



National Library
of Canada

Bibliothèque nationale
du Canada

Canadian Theses Service

Services des thèses canadiennes

Ottawa, Canada
K1A 0N4

CANADIAN THESES

THÈSES CANADIENNES

NOTICE

The quality of this microfiche is heavily dependent upon the quality of the original thesis submitted for microfilming. Every effort has been made to ensure the highest quality of reproduction possible.

If pages are missing, contact the university which granted the degree.

Some pages may have indistinct print especially if the original pages were typed with a poor typewriter ribbon or if the university sent us an inferior photocopy.

Previously copyrighted materials (journal articles, published tests, etc.) are not filmed.

Reproduction in full or in part of this film is governed by the Canadian Copyright Act, R.S.C. 1970, c. C-30.

**THIS DISSERTATION
HAS BEEN MICROFILMED
EXACTLY AS RECEIVED**

AVIS

La qualité de cette microfiche dépend grandement de la qualité de la thèse soumise au microfilmage. Nous avons tout fait pour assurer une qualité supérieure de reproduction.

S'il manque des pages, veuillez communiquer avec l'université qui a conféré le grade.

La qualité d'impression de certaines pages peut laisser à désirer, surtout si les pages originales ont été dactylographiées à l'aide d'un ruban usé ou si l'université nous a fait parvenir une photocopie de qualité inférieure.

Les documents qui font déjà l'objet d'un droit d'auteur (articles de revue, examens publiés, etc.) ne sont pas microfilmés.

La reproduction, même partielle, de ce microfilm est soumise à la Loi canadienne sur le droit d'auteur, SRC 1970, c. C-30.

**LA THÈSE A ÉTÉ
MICROFILMÉE TELLE QUE
NOUS L'AVONS REÇUE**

THE EFFECT OF A PRELIMINARY TASK
ON A BI-PHASIC AIMING MOVEMENT

by

Tamara Koivu

B.P.H.E. Laurentian University, 1983

Thesis submitted to the School of Graduate Studies
in partial fulfillment of the Degree of Master of
Science in Kinanthropology at the University of
Ottawa.

Ottawa, Ontario



Tamara L. Koivu, Ottawa, Canada, 1986.

Permission has been granted to the National Library of Canada to microfilm this thesis and to lend or sell copies of the film.

The author (copyright owner) has reserved other publication rights, and neither the thesis nor extensive extracts from it may be printed or otherwise reproduced without his/her written permission.

L'autorisation a été accordée à la Bibliothèque nationale du Canada de microfilmer cette thèse et de prêter ou de vendre des exemplaires du film.

L'auteur (titulaire du droit d'auteur) se réserve les autres droits de publication; ni la thèse ni de longs extraits de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation écrite.

ISBN 0-315-33339-1



UNIVERSITÉ D'OTTAWA
UNIVERSITY OF OTTAWA

Abstract

Preplanning has generally been associated with the reaction time interval and the end of this interval signified the end of programming. However, it is possible that preprogramming crosses the reaction time-movement time interval. A bi-phasic movement, with equal movement lengths in each phase, may facilitate the location of response programming through comparison of the two movement times in the two phases. Three conditions, preview, no preview and combination were used to test this concept.

Subjects completed 240 trials at four different target widths. Generally, results indicated that movement time during phase 1 was faster ($\bar{X} = 600$ msec) than movement time during phase 2 ($\bar{X} = 696$ msec). The preview and no preview groups performed equally well over the first part of the primary task but slowed for phase 2 suggesting that performance of the first phase of a bi-phasic movement will disrupt preplanning of the second phase. In addition, the combined group moved slower over the first part of the primary task likely as a result of the preliminary task disrupting preplanning of the primary task.

Table of Contents

CHAPTER I

Introduction	1
Rationale	2
Statement of the Problem	5
Hypothesis	5
Definition of Terms	6

CHAPTER II

Review of Literature	8
Fitts' Law	8
Generality of Fitts' Law	13
Discrete Aiming Movements	15
Decision Component	17
Hick-Hyman Law	17
Psychological Refractory Period	18
Factors That Influence Reaction Time	21
Movement Amplitude and Target Width	21
Complexity of Movement	24
One-choice Tasks	26
Multi-choice Tasks	26
Preview/No preview Tasks	29
A Preliminary Task	31

CHAPTER III

Method	35
Subjects	35
Apparatus and Task	35
Procedure	38
Design	41

CHAPTER IV

Results	43
Primary Task: Reaction Time	43
Primary Task: Movement Time	47
Preliminary Task: Reaction Time	54
Error Rate	56
Questionnaire	57

CHAPTER V

Discussion	59
References	70

APPENDICES

Appendix I	F-ratio Tables	76
Appendix II	Questionnaires	79

List of Figures and Tables

Figure 1	Experimental Design of the Bi-phasic Tapping Task	37
Figure 2	ISI X Condition Interaction	46
Figure 3	Phase X Condition Interactions	49
Figure 4	Phase X Width Interaction	51
Figure 5	Phase X ISI X Condition Interaction	53
Figure 6	Preliminary Task: Reaction Time (Go)	55
Table 1	Reaction times, movement times and standard deviations for the experimental groups	58
Table 2	Movement times of Phase X Width Interaction	58

CHAPTER I

Introduction

While undergoing several modifications to accommodate specific effects, the general underlying precepts of Fitts' Law have remained unchanged since its inception in 1954 and Fitts' Law has proved to be a valuable tool in the investigation of aiming movements. The law offers a means of varying the difficulty of a movement task in an organized manner by altering the parameters of movement precision and amplitude. These parameter variations require time for the subject to adopt appropriate cognitive processes. The time needed to organize and execute these processes will, in turn, be reflected in changes in either the reaction time or movement time interval.

Reaction time, however, can be modified somewhat if the planning of the movement is completed in advance. The preplanning of aimed movements shortens the reaction time. One means of studying preplanning and motor programming is to introduce a preliminary task immediately prior to the primary task and, thereby, discover whether preplanning remains possible or is interfered with in some consistent or predictable manner. Consequently, a task which takes advantage of the known relationship of Fitts' Law may be used to study the preprogramming of movements.

Rationale

The preplanning of movement varies with the conditions of the movement task. Some studies have shown that for two-choice tasks which are previewed and have the same movement distance, target size and duration could be programmed in advance (Fitts & Peterson, 1964; B. Kerr, 1979; Klapp & Greim, 1979). With preview and equal movement parameters, the task assumed the characteristics of a simple reaction time task. Even though the task increased in complexity, there was little effect on the reaction time.

Recently, B. Kerr (1983) suggested that preplanning of an aiming movement could be disrupted by a preliminary task. She demonstrated this by using both a manual and vocal preliminary task in conjunction with a computerized version of Fitts and Peterson's (1964) discrete tapping task. Although the targets could be previewed, introduction of an aiming movement during the psychological refractory period caused reaction time to decrease and movement time to increase as amplitude increased. These results indicated that response programming was carried over into the movement time interval and preplanning did not occur.

Klapp and Greim (1979) found that preprogramming was not possible when the target sizes were different for movements in two directions, even though the targets were the same distance apart and were visible. Choice reaction time as well as movement time increased as target diameter

decreased. This implied response programming during the reaction time interval may have carried over into the movement time interval and consequently the task was not programmed in advance.

As both B. Kerr (1983) and Klapp and Greim (1979) have implied that programming may be carried over into the movement time interval, the simple discrete task may be taken one step further by considering a bi-phasic movement. During the bi-phasic movement, both phases have equal movement lengths which provides an opportunity to assess the possibility that programming may cross into the movement time interval. If it does, the movement time of phase 1 will be different from the movement time of phase 2. Thus, the focus is not only directed to the reaction time interval but also to the movement time interval.

Additional support for the utilization of a bi-phasic movement in locating response programming comes from a recent study by Fischman (1984). In an experiment in which the complexity of the movement was increased by changing the movement parts from one to five, Fischman found that the greatest increases in simple reaction time and premotor time occurred as response complexity increased from one to two movement parts. He concluded that having to pause on a well-defined target was sufficient to cause programming time to increase. Fischman demonstrated that increases in movement complexity increased the reaction

time interval. However, Fischman did not consider that response programming may have been carried over into the movement time interval. Consequently, a bi-phasic movement is used to determine the exact location of response programming.

Furthermore, while B. Kerr (1983) varied the target amplitudes to increase the difficulty of the task, there is support that varying small target widths has a more consistent effect on reaction time than does varying the amplitude (Glencross, 1976; Klapp, 1975; Siegel, 1977). As a consequence, manipulation of the target width is emphasized rather than manipulation of the target amplitude.

Also, Klapp and Greim (1979) conducted a choice reaction time experiment in which the signal indicating direction of movement was at an angle with respect to the targets. Since the signal was located away from the targets, the targets could not be viewed while waiting for the signal. Klapp and Greim found that the significant increase in reaction time with decreasing target diameter reflected the time needed for response programming.

Likewise, Davis (1959) suggested that paying attention to a signal rather than performing any overt response to it produced the same results as if the subject had had to respond. In conjunction with Klapp and Greim's (1979) study in which the subject looks away from the targets prior to the movement task, and Davis' (1959) study in

which the subject attends to a signal, the experimental design and the location of the apparatus of this study mirror these studies. Even though the primary task is previewed, the subject's attention is diverted to the computer screen and the preliminary task located at an angle to the movement task.

The concepts of employing a bi-phasic movement along with a preliminary task, varying the target widths and looking away from the targets are investigated using Fitts' Law as a basis. Fitts' Law is applied to this study as it provides a chance to manipulate the parameters of movement complexity in an orderly fashion.

Statement of the Problem

The general problem was to examine the effects of a manual preliminary task on the preplanning of a bi-phasic movement over a range of movement difficulty. Specifically, to consider the impact of a preliminary task on the reaction time, movement time and error rate of a primary task with regard to the question of preprogramming.

Hypothesis

The hypotheses tested in this study were; 1) A manual preliminary task would disrupt preplanning of a simple reaction time task in that reaction time would increase with an increase in the difficulty of the movement even

though movement was previewed. 2) In a bi-phasic movement with equivalent movement complexity in each phase, an increase in difficulty of the overall movement (decreasing the target width) would lead to an increase in movement time of the first phase as compared to the movement time of the second phase due to an inability to preprogram both movements.

Definition of Terms

Fitts' Law is a mathematical relationship existing between target width and the amplitude of a movement. Proportional changes in either of these factors produces equivalent changes in the index of difficulty and the movement time.

Primary task consisted of a discrete aiming movement from a home plate to two distinct targets: a bi-phasic movement. The movement was divided into two phases with equal movement amplitudes and target widths and performed by striking the two targets consecutively with a stylus.

Reaction time (RT) was the time interval from the presentation of the tone to the initiation of a motor response.

Movement time one (MT_1) referred to the time interval from the initiation of a movement until touch down on the first target.

Movement time two (MT_2) was the time interval from touch down on the first target until completion of the movement.

Preliminary task was a visual discrimination task regarding a Go/Stop signal. The response (RT) was a manual key press performed with the left index finger.

Interstimulus interval (ISI) referred to the time interval from the Go/Stop signal until the onset of the tone signalling the beginning of the movement task.

Movement complexity was increased by decreasing the size of the target while other factors remained unchanged.

No preview condition was the group who looked at the computer screen in order to prevent preview of the primary task. They watched the complete display on the screen until the second stimulus signalling the start of the primary task. At this moment, they turned their heads, looked at the targets, and initiated the bi-phasic movement.

Preview condition was the group who looked at the primary task (previewed the targets).

CHAPTER II

Review of Literature

The review is presented under the following major headlines: 1) Fitts' Law, 2) Generality of Fitts' Law, 3) Discrete aiming tasks, 4) Decision component, 5) Factors influencing reaction time and 6) A preliminary task.

1) Fitts' Law

While the human motor system has been of interest to researchers for many years, it is only in the past few decades that considerable gains have been made towards understanding the underlying processes of motor programs. Much of the increased curiosity followed the work of Fitts (1954) who reasoned that the information-processing capacity of the motor system limited the speed with which movements were made. Fitts proposed a relationship between movement time and ratio of the required movement accuracy and movement length (the index of difficulty): $MT = \log_2 \frac{2A}{W}$. This equation predicted a linear relationship between the index of difficulty and movement time.

In Fitts' original study (1954), he applied the basic concepts of the information theory, amount of information, noise, channel capacity, and rate of information transmission, to the human motor system. Fitts reasoned that

if a subject made rapid and uniform responses that were overlearned, and all relevant stimulus conditions were held constant, an experimental situation could be created where performance was limited primarily by the capacity of the motor system (Fitts, 1954).

To devise a mathematical means of testing the information capacity of the motor system, Fitts likened it to the channel capacity theorem of physical communication systems put forward by Shannon in 1948 (Fitts & Peterson, 1964). The theorem stated that for physical communication systems having limited bandwidth (W) and signal power (S) and perturbed by white Gaussian noise of average power (N), channel capacity (C) was equal to

$$C = W \log_2 \frac{S+N}{N} \text{ bits per second (Fitts \& Peterson, 1964).}$$

This theorem was transformed into an equation whereby the index of difficulty of a task (ID) could be predicted from equating the average amplitude (A) of a movement to the average signal amplitude plus noise, and half the range of movement variability to peak noise amplitude (n). As a result,

$$ID = A \log_2 \frac{A}{n}$$

A further modification of the theorem was to equate $n = \frac{W}{2}$

where W is the target width. Consequently,

$$ID = \log_2 \frac{2A}{W}$$

From this equation, Fitts reasoned that as long as the index of difficulty was held constant, the movement times

should be equivalent for different pairs of targets regardless of changes in movement amplitude or target width. Therefore,

$$\text{Information processing capacity (C)} = \frac{ID}{MT}$$

If, by varying the amplitude and target widths, the value of the index of difficulty of the task changed, Fitts proposed that the average time per movement (MT) would be

$$MT = a + b(ID)$$

where a and b are constants (Fitts & Peterson, 1964).

Fitts, then, discussed movement complexity in terms of the index of difficulty which in turn was based on the amount of information that a subject must process to generate the correct response (Siegel, 1977).

To test these mathematical predictions, Fitts' experiments were limited to repetitive movements of a fixed average amplitude. He hypothesized that the average time per response would be directly proportional to the minimum average amount of information per response demanded by the difficulty of the task (Fitts, 1954). This hypothesis was tested through three different tasks.

The first experiment was a reciprocal tapping task. The apparatus consisted of two target plates of four different widths (2, 1, 0.5 and 0.25 inches). The distances between the target plates were 2, 4, 8 and 16 inches. The subject held a metal-tipped stylus weighing either one ounce or one pound. He was instructed to alternately tap the two targets

as quickly and accurately as possible for fifteen seconds.

The second task required the subject to transfer plastic washers from one pin to another. The hole in the center of the discs varied from $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$ to $\frac{1}{16}$ inches in diameter. The movement amplitudes used were 4, 8, 16 and 32 inches. The subject transferred the discs, one at a time, to another pin. Discs were moved from right to left as quickly as possible.

The final experiment was a pin transfer task. Four sizes of pins ($\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$ and $\frac{1}{32}$ inches in diameter) and five movement amplitudes (1, 2, 4, 8 and 16 inches) were used. Each set of pins was used with a set of holes whose diameter was twice that of the pins. The subject had to transfer pins from one set of holes to another as quickly as possible.

The results from all three experiments indicated that the rate of performance increased uniformly as movement amplitude decreased and as tolerance limits were extended (Fitts, 1954). It was also found that within limits, amplitude and target width could be varied without much effect on performance rate. The level of optimal performance for the three tasks was between 10 and 12 bits/sec. These results taken together suggested that the performance capacity of the human motor system was relatively constant over a considerable range of task conditions (Fitts, 1954).

Fitts also hinted that the results of the experiments could be applied in a more general context. To test the

generality of the theory, Fitts and Peterson (1964) conducted experiments on discrete movements. They also considered reaction time and movement time separately.

The apparatus Fitts and Peterson used was similar to that of the tapping task used in the previous study. However, this time the subject held a stylus midway between two signal lights. When one of the lights went on, the subject moved to hit the appropriate one of two alternative targets. Target widths (1.0, 0.5, 0.25 and 0.125 inches) and movement amplitudes (3, 6 and 12 inches) were varied. Three clocks recorded reaction time (RT), movement time (MT) and total time.

Fitts and Peterson found that reaction time increased only slightly as target width decreased and movement amplitude increased. The only variable which had an effect on reaction time was the relative probability of the two alternative targets (Fitts & Peterson, 1964). On the other hand, movement amplitude and the target width had a large and systematic effect on movement time. The correlation between movement time and the index of difficulty was above .99 for the range of difficulty between 2.6 and 7.6 bits per response (Fitts & Peterson, 1964). The index of difficulty, then, permitted a good prediction of movement times for discrete responses as well as repetitive responses.

Fitts and Peterson also observed that reaction times and movement times were independent of each other. They

suggested that reaction time reflected perceptual processes whereas movement time reflected the duration of motor system processes necessary for the control of timing and patterning of a movement (Fitts & Peterson, 1964).

2) Generality of Fitts' Law

Immediately following Fitts' proposals, several experiments were conducted to test Fitts' Law under a variety of conditions. Investigators have studied the generality of the relationship to different environmental conditions, age groups and to a diversity of tasks.

The universality of Fitts' Law has been documented by several studies (Carlton, 1979; Schmidt, Zelaznik & Frank, 1978) and even under adverse conditions (R. Kerr, 1978). R. Kerr (1978) tested scuba divers on land and underwater in a reciprocal tapping task. Working underwater placed the subjects under greater stress in terms of motor control. The results of this study supported the relationship put forward by Fitts in that the underwater environment did not change the relationship of the basic parameters of the task.

Fitts original experiments used male college-age students. Since then, several studies have been conducted across age groups (Welford, Norris & Shock, 1969) and on children (R. Kerr, 1975; Salmoni & McIlwain, 1979; Shellekens, Kalverboer & Scholten, 1984). The study of various age groups has revealed some interesting aspects concerning the

movement phase.

Welford et al. (1969) used subjects ranging in age from twenty to seventy years. These researchers were interested in the linear relationship observed by Fitts. Welford et al. found that with increasing age, movement time also increased. When studying the movement phase, Welford et al. noted that the total movement consisted of at least two submovements - a "distance covering" movement and a "homing-in on the target" movement. This has been documented by Carlton (1979) in a discrete aiming task and supports a discrete feedback interpretation of Fitts' Law (Carlton, 1979).

The two phases of the movement proposed by Welford et al. (1969) provided a valuable basis for understanding the slower movement patterns of children. It has been hypothesized that children have more difficulty with the "homing-in on target" phase. R. Kerr (1975) and Shellekens et al. (1984) have demonstrated that with increasing age, movement time as related to the "homing-in" time decreased. From regression analysis and from direct movement registrations, the "distance-covering" movement phase maintained a relatively constant duration over age groups (Shellekens et al., 1984). This agreed with R. Kerr (1975) but not with Salmoni and McIlwain (1979).

Nevertheless, the fundamental principles of Fitts' Law have been applied to various motor tasks. Fitts' original experiment consisted of reciprocal movements. Since then,

Fitts' Law has been applied to other movement tasks such as a discrete tapping movement (Fitts & Peterson, 1964) and a horizontal arm sweep to circular target (Glencross, 1976).

In addition, the original interpretation of Fitts' Law was that when a movement was made more difficult by either decreasing the target width or increasing movement amplitude, then more information would need to be processed. Because this information would require more time to process, this would be reflected in the movement time. Fitts' Law implies an inverse relationship between the difficulty of the movement and the movement time. To keep the rate of information processing constant, a person must either decrease speed in order to be more accurate or maintain speed at the risk of being less accurate. Fitts' Law, then, can describe the speed/accuracy tradeoff experienced in many motor skills.

3) Discrete aiming movements

To perform a motor task, decisions must be made prior to its execution. These decisions require time. The length of time needed to select and assemble the elements of a motor program is often reflected in the complexity of the movement. This planning period is often likened to a computer (Glencross, 1973). Keele (1973) identified time and space as two variables that limit internal processes within a computer and within a human system.

As previously mentioned, it takes time to process information concerning a movement. The more decisions that need to be made about a movement, the more time needed to analyze these decisions. Also, each mental decision demands space within a limited capacity system (R. Kerr, 1982). These two concepts, space and time, may compete with each other because of variations in a motor task and this is often reflected in reaction and/or movement time.

Posner and Keele (1972) proposed a model of the mental operations involved in a simple motor skill. The task Posner and Keele used was a discrete aiming task. A warning signal went on, followed shortly by a stimulus light to which the subject responded by moving to a target. The subjects were told that after a few practice trials, they would have to replicate the task blindfolded. The mental operations involved in this task were preparation, decision, movement and storage.

The time interval between the first warning signal and the stimulus light was termed the preparation phase. Time from the stimulus light to initiation of movement was the decision phase. Movement phase encompassed the time from the initiation of the movement to its termination. Storage was the representation of the skill recorded by the subject. Of these, the decision and movement phases are of importance to the present study. The movement component has been reviewed under Fitts' Law so the decision component will be

discussed next.

4) Decision component

The time between the onset of a signal and the initiation of the response is termed the decision component or reaction time (RT). This reflects the time needed to process information about the movement task. While simple reaction times normally range from 0.20 to 0.25 seconds (Henry & Rogers, 1960) choice reaction times are usually longer. This section will address the question of multiple responses in terms of a) Hick-Hyman Law and b) Psychological refractory period.

a) Hick-Hyman Law

Hyman (1953) studied the relationship between the amount of information processing and reaction time in a serial choice reaction time task. In a series of investigations, the amount of information that the subject had to process was varied. Hyman found that the RT increased as a linear function of the amount of information.

Earlier, Hick (1952) studied the relationship between the number of stimulus alternatives and the choice RT within the context of errors. It was observed that people made more errors under quick responses and consequently processed less information. The relationship between errors and response was referred to as the speed-accuracy trade-off (R. Kerr, 1982). Pachella and Pew (1968) also supported this notion. They found that subjects working with a speed

matrix were significantly faster and made significantly more errors than those subjects working with an accuracy matrix. A combination of the findings of Hick and Hyman has resulted in the Hick-Hyman Law. This law proposed that choice RT was linearly related to the number of stimulus-response alternatives or to the amount of information that must be processed.

b) Psychological refractory period

The psychological refractory period (PRP) refers to the time when a person is unable to respond to the second of two closely spaced stimuli until the first response has been initiated (R. Kerr, 1982). Researchers considered the nervous system in explaining this phenomenon. Stimulation produces a single momentary excitation followed by a reduction of specific irritability which is known as the refractory period (Telford, 1931). During this period of decreased excitability, the nervous system is unable to respond.

Several experiments, using the presentation of two successive stimuli, were conducted to test the "refractory period" principle. Researchers found that when discrete stimuli, were presented in a series of irregular intervals, the RT to the second of two stimuli separated by an interval of 0.5 seconds tended to be longer than to the first (Telford, 1931; Vince, 1948, 1949; Welford, 1952). If the

interstimulus interval (ISI) was less than 0.5 seconds, the RT to the second stimulus was significantly more while RT to the first stimulus remained constant. However, if the stimuli presentation was too rapid (ISI less than 0.1 seconds), both stimuli were grouped together and processed as one (Harrison, 1960; Vince, 1948). In addition, if the ISI was too long (greater than 0.5 seconds), the RT to the second stimulus had the same value as when the first stimulus was not performed (Henry & Harrison, 1961). Therefore, it is important that stimuli presentation not be so rapid that stimuli are grouped together and processed as one or that stimuli presentation be so distinct that the first response can be made before the second stimulus appears. Also, the uncertainty of a stimulus is a feature of the PRP. If the presentation of the second stimulus is at a fixed interval, the subject will be able to anticipate the signal.

The mode of stimuli presentation, whether visual or auditory, does not have an effect on the magnitude of delays (Davis, 1959). Davis (1959) conducted a set of experiments in which two consecutive signals were presented to the subjects. The ISI's were randomly varied. Subjects were required to respond to both signals or only to the first signal. Davis found that RT delays were the same in both situations and were not significantly different between cases where the signals were presented in the same sense modality (visual) or in different modalities (visual-

auditory). Because the magnitude of delays were the same under conditions when the subject had to respond to both stimuli or to only the second stimuli, Davis suggested that it was paying attention to a signal rather than performing any overt response to it which resulted in delays to subsequent responses. Furthermore, since the mode of presentation had no significant effect on RT delay, Davis suggested that the classifying of a signal and the organizing of a response to it was performed by the same central system. This suggestion agrees with the single-channel model put forth by many researchers as a means of explaining the PRP.

The single channel model proposes a correlation between humans and a central computing system. Essentially the theory states that two separate stimuli cannot co-exist in the central processes. Since no two central organizing times can overlap, the second stimulus and its associated response have to be held in storage until the central mechanisms are free and the subject can deal with them (Creamer, 1963; Davis, 1959; Telford, 1931; Vince, 1949; Welford, 1952). There is a definite organizing time required to process a stimulus and select an appropriate response. Also, this central delay can be influenced by feedback (Welford, 1952). However, the single-channel model only explains the increase in RT to the second stimulus. Consequently, Herman and Kantowitz (1970) proposed an

alternative theory, the "response-conflict" theory.

The response-conflict theory states that when stimuli for different responses are presented in rapid succession, the response tendencies aroused by the stimuli interact, and the RT's to both stimuli are affected (Herman & Kantowitz, 1970). Although this theory does explain the increase in RT of the first stimuli as well as the second, it offers no way of predicting the extent of the effects of the interaction of the two stimuli.

Vince (1948) identified some problems associated with the study of the PRP. Firstly, if the stimuli are presented simultaneously, they may be grouped together as a single unit and RT will decrease. Secondly, even though a subject is concentrating on the display, his attention and central mechanisms will occasionally be taken up by interference and therefore RT will increase.

5) Factors that influence reaction time

The time needed to process information concerning the movement task is reflected in the reaction time interval. Factors which influence reaction time and which will be discussed in the following section are a) movement amplitude and target width, b) complexity of movement, c) one-choice tasks, d) multi-choice tasks, and e) preview/no-preview tasks.

a) Movement amplitude and target width

Movement amplitude and target width fail to influence

reaction time in a consistent manner (B. Kerr, 1978). These two factors have been studied extensively by researchers, but only a few pertinent experiments will be outlined.

Klapp (1975) employed the Fitts paradigm in order to manipulate target width and movement amplitude in studying the process of programming. He used a choice RT experiment in which the number of alternative responses was kept constant while the nature of the response (target width or amplitude) was varied. The changes in RT, then, reflected the time required to generate the correct response (Henry & Rogers, 1960; Klapp, Wyatt & MacLingo, 1974; Klapp, 1975).

Klapp (1975) conducted two experiments. In the first experiment, subjects moved a stylus to the left or right of an initial rest position to a target. The target diameters were 2, 4, 8, 16, 32, and 64 mm and the target amplitudes were 2, 11, 70, and 336 mm. Klapp found that for short distances (2 and 11 mm), both movement time (MT) and reaction time (RT) increased as target diameter decreased, but only movement time increased as length increased. For long distances (70 and 336 mm), both MT and RT increased as target diameter decreased and amplitude increased. The data obtained by Klapp failed to support Fitts' Law for short movements but did for long movements. These findings were interpreted as implying that long movements are predominately programmed and ballistic (Klapp, 1975).

The second experiment, then, tested this hypothesis by

eliminating feedback by turning off the illumination of the targets once the stylus left its initial rest position. The same apparatus was used. The target diameter, however, was 2 mm or 336 mm. A signal lamp indicated which direction the subject was to move. When ready, the subject executed the movement. The short movements still proceeded with reasonable accuracy in the absence of feedback while long movements were virtually impossible (Klapp, 1975).

Glencross (1976) used a horizontal arm sweep aimed at small circular targets to study the effects of amplitude and target width on RT. His aim was to increase the complexity of the movement by increasing the degree of accuracy while maintaining the same basic movement pattern. The conditions ranged from "no target" (stopping the movement) to aiming at 2, 1, and 0.5 inch diameter circular targets. Glencross (1976) hypothesized if a response was completed in 250 msec or less, then the movement pattern would have to be prepared in advance and controlled by means of a motor program. This would be reflected in the RT. The results showed that RT increased with precision but it was not statistically significant. However, there was partial support for small target conditions (Glencross, 1976).

Siegel (1977) used a variation of Fitts' paradigm to examine the effects of variations in movement amplitude and target diameter on choice RT. Choice RT was used because the subject must wait for the stimulus to occur before implementing

a motor program. The subjects were required to move a stylus over a range of amplitudes (5 - 300 mm) to circular targets. Siegel observed that with targets below 15 mm, RT increased with increasing complexity of the task. Reaction time also varied as a U-shaped function with amplitude.

Reviewing these studies, RT is independent of both amplitude and target width for long movements (Fitts & Peterson, 1964; Klapp, 1975) but not for short movements (Klapp, 1975). This latter finding, RT increases as target width decreases, has more support when targets are very small (Glencross, 1976; Klapp, 1975; Siegel, 1977). As shown, amplitude and target widths do not consistently influence RT.

b) Complexity of movement

The characteristics of a movement have been studied quite extensively since Henry and Rogers (1960) introduced the "memory drum" theory. The theory suggests that the organization of the neuromotor program will take place before the movement starts. Henry and Rogers (1960) used three movements of different complexities under two experimental conditions. A reaction time value was obtained from a simple finger lift for the first movement. The second movement required the subject to reach forward and grasp a tennis ball. The final movement experiment included a series of movements and reversals. The subject had to reach up and touch one ball, reverse direction, touch a push button reaction key

and then reach up and strike down a second ball.

The results indicated that RT decreased as the movement became more complex. From this, Henry and Rogers (1960) supposed that increased movement complexity early in a movement would have a greater effect on RT than if the complexity appeared later in a movement.

The more complex movements outlined by Henry and Rogers required intermediate pauses on targets as well as movement reversals. This introduces a critical variable determining RT which B. Kerr (1978) identified as the complexity of timing requirements. Further support that RT varies in response to timing requirements for the components of movement was provided by Quinn and Sherwood (1983). These authors examined the differences in processing time for two types of modifications of a rapid ongoing movement. Subjects attempted to either increase speed or to reverse a horizontal arm movement when a signal was presented after the movement was started. Quinn and Sherwood found that RT was greater for reversing the direction of the movement. They suggested that an increase in the speed of an ongoing movement may require only modification of a parameter variable while reversing the movement direction required the implementation of a new motor program (Quinn & Sherwood, 1983). Timing requirements are primary components, then, that influence the time needed for movement selection and preparation processes (B. Kerr, 1978).

c) One-choice tasks

One-choice tasks also present problems when studying RT (B. Kerr, 1978). In these simple RT tasks, appropriate target and direction can be cued in advance of the RT interval and thus it is possible to preprogram the movement (Goggin & Christina, 1979; Klapp et al., 1974; Klapp, Abbott, Coffman, Greim, Snider & Young, 1979; Klapp & Greim, 1979).

Klapp et al. (1974) using a key-press task found RT differences between long-duration and short-duration key-presses under choice conditions. But, these RT differences disappeared under a one-choice condition. The authors concluded that motivated subjects who had sufficiently practiced the response had the opportunity to program the response in advance for simple RT. Support comes from a diversity of tasks such as speech paradigms (Klapp et al., 1979) and aiming movements (Goggin & Christina, 1979; Klapp & Greim, 1979).

d) Multi-choice tasks

Multi-choice tasks, on the other hand, provide a valuable means of interpreting RT. Direction uncertainty does not allow a subject to preprogram a response until he has information on which response to make. The choice RT paradigm has the desired property that programming time is a necessary component of the RT being measured (Klapp et al., 1974). Fitts and Peterson (1964) initiated interest in this idea when

They altered Fitts tapping task (1954) from a serial task to a two-choice discrete aiming task.

Klapp and Greim (1979) conducted two experiments using the Fitts' paradigm to measure choice RT as a function of the nature of the response to follow. In the first experiment, subjects moved a stylus over a 2 mm distance to targets of the same diameter under a choice visual, a simple auditory and a choice auditory condition. The target diameters were 2, 4, 8, 16, 32 and 64 mm. In the choice visual condition, the signal indicating direction of movement was small and at an angle of 72° with respect to the targets. Since the signal was located away from the targets, the targets could not be viewed while waiting for the signal. Under the simple auditory condition, the direction of movement was precued to the subject prior to the RT interval. Consequently, the subject could view the target while waiting for the auditory "go" signal. This simple RT condition acted as a control. The choice auditory condition combined the direction uncertainty of the choice visual condition with the auditory "go" signal of the simple condition. Under the choice auditory condition, then, even though the subject could view the targets, they did not know which direction to move until an auditory signal located to the left or right indicated which target to hit (beginning of RT interval). Each subject completed all three conditions.

Klapp and Greim found that RT under the choice visual

condition significantly increased as target diameter decreased. Under both the choice auditory and simple auditory conditions, target diameter did not have a significant effect on RT. Klapp and Greim reinforced this finding by observing a significant (condition X diameter) interaction effect between the choice visual and simple auditory conditions, and the effect of diameter. Because the target diameter effect was restricted to choice RT, the effect could not have been due to a non-programming variable such as a speed-accuracy trade-off strategy (Goggin & Christina, 1979; Klapp & Greim, 1979). If a speed-accuracy trade-off had been used, target diameter effects would have been produced in both simple and choice RT conditions. Therefore, the significant increase in choice RT was due to response programming (Goggin & Christina, 1979; Klapp, 1975; Klapp & Greim, 1979).

In the second experiment conducted by Klapp and Greim (1979), the target diameters on either side were different as opposed to pairs of targets of the same diameters used in the first experiment. The apparatus and procedures were identical to the first experiment except that only choice auditory and choice visual conditions, and two target diameters (2 mm and 8 mm) were included.

Consistent with the first experiment, RT was longer in the choice visual than in the choice auditory. For the choice visual condition, RT was longer for movements to the smaller target. By contrast, RT was longer for movements to the

larger target in the choice auditory condition. Klapp and Greim's interpretation of this choice auditory finding was that most subjects planned, in advance, for the more difficult target.

Results from the first experiment led to the conclusion that two different movements can both be programmed in advance if the target size, movement distance and duration are the same and both targets are visible. Results from the second experiment indicated advance programming is not possible when the target sizes are different for the two directions even though the targets are the same distance and are visible.

e) Preview/no-preview tasks

Another manipulation of RT is the comparison of situations with and without advance preview. When subjects can preview a task it introduces the possibility that programming the movement can occur before the stimulus and thereby shorten the RT period (B. Kerr, 1979; Klapp & Greim, 1979; Sheridan, 1981).

Sheridan (1981) conducted two experiments using tasks similar to those outlined by Fitts (1954). One task had advance preview while the other had no preview. Sheridan concluded that the no-preview design was more sensitive to changes in RT due to variations in task conditions than the preview design. Target preview eliminated some of the RT differences.

B. Kerr (1979) questioned whether prior knowledge about the movement, rather than preview, was a determinant factor on RT difference. She employed a computerized version of Fitts and Peterson's (1964) discrete tapping task. In the no-preview conditions the target appeared as the signal to begin. Targets occurred a) on the right only, b) on the left only, or c) equally often on the left and right of center. Reaction time decreased as distance increased. Times were faster when only one possible direction was presented.

To control for factors that may have been caused by the sudden display and/or related to perceiving and encoding information, subjects watched the no-preview display but pressed a RT key in response to all possible targets. Reaction time did not vary with distance. This finding suggested that decreases in RT with distance found in the movement responses in the no-preview situation was related to processes involved with selecting, preparing and executing the proper movement (B. Kerr, 1979).

In the preview conditions, when more than one choice was possible, the wrong target disappeared as the signal to move. The subjects performed on an apparatus similar to that used by Klapp and Greim (1979) in their first experiment. B. Kerr (1979) reproduced Klapp and Greim's (1979) findings in that mean RT did not vary with distance in the

preview condition. Results suggest that RT varied with distance with no-preview, but was independent of distance with preview (B. Kerr, 1979; Klapp & Greim, 1979; Sheridan, 1981).

To test whether advance distance information would be sufficient to eliminate the independence of RT and distance found in a preview situation, B. Kerr (1979) conducted a follow-up experiment. The task was identical to the no-preview study outlined earlier by B. Kerr (1979). Advance knowledge about target distance was given but direction and target width information was not available until the target appeared. The same distance occurred eight consecutive times.

Reaction time decreased as distance increased. This is similar to the no-preview situation reported earlier (B. Kerr, 1979). However, post hoc analysis on no-preview two-choice and no-preview precue data showed RT decreased over blocks of trials. B. Kerr (1979) suggested, with practice, distance precue permitted advance planning.

Nevertheless, no-preview situations can be regarded as a choice RT situation, producing similar results, whereas preview situations tend to represent a simple RT situation (Klapp & Greim 1979; Sheridan, 1981).

6) A Preliminary Task

Preplanning a movement can occur in one-choice tasks

(Goggin & Christina, 1979; Klapp et al., 1974; Klapp et al., 1979; Klapp & Greim, 1979), two-choice tasks that are pre-viewed and have the same movement distance, target size and duration (Fitts & Peterson, 1964; Klapp & Greim, 1979) and when targets are previewed (B. Kerr, 1979; Sheridan, 1981). Consequently, preplanning is conceivable. An aspect which intrigued B. Kerr (1983) was whether preplanning was still possible if subjects were engaged in a preliminary task prior to a movement. Preplanning would be maintained if RT's for different target distances were equivalent.

B. Kerr (1983) used a computerized version of the Fitts and Peterson joystick-controlled task. Her experiment consisted of two independent tasks, a preliminary task and a two-choice movement task.

The preliminary task was a go/no go auditory discrimination. When a "go" response was required, subjects either pressed a keypress with the left index finger (manual response) or said the word "bop" (vocal response).

In the two-choice movement task, the subject moved a cursor to one of two possible 2.7 mm-wide targets. The target distances (9.0, 13.5, 18.0 and 22.5 mm) were equidistant from the center grid. Both targets were displayed. When one target disappeared, the subject moved to the remaining target. RT was measured from the imperative stimulus until the cursor touched the boundary of the center grid. From this point until the cursor crossed the inside border

of the target was the movement time (MT).

Sixteen right-handed subjects were assigned to each of five possible conditions: 1) manual preliminary task, 2) vocal preliminary task, 3) movement task, 4) manual/movement task, and 5) vocal/movement task.

Subjects in the manual-only and vocal-only conditions first previewed the targets. Then, the auditory signal for the preliminary task came on for 75 msec. The time interval (250, 500, 750, 1000, 1250 and 1500 msec) between target preview and tone stimulus was randomly varied. Upon tone presentation, the subjects responded according to the condition requirements. Subjects in the manual/movement and vocal/movement conditions continued this sequence by moving to the appropriate target when one of the two targets disappeared. The interstimulus interval (ISI) of 100, 150 or 200 msec was the time between tone onset and the disappearance of one of the targets. Subjects in the movement-only condition interpreted the auditory signal as a warning tone.

Subjects participated in two sessions. The first session consisted of four blocks of forty-eight trials. They received knowledge of results after each trial. These results were summarized after blocks of trials.

Results were subjected to analysis of variance. The outcome of the movement parameters showed that without a preliminary task, RT did not vary significantly with target

distance but with the preliminary task, RT decreased significantly as target distance increased. As expected, MT increased as distance to be moved increased. Under both preliminary task conditions with no movement, RT decreased as target distance increased.

B. Kerr (1983) suggested that because RT decreased as target distance increased with the preliminary task, pre-planning was disrupted. The same results were observed by B. Kerr (1979) under no-preview conditions. B. Kerr (1983) noted that disruption occurred with both manual and vocal preliminary responses and therefore cannot be attributed to competition between two manual responses. Also, disruption occurred following no-go as well as go responses suggesting that overt responses were not the cause.

Consequently, the utilization of a preliminary task was similar to no-preview tasks (B. Kerr, 1979) and two-choice tasks (Goggin & Christina, 1979; Klapp & Greim, 1979) in that preplanning of a movement cannot occur.

CHAPTER III

Method

Subjects

Twenty-four male and twenty-four female undergraduate students from the Kinanthropology and Physical Education departments of the University of Ottawa served as subjects. They received partial course credit for their participation.

Subjects were all right-handed and ranged in age from nineteen to twenty-eight years.

Apparatus and task

The equipment was composed of an IBM personal computer, a metal stylus and a tapping task apparatus. The task was divided into two parts, a preliminary reaction time task and a primary tapping task.

The preliminary task was performed by depressing the spacebar on the computer key board in response to a "go" signal. The dependent variables of the preliminary task were a) reaction time, and b) number of errors. These factors were displayed on the computer screen after every trial.

The primary task was performed by tapping with a sharp metal stylus on sheets of white paper placed over a metal plate. The stylus and metal plate were connected to an IBM personal computer in order to record RT and MT's. The metal stylus was similar to a pen (11.5 cm in length, 0.5 cm in

diameter). Each tap would pierce a small hole in the paper, thereby completing the electrical circuit.

Pairs of targets, 6 cm long, were drawn across the width of the paper. The target widths were 4 mm, 6 mm, 8 mm, and 10 mm, and the target amplitude was 16 cm for both movements. A block consisted of 10 trials, and after every block the sheet was replaced. This was to help monitor errors and give the subject a short rest. The subject performed six blocks at each target width before proceeding to the next target width. The dependent variables measured in the tapping task were a) reaction time, b) movement time - phase 1, and c) movement time - phase 2.

Clocks inside the IBM computer recorded the RT and MT in msec. These clocks also controlled the time sequence for the two-part task. The clocks were activated when the stylus touched down on the home plate and time was terminated when the stylus made contact with the second target (see Figure 1).

One second after the stylus was set down on the home plate, "READY" appeared on the computer screen. At random intervals of 250, 500, 750, 1000, 1250 and 1500 msec later, a tone and the go/stop signal appeared. This instructed the subjects to either perform the preliminary task or not. Following this visual signal, a higher-pitched tone signalling the start of the movement sounded. The interstimulus interval (ISI) varied from 100, 150 to 200 msec. The RT and

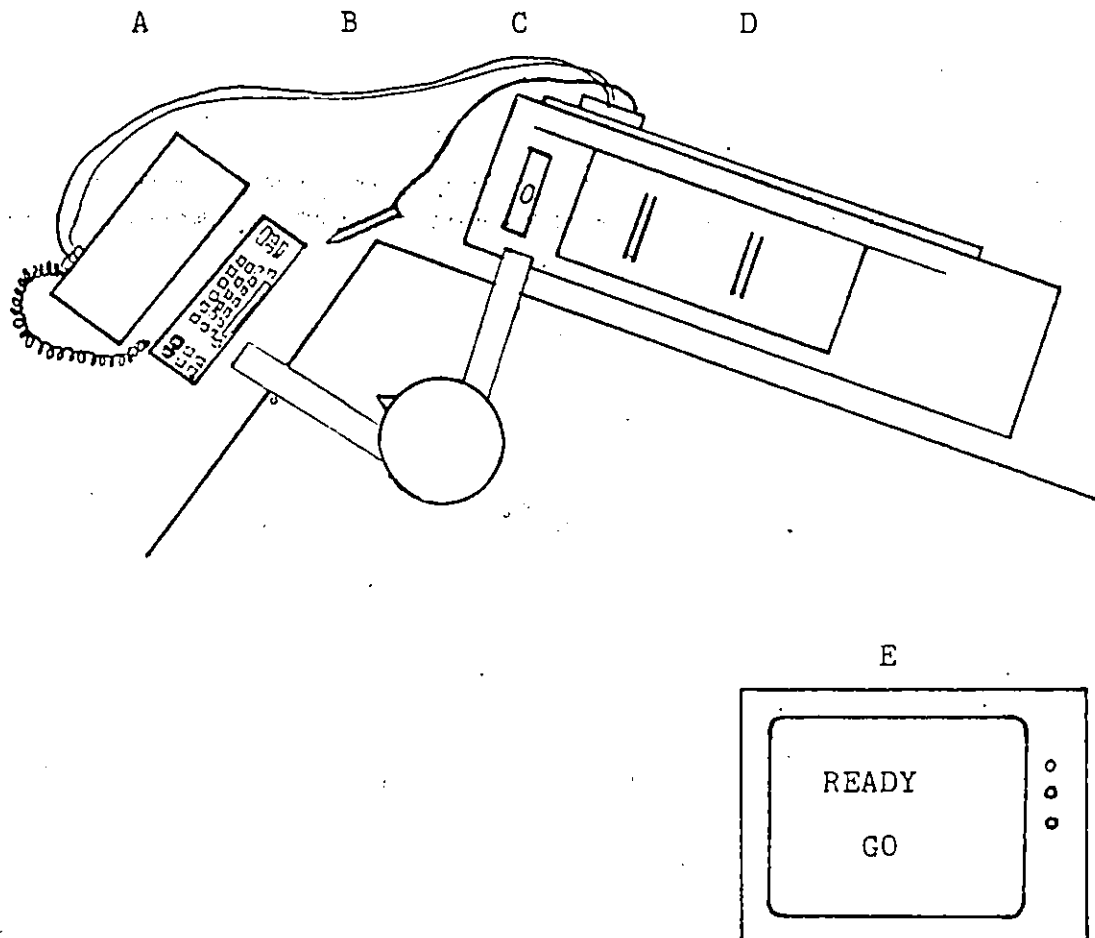


Figure 1. The experimental design of the bi-phasic tapping task: A) Computer screen and keyboard, B) Metal stylus, C) Home plate of bi-phasic task, D) Paper with pair of targets and E) Display of preliminary task instructions on computer screen.

MT's for each subject were displayed on the computer screen after every trial. If the movement was initiated prior to the second tone or the stylus did not make contact with the copper plate, the trial was aborted and repeated immediately. The subject and experimenter were located in the same room.

Procedure

The experimental session lasted approximately fifty minutes. Subjects were randomly assigned to one of four experimental groups upon entering the experimental room. They were told that they would practice first and then be tested.

The subjects sat in a chair with the tapping apparatus directly in front of them. The home plate was located approximately opposite the midline of the subject. The computer screen and keyboard were located 90° to the left of the tapping apparatus so that the subject could not have complete view of the tapping apparatus while observing the computer screen.

Subjects performed three training blocks of 24 trials each in the following sequence: one block of the preliminary task, one block of the primary task, and one block of a combination of the two tasks.

They were given instructions on the preliminary task

and then performed one block of trials. After each trial, the RT and error (responding to a stop signal) were displayed on the computer screen. Next, the subjects were given instructions on the primary task, and then performed one block of trials with a pair of targets present. The RT for the primary task, MT of phase 1 and MT of phase 2 were displayed on the screen after every trial. Finally, instructions concerning the third part of the practice were given and the subjects completed one block of trials with a pair of targets present. The reaction times for the preliminary task and to the second tone as well as the two movement times were displayed after each trial.

Immediately following their practice, the subjects were told which task they would be performing and then completed four blocks of 60 trials under their respective group conditions. In addition, the subjects were given a question on how they felt - "very nervous", "nervous" or "not nervous". They were asked to rate themselves on a scale from 0 to 10 prior to testing.

Subjects in the preliminary task group depressed the spacebar with their left index finger (preliminary task) as soon as the tone sounded and "go" appeared on the computer screen. In order to equate time across groups, this group also made a tapping movement with the stylus. If "stop" appeared on screen, the preliminary task group did not depress the space bar but still performed a tapping movement.

Reaction time and errors were displayed on the screen after every trial.

Those subjects in the no preview and preview groups regarded the first tone and the go/stop stimulus as a warning signal and thus performed only the tapping task. However, subjects in the no preview group were asked to observe the screen to decrease preview and, when the second tone sounded, to look at the targets and perform the movement. Subjects in the preview group previewed the tapping task and initiated a response at the sound of the second tone. Upon completion of a movement trial, subjects in both groups received knowledge of results in the form of RT and MT data. If the subject lifted the stylus prematurely, an error was indicated by the computer and the trial was repeated.

Subjects in the combined group performed both the preliminary and tapping task in sequence. The time interval (ISI) between the go/stop stimulus and the second tone onset was varied. Reaction time to the preliminary task and the primary task as well as the MT's were displayed on the screen after every trial.

The task was self-paced in that all clocks were stopped at the completion of each movement and were only re-started when the stylus made contact with the home plate. Thus, the next trial did not commence until the subject returned the stylus to the starting position.

The order of presentation of the target widths was

randomly varied to control effects that may have been caused due to the sequence of presentation.

After completing 240 trials, the subjects were given a second question concerning "how hard they tried". Again, the subjects were asked to rate themselves on a scale from 0 to 10.

Design

Before the main analysis was done on the computer, the subject's data was averaged across the interstimulus interval and the go/stop variables so that each subject had twenty-four time measurements. Analysis of variance with repeated measures was accomplished using a BMDP (P2V) package from the University of Ottawa.

The main analysis compared the primary movement time data of the three conditions (preview, no preview and combined task) to determine if response programming had been carried into the movement time intervals. A $3 \times 2 \times 4 \times 3 \times 2$ (Condition x Phase x Target widths x ISI x Go/stop) analysis of variance (ANOVA) with repeated measures on the last four factors was used.

In addition, the reaction time data of the preliminary task and combined task groups was subjected to a $2 \times 3 \times 2$ (Condition x ISI x Go/stop) ANOVA with repeated measures on the last two factors to establish the impact of the preliminary task. Finally, reaction time to the second stimulus was analysed across the preview, no preview and combined task

groups using a 3 x 4 x 3 x 2 (Condition x Target widths x ISI x Go/stop) ANOVA with repeated measures on the last three factors.

All significant main effect interactions were isolated through simple main analyses. Those comparisons which were significant were subjected to Tukey's post hoc analysis and then interpreted. Significant main effects which were significant but were not interactions were directly subjected to post hoc analysis and interpreted.

CHAPTER IV

Results

The results will be considered under the following sections: Primary task: reaction time; Primary task: movement time; Preliminary task: reaction time; Error rate and Questionnaire.

Primary task: Reaction time

In the main analysis (Condition x Width x Go/stop x ISI), the main effects of Condition $F(2.33) = 21.92, p < 0.01$ and Interstimulus Interval (ISI) $F(2.66) = 53.61, p < 0.01$ were significant. As well, the Condition x ISI interaction $F(4.66) = 12.03, p < 0.01$ and Go/stop x ISI x Condition interaction $F(4.66) = 3.73, p < 0.01$ were significant. There was no significant main effect for target width.

Though the main effect for Conditions was significant, the post hoc analysis did not separate the differences. This occurrence can be attributed to a large mean square value ($MS = 80,139$) relative to a small sample size ($n=12$). Because of this relationship, no post hoc differences were found. Examination of group means disclosed the no preview group as being the fastest ($\bar{X} = 143$ msec), the preview group next ($\bar{X} = 228$ msec) and the combined group as being the slowest ($\bar{X} = 299$ msec). The fast RT's of the no

preview group were surprising as these subjects were looking away from the primary task and attending to the computer screen. While the no preview group were watching the computer screen, they saw the complete display - READY followed by GO/STOP and the two response signals. Apparently the warning signal, READY, allowed them to prepare for or anticipate the movement signal and react quicker to the primary task. The preview group did not see the READY signal, and therefore, had no specific warning signal prior to reacting to the primary task. The combined group, as predicted, had the slowest RT's because they were engaged in the preliminary task at the same time they had to respond to the second stimulus. More attention was demanded of the combined group, as was evidenced by their slower RT's.

The analysis of primary task RT also indicated significant effects between the interstimulus intervals (ISI). The RT for ISI 100 was 241 msec, for ISI 150 219 msec, and for ISI 200 210 msec. Pairwise ~~post~~ hoc analysis revealed significant differences between ISI 100 and ISI 150 ($p < 0.05$) and ISI 100 and ISI 200 ($p < 0.05$). The reaction times of ISI 150 and ISI 200 were not significantly different. The slow RT for ISI 100 is due to the fact that the two signals were presented so closely together that the subject did not have time to prepare or initiate the response. The largest interval, ISI 200, possibly gave the subjects enough time to distinguish the two signals in that they

may have already initiated their response to the first signal. Consequently, the response to the second signal was not delayed as much as with the shorter ISI's (refer to Figure 2).

The Condition x ISI interaction was significant under the main analysis. Simple main effects used to isolate the interaction revealed that only interstimulus intervals in the combined group were different ($p < 0.05$). Post hoc analysis showed that the RT's for ISI 150 and ISI 200 were equal and both faster than ISI 100 ($p < 0.05$). This suggests that because the combined group had to do the preliminary task, ISI 150 and ISI 200 were long enough for the subjects to initiate their first response (reacting to Go/stop) and to concentrate on their second response. As ISI 150 and ISI 200 were equal it suggests that an ISI as low as 150 msec is sufficient for a subject to process information and be reacting to one stimulus while initiating a second response.

The three-way interaction, Go/stop x ISI x Condition, was also significant. To isolate this interaction, simple main effects were performed. Three simple main effects were found to be different: no preview group (Go) across ISI; combined group (Go) across ISI; and combined group (Stop) across ISI. Tukey's post hoc analysis confirmed the previous Condition x ISI interaction. In the no preview group (Go), combined group (Go) and combined group (Stop)

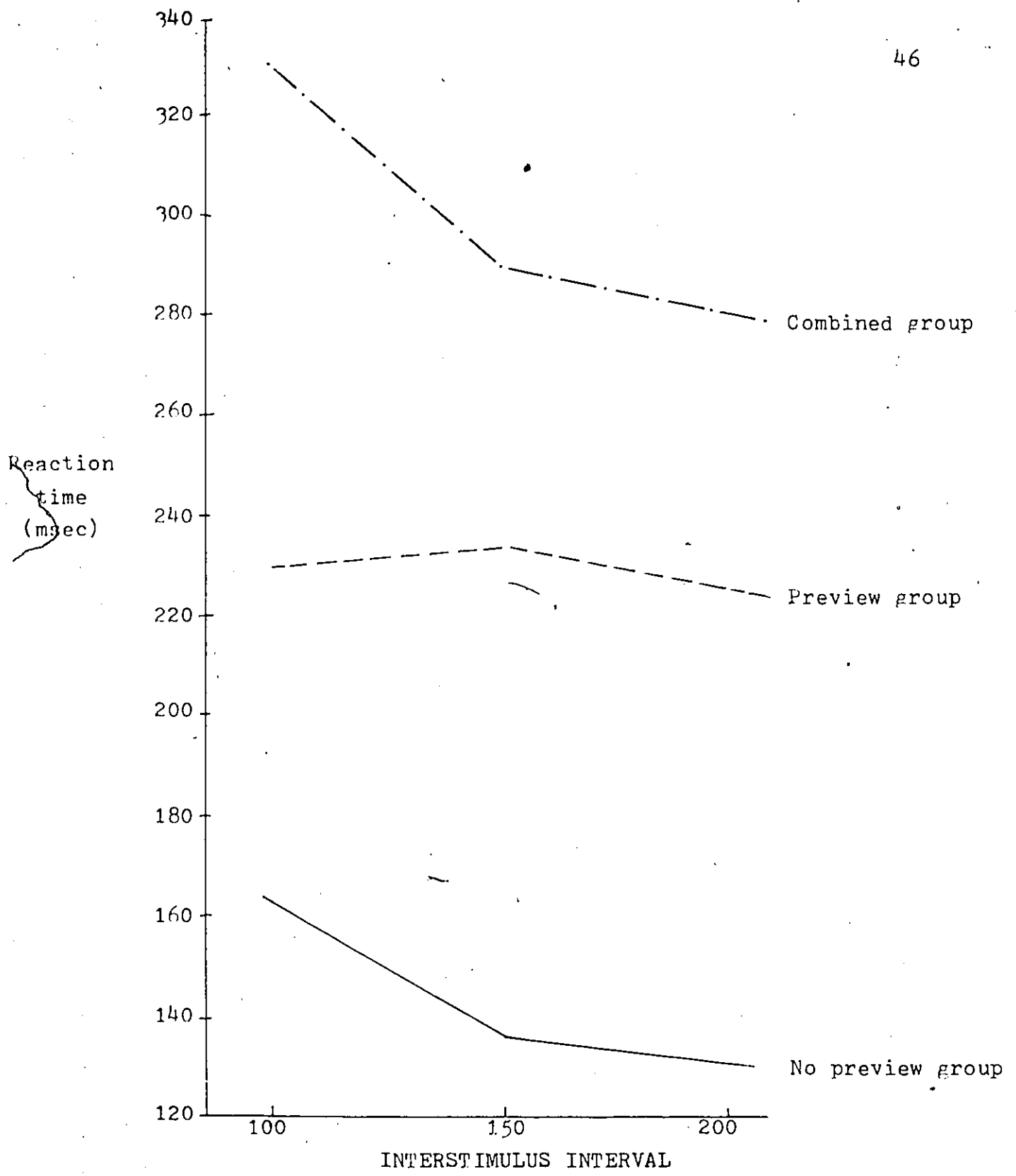


Figure 2. The ISI X Condition interaction for reaction time on the primary task.

conditions, RT's of ISI 150 and ISI 200 were faster than ISI 100. Also, the RT of ISI 150 was equivalent to ISI 200. The no preview group, under go conditions, obtained similar results to the combined group because they were also looking away from the primary task. Possibly the movement of the head (from regarding the screen to looking at the targets) was sufficient interference to warrant the similarity between the no preview and combined groups.

Primary task: Movement time

In the full analysis (Condition X Phase X Go/stop X ISI X Width), the main effects of Condition $F(2,33) = 5.35$, $p < 0.01$, Phase $F(1,33) = 117.73$, $p < 0.01$ and Target Width $F(3,99) = 84.46$, $p < 0.01$ were significant. In addition, the Phase X Condition interaction $F(2,33) = 10.42$, $p < 0.01$, Phase X Width interaction $F(3,99) = 14.98$, $p < 0.01$, Phase X Go/stop interaction $F(1,33) = 6.34$, $p < 0.02$, Phase X ISI X Condition interaction $F(4,66) = 3.73$, $p < 0.01$ and a Go/stop X ISI X Condition interaction $F(4,66) = 3.02$, $p < 0.02$ were also significant.

Overall, the difference between the Conditions was significant. The preview group had the fastest MT ($\bar{X} = 611$ msec), the no preview group the next fastest ($\bar{X} = 642$ msec) and the combined group the slowest ($\bar{X} = 692$ msec). Although there were no post hoc differences due to the relationship between the large mean square value ($MS = 970,635$) and the

small sample size ($n = 12$), the significant F-value indicated a difference between the preview group and the combined group.

The main effect of Phase was also significantly different. Phase 1 was completed by all groups faster ($\bar{X} = 600$ msec) than phase 2 ($\bar{X} = 696$ msec). Two reasons may explain this occurrence. Firstly, the movement to the first target was assumed to be programmed in advance and therefore had a faster MT whereas the second movement was assumed to be programmed either while the subject was doing the first movement or after completion of the first movement. Consequently, the delay may be attributed to some processing being performed. Secondly, because the time on target was not recorded, the second MT incorporates the time on the first target as well as the second MT. However, this addition should have been equivalent for all groups if movements for phase 2 were preplanned.

In addition, a Phase X Condition interaction was significant. Further analysis did not isolate the interaction. Consequently, there was a difference between the groups and the phases. This difference seemed to be confined to the fast MT of the preview group at phase 1. This is illustrated in the graph Phase X Condition (refer to figure 3).

The main effect of Target widths was also significant. The fastest time was recorded when the target width was

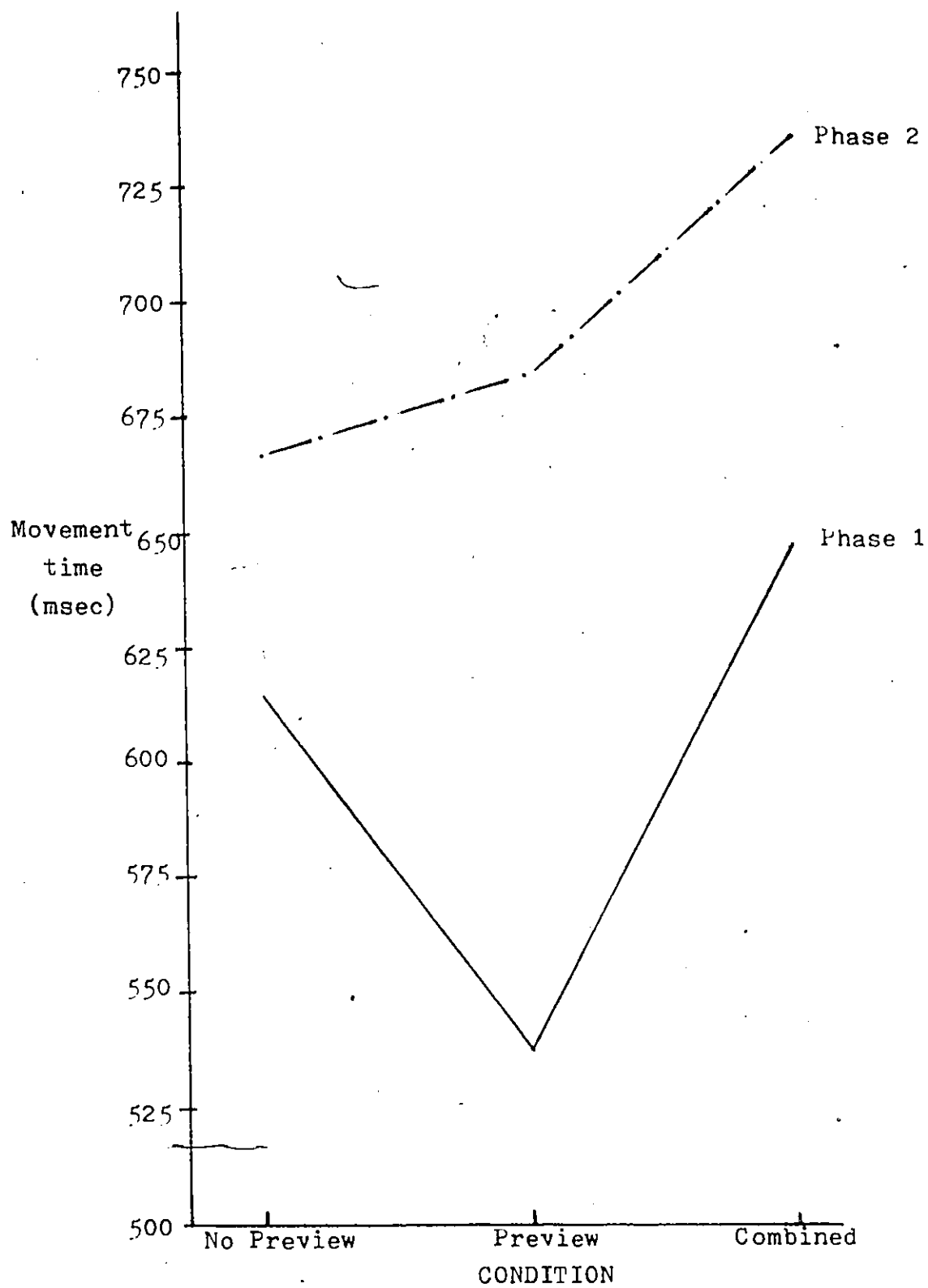


Figure 3. The Phase X Condition interaction of movement time for the primary task.

the widest ($\bar{X} = 573$ msec), while the slowest time was recorded when the target width was the narrowest ($\bar{X} = 742$ msec). Tukey's post hoc analysis revealed that the pairwise comparisons between the narrow target (4 mm) and all other targets were different at $p < 0.05$. Likewise, the pairwise comparison between the 6 mm target and the 10 mm target was different. The movement times of the 6 mm and 8 mm targets as well as the MT's of the 8 mm and 10 mm targets were equivalent.

A Phase X Width interaction was also significant. To isolate this interaction, simple main effects were performed. Phase at the 4 mm target was significant ($p < 0.05$) indicating that subjects moved slower over the second phase than the first. This was also the case with the 6 mm target. The second MT was substantially slower than the first MT. This implies that under the narrow target conditions (4 and 6 mm), subjects had difficulty moving from the first to the second target. Possibly they ~~preprogrammed~~ only the first movement and not the second because of the target size. Also, because the targets were always in the same place with equal amplitude, subjects had only one movement to learn. At narrow target widths, the movement required less variability and therefore slower MT's whereas at wide target widths the movement required less re-programming.

In addition to phase being significantly different

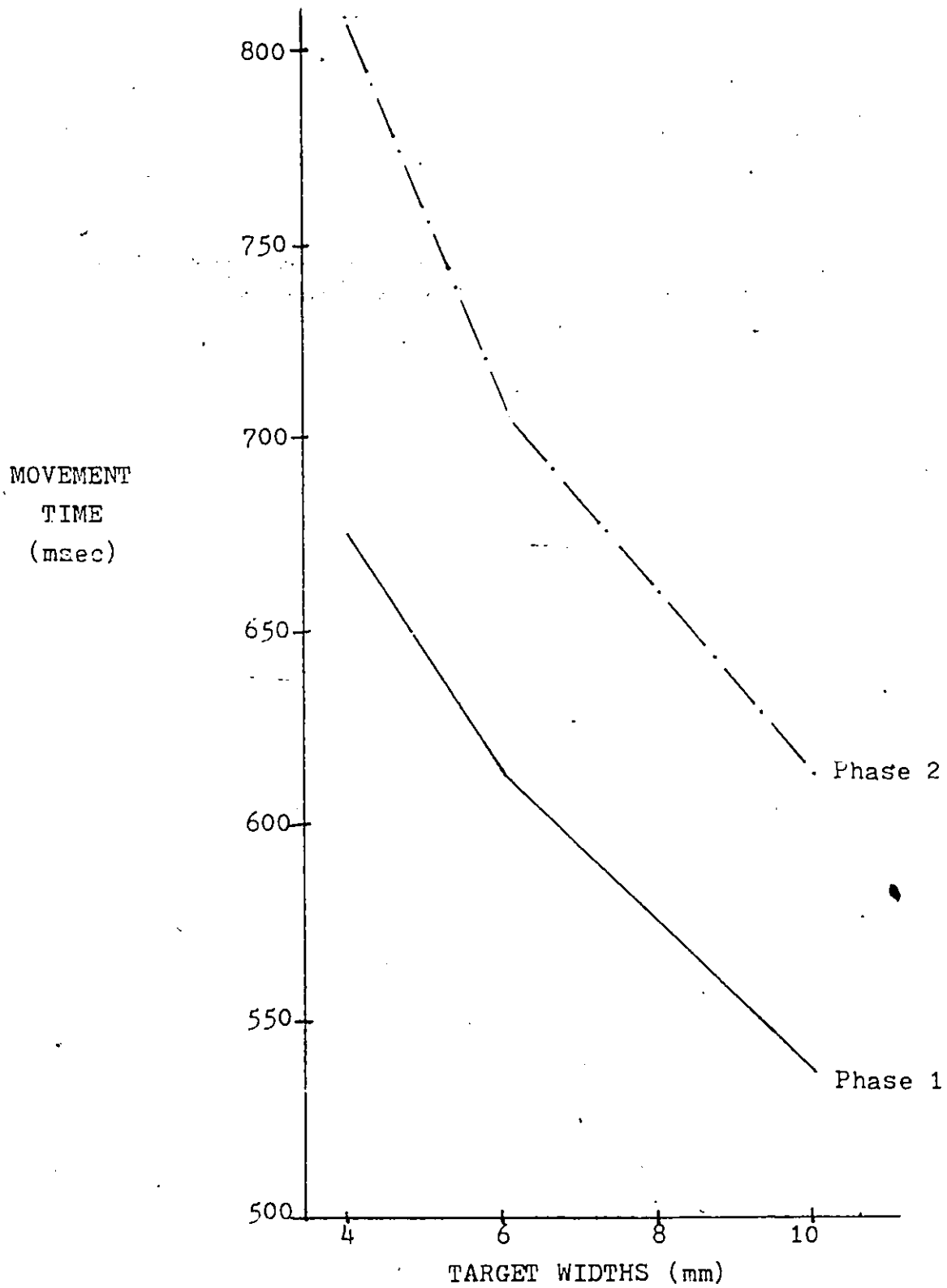


Figure 4. The Phase X Width interaction of movement time for the primary task.

under the two narrow targets, widths at phase 1 and at phase 2 ($p < 0.05$) were also different. To isolate these differences, post hoc analysis was applied. This analysis revealed that at phase 1, all pairs of targets were different except for the 6 and 8 mm targets and the 8 and 10 mm targets. At phase 2, all pairs of targets were different (refer to figure 4).

A Phase X Go/stop interaction was also significant. However, simple main analysis revealed that the interaction was limited to the two phases under go conditions ($p < 0.01$) and stop conditions ($p < 0.01$). Basically, the MT of the second phase was substantially slower than the MT of the first phase under both go and stop conditions. This correlates with previous observations from the data. Moreover, it is not surprising that the appearance of go or stop associated with the preliminary task did not have an effect on performance of the primary task because the subjects performed the movement regardless of the go or stop conditions.

Additionally, a Phase X ISI X Condition interaction was significant. Analyses to isolate the interaction revealed that phase by all the ISI and group conditions was different except for the no preview group at ISI 100. This supports previous statements in that there is a difference between phase 1 and phase 2 and that this difference is due to the fact that the second MT is slower

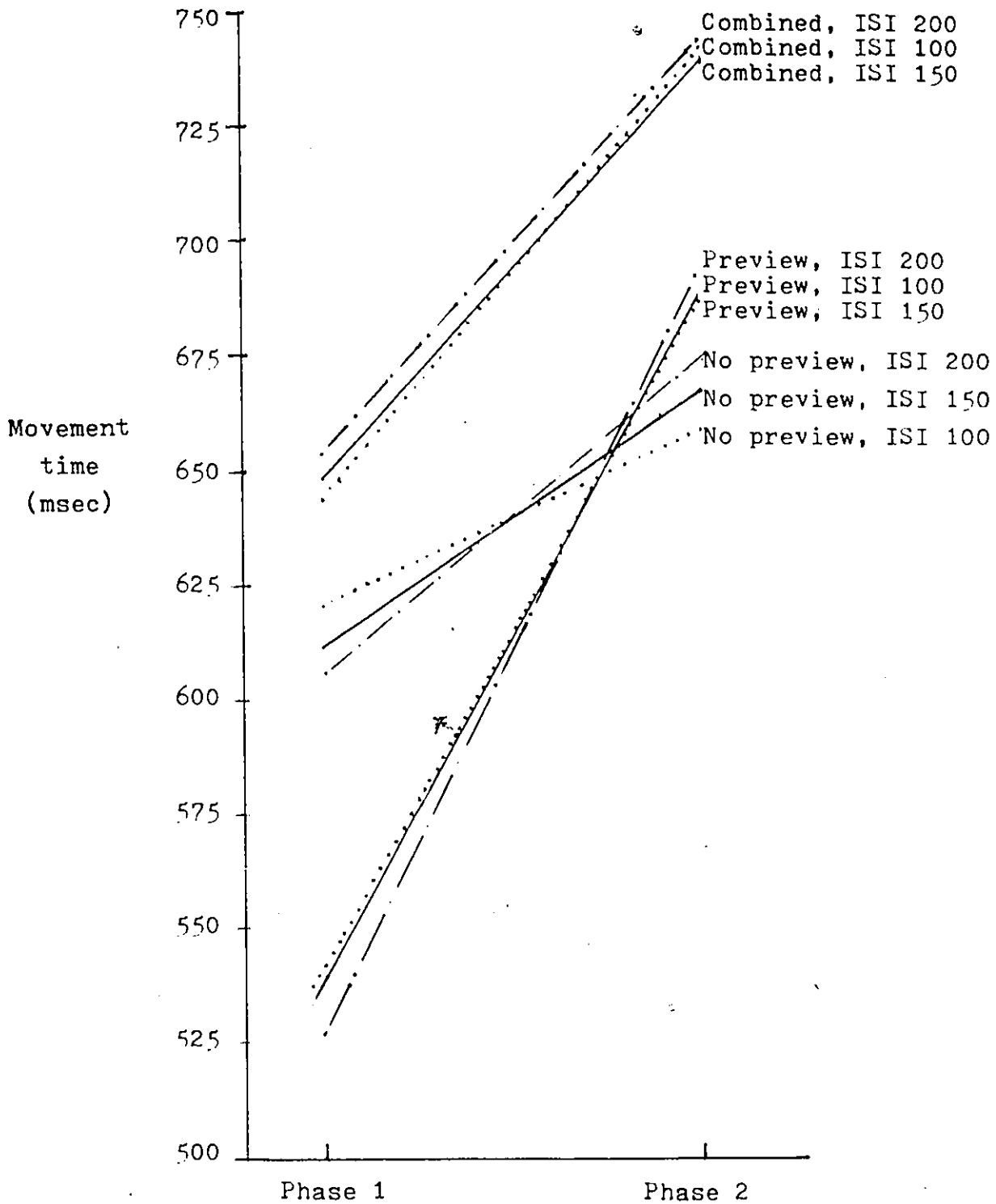


Figure 5. The Phase X ISI X Condition interaction of movement time for the primary task.

than the first MT. This is depicted by the preview group in figure 5.

The final interaction which was significant under the main effects was Go/stop X ISI X Condition. However, simple main effects did not isolate the interaction. One can only state that there is a significant three-way interaction due to slight variations across the variables.

Preliminary task: Reaction time

The main analysis revealed significant Interstimulus Interval (ISI) effects $F(2,188) = 22.94, p < 0.01$ and an ISI X Condition interaction $F(2,188) = 12.47, p < 0.01$. The ISI X Condition interaction was isolated through simple main effects to the difference between the preliminary task group and the combined group at ISI 200 ($p < 0.05$). To pinpoint the exact differences within the combined group, pairwise comparisons were performed. Reaction times at ISI 200 were slower than those of ISI 100 and ISI 150, $p < 0.05$. However, the RT's of ISI 100 and 150 were not significantly different. The main effect of ISI confirmed this finding in that the RT's at ISI 200 were slower than those at ISI 100 and ISI 150.

The two stimuli associated with ISI 100 and ISI 150 were possibly treated as one signal and consequently both the preliminary task and combined task groups performed identically. On the other hand, ISI 200 was long enough

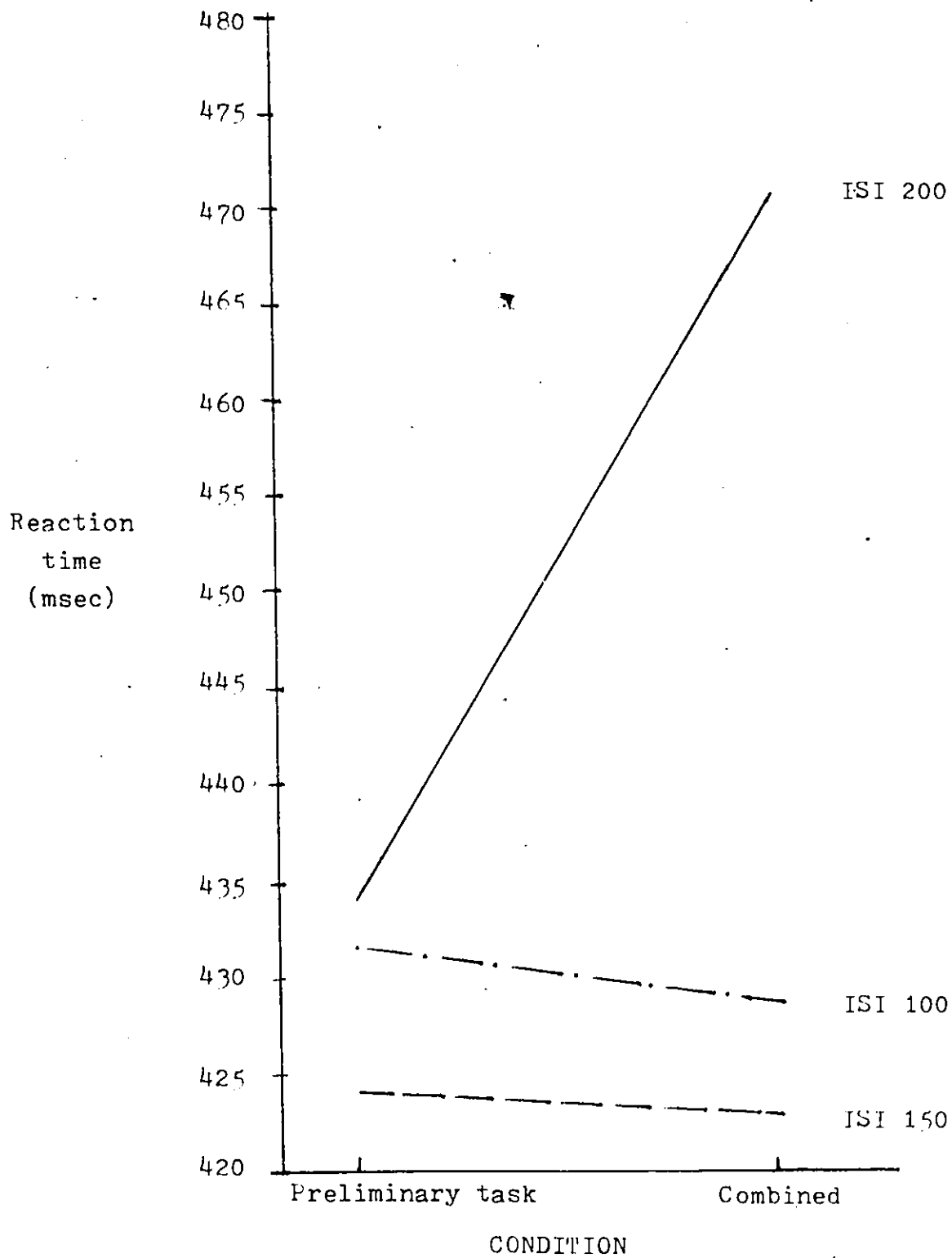


Figure 6. Reaction times for the preliminary task under "Go" conditions.

to interfere in some manner with the combined group. Because the preliminary task group and the combined group performed equally across ISI 100 and ISI 150, this suggests that both groups were performing the preliminary task in the same manner. Thus, the combined group was attending to the preliminary task and, in effect, performing the combined task appropriately.

Error rate:

The error rates of the subjects were analyzed. Under the preliminary task, responding to a stop signal, the preliminary task group had a 3.4% error rate whereas the combined group had an error rate of 1.9%. Since both error rates were very low, this indicates that both groups attended to the "go" and "stop" signals and responded accordingly. In addition, the anticipation rate, responding to a signal before it was displayed, was negligible. Errors due to anticipation were 0.38% for the preliminary task group and 0.07% for the combined group.

Anticipating the second signal was also recorded. Once again the error rate, lifting the stylus before the second stimulus, was negligible. Errors due to anticipation were 0.73% for the no preview group, 0.14% for the preview group and 0.83% for the combined group.

The very low error rates observed in the experiment indicates that the subjects attended to the instructions

given by the experimenter and attempted to follow them throughout the experiment.

Questionnaire:

Subjects were given a question prior to testing on how they felt - very nervous (0), nervous (5), or not nervous (10) and were asked to rate themselves on a scale from 0 to 10. The groups scored 7.3. This score would seem to indicate that the subjects were a little anxious as to the task they would be performing and thus were aroused by the experiment. The inverted-U hypothesis where optimal performance level is associated with a slightly aroused state would support the supposition that the subjects were in an appropriate state to perform the task.

In addition, there appears to be a relationship between the second question on "how hard you tried" and optimal performance. The average score across the groups was 8.2 indicating that the subjects felt that they had tried hard to perform to the best of their capabilities.

Table 1. Reaction times (RT) and movement times (MT) in msec and the standard deviations (SD) for the experimental groups.

CONDITION	RT PRELIMINARY TASK	RT PRIMARY TASK	MT1	MT2
Preliminary task	430	-	-	-
SD	78	-	-	-
No preview	-	143	616	668
SD	-	60	75	100
Preview	-	228	536	685
SD	-	65	101	124
Combined	441	299	650	734
SD	46	93	93	128

Table 2. Movement times (MT) in msec of the Phase X Width interaction.

TARGET WIDTH	4mm	6mm	8mm	10mm	MARGINAL MEANS
Phase 1	676	612	575	539	600
Phase 2	808	707	660	607	696
MARGINAL MEANS	742	660	617	573	648

CHAPTER V

Discussion

The discussion will be considered under three sections. The first section will examine the hypotheses of the experiment in relation to the results, the second section will discuss the implications of the results and the third section will compare the results to other studies.

The first hypothesis, that a manual preliminary task would disrupt preplanning of a simple RT task in that RT would increase with an increase in the difficulty of the movement, was not directly supported. Variations in the target widths did not have an effect on the RT to the primary task. However, those subjects engaged in the preliminary task (combined group) did have a significantly slower RT than those subjects who did not have to perform the task. Thus, in general, preplanning was disrupted by the preliminary task.

The second hypothesis proposed that an increase in the difficulty of the movement would lead to an increase in MT in phase 1 as compared with phase 2. Results of this experiment showed that an increase in the difficulty of the movement (decreasing the target width) led to an increase in the overall MT. But, this increase in MT was greater in phase 2 and not in phase 1. In addition, under narrow

target conditions (4 and 6 mm) the difference in the MT's between phase 1 and phase 2 was more apparent. Although this finding can be attributed to the fact that some of MT in phase 2 incorporated time on the first target as well as the movement time to the second target, this cannot be the only explanation. If time on target was solely responsible for the increase in MT in phase 2, the two phases would have similar slopes across the group conditions (see figure 3) to correspond with the identical slopes of the two phases across the target widths (see figure 4). Since this is not the case, the slower MT during phase 2 as compared with phase 1 is due to time on target as well as time needed to program the second part of the primary task. This is reinforced when considering the narrow targets. More time was needed to process information about the 4 and 6 mm target widths which resulted in the MT in the second phase increasing more in comparison to the MT in the first phase for narrow target widths.

The implications of the results will be discussed under three sections, the primary task RT, the primary task MT and the preliminary task RT.

An interesting finding under the primary task RT was the significant difference between the conditions in that the no preview group recorded the fastest RT, the preview group the next fastest RT and the combined group the slowest RT. It was expected that the group who could preview the task and possibly preprogram their response would react the quickest.

However this was not the case for the primary task RT. The no preview group watched the complete display on the computer and could anticipate the second signal whereas the preview group did not see the complete display and could not anticipate the second signal. Also, they were required to maintain a readiness state for a longer period of time. Consequently, the preview group recorded slower RT's.

The significant difference between the interstimulus intervals showed that the RT at ISI 100 was slower in comparison to the other two intervals. At ISI 100, the signals were presented so closely together that the subjects did not have time to respond to each stimuli. Possibly at ISI 150 and ISI 200 the intervals were long enough for the subjects to initiate a response to the first signal. Therefore, the response to the second signal was not delayed as much as with the ISI 100.

This finding was reinforced by the Condition x-ISI interaction. The combined group, who had to respond to both signals, recorded significantly faster RT's at ISI 150 and ISI 200. This suggests that an ISI as low as 150 msec is sufficient for a subject to process information and be reacting to one stimulus while initiating a second response in a simple RT, one-choice task. Furthermore, the Go/stop x ISI x Condition interaction reinforces this statement.

Analysis of the primary task MT revealed significant

differences between the three conditions. As expected, the preview group was the fastest, the no preview group the next fastest and the combined group the slowest.

A significant difference between the two phases was noted. Overall, subjects moved faster to the first target than to the second target possibly because they only preprogrammed the first phase and not the second. Moreover, the Phase x Condition interaction supports this observation. Subjects in the preview group moved very quickly to the first target and appear to have preplanned phase 1 but not phase 2. On the other hand, subjects in the no preview group and the combined group appear to plan the task as a whole as MT's at phase 1 are equal to MT's at phase 2 in addition to time on target 1 (see figure 3).

Similarly, the Phase x ISI x Condition interaction revealed that the second MT was slower than the first MT. As well, the Phase x Go/stop interaction indicated that subjects moved slower over the second phase of the primary task regardless of instructions (go or stop) of the preliminary task. Therefore, the interactions Phase x Go/stop and Phase x ISI x Condition reinforce previous findings of the data.

The Phase x Width interaction disclosed only significant differences between the two phases at the two narrow targets (4 and 6 mm). Basically, the subjects moved slower over the second phase of the primary task. The Force - variability model proposed by Schmidt (1982) may explain this observation.

Because the targets were always in the same place with equal amplitude, the subjects only had one movement to learn and consequently one force to apply to the movement. At the wide targets (8 and 10 mm), the movement required little reprogramming. However, at the narrow targets (4 and 6 mm) in order to decrease the movement variability, the subjects had to move slower to the narrow targets.

The results of the preliminary task R^T indicated that the preliminary task group and the combined group performed equally across ISI 100 and ISI 150. This suggests that, indeed, the combined group performed the tasks sequentially. However, at ISI 200, the R^T of the combined group was substantially slower than the R^T of the preliminary task group. Possibly, ISI 200 was long enough to interfere in some manner with the combined group.

Generally, the R^T results of the preliminary task which showed that the preliminary task and combined groups performed equally across ISI 100 and ISI 150 were supported by studies which predicted that the R^T to the first stimuli would remain constant when the psychological refractory period (ISI in this case) was less than 500 msec (Harrison, 1960; Vince, 1948). Vince (1948) also suggested that if the psychological refractory period was too close together (less than 100 msec) the stimuli may be grouped together. Since the interstimulus intervals, 100 and 150, were very small, both stimuli may have been grouped together. This explains the similarity of

the RT's between the preliminary task and combined groups at these intervals.

However, at ISI 200, the interval was long enough for subjects to differentiate between the two stimuli and consequently interfere with subjects in the combined group as they had to respond to both stimuli. The RT of this group was significantly slower than that of the preliminary group. This finding supports the response-conflict theory proposed by Herman and Kantowitz (1970). Basically, stimuli for different responses presented in rapid succession will cause the response tendencies to interact affecting both reaction times. As the combined group had to perform different responses to the two different stimuli, there was competition between the responses resulting in a significantly slower RT (at ISI 200) in the preliminary task. In addition, subjects in the combined group had the slowest RT's in the primary task.

It was interesting to note that the RT of the no preview group was quicker than that of the preview group. Subjects in the preview group who were able to preview the primary task and possibly preprogram the movement, were expected to have the fastest RT (Klapp et al., 1974; Goggin Christina, 1979; Klapp Greim, 1979; B. Kerr, 1979; Sheridan, 1981). This was not the case. The no preview group was faster. However, this group had the advantage over the preview group in that they were given a warning signal, "READY", prior to the two stimuli indicating the interstimulus interval. Thus, they were more primed for the task. The preview group, on

the other hand, was not looking at the computer screen and therefore when they heard the two signals were not primed. Consequently, this difference with previous reaction time studies can be explained by differences in the experimental design between the preview and no preview groups.

At first glance, the findings that target width had no effect on RT to the primary task were unexpected. However, all subjects had to perform the same amplitude of movement on every trial regardless of previous instructions. As a result, the response to the second signal was similar to a simple reaction time. The marginal mean of the primary task RT was 224 msec. This confirms observations by Henry and Rogers (1960) who found simple RT to be between 200 and 250 msec. In addition, several studies on simple RT tasks have found that increases in the complexity of the movement had no effect on RT (Fitts & Peterson, 1964, B. Kerr, 1979; Klapp & Greim, 1979). Accordingly, the observation that target width had no effect on RT was confirmed in this study.

Fitts and Peterson (1964) in their choice RT experiment found that target width had the largest effect on MT. These findings were supported by data collected from this experiment. As target width increased, the subject had less information to process about the movement and MT to the targets decreased confirming Fitts' Law. This observation was identical across the bi-phasic movement.

The preview group had the fastest overall MT's indicating

that they were able to preprogram part or all of the primary task. Findings from this experiment tend to favour the suggestion that subjects in this group were only able to preprogram the first part of the movement. Their MT's over the first phase were substantially quicker than the other groups, yet their MT's over the second phase were equal to those subjects in the no preview group. Fischman (1984) proposed that having to pause on a well-defined target was sufficient to cause programming time to increase resulting in longer MT's. The comparison between the MT's of the no preview and preview groups in addition to the significant difference between the two phases lends support to Fischman's (1984) proposal. When performing a bi-phasic movement, only the first part of the movement can be programmed in advance whether the whole movement is previewed or not.

Notwithstanding, the difference between the MT's of the no preview and preview groups can be interpreted in another way. In addition to the no preview group not looking at the primary tapping task, their attention was diverted by the computer screen. As a result, the first MT's of the no preview group were not only slower than the preview group but similar to the combined group. Even though the no preview group did not have to perform the preliminary task, they attended to the stimuli of the preliminary task. Consequently, paying attention to the stimuli rather than performing a response produced the same results. This finding is in

agreement with studies by Klapp and Greim (1979) and Davis (1959).

Generally, the RT's and MT's of the combined group were slower than those of the other groups. The combined group had to perform the preliminary task and primary task sequentially. The interference or competition between the central mechanisms caused all responses to be delayed. In accordance with B. Kerr (1983), programming was carried into the movement time intervals. Performing the preliminary task, then, interfered with programming the primary tapping task. However, the extent of the consequence that the preliminary task had on the preprogramming was not great. The significant main effects (Phase x Go/stop) and (Phase x ISI x Condition) revealed that the interactions were limited to the difference in MT's between the two phases. Go/stop and ISI did not have an effect on the MT's.

In conclusion, two observations that preplanning may be disrupted dominate this study. Firstly, the no preview group and combined group performed similarly over the bi-phasic movement suggesting that the conditions of looking away from the primary task and performing the preliminary task both delayed preplanning (see figure 2). Even if there was preplanning, it was limited to the first phase of the movement. This was clearly illustrated by the preview group who moved substantially quicker than the other groups over the first phase yet had equivalent MT's over the second phase.

Consequently, the performance of the first phase of a bi-phasic movement will disrupt or prevent preplanning of the second phase.

Secondly, even though the no preview group had the fastest RT's in the primary task, the planning of the primary task was carried into the MT of the first phase. The combination of the RT and the MT of the first phase of the primary task of the no preview group (759 msec) and the RT and MT of the preview group (764 msec) are similar. This indicates that although the preview group was not able to anticipate the second signal, they were able to preplan the first movement as indicated by their fast MT's over phase 1. Thus, the no preview and preview groups performed equally well over the first part of the primary task; but slowed for phase 2. On the other hand, the combined group moved much slower over the first part of the primary task (949 msec), which would seem to be as a result of the preliminary task disrupting preprogramming of the first part of the primary task.

In summary, the present study examined the effects of a manual preliminary task on the preprogramming of a bi-phasic aiming movement and in the process found that a preliminary task did disrupt preplanning. Furthermore, comparison of the preview and no preview groups indicated that performance of the first phase of a bi-phasic movement will disrupt preplanning of the second phase. However, additional research to support these findings is recommended. Specifically, the complexity of the movement can be altered by using unequal target widths

instead of equal target widths. Also, the target width can be changed every trial as opposed to every sixty trials. In addition, the READY signal indicated by the computer can be accompanied with a long tone so that the subjects in the preview group (who were not looking at the computer screen) will have a warning prior to the two short tones signalling the start of the movement. Consequently, all groups, regardless of where they are looking, will receive similar stimuli. Moreover, time on the first target was not controlled in this experiment due to limitations of the apparatus. An instrument to record time on target will aid in obtaining a more accurate measurement of the MT in phase 2. Lastly, other techniques of observing and recording movement in conjunction with the bi-phasic tapping task will allow the consideration of other aspects of the task besides the movement time. For example, examination of the displacement, velocity and/or acceleration of the arm may reveal different movement patterns between the groups which will help the understanding of motor programming.

References

- Carlton, L.G. (1979). Control processes in the production of discrete aiming responses. Journal of Human Movement Studies, 5, 115-124.
- Creamer, L.R. (1963). Event uncertainty, psychological refractory period and human data processing. Journal of Experimental Psychology, 66, 187-194.
- Davis, R. (1959). The role of "attention" in the psychological refractory period. Quarterly Journal of Experimental Psychology, 11, 211-220.
- Fischman, M.G. (1984). Programming time as a function of number of movement parts and changes in movement direction. Journal of Motor Behavior, 16, 405-423.
- Fitts, P.M. (1954). The information capacity of the human motor system in controlling the amplitude of movement. Journal of Experimental Psychology, 47, 381-391.
- Fitts, P.M., & Peterson, J.R. (1964). Information capacity of discrete motor responses. Journal of Experimental Psychology, 67, 103-112.
- Glencross, D.J. (1973). Response complexity and the latency of different movement responses. Journal of Motor Behavior, 5, 95-104.
- Glencross, D.J. (1976). The latency of aiming movements. Journal of Motor Behavior, 8, 27-34.
- Goggin, N.L., & Christina, R.W. (1979). Reaction time analysis of programmed control of short rapid aiming movements. Research Quarterly, 50, 360-368.

- Harrison, J.S. (1960). Psychological refractoriness and the latency time of two consecutive motor responses. Research Quarterly, 31, 590-600.
- Henry, F.M., & Harrison, J.S. (1961). Refractoriness of a fast movement. Perceptual and Motor Skills, 13, 351-354.
- Henry, F.M., & Rogers, D.E. (1960). Increased response latency for complicated movements and a "memory drum" theory of neuromotor reaction. Research Quarterly, 31, 448-458.
- Herman, L.M., & Kantowitz, B.H. (1970). The psychological refractory period effect: Only half the double stimulation story? Psychological Bulletin, 73, 74-88.
- Hick, W.E. (1952). On the rate of gain of information. Quarterly Journal of Experimental Psychology, 4, 11-26.
- Hyman, R. (1953). Stimulus information as a determinant of reaction time. Journal of Experimental Psychology, 45, 188-196.
- Jagacinski, R.J., Shulman, H.G., & Burke, M.W. (1980). Motor programming and alerting. Journal of Human Movement Studies, 6, 151-164.
- Kantowitz, B.H. (1974). Double stimulation. In B.H. Kantowitz (Ed.), Human Information Processing: Tutorial in Performance and Cognition (pp. 83-131). New Jersey: Erlbaum Ass., Pub.

- Kantowitz, B.H., & Knight, J.L. Jr. (1978). Testing tapping time-sharing: Attention demands of movement amplitude and target width. In G.E. Stelmach (Ed.), Information Processing in Motor Control and Learning (pp. 205-227). New York: Academic Press.
- Keele, S.W. (1973). Attention and Human Performance. Pacific Palisades, CA: Goodyear Publishing.
- Kerr, B. (1976). Decisions about movement direction and extent. Journal of Human Movement Studies, 3, 199-213.
- Kerr, B. (1978). Task factors that influence selection and preparation for voluntary movements. In G.E. Stelmach (Ed.), Information Processing in Motor Control and Learning (pp. 55-67). New York: Academic Press.
- Kerr, B. Initiating short movements without target preview. Paper presented at the meeting of the Psychonomics Society, San Antonio, Texas, November 1978.
- Kerr, B. (1983). Preplanning for aimed movements: Disruption from a preliminary task. Journal of Experimental Psychology: Human Perception and Performance, 9, 596-606.
- Kerr, R. (1975). Movement control and maturation in elementary grade children. Perceptual and Motor Skills, 41, 151-154.
- Kerr, R. (1978). Diving, adaptation, and Fitts Law. Journal of Motor Behavior, 10, 255-260.

- Kerr, R. (1982). Psychomotor Learning. New York: Saunders College Publishing.
- Klapp, S.T., Wyatt, E.P., & MacLingo, W. (1974). Response programming in simple and choice reactions. Journal of Motor Behavior, 6, 263-271.
- Klapp, S.T. (1975). Feedback versus motor programming in the control of aimed movements. Journal of Experimental Psychology, 104, 147-153.
- Klapp, S.T., Abbott, J., Coffman, K., Greim, D., Snider, R., & Young, F. (1979). Simple and choice reaction time methods in the study of motor programming. Journal of Motor Behavior, 11, 91-101.
- Klapp, S.T., & Greim, D.M. (1979). Programmed control of aimed movements revisited: The role of target visibility and symmetry. Journal of Experimental Psychology: Human Perception and Performance, 5, 509-521.
- Pachella, R.G., & Pew, R.W. (1968). Speed accuracy tradeoff in reaction time: Effect of discrete criterion times. Journal of Experimental Psychology, 76, 19-24.
- Posner, M.I., & Keele, S.W. (1972). Skill learning. In R.M.W. Travers (Ed.), Handbook of Research on Teaching (pp. 56-63). Washington, DC: American Educational Research Association.

- Quinn, J.T. Jr., & Sherwood, D.E. (1983). Time requirements of changes in program and parameter variables in rapid ongoing movements. Journal of Motor Behavior, 15, 163-178.
- Salmoni, A.W., & McIlwain, J.S. (1979). Fitts reciprocal tapping task, a measure of motor capacity. Perceptual and Motor Skills, 49, 403-413.
- Schellekens, J.M.H., Kalverboer, A.F., & Scholten, C.A. (1984). The micro-structure of tapping movements in children. Journal of Motor Behavior, 16, 20-39.
- Schmidt, R.A. (1982). Motor Control and Learning. Champaign, Illinois: Human Kinetics Publishers, Inc.
- Schmidt, R.A., Zelaznik, H.N., & Frank, J.S. (1978). Sources of inaccuracy in rapid movement. In G.E. Stelmach (Ed.), Information Processing in Motor Control and Learning (pp. 184-186). New York: Academic Press.
- Semjen, A., & Requin, J. (1976). Movement amplitude, pointing accuracy and choice-reaction time. Perceptual and Motor Skills, 43, 807-812.
- Sheridan, M.R. (1979). A reappraisal of Fitts' Law. Journal of Motor Behavior, 11, 179-188.
- Sheridan, M.R. (1981). Response programming and reaction time. Journal of Motor Behavior, 13, 161-176.

- 5
- Siegel, D.S. (1977). The effect of movement amplitude and target diameter on reaction time. Journal of Motor Behavior, 9, 257-265.
- Telford, C.W. (1931). The refractory phase of voluntary and associative responses. Journal of Experimental Psychology, 14, 1-36.
- Vince, M.A. (1948). The intermittency of control movements and the psychological refractory period. British Journal of Experimental Psychology, 38, 149-157.
- Vince, M.A. (1949). Rapid response sequences and the psychological refractory period. British Journal of Experimental Psychology, 40, 23-40.
- Welford, A.T. (1952). The "psychological refractory period" and the timing of high-speed performance - A review and a theory. British Journal of Psychology, 43, 2-19.
- Welford, A.T., Norris, A.H., & Shock, N.W. (1969). Speed and accuracy of movement and their changes with age. Acta Psychologica, 30, 3-15.

Appendix I

F-ratio Tables

Table 1. Abbreviated F-ratio table of the preliminary task reaction time.

SOURCE	MEAN SQUARE	DEGREES OF FREEDOM	F	TAIL PROBABILITY
Condition	8053.92	1	0.83	N.S.
Error	9666.68	94		
ISI	23229.75	2	22.94	0.01
ISI X Condition	12625.55	2	12.47	0.01
Error	1012.42	188		

Table 2. Abbreviated F-ratio table of the primary task reaction time.

SOURCE	MEAN SQUARE	DEGREES OF FREEDOM	F	TAIL PROBABILITY
Condition	1756762.88	2	21.92	0.01
Error	80139.88	33		
ISI	73385.40	2	53.61	0.01
ISI X Condition	16472.38	4	21.03	0.01
Error	1368.82	66		
Go/stop X ISI X Condition	3681.17	4	3.73	0.01
Error	986.27	66		

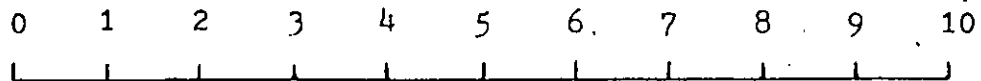
Table 3. Abbreviated F-ratio table of the primary task movement time.

SOURCE	MEAN SQUARE	DEGREES OF FREEDOM	F	TAIL PROBABILITY
Condition	970635.10	2	5.35	0.01
Error	181312.38	33		
Phase	3922300.31	1	117.73	0.01
Phase X Condition	347207.56	2	10.42	0.01
Error	33315.01	33		
Width	2230189.46	3	84.46	0.01
Error	26405.17	99		
Phase X Go/stop	14346.32	1	6.34	0.02
Error	2263.95	33		
Phase X ISI X Condition	4102.96	4	3.73	0.01
Error	1099.90	66		
Go/stop X ISI X Condition	2720.67	4	3.02	0.02
Error	901.93	66		

Appendix II

Questionnaires

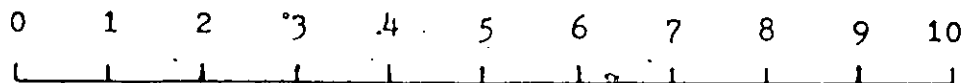
Question 1. Given to the subjects prior to testing and asked to rate themselves on the scale regarding "how they felt".



very nervous

not nervous

Question 2. Given to the subjects immediately following testing and asked to rate themselves on the scale regarding "how hard they tried".



tried not so hard

tried hard