAL*1 COND(6)
      REAL*4 LHR,LVOLT,MHR,MVOLT,LS,HRV(4,99)
      COMMON UHR,UVOLT,LHR,LVOLT,MHR,MVOLT,IHR,COND,
     *ITICK,IREP,ICOND,IFLAG1,LS,US,ZERO,ITEMS,HRV,
     *ICHHR,ICHSE,ICHST,ICHPR,ICHRE,ICHED,LUNCRT,LUNPRN
      CALL CLEAR
      TYPE 100
100   FORMAT(' '/' HR AND HRV DATA-SAMPLING PROGRAM'/)
500   TYPE 1000
1000  FORMAT(' DO YOU NEED ANY HELP ?       <TYPE YES OR NO>'/)
      CALL YESNO(ANS)
      IF(ANS)500,600,510   !IF YES FOOL-PROOF-MODE ENABLE
510   CALL INTRO0
      CALL INTRO1
      IFOOL=1
621   CALL YESNO(ANS)
      IF(ANS) 620,630,130
630   TYPE 121
121   FORMAT(' '/' ASSIGN LOGICAL UNIT NUMBERS TO THE DEVICES. '/
     *' '////' BYE BYE')
      STOP
620   TYPE 122
122   FORMAT(' TRY AGAIN !')
      GO TO 621
600   IFOOL=0
130   CALL IASS
160   WRITE(LUNCRT,100)
      IF(IFOOL.EQ.0) GO TO 202
      CALL INTRO2(LUNCRT)
202   CALL ISPEC1
      WRITE(LUNCRT,204)
204   FORMAT(' '/' DO YOU WANT TO VERIFY THE SPECIFICATION ?',
     *'   <YES OR NO>'/)
      IF(YESNO2(LUNCRT)) 202,212,214
214   CALL ISPEC2
      CALL ISPEC3(ICONT,K)
      IF(ICONT.EQ.0) GO TO 212
      CALL ISPEC4(K)
      GO TO 214
212   IF(IFOOL.EQ.0) GO TO 300
      CALL INTRO3(LUNCRT)
300   CALL CALSEC
      IF(IFOOL.EQ.0) GO TO 690
      CALL INTRO4(LUNCRT)
690   RETURN
      END
```

```
      SUBROUTINE IFILE
      INTEGER*2 IHR(2,1000),ITEMS(13),YESNO2
      LOGICAL*1 COND(6),EXTENT(4)
      REAL*4 LHR,LVOLT,MHR,MVOLT,LS,HRV(4,99)
      COMMON UHR,UVOLT,LHR,LVOLT,MHR,MVOLT,IHR,COND,
     *ITICK,IREP,ICOND,IFLAG1,LS,US,ZERO,ITEMS,HRV,
     *ICHHR,ICHSE,ICHST,ICHPR,ICHRE,ICHED,LUNCRT,LUNPRN
      DATA EXTENT/'.','D','A','T'/
690   WRITE(LUNCRT,691)
691   FORMAT(' '/' SUBJECT NUMBER ?  <"I2">'/)
      READ(LUNCRT,692) (COND(I),I=2,3)
692   FORMAT(2A1)
      WRITE(LUNCRT,693)
693   FORMAT(' '/' RUN <CONDITION> NUMBER ?  < UP TO 3 LETTERS>'/)
      READ(LUNCRT,694) (COND(I),I=4,6)
694   FORMAT(3A1)
      WRITE(LUNCRT,695) (COND(I),I=1,6),(EXTENT(J),J=1,4)
695   FORMAT(' '/' FILE NAME WILL BE;   ',6A1,4A1)
696   WRITE(LUNCRT,697)
697   FORMAT(' '/' IS THE FILE NAME CORRECT ?'/)
      IF(YESNO2(LUNCRT)) 696,690,700
700   RETURN
      END
```

```
0001            SUBROUTINE CALSEC
0002            LOGICAL*1 COND(6)
0003            INTEGER*2 IHR(2,1000),ITEMS(13),YESNO2
0004            REAL*4 LS,LOHALF,LOWER,LHR,LVOLT,MHR,MVOLT,HRV(4,99)
0005            COMMON UHR,UVOLT,LHR,LVOLT,MHR,MVOLT,IHR,COND,
               *ITICK,IREP,ICOND,IFLAG1,LS,US,ZERO,ITEMS,HRV,
               *ICHHR,ICHSE,ICHST,ICHPR,ICHRE,ICHED,LUNCRT,LUNPRN
0006            IBELL=8199
0007            WRITE(LUNCRT,131)
0008      131   FORMAT(' '///' A/D CONVERTER CALIBRATION'/
               *'  FOLLOW THE INSTRUCTIONS BELOW'/)
0009      22    WRITE(LUNCRT,132)IBELL
0010      132   FORMAT(' ',A1/' SET TACH SCALE SWITCH TO THE CENTER')
0011      21    WRITE(LUNCRT,133)
0012      133   FORMAT(//' ARE YOU READY ?  <YES OR NO> ---> '$)
0013            IF(YESNO2(LUNCRT)) 21,22,23
0014      23    WRITE(LUNCRT,20)
0015      20    FORMAT(/' Working !!'/)
0016            CALL CAL(ZERO,ICHHR)
0017            CALL CLEAR
0018      24    WRITE(LUNCRT,134)IBELL
0019      134   FORMAT(' ',A1/' SET TACH SCALE SWITCH TO -2CM.')
0020      25    WRITE(LUNCRT,133)
0021            IF(YESNO2(LUNCRT)) 25,24,26
0022      26    WRITE(LUNCRT,20)
0023            CALL CAL(LOWER,ICHHR)
0024            CALL CLEAR
0025      28    WRITE(LUNCRT,135)IBELL
0026      135   FORMAT(' ',A1/' SET TACH SCALE SWITCH TO +2CM.')
0027      27    WRITE(LUNCRT,133)
0028            IF(YESNO2(LUNCRT)) 27,28,29
0029      29    WRITE(LUNCRT,20)
0030            CALL CAL(UPPER,ICHHR)
0031            WRITE(LUNCRT,136)
0032      136   FORMAT(' CALIBRATION COMPLETED'/)
0033            UPHALF=UPPER-ZERO
0034            LOHALF=LOWER-ZERO
0035            SCALE=(UHR-LHR)/2.0
0036            IF(UPHALF.NE.0.0) GO TO 200
0038            US=0.0
0039            GO TO 210
0040      200   US=SCALE/UPHALF
0041      210   IF(LOHALF.NE.0.0) GO TO 220
0043            LS=0.0
0044            GO TO 230
0045      220   LS=SCALE/LOHALF
0046      230   RETURN
0047            END
```

```
      SUBROUTINE CAL(AVE,ICHAN)
      SUM=0.
      DO 1 I=1,30
      J=ISLEEP(0,0,0,10)
      SUM=SUM+IADC(ICHAN)
1     CONTINUE
      AVE=SUM/30.
      RETURN
      END
```

```
0001          SUBROUTINE ISPEC1
0002          LOGICAL*1 CARD(80),CHA(12),COND(6)
0003          DATA CHA/'1','2','3','4','5','6','7','8','9',
             *'0',' ',1H,/
0004          INTEGER*2 ITEMS(13),IHR(2,1000)
0005          REAL*4 LHR,LVOLT,MHR,MVOLT,LS,HRV(4,99)
0006          COMMON UHR,UVOLT,LHR,LVOLT,MHR,MVOLT,IHR,COND,
             *ITICK,IREP,ICOND,IFLAG1,LS,US,ZERO,ITEMS,HRV,
             *ICHHR,ICHSE,ICHST,ICHPR,ICHRE,ICHED,LUNCRT,LUNPRN
        C
        C     INITIALIZATION OF THE VALUES.
        C     TO CHANGE THE SPEC. PARMANENTLY, REPLACE THE VALUE BY USING
        C     .EDIT.
        C
0007          LHR=40.               !HR VALUE WHEN THE PEN IS AT -2 CM
0008          LVOLT=-1.3    !CORRESPONDING VOLTAGE
        C
0009          MHR=80.               !HR VALUE WHEN THE PEN IS AT BASE LINE
0010          MVOLT=0.0     !CORRESPONDING VOLTAGE
        C
0011          UHR=120.      !HR VALUE WHEN THE PEN IS AT +2 CM
0012          UVOLT=1.3     !CORRESPONDING VOLTAGE
        C
0013          ITICK=20      !HR SAMPLING INTERVAL
        C
0014          IREP=5                !NUMBER OF REPLICATIONS IN THE EXP.
        C
0015          ICOND=1               !NUMBER OF CONDITIONS IN THE EXPERIMENT
        C
0016          IFLAG1=1      !IF 1 STARTING/ENDING SIGNAL IS SUPPLIED, =0 NOT
        C
        C     PRESET CHANNEL NUMBERS
        C
0017          ICHHR=2               !HR DATA FROM POLYGRAPH  <J6>
0018          ICHSE=3               !STARTING/ENDING SIGNAL
0019          ICHST=6               !START-SWITCH
0020          ICHPR=7               !PAUSE/RESUME-SWITCH
0021          ICHRE=10      !RESET-SWITCH
0022          ICHED=11      !END-SWITCH
0023          RETURN
0024          END
```

```
      SUBROUTINE ISPEC2
      LOGICAL*1 CARD(80),CHA(12),COND(6)
      DATA CHA/'1','2','3','4','5','6','7','8','9',
     *'0',' ',1H,/
      INTEGER*2 ITEMS(13),IHR(2,1000)
      REAL*4 LHR,LVOLT,MHR,MVOLT,LS,HRV(4,99)
      COMMON UHR,UVOLT,LHR,LVOLT,MHR,MVOLT,IHR,COND,
     *ITICK,IREP,ICOND,IFLAG1,LS,US,ZERO,ITEMS,HRV,
     *ICHHR,ICHSE,ICHST,ICHPR,ICHRE,ICHED,LUNCRT,LUNPRN
C
C     PRINT OUT THE TABLE CONTAINS ABOVE INFORMATION
C
      CALL CLEAR
   60 WRITE(LUNCRT,90)
      WRITE(LUNCRT,100) UHR,UVOLT,MHR,MVOLT,LHR,LVOLT,
     *ITICK,IREP,IFLAG1,ICOND,
     *ICHHR,ICHSE,ICHST,ICHPR,ICHRE,ICHED
  100 FORMAT(
     *'   1.       HEART RATE VALUE WHEN THE PEN IS AT +2CM',T60,F5.1,
     *' B/M'/
     *'            CORRESPONDING VOLTAGE',T60,F5.1,' DCV'/
     *'   2.       HEART RATE VALUE WHEN THE PEN IS AT  BASE LINE',
     *T60,F5.1,' B/M'/
     *'            CORRESPONDING VOLTAGE',T60,F5.1,' DCV'/
     *'   3.       HEART RATE VALUE WHEN THE PEN IS AT -2CM',T60,
     *F5.1,' B/M'/
     *'            CRRESPONDING VOLTAGE',T60,F5.1,' DCV'/
     *'   4.       HR-SAMPLING INTERVAL  <1 TICK=1/60 SEC.>',T62,I3,
     *' TICK'/
     *'   5.       NUMBER OF REPLICATIONS',T62,I3,' CYCS'/
     *'   6.       STARTING/ENDING SIGNAL IS SUPPLIED YES=1 NO=0',
     *T64,I1/
     *'   7.       NUMBER OF EXPERIMENTAL CONDITIONS',T62,I3/
     */'        A/D CONVERTER CHANNEL ASSIGNMENT',T61,'CHANNEL'//
     *'   8.       HR-DATA FROM POLYGRAPH  <J6>',T63,I2/
     *'   9.       STARTING/ENDING SIGNAL',T63,I2/
     *'  10.       START-SWITCH',T63,I2/
     *'  11.       PAUSE/RESUME-SWITCH',T63,I2/
     *'  12.       RESET-SWITCH',T63,I2/
     *'  13.       END-SWITCH',T63,I2)
   90 FORMAT(' '//////' ITEM NO.',15X'DEFINITION',T60,'VALUE UNIT'/)
      RETURN
      END
```

```
      SUBROUTINE ISPEC3(ICONT,K)
      LOGICAL*1 CARD(80),CHA(12),COND(6)
      DATA CHA/'1','2','3','4','5','6','7','8','9',
     *'0',' ',1H,/,LUN/6/
      INTEGER*2 ITEMS(13),IHR(2,1000),YESNO2
      REAL*4 LHR,LVOLT,MHR,MVOLT,LS,HRV(4,99)
      COMMON UHR,UVOLT,LHR,LVOLT,MHR,MVOLT,IHR,COND,
     *ITICK,IREP,ICOND,IFLAG1,LS,US,ZERO,ITEMS,HRV,
     *ICHHR,ICHSE,ICHST,ICHPR,ICHRE,ICHED,LUNCRT,LUNPRN
91    WRITE(LUNCRT,110)
110   FORMAT(' ARE THE ALL INFORMATIONS CORRECT ?'/)
      IF(YESNO2(LUNCRT)) 91,20,30
20    WRITE(LUNCRT,120)
120   FORMAT(' '/' ENTER THE ITEM NO. FOR THE VALUE TO BE CHANGED'/
     *' MORE THAN ONE NO. CAN BE ENTERED AT A TIME'/)
31    READ(LUNCRT,200)(CARD(I),I=1,80)
200   FORMAT(80A1)
      ITEM=0
      K=0
      DO 21 I=1,80
      DO 40 J=1,12
      IF(CARD(I).EQ.CHA(J)) GO TO 10
40    CONTINUE
      WRITE(LUNCRT,130) CARD(I)
130   FORMAT(' '/' ',A1,': INVALID.  RETYPE NUMBER(S)'/)
      GO TO 31
10    IF(J.GE.11) GO TO 11
      IFLAG=0
      IF(J.EQ.10) J=0
      IF(ITEM.NE.0) GO TO 12
      IF(J.EQ.0) IFLAG2=1
      IF(J.NE.0) IFLAG2=0
      ITEM=J
      GO TO 13
12    ITEM=ITEM*10+J
      IF((ITEM.GT.13).OR.(ITEM.LT.1)) GO TO 14
      GO TO 13
11    IFLAG=1
13    IF(IFLAG.NE.1) GO TO 21
      IF(IFLAG2.EQ.1) GO TO 14
      IF(ITEM.EQ.0) GO TO 21
      K=K+1
      ITEMS(K)=ITEM
      IFLAG=0
      ITEM=0
      IF(K.GE.13) GO TO 15
      GO TO 21
14    WRITE(LUNCRT,140) ITEM
140   FORMAT(' '/' ',I3,': INVALID. PROGRAM IGNORES THIS NUMBER'/)
      IFLAG2=0
      ITEM=0
      IFLAG=0
      GO TO 21
15    WRITE(LUNCRT,150) (CARD(L),L=I+1,80)
150   FORMAT(' '/' TOO MANY NUMBERS.  THE REST ARE IGNORED --->',80A1/)
      GO TO 22
```

```
0064   21   CONTINUE
0065   22   CONTINUE
0066        WRITE(LUNCRT,159)
0067  159   FORMAT(' '/' THE VALUES FOR THE ITEMS 1 - 3 ARE REAL'
           *' NUMBERS, SUCH AS 12.3  '/' I.E. MUST HAVE A DECIMAL POINT'//
           *' THE REST, ITEMS 4 - 13, ARE ALL INTEGER NUMBERS.'/
           *' I.E. MUST NOT HAVE ".".'//)
0068        NN=ISLEEP(0,0,5,0)
0069        IF(K.EQ.0) GO TO  91
0071        ICONT=1
0072        RETURN
0073   30   ICONT=0
0074        RETURN
0075        END
```

```
0001          SUBROUTINE ISPEC4(K)
0002          LOGICAL*1 CARD(80),CHA(12),COND(6)
0003          DATA CHA/'1','2','3','4','5','6','7','8','9',
             *'0',' ','H,/,LUN/6/
0004          INTEGER*2 ITEMS(13),IHR(2,1000)
0005          REAL*4 LHR,LVOLT,MHR,MVOLT,LS,HRV(4,99)
0006          COMMON UHR,UVOLT,LHR,LVOLT,MHR,MVOLT,IHR,COND,
             *ITICK,IREP,ICOND,IFLAG1,LS,US,ZERO,ITEMS,HRV,
             *ICHHR,ICHSE,ICHST,ICHPR,ICHRE,ICHED,LUNCRT,LUNPRN
0007          DO 50 I=1,K
0008          GO TO (301,302,303,304,305,306,307,308,309,310,311,312,313),
             *ITEMS(I)
0009    301   WRITE(LUNCRT,160)
0010    160   FORMAT(' '/' ENTER THE HR VALUE  WHEN THE PEN IS AT  +2CM'/)
0011          READ(LUNCRT,210) UHR
0012    210   FORMAT(F6.2)
0013          WRITE(LUNCRT,161)
0014    161   FORMAT(' '/' WHAT IS THE VOLTAGE THEN ?'/)
0015          READ(LUNCRT,210) UVOLT
0016          GO TO 50
0017    302   WRITE(LUNCRT,162)
0018    162   FORMAT(' '/' ENTER THE HR VALUE WHEN THE PEN IS AT BASE LINE'/)
0019          READ(LUNCRT,210) MHR
0020          WRITE(LUNCRT,161)
0021          READ(LUNCRT,210) MVOLT
0022          GO TO 50
0023    303   WRITE(LUNCRT,163)
0024    163   FORMAT(' '/' ENTER THE HR VALUE WHEN THE PEN IS AT -2CM'/)
0025          READ(LUNCRT,210) LHR
0026          WRITE(LUNCRT,161)
0027          READ(LUNCRT,210) LVOLT
0028          GO TO 50
0029    304   WRITE(LUNCRT,164)
0030    164   FORMAT(' '/' ENTER DESIRED HR SAMPLING INTERVAL',
             *' IN TICKS <=1/60 SEC.>'/)
0031          READ(LUNCRT,220) ITICK
0032    220   FORMAT(I2)
0033          GO TO 50
0034    305   WRITE(LUNCRT,165)
0035    165   FORMAT(' '/' ENTER THE NO. OF REPLICATIONS IN AN',
             *' EXPERIMENTAL CONDITION'/)
0036          READ(LUNCRT,220) IREP
0037          GO TO 50
0038    306   WRITE(LUNCRT,166)
0039    166   FORMAT(' '/' TYPE 1 IF STARTING/ENDING SIGNAL IS SUPPLIED'/
             *' OTHERWISE TYPE 0'/)
0040          READ(LUNCRT,220) IFLAG1
0041          GO TO 50
0042    307   WRITE(LUNCRT,167)
0043    167   FORMAT(' '/' ENTER THE NO. OF EXPERIMENTAL CONDITIONS'/)
0044          READ(LUNCRT,220) ICOND
0045          GO TO 50
0046    308   WRITE(LUNCRT,168)
0047    168   FORMAT(' '/' ENTER THE CHANNEL NO. FOR  THE HR-INPUT'/)
0048          READ(LUNCRT,220) ICHHR
0049          GO TO 50
```

```
309   WRITE(LUNCRT,169)
169   FORMAT(' '/' ENTER THE CHANNEL NO. FOR  STARTING/ENDING',
     *' SIGNAL'/)
      READ(LUNCRT,220) ICHSE
      GO TO 50
310   WRITE(LUNCRT,170)
170   FORMAT(' '/' ENTER THE CHANNEL NO. FOR START-SWITCH'/)
      READ(LUNCRT,220) ICHST
      GO TO 50
311   WRITE(LUNCRT,171)
171   FORMAT(' '/' ENTER THE CHANNEL NO. FOR PAUSE/RESUME-SWITCH'/)
      READ(LUNCRT,220) ICHPR
      GO TO 50
312   WRITE(LUNCRT,172)
172   FORMAT(' '/' ENTER THE CHANNEL NO. FOR RESET-SWITCH'/)
      READ(LUNCRT,220) ICHRE
      GO TO 50
313   WRITE(LUNCRT,173)
173   FORMAT(' '/' ENTER THE CHANNEL NO. FOR END-SWITCH'/)
      READ(LUNCRT,220) ICHED
50    CONTINUE
      RETURN
      END
```

```
0001        SUBROUTINE INTROO
0002        TYPE 1001
0003   1001 FORMAT(' THIS PROGRAM IS USED TO MESURE HR AND HRV OF A',
           *' SUBJECT'/
           *' IT IS ASSUMED THAT THE USER OF THIS PROGRAM IS FAMILIAR TO '/
           *'   1. HR AND HRV,'/
           *'   2. GRASS POLYGRAPH AND'/
           *'   3. PDP-11/03 AND RT-11'/
           *' '/' ',' THIS PROGRAM CONSISTES OF THE FOLLOWING SECTIONS;'/
           *'   1. INPUT-DATA SPECIFICATIONS SECTION'/
           *'   2. CALIBRATION SECTION'/
           *'   3. DATA-SAMPLING SECTION'//
           *' IN THE FIRST SECTION, SPECIFICATIONS ON THE INPUT DATA'/
           *' ARE DEFINED.  IN CASE THE SPECIFICATIONS ARE DIFFERNT'/
           *' FROM THE ONES YOU INTEND TO USE, YOU MUST REDEFINE THEM'/
           *' '/' IN THE SECOND SECTION, THE CALIBRATION OF THIS PROGRAM'/
           *' IS PERFORMED.  THE CALIBRATION OF GRASS POLYGRAPH IS A'/
           *' PREREQUISITE FOR THIS SECTION'/
           *' '/' THE LAST SECTION IS FOR COLLECTING THE DATA.  THIS IS'/
           *' DONE BY  USING THE INFORMATION WHICH HAS BEEN GIVEN IN THE'/
           *' FIRST SCETION. THE PROGRAM CAN OBSERVE UP TO 1000 HEART'/
           *' BEATS OR AT LEAST 8 MINUTES IN A CONTINUOUS RUN, WHEN THE'/
           *' AVERAGE HEART RATE IS LESS THAN 120 BEATS PER MIN.'//
           *' IT WAS INTENDED TO WRITE THIS PROGRAM IN A STYLE, SO-CALLED'/
           *' INTERACTIVE SYSTEM FOR USER CONVINIENCE.  ONCE THE PROGRAM'/
           *' HAS BEEN STARTED TO EXECUTE, THE PROGRAM SHOULD BE CONTROLED'/
           *' BY THE CONTROLER BUILT FOR THIS PROGRAM.  THE USE OF KEY-BOARD'/
           *' COMMANDS SUCH AS CTRL/C AND CTRL/A ETC. IS NOT RECOMMENDED'/
           *' THE FUNCTION OF THE FOUR SWITCHES ON THE CONTROLER IS'/
           *' EXPLAIND BELOW.'//
           *' 1. START-SWITCH'/
           *'   ENABLES FOR THE PROGRAM TO START COLLECTING HR DATA.'/
           *'   WHEN STARTING/ENDING SIGNAL IS SUPPOSED TO BE SUPPLIED'/
           *'   FROM ANOTHER SOURCE, PROGRAM WILL NOT START UNTILL THE'/
           *'   SIGNAL IS GIVEN.  OTHERWISE PROGRAM'/
           *'   STARTS IMMIDIATELY.'/)
0004        RETURN
0005        END
```

```
FORTRAN IV        V02.5-2    Thu 10-Jun-82 16:42:16                PAGE 001

0001             SUBROUTINE INTRO1
0002             TYPE 120
0003     120     FORMAT(' 2. PAUSE/RESUME-SWITCH'/
                *'    WHEN THIS SWITCH IS AT THE PAUSE POSITION, THE'/
                *'    EXECUTION OF THE PROGRAM IS TEMPORARY HELD.  WHEN THE '/
                *'    SWITCH IS REPOSITIONED, PROGRAM RESUMES ITS'/
                *'    EXECUTION.  EXCESSIVE USE OF PAUSE CAUSES THE DIS-'/
                *'    CHARGE OF BATTERY.'//
                *' 3. RESET-SWITCH'/
                *'    IS TO DISCONTINUE THE EXECUTION OF THE PROGRAM FOR THE'/
                *'    RUN.  THE DATA COLLECTED IN THE RUN WILL BE LOST.'/
                *'    TO RE-START, PRESS THE START-SWITCH.'//
                *' 4. END-SWITCH'/
                *'    CAUSES TERMINATION FROM THE DATA-COLLECTION FOR THE'/
                *'    RUN.  HR AND HRV FOR THE RUN WILL BE COMPUTED AND'/
                *'    STORED ON THE DISK.  WHEN STARTING/ENDING SIGNAL IS'/
                *'    SUPPOSED TO BE SUPPLIED FROM ANOTHER SOURCE, PROGRAM'/
                *'    WILL NOT TERMINATES TILL THE SIGNAL IS GIVEN.'//
                *' '/' TO USE THIS  PROGRAM AS  EFFECTIVE AS IT WAS DESIGNED'/
                *' THE FOLLOWING PROCEDURES MUST BE EXECUTED.'//
                *' 1. ASSIGN A NUMBER <LOGICAL UNIT NUMBERR> TO THE CRT'/
                *'      TERMINAL AND ENTER THE NUMBER TO THIS PROGRAM AS LUNCRT.'/
                *' 2. ASSIGN ANOTHER NUMBER <LOGICAL UNIT NUMBER> TO THE'/
                *'      PRINTER AND ENTER THIS NUMBER AS LUNPRN.'/
                *' '/' HOWEVER, THESE LOGICAL UNIT NUMBERS MUST HAVE BEEN'/
                *' ASSIGNED TO THE DEVICES <TT: AND LP:> BEFORE THEY ARE ENTERED '/
                *' INTO THIS PROGRAM.'/
                *' '/' IF YOU ARE READY TO ENTER THESE LUNCRT AND LUNPRN'/
                *' TYPE YES, IF NOT TYPE NO')
0004             RETURN
0005             END
```

```
FORTRAN IV      V02.5-2    Thu 10-Jun-82 16:42:37              PAGE 001

0001            SUBROUTINE INTRO2(LUNCRT)
0002            WRITE(LUNCRT,162)
0003            REWIND LUNCRT
0004            END FILE LUNCRT
0005      162   FORMAT(' '/' INPUT-DATA SPECIFICATIONS SECTION'/
               *' '/' ALL THE SPECIFICATIONS ARE PRESET IN THIS'/
               *' PROGRAM.  HOWEVER, THEY MAY NOT BE SUITABLE FOR THE PURPOSE OF'/
               *' YOUR STUDY.  IF THIS IS THE CASE, THEN YOU MUST REDEFINE'/
               *' THE SPACIFICATIONS.  '//
               *' SOMETIMES, DURING THE EXPERIMENT, IT MAY HAPPEN '/
               *' THAT IT IS NECESSARY TO CHANGE SOME OF THE SPACIFICATIONS.'/
               *' IN SUCH A CASE, PROGRAM PROMPTS TO MAKE SUCH A REQUEST '/
               *' BETWEEN THE RUNS'//)
0006            RETURN
0007            END
```

```
0001            SUBROUTINE INTRO3(LUNCRT)
0002      300   WRITE(LUNCRT,302)
0003            REWIND LUNCRT
0004            END FILE LUNCRT
0005      302   FORMAT(' '/' CALIBRATION SECTION'//
               *' THIS SECTION IS FOR CALIBRATING THE  SCALE FACTORS IN THE'/
               *' PROGRAM LOGIC WHICH CONVERTS INPUT ANALOG HR DATA IN TO'/
               *' DIGITAL HR VALUE.  THIS PROCEDURE MUST BE PERFORMED AT THE'/
               *' BEGINING OF THE EXPERIMENT AND WHENEVER THE GRASS POLYGRAPH'/
               *' HAS BEEN RECALIBRATED.'/)
0006            RETURN
0007            END
```

```
0001          SUBROUTINE INTRO4(LUNCRT)
0002          WRITE(LUNCRT,140)
0003    140   FORMAT(' '///' DATA-SAMPLING SECTION'/
             *' '//' IN THIS SECTION  THE HR DATA IS ACTUALLY'/
             *' COLLECTED.  AT THE  BEGINNING OF EACH RUN <EXPERIMENTAL'/
             *' CONDITION>,  PROGRAM PROMPTS TO INPUT SUBJECT NUMBER AND'/
             *' RUN NUMBER.  SUBJECT NUMBER IS USE TO IDENTIFY THE SUBJECTS'/
             *' AND THE NUMBER CAN BE 00 TO 99 INCLUSIVE.  THE RUN NUMBER IS'/
             *' FOR RECORDING THE EXPERIMENTAL CONDITION. THE FORMAT FOR '/
             *' THE RUN NUMBER IS "A3", THEREFOR EXPERIMENTS WITH UP TO'/
             *' 999 CONDITIONS CAN BE HANDLED BY THIS PROGRAM.) HOWEVER, WHEN'/
             *' THE NUMBER OF CONDITIONS IS LESS THAN 99, THE(THIRD DIGIT'/
             *' CAN BE LEFT BLANK OR CAN BE FILLED WITH YOUR INITIAL.'/
             *' '/' THE DATA WILL BE STORED ON THE DISK WITH FILE NAME'/
             *' SXXYYY.DAT      , WHEN THE RUN HAS BEEN COMPLETED.   THESE'/
             *' X"S INDICATE THE SUBJECT NUMBER AND YYY IS FOR THE RUN NUMBER.'/
             *' EACH RUN <CONDITION> NUMBER MUST BE DIFFERENT FOR A SUBJECT.'/
             *' GIVING <USING> THE SAME RUN NUMBER WILL RESULT'/
             *' IN DELETING THE DATA-FILE ON THE DISK WITH THE SAME FILE NAME.'/
             *' TO AVOID THIS INCONVENIENCE <LOSING THE DATA FOR A CONDITION>'/
             *' THE SIXTH COL. OF  THE FILE NAME <THIRD "Y"> SHOULD BE CHANGED'/
             *' WHEN AN EXPERIMENTAL CONDITION IS REPEATED, OR WHEN A FILE'/
             *' WITH THE SAME FILE NAME IS ALREADY STORED ON THE DISK.'/
             *' '/' AFTER THE EXPERIMENT,  THE EXTENTION OF THE FILE'/
             *' NAMES "DAT" SHOULD BE CHANGED TO A UNIQUE EXTENTION NAME'/
             *' TO AVOID DELETING A FILE "ACCIDENTALLY".'//
             *' AFTER THIS MESSAGE,  THE PROGRAM SHOULD ONLY BE CONTROLED'/
             *' BY THE CONTROLER.  AN ATEMPT TO TERMINATE FROM THE RUN '/
             *' BY USING CTRL/C WILL RESULT IN LOSING THE DATA FOR THE RUN'/
             *' AND  YOU WILL HAVE TO  REDEFINE THE SPEC.'/)
0004          RETURN
0005          END
```

```
0001          SUBROUTINE ISTORE(IBEAT)
0002          LOGICAL*1 COND(6)
0003          INTEGER*2 OSIGN,OLDID,OLDHR,IHR(2,1000),ITEMS(13)
0004          REAL*4 HRV(4,99),LHR,LVOLT,MHR,MVOLT,LS
0005          COMMON UHR,UVOLT,LHR,LVOLT,MHR,MVOLT,IHR,COND,
             *ITICK,IREP,ICOND,IFLAG1,LS,US,ZERO,ITEMS,HRV,
             *ICHHR,ICHSE,ICHST,ICHPR,ICHRE,ICHED,LUNCRT,LUNPRN
0006          WRITE(LUNPRN,1100) (COND(I),I=1,6)
0007     1100 FORMAT(' '//////' HR AND HRV DATA',5X,'CONDITION=',6A1//
             *' ',10(' BEAT CYC  HR'),/)
0008          DO 1110 I=1,IBEAT,10
0009          IF(I+9.LE.IBEAT) GO TO 1111
0011          II=IBEAT
0012          GO TO 1112
0013     1111 II=I+9
0014     1112 WRITE(LUNPRN,1113) (J,IHR(1,J),IHR(2,J),J=I,II)
0015     1113 FORMAT(' ',10(I4,I3,I6))
0016     1110 CONTINUE
0017          REWIND LUNPRN
0018          WRITE(LUNPRN,1120)
0019     1120 FORMAT(' '/////' ','ITEM',5(' CYC       VALUE        ')//)
0020          DO 1116 I=1,IREP,5
0021          IF(I+4.LE.IREP) GO TO 1122
0023          II=IREP
0024          GO TO 1114
0025     1122 II=I+4
0026     1114 CONTINUE
0027          WRITE(LUNPRN,1118) (J,HRV(1,J),J=I,II)
0028          WRITE(LUNPRN,1124) (J,HRV(2,J),J=I,II)
0029          WRITE(LUNPRN,1125) (J,HRV(3,J),J=I,II)
0030          WRITE(LUNPRN,1126) (J,HRV(4,J),J=I,II)
0031     1118 FORMAT(' NEUM',5(I4,1X,F16.2))
0032     1124 FORMAT(' DENO',5(I4,1X,F16.0))
0033     1125 FORMAT(' HRV ',5(I4,1X,F16.7))
0034     1126 FORMAT(' HR  ',5(I4,1X,F16.2))
0035          WRITE(LUNPRN,1119)
0036          REWIND LUNPRN
0037     1119 FORMAT(' ')
0038     1116 CONTINUE
0039          IREC=1
0040          II=IBEAT+1
0041          IHR(1,II)=99
0042          IHR(2,II)=0
0043          CALL ASSIGN(4,COND,6)
0044          DEFINE FILE 4 (II,2,U,IREC)
0045          DO 1130 I=1,II
0046          WRITE(4'IREC) IHR(1,I),IHR(2,I)
0047     1130 CONTINUE
0048          CALL CLOSE(4)
0049          RETURN
0050          END
```

```
      SUBROUTINE IEXAM(IBEAT)
      LOGICAL*1 COND(6)
      INTEGER*2 OSIGN,OLDHR,IHR(2,1000),ITEMS(13)
      REAL*4 HRV(4,99),LHR,LVOLT,MHR,MVOLT,LS
      COMMON UHR,UVOLT,LHR,LVOLT,MHR,MVOLT,IHR,COND,
     *ITICK,IREP,ICOND,IFLAG1,LS,US,ZERO,ITEMS,HRV,
     *ICHHR,ICHSE,ICHST,ICHPR,ICHRE,ICHED,LUNCRT,LUNPRN
      ICYC=0
      IB=0
      DO 999 I=1,IBEAT
      IB=IB+1
      IF(IHR(1,I).EQ.ICYC) GO TO 900
      ICYC=ICYC+1
      OLDHR=IHR(2,I)
      OSIGN=0
      HR=OLDHR*0.1
      HRO=HR
      IFLAG=0
      GO TO 960
  900 NEWHR=IHR(2,I)
      HR=NEWHR*0.1
      HRD=HR-HRO
      IF(IFLAG.EQ.1) GO TO 920
      IF(HRD) 910,960,910
  910 IFLAG=1
  920 IF(HRD) 930,960,940
  930 NSIGN=-1
      HRV(1,ICYC)=HRV(1,ICYC)-HRD
      GO TO 950
  940 NSIGN=1
  950 IF(OSIGN.EQ.0) GO TO 952
      IF(OSIGN.NE.NSIGN) HRV(2,ICYC)=HRV(2,ICYC)+1.
  952 OSIGN=NSIGN
      OLDHR=NEWHR
      HRO=HR
  960 HRV(4,ICYC)=HRV(4,ICYC)+HR
      IF(I.EQ.IBEAT) GO TO 970
      IF(IHR(1,I).EQ.IHR(1,I+1)) GO TO 999
  970 IF(HRV(2,ICYC).EQ.0.0) GO TO 980
      HRV(3,ICYC)=HRV(1,ICYC)/HRV(2,ICYC)
  980 HRV(4,ICYC)=HRV(4,ICYC)/IB
      IB=0
  999 CONTINUE
      RETURN
      END
```

```
FORTRAN IV      V02.5-2    Thu 10-Jun-82 16:50:41                PAGE 001

              SUBROUTINE IEXAM2(IBEAT)
              LOGICAL*1 COND(6)
              INTEGER*2 OSIGN,OLDHR,IHR(2,1000),ITEMS(13)
              REAL*4 HRV(4,99),LHR,LVOLT,MHR,MVOLT,LS
              COMMON UHR,UVOLT,LHR,LVOLT,MHR,MVOLT,IHR,COND,
             *ITICK,IREP,ICOND,IFLAG1,LS,US,ZERO,ITEMS,HRV,
             *ICHHR,ICHSE,ICHST,ICHPR,ICHRE,ICHED,LUNCRT,LUNPRN
              ICYC=0
              IB=0
              HRV(1,1)=0.
              HRV(2,1)=0.
              HRV(3,1)=0.
              HRV(4,1)=0.
              DO 999 I=1,IBEAT
              IB=IB+1
              IF(ICYC.EQ.1) GO TO 900
              ICYC=1
              OLDHR=IHR(2,I)
              OSIGN=0
              HR=OLDHR*0.1
              HRO=HR
              IFLAG=0
              GO TO 960
        900   NEWHR=IHR(2,I)
              HR=NEWHR*0.1
              HRD=HR-HRO
              IF(IFLAG.EQ.1) GO TO 920
              IF(HRD) 910,960,910
        910   IFLAG=1
        920   IF(HRD) 930,960,940
        930   NSIGN=-1
              HRV(1,ICYC)=HRV(1,ICYC)-HRD
              GO TO 950
        940   NSIGN=1
        950   IF(OSIGN.EQ.0) GO TO 952
              IF(OSIGN.NE.NSIGN) HRV(2,ICYC)=HRV(2,ICYC)+1.
        952   OSIGN=NSIGN
              OLDHR=NEWHR
              HRO=HR
        960   HRV(4,ICYC)=HRV(4,ICYC)+HR
              IF(I.EQ.IBEAT) GO TO 970
              GO TO 999
        970   IF(HRV(2,ICYC).EQ.0.0) GO TO 980
              HRV(3,ICYC)=HRV(1,ICYC)/HRV(2,ICYC)
        980   HRV(4,ICYC)=HRV(4,ICYC)/IB
        999   CONTINUE
              WRITE(LUNPRN,1) (HRV(I,ICYC),I=1,4)
        1     FORMAT(' '//
             *' OVERALL NEUM. ',T20,F16.2/
             *'         DENO. ',T20,F16.0/
             *'         HRV.',T20,F16.5/
             *'         HR',T20,F16.4)
              REWIND LUNPRN
              RETURN
              END
```

```
0001          SUBROUTINE LOOP(IBEAT)
0002          INTEGER*4 JTIME
0003          INTEGER*2 IHR(2,1000),ITEMS(13),YESNO2,ON,OFF,
             *SWITCH,OLDHR
0004          LOGICAL*1 COND(6)
0005          REAL*4 LHR,LVOLT,MHR,MVOLT,LS,HRV(4,99)
0006          COMMON UHR,UVOLT,LHR,LVOLT,MHR,MVOLT,IHR,COND,
             *ITICK,IREP,ICOND,IFLAG1,LS,US,ZERO,ITEMS,HRV,
             *ICHHR,ICHSE,ICHST,ICHPR,ICHRE,ICHED,LUNCRT,LUNPRN
0007          TICK=ITICK
0008     690  CALL IFILE
0009          WRITE(LUNCRT,701)
0010     701  FORMAT(' '/' TO START SAMPLING PRESS START SWITCH'/)
0011     700  CALL INITIA
0012          ON=1
0013          OFF=-1
0014          IFLAGT=0
0015          IFLAGS=0
0016          IFLAGP=0
0017          IFLAGE=0
0018          LASTSE=OFF
0019          IBEAT=0
0020          OLDHR=0
0021          ID=0
0022          IAHR=0
0023          ISTOP=0
0024          IF(IFLAG1.EQ.0) ID=1
0026          CALL NAP(ICHST,ZERO)
0027     705  IF(IFLAG1.EQ.0) GO TO 720
0029          IF(IFLAGS.EQ.1) GO TO 708
0031          IFLAGS=1
0032          CALL NAP(ICHSE,ZERO)
0033     708  IF(SWITCH(ICHSE,ZERO).EQ.OFF) GO TO 710
0035          IF(LASTSE.EQ.ON) GO TO 720
0037          LASTSE=ON
0038          ID=ID+1
0039          IF(ID.GT.IREP) GO TO 900
0041          IF(IFLAGE.EQ.1) GO TO 900
0043          GO TO 720
0044     710  LASTSE=OFF
0045          GO TO 720
0046     718  IFLAGT=0
0047     720  IF(SWITCH(ICHPR,ZERO).EQ.ON) GO TO 718
0049          IF(SWITCH(ICHRE,ZERO).EQ.OFF) GO TO 730
0051          WRITE(LUNCRT,200)
0052     200  FORMAT(' '/'  A RESET REQUEST HAS BEEN ACCEPTED'/)
0053     722  WRITE(LUNCRT,201)
0054     201  FORMAT(' '/'  SAME EXPERIMENTAL CONDITION ?  <YES OR NO>'/)
0055          IF(YESNO2(LUNCRT)) 722,690,725
0056     725  WRITE(LUNCRT,203)
0057     203  FORMAT(' '/' TO RESTART, PRESS START-SWITCH'/)
0058          GO TO 700
0059     730  IF(SWITCH(ICHED,ZERO).EQ.ON) IFLAGE=1
0061          IF((IFLAGE.EQ.1).AND.(IFLAG1.EQ.0)) GO TO 900
0063          IF(IFLAGT.EQ.1) GO TO 790
0065          IFLAGT=1
```

```
      CALL GTIM(JTIME)
      CALL CVTTIM(JTIME,IH,IM,IS,IT)
790   IT=IT+ITICK
      IF(IT.LE.59) GO TO 800
      IT=IT-60
      IS=IS+1
      IF(IS.LE.59) GO TO 800
      IS=0
      IM=IM+1
      IF(IM.LE.59) GO TO 800
      IH=IH+1
      IM=0
      IF(IH.LE.23) GO TO 800
      IH=0
800   JTIME=IUNTIL(IH,IM,IS,IT)
      DIFF=IADC(ICHHR)-ZERO
      IF(DIFF)804,803,802
802   HR=MHR-DIFF*LS
      GO TO 805
803   HR=MHR
      GO TO 805
804   HR=MHR+DIFF*US
805   NEWHR=(HR+0.05)*10.0
      IF(IABS(OLDHR-NEWHR).GT.90) GO TO 812
811   ICOUNT=ICOUNT+1
      IAHR=IAHR+NEWHR
      NEWHR=IAHR/ICOUNT
      ELAPSD=(TICK+1.5)*ICOUNT/60.
      CHR=NEWHR
      CHR=CHR*0.1
      XLIMIT=60./CHR
      IF(ELAPSD.LE.XLIMIT) GO TO 705
812   IBEAT=IBEAT+1
      IF(IBEAT.GE.999) ISTOP=1
      IAHR=0
      ICOUNT=0
820   IHR(1,IBEAT)=ID
      IHR(2,IBEAT)=NEWHR
      OLDHR=NEWHR
      WRITE(LUNCRT,1) ID,IBEAT,HR
1     FORMAT(' ',2I4,F8.0)
      IF(ISTOP.EQ.1) GO TO 850
      GO TO 705
850   IBELL=8199
      WRITE(LUNCRT,860)IBELL
860   FORMAT(' ',A1/' NO. OF BEATS HAS REACHED TO 999.'/
     *' PROGRAM STOPED COLLECTING DATA.'//)
900   RETURN
      END
```

```
FORTRAN IV      V02.5-2     Thu 10-Jun-82 16:51:51              PAGE 001

        FUNCTION SWITCH(ICHAN,ZERO)
        INTEGER*2 SWITCH
        SWITCH=-1
        IF(IADC(ICHAN).GE.ZERO+500.) SWITCH=1
        RETURN
        END
```

```
      SUBROUTINE IASS
      INTEGER*2 IHR(2,1000),ITEMS(13)
      LOGICAL*1 COND(6),EXTENT(4)
      REAL*4 LHR,HRV(4,99),LVOLT,MHR,MVOLT,LS
      COMMON UHR,UVOLT,LHR,LVOLT,MHR,MVOLT,IHR,COND,
     *ITICK,IREP,ICOND,IFLAG1,LS,US,ZERO,ITEMS,HRV,
     *ICHHR,ICHSE,ICHST,ICHPR,ICHRE,ICHED,LUNCRT,LUNPRN
      TYPE 131
131   FORMAT(' '/' ENTER LUNCRT'/)
      ACCEPT 132,LUNCRT
132   FORMAT(I2)
      TYPE 133
133   FORMAT(' '/' ENTER LUNPRN'/)
      ACCEPT 134,LUNPRN
134   FORMAT(I2)
      TYPE 135
135   FORMAT(' '/' AFTER THIS MESSAGE THE CONTROL OF THIS',
     *' PROGRAM IS MOVED TO THE CRT.'////' BYE'///)
      RETURN
      END
```

```
        SUBROUTINE NAP(ICHAN,ZERO)
 1      IF(IADC(ICHAN).LT.ZERO+500.) GO TO 1
        RETURN
        END
```

```
FORTRAN IV        V02.5-2     Thu 10-Jun-82 16:52:03                PAGE 001

              SUBROUTINE YESNO(ANSWER)
      C       ANSWER=1  WHEN ANSWER IS YES
      C       ANSWER=0  WHEN ANSWER IS NO
      C       ANSWER=-1  WHEN ANSWER IS INVALID
              INTEGER*2 ANSWER,YESNO
              LOGICAL*1 ANS(11),Y,E,S,N,O,BLANK
              DATA Y/'Y'/,E/'E'/,S/'S'/,N/'N'/,O/'O'/,BLANK/' '/,IBELL/8199/
              ANS(11)=BLANK
              ACCEPT 201,(ANS(I),I=1,10)
        201   FORMAT(10A1)
              DO 1 I=1,10
              IF(ANS(I).EQ.BLANK) GO TO 1
              IF((ANS(I).EQ.N).AND.(ANS(I+1).EQ.O).AND.(ANS(I+2).EQ.BLANK)
             *) GO TO 2
              IF((ANS(I).EQ.Y).AND.(ANS(I+1).EQ.E).AND.(ANS(I+2).EQ.S)
             *.AND.(ANS(I+3).EQ.BLANK)) GO TO 3
              GO TO 200
        1     CONTINUE
        200   TYPE 102,IBELL,(ANS(II),II=1,10)
        102   FORMAT(' ',A1/' ',10A1,' : INVALID')
              ANSWER=-1.
              RETURN
        2     ANSWER=0.
              RETURN
        3     ANSWER=1.
              RETURN
              END
```

```
      FUNCTION YESNO2(LUNCRT) .
      INTEGER*2 YESNO2
      LOGICAL*1 ANS(11),Y,E,S,N,O,BLANK
      DATA Y/'Y'/,E/'E'/,S/'S'/,N/'N'/,O/'O'/,BLANK/' '/,IBELL/8199/
      ANS(11)=BLANK
      READ(LUNCRT,201) (ANS(I),I=1,10)
201   FORMAT(10A1)
      DO 1 I=1,10
      IF(ANS(I).EQ.BLANK) GO TO 1
      IF((ANS(I).EQ.N).AND.(ANS(I+1).EQ.O).AND.(ANS(I+2).EQ.BLANK)
     *) GO TO 2
      IF((ANS(I).EQ.Y).AND.(ANS(I+1).EQ.E).AND.(ANS(I+2).EQ.S)
     *.AND.(ANS(I+3).EQ.BLANK)) GO TO 3
      GO TO 200
1     CONTINUE
200   TYPE 102,IBELL,(ANS(II),II=1,10)
102   FORMAT(' ',A1/' ',10A1,' : INVALID')
      YESNO2=-1.
      RETURN
2     YESNO2=0.
      RETURN
3     YESNO2=1.
      RETURN
      END
```

```
      SUBROUTINE INITIA
      INTEGER*2 IHR(2,1000),ITEMS(13),YESNO2,ON,OFF,YESNO,ANS,
     *SWITCH,OLDHR
      LOGICAL*1 COND(6),EXTENT(4)
      REAL*4 LHR,LVOLT,MHR,MVOLT,LS,HRV(4,99)
      COMMON UHR,UVOLT,LHR,LVOLT,MHR,MVOLT,IHR,COND,
     *ITICK,IREP,ICOND,IFLAG1,LS,US,ZERO,ITEMS,HRV,
     *ICHHR,ICHSE,ICHST,ICHPR,ICHRE,ICHED,LUNCRT,LUNPRN
      DO 2 I=1,4
      DO 2 J=1,99
      HRV(I,J)=0.0
    2 CONTINUE
      DO 3 I=1,2
      DO 3 J=1,1000
      IHR(I,J)=0
    3 CONTINUE
      RETURN
      END
```

APPENDIX E.2

The Computer Program for The PDP 11/03 To Communicate with WYLBUR

```
0001          PROGRAM WYLBUR
0002          IMPLICIT INTEGER (C,N,R,X,Q,S)
0003          COMMON RCSR1,RBUF1,XCSR1,XBUF1,RCSR2,RBUF2,XCSR2,XBUF2,READY,
             *NEWCHA
0004          LOGICAL*1 WHAT(18),WNAME(20),FET(10)
0005          INTEGER FILE(10500)
0006          COMMON/BIG/ FILE
0007          DATA FET/'F','E','T',' ','*',' ','C','L','E',"015/,
             *WHAT/'W','h','a','t',' ','d','o',' ','y','o','u',' ',
             *'m','e','a','n',' ','?'/
        C
0008          CALL COMDAT
0009    900   IESCS=0
0010          CALL WYLOOP(IGOTO)
0011          GO TO(1100,1050,3000,4000,5000,6000,1010,1200) IGOTO
0012    1010  DO 1015 I=1,18
0013          NEWCHA=WHAT(I)
0014          CALL SNDCRT
0015    1015  CONTINUE
0016          NEWCHA="7
0017          CALL SNDCRT
0018          NEWCHA="215
0019          CALL SNDWYL
0020          GO TO 900
0021    1050  IESCS=1
0022    1100  NEWCHA="012
0023          CALL SNDCRT
0024          NEWCHA="215
0025          CALL SNDCRT
0026          CALL IPOKEB(RCSR1,"100)            ! ENABLE INTERRUPT SERVICE
0027          CALL ASSIGN(1,,-1)
0028          CALL IPOKEB(RCSR1,0)               ! DISABLE INTERRUPT SERVICE
        C
0029          IF(IESCS.NE.0) GO TO 2000
0031          CALL RCV
0032          GO TO 900
        C                                                ! ESC S
0033    2000  CALL SEND
0034          GO TO 900
        C
0035    1200  CALL ACC
0036          GO TO 900
        C
0037    3000  DO 3010 I=1,10
0038          NEWCHA=FET(I)
0039          CALL SNDWYL
0040          CALL SNDCRT
0041    3010  CONTINUE
0042          I=0
0043    3020  CALL FRMWYL
0044          CALL SNDCRT
0045          IF(NEWCHA.EQ."21) GO TO 3030
0047          I=I+1
0048          GO TO 3020
0049    3030  IF(I.GT.6) GO TO 900
0051          NEWCHA="314
```

```
      CALL SNDCRT
      CALL SNDWYL
      NEWCHA="215
      CALL SNDCRT
      CALL SNDWYL
      GO TO 900
C
4000  IF(NOCHA.EQ.0) CALL WNAM(WNAME,20,NOCHA)
      CALL GO(WNAME,20,NOCHA)
      GO TO 3000
C
5000  CALL WNAM(WNAME,20,NOCHA)
      GO TO 900
C
6000  IF(NOCHA.EQ.0) CALL WNAM(WNAME,20,NOCHA)
      CALL USE(WNAME,20,NOCHA)
      GO TO 900
      END
```

```
      C
0001          SUBROUTINE NAP
0002          IMPLICIT INTEGER (R,X)
0003          COMMON RCSR1,RBUF1,XCSR1,XBUF1,RCSR2,RBUF2,XCSR2,XBUF2,READY,
             *NEWCHA
0004  1       CALL FRMWYL
0005          IF(NEWCHA.EQ."21) GO TO 2
0007          CALL SNDCRT
0008          GO TO 1
0009  2       RETURN
0010          END
```

```
      C
0001          SUBROUTINE SNDCRT
0002          IMPLICIT INTEGER (R,X)
0003          COMMON RCSR1,RBUF1,XCSR1,XBUF1,RCSR2,RBUF2,XCSR2,XBUF2,READY,
             *NEWCHA
0004    10    IF(IPEEKB(XCSR1).LT.READY) GO TO 10
0006          CALL IPOKEB(XBUF1,NEWCHA)
0007          RETURN
0008          END
```

```
      C
              SUBROUTINE SNDWYL
              IMPLICIT INTEGER (R,X)
              COMMON RCSR1,RBUF1,XCSR1,XBUF1,RCSR2,RBUF2,XCSR2,XBUF2,READY,
             *NEWCHA
      60      IF(IPEEK(XCSR2).LT.READY) GO TO 60    ! IF WYL NOT READY LOOP
              CALL IPOKEB(XBUF2,NEWCHA)             ! SEND THE CHAR. TO WYL.
              RETURN
              END
```

```
C
      SUBROUTINE FRMWYL
      IMPLICIT INTEGER (R,X)
      COMMON RCSR1,RBUF1,XCSR1,XBUF1,RCSR2,RBUF2,XCSR2,XBUF2,READY,
     *NEWCHA
10    IF(IPEEKB(RCSR2).LT.READY) GO TO 10 ! IF WYL. HAS NOT SENT
      NEWCHA=IPEEKB(RBUF2)                ! YES THEN READ IT
      RETURN
      END
```

```
C
      SUBROUTINE WYLOOP(IGOTO)
      IMPLICIT INTEGER (C,N,R,X,Q,S)
      COMMON RCSR1,RBUF1,XCSR1,XBUF1,RCSR2,RBUF2,XCSR2,XBUF2,READY,
     *NEWCHA
      LOGICAL*1 ESC(4)
      DATA ESC/'E','S','C',' '/
      CTRLC="203
      CTRLD="204
      LF="012
      CR="215
      IESC="233
      A="301
      F="306
      G="307
      L="314
      N="316
      R="322
      S="323
      U="325
C
      CALL IPOKE(RCSR1,0)
 900  IF(IPEEKB(RCSR1).LT.READY) GO TO 950
      NEWCHA=IPEEKB(RBUF1)
      IF(NEWCHA.EQ.CTRLC) CALL EXIT
      IF(NEWCHA.EQ.CTRLD) GO TO 990
      IF(NEWCHA.EQ.IESC) GO TO 1000
      IF(NEWCHA.EQ."377) NEWCHA="210
      CALL SNDCRT
      CALL SNDWYL
 950  IF(IPEEKB(RCSR2).LT.READY) GO TO 900
      NEWCHA=IPEEKB(RBUF2)
      CALL SNDCRT
      GO TO 900
C
 990  NEWCHA=CTRLD
      DO 995 I=1,5
      CALL SNDWYL
 995  CONTINUE
      GO TO 900
C
 1000 IF(IPEEKB(RCSR1).LT.READY) GO TO 1000
      NEWCHA=IPEEKB(RBUF1)
      IF(NEWCHA.EQ.A) GO TO 1200
      LSTCHA=NEWCHA
      DO 1005 I=1,4
      NEWCHA=ESC(I)
      CALL SNDCRT
 1005 CONTINUE
      NEWCHA=LSTCHA
      CALL SNDCRT
      NEWCHA=LF
      CALL SNDCRT
      NEWCHA=CR
      CALL SNDCRT
      NEWCHA=LSTCHA
```

```
0060          IGOTO=0
0061          IF(NEWCHA.EQ.R) IGOTO=1
0063          IF(NEWCHA.EQ.S) IGOTO=2
0065          IF(NEWCHA.EQ.F) IGOTO=3
0067          IF(NEWCHA.EQ.G) IGOTO=4
0069          IF(NEWCHA.EQ.N) IGOTO=5
0071          IF(NEWCHA.EQ.U) IGOTO=6
0073          IF(IGOTO.EQ.0) IGOTO=7
0075          RETURN
0076    1200  IGOTO=8
0077          RETURN
0078          END
```

```
FORTRAN IV      V02.5-2     Thu 10-Jun-82 17:07:25              PAGE 001

      SUBROUTINE COMDAT
      IMPLICIT INTEGER (C,N,R,X,Q,S)
      COMMON RCSR1,RBUF1,XCSR1,XBUF1,RCSR2,RBUF2,XCSR2,XBUF2,READY,
     *NEWCHA
      RCSR1="177560
      RBUF1="177562
      XCSR1="177564
      XBUF1="177566
      RCSR2="175610
      RBUF2="175612
      XCSR2="175614
      XBUF2="175616
      READY="200
      RETURN
      END
```

```
C
      SUBROUTINE GO(WNAME,I1,NOCHA)
      IMPLICIT INTEGER (C,N,R,X,Q,S)
      COMMON RCSR1,RBUF1,XCSR1,XBUF1,RCSR2,RBUF2,XCSR2,XBUF2,READY,
     *NEWCHA
      LOGICAL*1 WNAME(I1),RUN(8),SAV(4),REP(5)
      DATA RUN/'R','U','N',' ','H','O','L',"215/,
     *SAV/'S','A','V',' '/,
     *REP/' ','R','E','P',"215/
      DO 4010 I=1,8
      NEWCHA=RUN(I)
      CALL SNDCRT
      CALL SNDWYL
 4010 CONTINUE
      CALL NAP
      DO 4020 I=1,4
      NEWCHA=SAV(I)
      CALL SNDCRT
      CALL SNDWYL
 4020 CONTINUE
      DO 4030 I=1,NOCHA
      NEWCHA=WNAME(I)
      CALL SNDCRT
      CALL SNDWYL
 4030 CONTINUE
      DO 4040 I=1,5
      NEWCHA=REP(I)
      CALL SNDCRT
      CALL SNDWYL
 4040 CONTINUE
      CALL NAP
      RETURN
      END
```

```
      SUBROUTINE USE(WNAME,I2,NOCHA)
      IMPLICIT INTEGER (C,N,R,X,Q,S)
      COMMON RCSR1,RBUF1,XCSR1,XBUF1,RCSR2,RBUF2,XCSR2,XBUF2,READY,
     *NEWCHA
      LOGICAL*1 WNAME(I2),U(4),CLE(4)
      DATA U/'U','S','E',' '/,
     *CLE/'C','L','E',"215/
      DO 6010 I=1,4
      NEWCHA=U(I)
      CALL SNDCRT
      CALL SNDWYL
6010  CONTINUE
      DO 6020 I=1,NOCHA
      NEWCHA=WNAME(I)
      CALL SNDCRT
      CALL SNDWYL
6020  CONTINUE
      DO 6030 I=1,4
      NEWCHA=CLE(I)
      CALL SNDCRT
      CALL SNDWYL
6030  CONTINUE
      CALL NAP
      NEWCHA="114
      CALL SNDCRT
      CALL SNDWYL
      NEWCHA="215
      CALL SNDCRT
      CALL SNDWYL
      RETURN
      END
```

```
      SUBROUTINE WNAM(WNAME,I2,NOCHA)
      IMPLICIT INTEGER (C,N,R,X,Q,S)
      COMMON RCSR1,RBUF1,XCSR1,XBUF1,RCSR2,RBUF2,XCSR2,XBUF2,READY,
     *NEWCHA
      LOGICAL*1 NAME(18),WNAME(I2)
      DATA NAME/'W','Y','L','B','U','R',' ','f','i','l','e',
     *'n','a','m','e',' ','?',' '/
      NEWCHA="212
      CALL SNDCRT
      NEWCHA="215
      CALL SNDCRT
      DO 5010 I=1,18
      NEWCHA=NAME(I)
      CALL SNDCRT
5010  CONTINUE
      NOCHA=1
5020  IF(IPEEKB(RCSR1).LT.READY) GO TO 5020
      NEWCHA=IPEEKB(RBUF1)
      IF(NEWCHA.EQ."215) GO TO 5030
      WNAME(NOCHA)=NEWCHA
      NOCHA=NOCHA+1
      CALL SNDCRT
      GO TO 5020
5030  WNAME(NOCHA)="240
      NEWCHA="212
      CALL SNDCRT
      NEWCHA="215
      CALL SNDCRT
      CALL SNDWYL
      CALL NAP
      RETURN
      END
```

```
      SUBROUTINE SEND
      IMPLICIT INTEGER (C,N,R,X,Q,S)
      COMMON RCSR1,RBUF1,XCSR1,XBUF1,RCSR2,RBUF2,XCSR2,XBUF2,READY,
     *NEWCHA
      IWORD=0
      IADRSW=IADDR(IWORD)
      IADRSB=IADRSW+1
      IREC=1
      DEFINE FILE 1 (10500,1,U,IREC)
      NEWCHA="103
      CALL SNDCRT
      CALL SNDWYL
      NEWCHA="215
      CALL SNDCRT
      CALL SNDWYL
      CALL NAP
      DO 2100 I=1,11000
      READ(1'IREC) IWORD
      IF(IWORD.EQ.0) GO TO 2200
      NEWCHA=IPEEKB(IADRSW)
      CALL SNDCRT
      CALL SNDWYL
      IF(NEWCHA.EQ."12) CALL NAP
      NEWCHA=IPEEKB(IADRSB)
      IF(NEWCHA.EQ.0) GO TO 2200
      CALL SNDCRT
      CALL SNDWYL
      IF(NEWCHA.EQ."12) CALL NAP
 2100 CONTINUE
 2200 NEWCHA="215
      CALL SNDWYL
      CALL SNDCRT
      CALL NAP
      CALL CLOSE(1)
      NEWCHA="4
      CALL SNDWYL
      RETURN
      END
```

```
      SUBROUTINE RCV
      IMPLICIT INTEGER (C,N,R,X,Q,S)
      COMMON RCSR1,RBUF1,XCSR1,XBUF1,RCSR2,RBUF2,XCSR2,XBUF2,READY,
     *NEWCHA
      INTEGER*2 FILE(10500)
      COMMON/BIG/FILE
      LOGICAL*1 MESSG1(6)
      DATA MESSG1/"114,"040,"125,"116,"116,"015/
      IZERO=0
      IWORD=0
      IADRSW=IADDR(IWORD)
      IADRSB=IADRSW+1
      DO 1 I=1,6                                        ! ESC R
      NEWCHA=MESSG1(I)
      CALL SNDWYL
      CALL SNDCRT
    1 CONTINUE
C
      LREC=1
      ICOUNT=1
    2 CALL FRMWYL
      IF(NEWCHA.EQ."215) GO TO 3
      IF(NEWCHA.EQ."012) GO TO 3
      GO TO 110
    3 CALL SNDCRT
      GO TO 2
  100 CALL FRMWYL
      IF(LSTCHA.EQ."012.AND.NEWCHA.EQ."077) GO TO 300
  110 ICOUNT=ICOUNT*-1
      IF(ICOUNT.EQ.-1) GO TO 200
      CALL IPOKE(IADRSW,LSTCHA)
      CALL IPOKEB(IADRSB,NEWCHA)
      FILE(LREC)=IWORD
      LREC=LREC+1
  200 LSTCHA=NEWCHA
      CALL SNDCRT
      GO TO 100
  300 IEVEN=0
      IF(ICOUNT.EQ.1) GO TO 310
      CALL IPOKE(IADRSW,LSTCHA)
      CALL IPOKEB(IADRSB,0)
      FILE(LREC)=IWORD
      LREC=LREC+1
      IEVEN=1
  310 IREC=1
      KREC=LREC-1
      KKREC=KREC+256
      DEFINE FILE 1 (KKREC,1,U,IREC)
      DO 350 I=1,KREC
      WRITE(1'IREC) FILE(I)
  350 CONTINUE
      NOC=KREC*2
      IF(IEVEN.EQ.1) NOC=NOC-1
      TYPE 360,NOC
  360 FORMAT('0','NO. OF CHARACTERS TRANSFERRED : ',I5,
     *'   <includes CR and LF>'/)
```

```
      IREST=257-MOD(IREC,256)
      DO 400 I=1,IREST
      WRITE(1'IREC) IZERO
400   CONTINUE
      CALL CLOSE(1)
      NEWCHA="212
      CALL SNDCRT
      NEWCHA="215
      CALL SNDCRT
      NEWCHA="215
      CALL SNDWYL
      CALL NAP
      RETURN
      END
```

```
      SUBROUTINE ACC
      IMPLICIT INTEGER (C,N,R,X,Q,S)
      COMMON RCSR1,RBUF1,XCSR1,XBUF1,RCSR2,RBUF2,XCSR2,XBUF2,READY,
     *NEWCHA
      LOGICAL*1 ACC(11),KEY(4),VOL(15),TER(4),TIM(10)
      DATA ACC/'?','?','?','?','?','?','?','?','?','?',"015/,
     *KEY/'?','?','?',"015/,
     *TER/"113,"60,"60,"015/,
     *VOL/'S','E','T',' ','V','O','L',' ','D','I','S','K',"60,"63,"015/,
     *TIM/'S','E','T',' ','N','O','T','I','M',"015/
      DO 1210 I=1,11                                    ! ESC A
      NEWCHA=ACC(I)
      CALL SNDWYL
 1210 CONTINUE
      CALL NAP
      DO 1230 I=1,4
      NEWCHA=KEY(I)
      CALL SNDWYL
 1230 CONTINUE
      CALL NAP
      DO 1240 I=1,4
      NEWCHA=TER(I)
      CALL SNDWYL
      CALL SNDCRT
 1240 CONTINUE
      CALL NAP
      DO 1250 I=1,15
      NEWCHA=VOL(I)
      CALL SNDWYL
      CALL SNDCRT
 1250 CONTINUE
      CALL NAP
      DO 1260 I=1,10
      NEWCHA=TIM(I)
      CALL SNDWYL
      CALL SNDCRT
 1260 CONTINUE
      RETURN
      END
```

APPENDIX F

Tables for The Heart Rate analysis

1. Standardized Heart Rate Data

2. The Results of The Analysis of Variance for HR

3. The Results of The analysis of variance for HR After insignificant factors have been pooled

4. The Results of The Analysis of Variance Using Factors DIS and CLE

5. The Results of The Analysis of Variance for The model with SUB AND DIS

	AR	AL	DIS	CLE	SUB1	SUB2	SUB3	SUB4	SUB5	SUB6	SUB7	SUB8	SUB9
1	0	0	150	0.65	2.4	2.0	69.0	38.5	44.2	47.8	15.4	26.9	17.9
2	0	0	150	8.65	0.0	25.8	0.0	85.6	47.9	60.0	63.1	40.6	18.5
3	0	0	350	0.65	63.2	62.7	76.0	48.4	66.5	83.4	63.8	47.7	88.5
4	0	0	350	8.65	54.6	53.5	74.0	86.6	25.3	96.2	90.2	57.5	73.6
5	30	0	150	0.65	46.2	88.6	55.3	20.6	15.9	63.3	34.8	13.4	22.0
6	30	0	150	8.65	51.1	7.0	37.4	18.7	52.3	72.8	22.0	82.8	48.0
7	30	0	350	0.65	92.4	39.0	100.0	64.6	25.2	58.4	52.6	64.2	95.4
8	30	0	350	8.65	61.0	16.5	61.7	100.0	57.4	78.2	70.5	79.8	100.0
9	60	0	150	0.65	21.5	31.5	69.6	31.7	100.0	53.7	82.0	67.1	32.3
10	60	0	150	8.65	32.1	100.0	51.6	35.6	27.2	85.4	26.5	61.0	73.8
11	60	0	350	0.65	23.2	15.3	47.5	29.6	29.2	63.5	33.9	77.2	77.7
12	60	0	350	8.65	75.7	48.7	94.6	15.4	19.8	74.2	27.8	44.3	50.5
13	0	30	150	0.65	32.4	53.9	50.0	0.0	23.1	80.0	72.1	34.6	87.8
14	0	30	150	8.65	36.1	6.2	15.7	40.5	40.5	2.5	22.3	0.0	83.1
15	0	30	350	0.65	29.5	19.3	89.8	68.3	12.5	83.4	18.0	77.5	33.2
16	0	30	350	8.65	15.4	23.0	61.0	72.6	66.0	74.0	69.3	100.0	53.1
17	30	30	150	0.65	49.1	63.3	52.3	31.5	17.5	64.6	23.0	22.9	4.8
18	30	30	150	8.65	63.3	0.0	62.4	34.6	57.8	49.1	80.1	48.8	24.5
19	30	30	350	0.65	58.9	70.4	88.2	20.6	55.5	91.2	99.9	70.9	5.8
20	30	30	350	8.65	33.2	34.9	64.1	67.1	54.1	91.3	35.6	94.8	59.4
21	60	30	150	0.65	20.8	56.0	21.7	47.9	44.3	100.0	38.8	39.1	82.7
22	60	30	150	8.65	53.3	59.5	49.7	13.4	49.5	40.6	96.3	64.0	70.1
23	60	30	350	0.65	44.1	9.3	40.5	77.6	67.5	87.5	61.8	58.5	40.4
24	60	30	350	8.65	65.5	23.9	36.0	19.8	61.0	88.4	100.0	26.7	33.9
25	0	60	150	0.65	57.5	14.4	94.8	66.3	42.3	57.8	30.0	92.6	73.7
26	0	60	150	0.65	100.0	60.5	49.1	42.0	61.4	47.7	0.0	60.7	90.7
27	0	60	350	0.65	65.0	15.1	67.9	58.4	46.6	83.4	60.9	43.5	72.7
28	0	60	350	8.65	57.9	68.9	44.6	48.8	48.8	80.2	16.5	69.7	41.1
29	30	60	150	0.65	16.6	19.1	44.4	30.2	58.5	60.1	83.2	43.1	43.0
30	30	60	150	8.65	36.6	1.7	46.6	51.9	64.8	91.6	9.3	32.7	0.0
31	30	60	350	0.65	32.2	46.1	90.3	29.6	15.8	65.3	26.8	37.1	78.5
32	30	60	350	8.65	22.2	96.6	87.3	81.5	49.7	78.7	23.9	56.7	87.6
33	60	60	150	0.65	49.5	23.1	27.3	12.6	41.7	74.7	65.6	20.0	41.4
34	60	60	150	8.65	70.3	58.7	47.5	19.1	80.9	0.0	92.8	84.8	34.6
35	60	60	350	0.65	53.6	68.0	47.6	65.8	0.0	72.4	46.6	36.6	29.2
36	60	60	350	8.65	52.5	22.3	68.2	33.7	22.0	83.6	15.3	66.7	24.7

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   1
0:34 SATURDAY, JUNE 12, 1982

ANALYSIS OF VARIANCE PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
SUB	9	1 2 3 4 5 6 7 8 9
TD	4	10.0727 5.116119 6.338511 8.850307
AL	3	0 30 60
AR	3	0 30 60

NUMBER OF OBSERVATIONS IN DATA SET = 324

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   2
0:34 SATURDAY, JUNE 12, 1982

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: HR

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	71	59272.43006174	834.82295862
ERROR	252	163362.31833333	648.26316799
CORRECTED TOTAL	323	222634.74839507	

MODEL F = 1.29   PR > F = 0.0815

R-SQUARE	C.V.	STD DEV	HR MEAN
0.266232	50.2287	25.46101271	50.69012346

SOURCE	DF	ANOVA SS	F VALUE	PR > F
SUB	8	23231.11672840	4.48	0.0001
TD	3	9855.76469137	5.07	0.0022
SUB*TD	24	13459.84030863	0.87	0.6499
AL	2	155.60598766	0.12	0.8870
SUB*AL	16	7500.33234567	0.72	0.7695
AR	2	290.42302470	0.22	0.7995
SUB*AR	16	4779.34697530	0.46	0.9632

ANALYSIS OF VARIANCE PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
SUB	9	1 2 3 4 5 6 7 8 9
TD	4	10.0727 5.116119 6.338511 8.850307

NUMBER OF OBSERVATIONS IN DATA SET = 324

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   2

0:55 SATURDAY, JUNE 12, 1982

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: HR

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	11	33086.88141977	3007.89831089
ERROR	312	189547.86697530	607.52521466
CORRECTED TOTAL	323	222634.74839507	

MODEL F =	4.95		PR > F = 0.0001
R-SQUARE	C.V.	STD DEV	HR MEAN
0.148615	48.6249	24.64802659	50.69012346

SOURCE	DF	ANOVA SS	F VALUE	PR > F
SUB	8	23231.11672840	4.78	0.0001
TD	3	9855.76469137	5.41	0.0014

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE HR

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05   DF=312   MS=607.525

GROUPING	MEAN	N	TD
A	57.548148	81	6.338511
A			
A	54.619753	81	10.0727
B	46.008642	81	5.116119
B			
B	44.583951	81	8.850307

ANALYSIS OF VARIANCE PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
SUB	9	1 2 3 4 5 6 7 8 9
DIS	2	150 350
CLE	2	0.65 8.65

NUMBER OF OBSERVATIONS IN DATA SET = 324

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: HR

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	35	46546.72172840	1329.90633510
ERROR	288	176088.02666667	611.41675926
CORRECTED TOTAL	323	222634.74839507	

MODEL F =	2.18		PR > F = 0.0003
R-SQUARE	C.V.	STD DEV	HR MEAN
0.209072	48.7804	24.72684289	50.69012346

SOURCE	DF	ANOVA SS	F VALUE	PR > F
SUB	8	23231.11672840	4.75	0.0001
DIS	1	9426.25234568	15.42	0.0001
SUB*DIS	8	7384.71043210	1.51	0.1533
CLE	1	383.72456790	0.63	0.4289
SUB*CLE	8	3738.36598765	0.76	0.6346
DIS*CLE	1	45.78777778	-0.07	0.7845
SUB*DIS*CLE	8	2336.76388889	0.48	0.8716

ANALYSIS OF VARIANCE PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
SUB	9	1 2 3 4 5 6 7 8 9
DIS	2	150 350

NUMBER OF OBSERVATIONS IN DATA SET = 324

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: HR

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	9	32657.36907408	3628.59656379
ERRQR	314	189977.37932098	605.02350102
CORRECTED TOTAL	323	222634.74839507	

MODEL F = 6.00   PR > F = 0.0001

R-SQUARE	C.V.	STD DEV	HR MEAN
0.146686	48.5247	24.59722547	50.69012346

SOURCE	DF	ANOVA SS	F VALUE	PR > F
SUB	8	23231.11672840	4.80	0.0001
DIS	1	9426.25234568	15.58	0.0001

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE HR

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05   DF=314   MS=605.024

GROUPING	MEAN	N	DIS
A	56.083951	162	350
B	45.296296	162	150

APPENDIX G.1

The Results of The Analysis of Variance for The HRVI with All The Main Effects

```
NOTE: THE JOB HRVIB HAS BEEN RUN UNDER RELEASE 79.5 OF SAS
      AT THE UNIVERSITY OF WINDSOR (00666).

NOTE: SAS OPTIONS SPECIFIED ARE:
      LS=65


1          DATA;
2          INPUT CNDTN SUB AL AR DIS CLE;
3               X=2.*DIS/CLE;
4               TD=LOG2(X);
5               RETAIN SUB AL AR DIS CLE TD;
6            DO I=1 TO 15;
7               INPUT R L @@;
8               R=R*100.0;
9               L=L*100.0;
10              IF L GE R THEN PT=L;
11              IF L LT R THEN PT=R;
12              OUTPUT;
13           END;
14         DROP I X L R;
15         CARDS;

NOTE: SAS WENT TO A NEW LINE WHEN INPUT STATEMENT
      REACHED PAST THE END OF A LINE.
NOTE: DATA SET WORK.DATA1 HAS 4860 OBSERVATIONS AND 8 VARIABLES.
191 OBS/TRK
NOTE: THE DATA STATEMENT USED 4.53 SECONDS AND 160K.

1312       PROC SORT;
1313       BY SUB AL AR DIS CLE;

NOTE: DATA SET WORK.DATA1 HAS 4860 OBSERVATIONS AND 8 VARIABLES.
191 OBS/TRK
NOTE: THE PROCEDURE SORT USED 3.85 SECONDS AND 282K.

1314       PROC MEANS NOPRINT;
1315       VAR PT;
1316       BY SUB AL AR DIS CLE;
1317       OUTPUT OUT=DATA2
1318       MEAN=MEANPT;
1319       ID SUB AL AR DIS CLE;

NOTE: DATA SET WORK.DATA2 HAS 324 OBSERVATIONS AND 11 VARIABLES.
141 OBS/TRK
NOTE: THE PROCEDURE MEANS USED 3.00 SECONDS AND 164K.

1320       PROC SORT;
1321       BY SUB AL AR DIS CLE;

NOTE: DATA SET WORK.DATA2 HAS 324 OBSERVATIONS AND 11 VARIABLES.
141 OBS/TRK
NOTE: THE PROCEDURE SORT USED 0.75 SECONDS AND 282K.

1322       DATA DATA3;
1323       INPUT CNDTN AL AR DIS CLE;
1324       TD=LOG2(2.0*DIS/CLE);
1325       DO SUB= 1 TO 9;
1326       INPUT HRV @@;
1327       OUTPUT;
1328       END;
1329       CARDS;

NOTE: SAS WENT TO A NEW LINE WHEN INPUT STATEMENT
      REACHED PAST THE END OF A LINE.
NOTE: DATA SET WORK.DATA3 HAS 324 OBSERVATIONS AND 8 VARIABLES. 1
91 OBS/TRK
NOTE: THE DATA STATEMENT USED 0.42 SECONDS AND 162K.

1402       PROC SORT;
1403       BY SUB AL AR DIS CLE;

NOTE: DATA SET WORK.DATA3 HAS 324 OBSERVATIONS AND 8 VARIABLES. 1
91 OBS/TRK
NOTE: THE PROCEDURE SORT USED 0.72 SECONDS AND 282K.
```

```
DATA DATA4;
MERGE DATA2 DATA3;
BY SUB AL AR DIS CLE;
NEWHRV=HRV/MEANPT*100.0;
DROP CNDTN ;
```

NOTE: DATA SET WORK.DATA4 HAS 324 OBSERVATIONS AND 9 VARIABLES. 1
71 OBS/TRK
NOTE: THE DATA STATEMENT USED 0.60 SECONDS AND 162K.

```
PROC ANOVA;
CLASSES SUB TD;
MODEL NEWHRV=SUB TD ;
MEANS TD/DUNCAN;
```

NOTE: THE PROCEDURE ANOVA USED 1.30 SECONDS AND 182K
AND PRINTED PAGES 1 TO 3.

NOTE: SAS INSTITUTE INC.
SAS CIRCLE
BOX 8000
CARY, N.C. 27511

```
              ANALYSIS OF VARIANCE PROCEDURE
                 CLASS LEVEL INFORMATION

CLASS      LEVELS    VALUES

SUB           9      1 2 3 4 5 6 7 8 9

TD            4      10.0727 5.116119 6.338511 8.850307

        NUMBER OF OBSERVATIONS IN DATA SET = 324
```

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: NEWHRV

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	11	418.87603063	38.07963915
ERROR	312	1638.73857741	5.25236724
CORRECTED TOTAL	323	2057.61460804	
MODEL F =	7.25		PR > F = 0.0001

R-SQUARE	C.V.	STD DEV	NEWHRV MEAN
0.203574	52.7941	2.29180436	4.34102550

SOURCE	DF	ANOVA SS	F VALUE	PR > F
SUB	8	292.24541406	6.96	0.0001
TD	3	126.63061657	8.04	0.0001

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE NEWHRV

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05   DF=312   MS=5.25237

GROUPING	MEAN	N	TD
A	5.026034	81	5.116119
A			
A	4.889636	81	6.338511
B	3.851146	81	8.850307
B			
B	3.597286	81	10.0727

APPENDIX G.2

The Results of The Analysis of Variance Using New Model

```
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
                                 9:41 WEDNESDAY, JUNE 9, 1982
NOTE: THE JOB HRV HAS BEEN RUN UNDER RELEASE 79.5 OF SAS
      AT THE UNIVERSITY OF WINDSOR (00666).
NOTE: SAS OPTIONS SPECIFIED ARE:
      LS=65

          DATA;
          INPUT COND AL AR DIS CLE;
          TD=LOG2(2.0*DIS/CLE);
          DO SUB= 1 TO 9;
          INPUT HRV @@;
          OUTPUT;
          END;
          CARDS;

NOTE: SAS WENT TO A NEW LINE WHEN INPUT STATEMENT
      REACHED PAST THE END OF A LINE.
NOTE: DATA SET WORK.DATA1 HAS 324 OBSERVATIONS AND 8 VARIABLES. 1
91 OBS/TRK
NOTE: THE DATA STATEMENT USED 0.43 SECONDS AND 160K.

          PROC ANOVA;
          CLASSES SUB TD AL AR;
          MODEL HRV=SUB TD AL AR SUB*TD SUB*AL SUB*AR;
          MEANS TD AL AR/DUNCAN;
          TEST H=TD E=SUB*TD;
          TEST H=AL E=SUB*AL;
          TEST H=AR E=SUB*AR;

NOTE: THE PROCEDURE ANOVA USED 2.28 SECONDS AND 188K
      AND PRINTED PAGES 1 TO 5.

NOTE: SAS INSTITUTE INC.
      SAS CIRCLE
      BOX 8000
      CARY, N.C. 27511
```

```
      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     1
                                 9:41 WEDNESDAY, JUNE 9, 1982

               ANALYSIS OF VARIANCE PROCEDURE

                  CLASS LEVEL INFORMATION

     CLASS      LEVELS    VALUES

     SUB           9      1 2 3 4 5 6 7 8 9

     TD            4      10.0727 5.116119 6.338511 8.850307

     AL            3      0 30 60

     AR            3      0 30 60

          NUMBER OF OBSERVATIONS IN DATA SET = 324
```

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: HRV

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	71	64537.09750001	908.97320423
ERROR	252	129090.87888889	512.26539242
CORRECTED TOTAL	323	193627.97638889	

MODEL F = 1.77   PR > F = 0.0007

R-SQUARE	C.V.	STD DEV	HRV MEAN
0.333305	50.5845	22.63328064	44.74351852

SOURCE	DF	ANOVA SS	F VALUE	PR > F
SUB	8	23094.91500001	5.64	0.0001
TD	3	7943.01935186	5.17	0.0019
AL	2	3161.19685186	3.09	0.0474
AR	2	533.82907408	0.52	0.5945
SUB*TD	24	17139.32870370	1.39	0.1092
SUB*AL	16	8554.19037036	1.04	0.4111
SUB*AR	16	4110.61814814	0.50	0.9453

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*TD AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
TD	3	7943.01935186	3.71	0.0253

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*AL AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
AL	2	3161.19685186	2.96	0.0808

TESTS OF HYPOTHESES USING THE ANOVA MS FOR SUB*AR AS AN ERROR TERM

SOURCE	DF	ANOVA SS	F VALUE	PR > F
AR	2	533.82907408	1.04	0.3765

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   3
9:41 WEDNESDAY, JUNE 9, 1982

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE HRV

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05   DF=252   MS=512.265

GROUPING		MEAN	N	TD
	A	51.664198	81	6.338511
	A			
B	A	47.190123	81	10.0727
B				
B	C	40.451852	81	8.850307
	C			
	C	39.667901	81	5.116119

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   4
9:41 WEDNESDAY, JUNE 9, 1982

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE HRV

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05   DF=252   MS=512.265

GROUPING		MEAN	N	AL
	A	47.742593	108	30
	A			
B	A	46.052778	108	0
B				
B		40.435185	108	60

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE HRV

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05   DF=252   MS=512.265

GROUPING	MEAN	N	AR
A	45.953704	108	30
A			
A	45.310185	108	0
A			
A	42.966667	108	60