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A STUDY OF THE EFFECT OF DIFFERING FOREPERIODS ON PERFORMANCE OF THE FORWARD GRAB SWIMMING START

by

Carol Ann Cooper

A Dissertation Submitted to
the Faculty of the Graduate School at
The University of North Carolina at Greensboro
in Partial Fulfillment
of the Requirements for the Degree
Doctor of Education

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1975

Approved by

Gail M. Hennis
Dissertation Adviser

APPROVAL PAGE

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COOPER, CAROL ANN. A Study of the Effect of Differing Foreperiods on Performance of the Forward Grab Swimming Start. (1975) Directed by: Dr. Gail Hennis. Pp. 86.

The purpose of this study was to determine if there is an optimal length of foreperiod between the commands given by the starter and the sound of the gun to elicit a fast response when the grab start is used in competitive swimming. Measured responses were the time of initial hand movement (hand movement time) and time of the swimmer's feet leaving the block (starting time).

A specially designed electronic timing device was utilized to control the length of the foreperiod interval, to activate the gun, and to measure hand movement time and starting time.

Blocks of four trials at each controlled foreperiod interval of .5, 1, and 1.5 seconds and at one interval during which the length of the foreperiod was varied for each trial in the block (varied foreperiod) were presented in random order to 24 skilled competitive swimmers, 12 males and 12 females. Ages ranged from 12 to 17 years.

Data were analyzed by a 2 x 4 analysis of variance with repeated measures on the last factor. Sex was the first independent variable, and length of the foreperiod was the independent variable having repeated measures. For hand movement time, a calculated $\underline{F}$ (1, 46) = 3.2549 ($\underline{p} < .05$) indicated that there were significant differences due to treatment effects. When the Newman-Keuls procedure was applied, the 1.5 second interval was shown to elicit slower times than any other interval, and the varied foreperiod interval produced slower times than the .5 second interval. Neither the effect of sex nor interaction was significant.

For starting time, no significant effects were found due to sex, to treatments, or to interaction between the two variables. When Pearson Product Moment method of linear correlation was applied to hand movement time and starting time, no relationship was found between those two variables.

It was concluded that among the foreperiod intervals of .5, 1, and 1.5 seconds and varied foreperiod there was no optimal foreperiod interval which elicited a faster response in the grab start racing dive than any other interval.

ACKNOWLEDGEMENTS

Appreciation is accorded Dr. Gail Hennis, advisor, for her advice and support from comprehensives through the dissertation; Dr. Shirley Winsberg, colleague at University of Northern Iowa, for her thoroughness as design critic and dissertation reader; and members of the doctoral committee for their help throughout the graduate program.

Special appreciation is extended to Dr. Doris McKinney and Dr. Celeste Ulrich for their willingness to discuss motor learning and professional directions. These discussions were, in the final analysis, the essence of my graduate education.

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CHAPTER I

INTRODUCTION

The forward start is used in all swimming races with the exception of the backstroke. Required specifications for the height and angle of the starting blocks are common to the rules of all governing bodies. However, none of the official rules set restrictions upon the forward start except that a balanced position must be attained prior to the start. Within the last five years, the majority of competitors have begun to use the grab start. The grab start has been shown to project the swimmer into the water in the fastest manner (Hanauer, 1972; Roffer, 1972; Michaels, 1973; Van Slooten, 1973).

Although the starting position is somewhat dependent upon individual preference, four general styles, differentiated primarily by arm patterns, have evolved. From the 1930's to the 1950's, a position with the arms held straight back was used almost universally. Because both arms were extended back while the body weight was forward over the toes, an unstable position was assumed. It was hypothesized that when the arms were projected forward, they initiated the forward motion of the body. During the 1960's the straight backswing and circular backswing became popular. As the arms circled back, the forward body movement was initiated by a sudden forward displacement of the center of gravity. As the arms swung forward they added to the accelerating forces of the body. In the 1970's, the grab start was introduced. In the grab start the hands grip the forward edge of the starting block. Although the weight of the body is held forward, the grip of the hands on the block allows for the body position to remain stable.

Early studies of reaction time conducted in the laboratory, as cited by Woodworth and Schlosberg (1954), indicated that when the length of the foreperiods between the starting command and the sound of the gun was increased, the length of reaction time followed a curvilinear graphic pattern. Experimental practice established that a time of approximately two seconds was optimal. When the foreperiod time greatly exceeded two seconds, reaction time slowed.

Experiments in the laboratory were expanded through studies of reaction time in relation to track and field. Walker and Hayden (1933) tested the speed of reaction in relation to a track start. Varied intervals of one to three seconds were spaced between the sound of the gun and the athlete's first movement in the response. Their results indicated that an optimal interval of foreperiod was between one and two seconds. Tuttle, Armbruster, and Morehouse (1940) duplicated the study using the swimming start. Although the starting position for swimming was less stable than for track, they, too, found that one to two seconds was optimal. False starts occurred more frequently in swimming than in track probably because of the relatively unstable position of the swimmer.

Because of the initial unstable position of the early type of racing dives, the starter of the swimming meet traditionally has been instructed simply to get the complement of swimmers off to a fair start. The starter's instructions have been to see that the contestants are completely motionless before the gun is fired. The length of the time between the signal and the gun has varied although generally it has been between two and four seconds. The starter has varied his timing to hinder a swimmer from going down to the balanced position unduly slow so that opponents must hold their unbalanced position longer and be vulnerable to a false start. With the grab start, swimmers under Amateur Athletic Union rules have been required to go immediately to the set position and the swimmer who has gone down too slowly has been penalized with a false start. With the change in starting techniques of the swimmers, unrhythmical timing of the starts seem unnecessary. Investigation needs to be made of the length of time of the foreperiod to find the optimal length of foreperiod for most effective starts.

Statement of the Problem

It was the purpose of this study to investigate the effects of varying the time between the starting command and the stimulus (sound of the gun) on the time of the hands moving on the blocks and the time of the feet leaving the blocks in the forward swimming grab start. Subproblems concerning the influence of sex and the interrelationship between hand movement time and starting time also were studied.

Specifically the following questions were to be answered:

(a) Is there a difference in starting time in the grab start after foreperiods of .5, 1, and 1.5 seconds and varied foreperiods assigned in random order?

(b) Is there a difference in hand movement time in the grab start after foreperiods of .5, 1, and 1.5 seconds and varied foreperiods assigned in random order?

(c) Is there a difference in starting time from the grab start due to the interaction between sex and the length of the foreperiod?

(d) Is there a difference in hand movement time in the grab start due to the interaction between sex and the length of the foreperiod?

(e) What is the relationship between hand movement time and starting time considering the length of the foreperiod?

(f) What is the relationship between hand movement time and starting time considering sex and the length of the foreperiod?

Definition of Terms

Foreperiod. The time between the command, "Take your mark," and the sound of the gun is designated as the "foreperiod."

Controlled foreperiod. The specific foreperiod when the length of the interval is selected by the starter and controlled by the timing device is called "controlled foreperiod."

Varied foreperiod. The foreperiod when the starter watches the swimmer and fires the gun with the same interval timing as would be used in a meet is called "varied foreperiod." The timing device does not control the length of the interval.

Manual start. The starter activates the foreperiod timer by pushing the "start" button to effect a "manual start." In the varied foreperiod starts, the starter used a manual start with the foreperiod being controlled at .1 second which is as close to a purely manual start that the limits of the instrument allow.

Automatic start. When the swimmer touches the hand switch, and the pressure automatically activates the foreperiod counter and the timing device, an "automatic start" occurs.

Hand movement time. The time between the sound of the gun and the first movement of the hands in the grab start is called the "hand movement time."

Starting time. The time between the starting gun and the feet leaving the blocks is designated as "starting time."

Short-course start. The swimmer has his feet in position on the blocks when the starter gives the commands in an AAU official "short-course start."

Limitations of the Study

The following limitations set the scope of the study:

(a) Subjects were members of the Scottsdale Swim Club senior men's and women's teams who had competed for a minimum of one year at that level of competition. All swimmers were considered to be highly skilled and were expected to be consistent in performance of the grab start.

(b) Subjects were males and females with ages ranging from 12 to 17. This allowed for study of effects due to sex as well as length of foreperiods while controlling for age range.

(c) Only hand movement time and starting time of each swimmer were measured. No attempt was made to study other variables which might affect performance.

(d) All starts were conducted by the same trained starter. The time between the commands and the gunshot was altered according to a prearranged schedule having a randomly ordered sequence of varying lengths of foreperiods.

(e) Swimmers were tested in a practice situation. Although standard directions which emphasized concentrating on the start as one would in competition were given to each swimmer, no effort was made to simulate exact competitive situations.

(f) Only short-course starts off level blocks were studied.

Remainder of the Thesis

The remainder of this thesis was divided into four sections. Research related to the racing dive and the optimal length of foreperiod is reviewed in Chapter II. In Chapter III the apparatus and testing procedures are described. Chapter IV is devoted to presentation and discussion of results, and Chapter V includes the summary and conclusions.

CHAPTER II

REVIEW OF RELATED LITERATURE

Varied factors influence the performance of the forward grab racing start in competitive swimming. Several contributing variables must be assessed in order to understand all ramifications of the problem. The nature of the performer, the definition of the task, and the parameters of the foreperiod or preparatory interval must be scrutinized. An analysis of the precise interaction of that triad of factors is the core of this investigation.

Reaction time or response latency is defined as the time taken to respond to a stimulus. Singer's (1975) definition is probably the most informative: reaction time involves the visual, auditory, and kinesthetic sensors' perception of the stimulus and the time elapsed before the initiation of the movement response. Simple reaction time occurs when there is only one stimulus which initiates only one response. There are no alternatives to complicate the task.

Studies have been conducted of fractionated reaction time in the laboratory. McCormack (1961) subdivided reaction time into several components: premotor time consisting of receptor time, afferent nerve conduction time, brain time, efferent nerve conduction time; and effector time. McCormack found that the individual differences in measured reaction time are primarily functions of premotor time. Premotor time extends from the presentation of the stimulus until the efferent nerve impulse activates the effector or response mechanism.

Several other terms are frequently associated with reaction time. Movement time is the time the body requires to complete a movement once the initial movement response has been initiated. Response time is the time required to complete the entire act in that it is a combination of foreperiod, reaction time, and movement time (Singer, 1975).

The swimming start is classified as a task of simple reaction time. A uniform stimulus of the gunshot is presented. An auditory stimulus elicits a reaction time of about .150 seconds after some practice by subjects and as little as .100 to .120 seconds in some individuals after much practice (Woodworth & Schlosberg, 1954). The uniform response is the racing dive. The swimmer knows in advance what the stimulus will be and what response he will make. The foreperiod time is between the command and the gun signal. Even though the length of the foreperiod cannot be predicted by the competitor, there are no major alternative stimuli choices to complicate the task. The time between the gun sound and the sprinter's response is the reaction time. The movement time commences with the first physical response the competitor makes to the sound of the gun and ceases when the feet of the swimmer leave the blocks.

Due to the similarities of the starting tasks in track and in swimming, studies projecting the optimal temporal sequence for the starter to use in order to elicit the fastest response from the competitors will be presented for track as well as for swimming. In swimming the type of forward start which the individual performer chooses to utilize can influence the method of collecting the data regarding reaction time and movement time. Studies of the various forward swimming starts will be reviewed, therefore, primarily to analyze the instrumentational and methodological procedures.

Nature of the Performer

Numerous studies have been completed which emphasize the unique characteristics each individual brings to the task. Individual differences of age and sex as well as skill level and motivation can interact to influence measurably data relating to reaction time and movement time.

Reaction time and movement time.

Individual differences of subjects have contributed to controversy which has existed regarding the relationship between the two variables of reaction time and movement time. Early studies by Tuttle and Westerland (1931) indicated a correlation coefficient of *r* = .836 between reaction time as measured by a switch-pressing task and movement time as indicated by the speed with which a track sprinter completed the 75-yard dash. Subsequent studies of the correlation between movement time and reaction time have shown no relationship between the two factors. With specific reference to track, Henry and Trafton (1951) found virtually no correlation between reaction time and sprint performance in the 50-yard dash. For physical education students, the correlation between the two factors was *r* = .14. For highly skilled track men, a similar coefficient of *r* = .18 was obtained.

Henry (1952, 1960a) conducted a series of experiments to assess the relative independence of reaction time and motor time as well as to study additional factors which might have a large influence on those response times. Initially, Henry (1952) used the movement tasks of snatching at a suspended tennis ball and pressing a treadle and the simple reaction-time task of releasing a key in order to measure interrelationships between movement time and reaction time. Sixty college males completed 50 trials on the ball-snatching task, and 43 additional men completed 20 trials on the treadle-pressing task. Responses were divided into reaction time and movement time. Henry interpreted the resulting linear correlation coefficient $r = -.07$ as indicating that those two factors were independent.

Slater-Hammel (1952) hypothesized that the specific tasks Henry selected might have influenced the results unduly. Slater-Hammel designed an instrument to avoid a terminal response which required a controlled movement such as snatching a ball or pressing a treadle. He compared reaction time and movement time through a movement excursion task which involved using a ballistic action of sweeping the right arm through a horizontal arc and slamming the arm against a pad 30 degrees beyond the midline of the subject's body. Subjects were 25 male physical education majors who completed 25 trials, each after a randomly varied foreperiod of one, two, or three seconds. The correlation coefficients obtained between reaction time and movement time of $r = -.07$ to $r = .17$ indicated no relationship between the two factors. Although Slater-Hammel's findings concur with Henry's, Slater-Hammel criticized Henry's conclusion that reaction time and movement time were independent factors. Slater-Hammel was willing to conclude only that there was no relationship between the factors.

Henry (1960a) described his "Memory Drum" theory to explain neuromotor response patterns. In inspecting the reaction latency between simple and more complex reactions, he hypothesized that longer reaction latencies were necessary for more complex skills because a more complicated circuit was transversed by neural impulses traveling through the coordination centers of the nervous system.

Three tasks, selected to represent three intervals on a continuum from simple to complex, were presented: (a) lifting the forefinger from a key, (b) reaching forward to grasp a suspended tennis ball, and (c) completing a sequential pattern which necessitated touching two balls in order. All responses were to a gong which was preceded by a one to four second foreperiod interval presented in random order to avoid anticipation of the stimulus by the subject.

In Experiment 1, tasks were presented in order ABC in continuous rotation trial-by-trial until 10 trials had been completed for each task. Experiment 2 involved 10 trials for Task A, followed by 10 trials for Task B, then 10 trials for Task C. Order of presentation of trials within the sequence was balanced among groups of subjects.

There was virtually no correlation discovered between reaction time and movement time for any task. When sex or age factors were considered separately, there still was no correlation between the two response factors.

<u>Sensory or motor set</u>. Henry (1960b) compared the effects of reaction time after a sensory set to one following a motor set. In a sensory set, the individual was told to concentrate on attending to the stimulus. In a motor set, the respondent was to concentrate on the

motor action he was to perform in response to the stimulus. Henry hypothesized that a motor set would yield a slower reaction time than a sensory set and that there could be a difference depending upon the sex of the subject.

Following a randomly projected foreperiod of one to four seconds, a movement task was presented. The task consisted of lifting a finger from a key upon the sound of a gong and then touching a button 18 inches to the side before returning the hand to sweep a tennis ball which was suspended over the key. Forty female and 40 male college students completed alternating treatments composed of: (a) spontaneous set for 15 trials (set being determined by introspection after each trial) and (b) enforced set for a total of 40 trials. The enforced-set trials were blocked in groups of 10 trials with each block alternating between enforced sensory or enforced motor set. Results indicated that a motor set elicited reaction time 2.6% slower than sensory set and movement time 2.1% slower than sensory set. When the selection of set was left to the performer, faster reaction and movement times were elicited in the set of the subject's choice as compared to use of the required alternative set.

Henry (1961) further studied the amount of correlation between individual differences in reaction time and movement time. Auditory and visual stimuli were utilized as well as simple and discriminatory reaction time tasks. The response involved moving the arm through a continuum of discrete tasks ranging in difficulty from simple to complex. The resulting reaction time and movement time score distributions were skewed which necessitated converting the scores to their reciprocal or to speed scores. This transformation allowed for normal distribution of the scores in each cell. Since there was no difference in correlation coefficients between the raw and the transformed data as indicated by coefficients of $\underline{r}$ = .013 and $\underline{r}$ = .003, respectively, no need to transform scores in future studies was indicated. Results showed that there was no difference in movement time or reaction time regardless of the complexity of the task.

Christina (1973) projected that enforced motor set would lead to longer reaction and movement time in a complex task than would an enforced sensory set. After a randomly varied foreperiod of one to four seconds, a buzzer sound was the stimulus for 30 male college students to complete a novel task which involved hitting three switches arranged in a diamond-shaped pattern. Two groups were each assigned to either sensory or motor set for the whole experiment. Each subject then completed a block of trials on the reaction-time task followed by a block of trials on the motor-time task. Scores on this pretest were combined to serve as a covariate in the final analysis of the data. During the experiment, the total task was completed although the times from the reaction-time portion of the task and the motor-time portion were recorded separately. Results showed that the variate reaction time was slower for motor set than for sensory set. There was no influence of enforced set on motor time. Christina felt the lack of influence of set on motor time could be moderated if the task was practiced to sufficient extent that it could be performed at a subconscious level.

Sex and age. Secondary to his basic premise regarding the relationship between reaction time and movement time, Henry related the effects of sex and age to the measurement of the response variables (1960a, 1960b, 1961).

When testing his "Memory Drum" theory, Henry (1960a) found there was no difference in reaction time or movement time between college men and women nor among persons of ages 8, 12, and 24 years. In all groups, reaction time increased as the complexity of the task increased. When 8-year-olds and 12-year-olds were compared, the younger subjects were slower on all movement time responses with the differential being greater when the tasks were performed in random order as compared to blocked order. For measures of movement time, the women were 40% slower than the men in reaching for a ball, but the women were only 14% slower in the more complex sequence which involved reaching for two tennis balls in order.

When Henry (1960b) compared results depending upon the use of sensory or motor set, women responded 13.9% slower than men on the reaction-time criterion and 30.3% slower for the movement-time criterion regardless of the set.

In a later study, Henry (1961) found no difference in movement time when different complexities of response tasks were presented to subjects with mean ages of 8, 12, 24, and 30 years. There were small (.01 seconds) differences in reaction time between members of the sexes showing the women to be slightly but significantly slower than the men. Sex differentials in speed of movement were .20 to .90 seconds, indicating larger differences than occurred in reaction time. Through the continuum of task difficulty, women produced slower mean movement time than the men by .45 seconds which was equivalent to a 22% difference.

When the maturational effects of ages 8, 12, 24, and 30 years were manipulated statistically, the reaction time and movement time correlations showed no influence due to those variables as either a linear or curvilinear function.

Pierson (1959) studied age in relation to the factors of reaction time and movement time as well as the interrelations between the two factors. The reaction time task involved releasing a hand switch upon a signal, and the movement time task involved moving the hand through an 11-inch horizontal sweep to break a beam switch. For male subjects correlations between reaction time and movement time were as follows: (a) age 12, $\underline{r} = .50$; (b) age 13, $\underline{r} = .10$; (c) age 14, $\underline{r} = .20$; (d) age 15, $\underline{r} = .50$; (e) age 16, $\underline{r} = .35$; (f) age 17, $\underline{r} = .20$; (g) age 22, $\underline{r} = .58$. Overall reaction time and movement time showed a correlation coefficient of $\underline{r} = .31$. When 400 subjects' scores were examined with the effects of age removed statistically, correlation between the two factors was $\underline{r} = .33$.

Mendryk (1960) used the same task as Pierson to study relationships between reaction time and movement time as well as the reliability of measurement of those factors. The nominal mean ages of 12 and 22 were selected because Pierson's correlations at these ages had been high and the age of 48 because Pierson's relationships had been low. The intent of the study was to ascertain if the degree of relationship was due to the independence of the variables, to task definition, to low measurement reliability, or to the heterogeneous grouping of subjects.

The 22-year-olds were found to be 15% faster than 12-year-olds in reaction time and 13% faster than the 48-year-olds. In movement time the 22-year-olds were faster than either the 12- or the 48-year-olds by percentages of 15 and 18, respectively. There was no difference in either reaction time or movement time between 12- and 48-year-old males.

There was no statistically significant correlation between the factors of reaction time and movement time in any single group. However, when the groups of subjects were pooled, the resulting correlation of _r_ = .231 was significantly higher than the correlation for the within groups of _r_ = .127. This difference would support the hypothesis that the higher reaction time and movement time interrelationships would be found in heterogeneous groups.

Hodgkins (1963) used the same specific task as Pierson and Mendryk, but she enlarged her sample of subjects to include both males and females at each age level. At all ages within the range of 6 to 84, males were faster than females in both reaction time and movement time. Times for members of both sexes decreased linearly until early adulthood with the exception of boys, who were slightly slower at ages 12 to 15 when compared to ages 6 to 11. Most decrease for both males (82%) and females (86%) occurred between the ages of 6 and 12. The females' reaction time scores tended to remain high until their late 30's or early 40's while the male's reaction time tended to stabilize around age 20. Maturational changes in movement time tended to follow the same pattern. However, although males increased in movement speed about 68% between the ages of 6 and 12, the increase in movement speed of 81% for the females more closely approximated the qualitative pattern of change in reaction time for the total group. Reaction time and movement time appeared to peak between 18 to 21 years and 15 to 17 years for both males and females, respectively.

Hodgkins then grouped all ages within the range of ages 6 to 84 and found the correlation between reaction time and movement time was $\underline{r} = .824$; for all females, $\underline{r} = .540$; and for all males, $\underline{r} = .680$. However, when correlations were computed for reaction time and movement time at different ages, the only significant relationships were 22- to 38-year-old females and males with $\underline{r} = .453$ and $\underline{r} = .450$, respectively, and 70- to 84-year-old subjects with a correlation of $\underline{r} = .713$.

Hodgkins' findings agree with Mendryk and Pierson both of whom found the correlation between reaction time and movement time to be higher in heterogeneous groups than in those groups homogeneous in composition with respect to age. Hodgkins attributed the high correlations to lack of control of the type of set, sensory or motor, and to the short length of practice time allotted.

Motivation. Motivation can direct behavior by influencing the extent to which an activity is sustained. Motivational constructs may be generated intrinsically by the person, or they may be applied externally through presentation of shock or information.

Henry (1951), Munro (1951), Howell (1953), and Hipple (1954) gave cues to motivate. Information was an implicit part of the motivating agent: shock, bright light, or noise.

Henry (1951) applied a mild electric shock on the upper arm to subjects who performed a simple reaction time task of releasing a key after visual stimulus. Groups were equated on mean reaction time. Each of 10 men received shock when his reaction time for a given trial was slower than his mean reaction time, while each of 10 men in the control group received no shock. The information supplied by mild shock was hypothesized to have a motivating effect on the subjects. Comparing results of the first five trials with the last five, the experimental group improved 9.4% in reaction time as compared to the control group. Improvement continued for 25 trials and then plateaued. The control group did not change.

Munro (1951) submitted 60 college men to a series of tests to measure retention of a movement speed task in which movement time had been decreased through application of mild shock as a motivating agent. Tasks developed by Henry (1951) were utilized. It was concluded that effects from the motivating treatment lasted seven weeks before the reaction and movement time speeds began to regress significantly.

Henry (1952) used motivating devices of change in illumination, presentation of shock, and amplification of sound when the subject reached his median time on a given trial. With this motivational information, all groups improved in reaction time. Most groups improved in movement time depending upon the stimulus received.

Using Henry's task of hitting a suspended tennis ball, Howell (1953) considered reaction time and movement time separately and then combined them to find total response time. Electric shock was imposed of sufficient magnitude (.7 to .16 amperes) to make the subject "emotionally disturbed." Fifty male subjects were exposed to three series: (a) without shock, (b) with shock imposed for slowness, and (c) with shock prevented by quickness. At the conclusion of the experiment the men evaluated subjectively their degree of tenseness. Using that information combined with data from physiological and observational techniques employed by the experimenter, subjects were placed into a "tense group" and a "less tense group." Howell projected that some subjects would gain in reaction time and others in movement time so that there would be a negative relationship between the two factors. A negative correlation of $r = -.382$ which was obtained supported this hypothesis. The "tense group" improved 33.3% more than the "less tense group" when shock was imposed at regular intervals.

Although Hipple's (1954) purpose was to modify motivation and tenseness variables, using 12- to 14-year-old Black and White boys as subjects, to find effects on reaction time and movement time, only the results of the White sample which would be pertinent to the present investigation will be reported. Muscular tension was measured by a pneumonic bulb technique developed by Henry. Information motivation was assumed to be provided by presentation of a buzzer within the response when the reaction became longer than the mean reaction time for that subject. Members of the experimental White group increased in reaction speed and movement speed as well as gross tenseness when compared with the White control group. The increase was 2.5 to 3 times as great for the net movement time as for the net reaction time.

Nash, Phelan, Demas, and Bittner (1966) studied shock treatment as a form of induced anxiety in a reaction time task. Two types of anxiety measures, general or manifest anxiety as measured by the Taylor Manifest Anxiety Test (TMAT) and stress, were introduced into a situation which caused subject discomfort. Induced anxiety such as shock treatment has been suggested to influence reaction time more than manifest anxiety.

Seventeen college students were tested in a pilot study, and an interaction between the individual level of manifest anxiety and the presence or absence of stress was found. Simple reaction time of the person subjected to induced anxiety was slower than that of members of the control group. In the final experiment, 36 college females were given the TMAT. Results were ranked and subjects were placed in "low," "medium," and "high" manifest anxiety groups and in "stress" or "no stress" groups at random. The experimental group was administered shock of sufficient amplitude to cause distress before trials 1, 3, 5, 6, and 9 of a task which involved lifting the forefinger from the key upon presentation of a visual stimulus. The individual threshold of reaction to shock had been predetermined. Simple reaction time scores of women subjected to stress were slower than the non-stressed women. Levels of manifest anxiety did not affect reaction time. The results were interpreted as being caused in part by distraction since the women had two concurrent concerns: wondering whether they would receive shock and having to respond to the stimulus by lifting the finger from the key.

Skill. A number of studies have been conducted to compare the skilled and unskilled performer on reaction time and movement time performance. In general, athletes appear to perform more quickly in these variables than nonathletes.

Keller (1942) attempted to verify the intuition of coaches that men who move their bodies adroitly and quickly are successful in athletics. Measures of movement time were taken from a task of moving diagonally forward to touch a target. Athletes were found to be superior to nonathletes in this specific task.

Beise and Peaseley (1937) completed an early study to differentiate agility, gross reaction time, and gross movement time in total body movements. Women were divided into "skilled" and "unskilled" groups on the basis of teacher's ratings in college physical education classes, scores on a motor ability test, and performance on competitive teams. Skilled and unskilled subjects were compared on two tasks. In one task, reaction time was indicated as the subject left a switch plate and movement time was signaled as the subject stepped on switch plates placed in two separate parts of the circuitous path of a motor ability test. For the other test, each subject sat near the switch plate and pushed down with her hand when a light was flashed. This continuous pattern was completed at least five times in sequence. The skilled subjects were faster than the unskilled in both tasks. The experiment was extended to see if training for seven weeks in a sport within a physical education class had any effect on reaction time or movement time. No changes in these responses were noted.

Olsen (1956) designated 300 male college students as (a) athletic (earned varsity letter), (b) intermediate (intramural participant), and (c) nonathletic (no history of participation). Three tests to a visual stimulus were presented which measured simple, choice, or discriminatory reaction responses. Athletes performed faster on all tests than did intermediate skilled subjects or nonathletes. The intermediate subjects were faster than nonathletes on reaction time measures. When athletes' scores on skill were correlated with reaction time, no relationship was found, possibly due to the homogeneity of the select group.

Reaction time and arm movement time scores were compared for college women athletes and nonathletes by Youngen (1959). The arm movement task included, after a visual stimulus, lifting the forefinger from a key to enact reaction time and then moving the arm toward a target 13 inches in front of the subject. Closing a photoelectric beam switch deactivated the clock which indicated the time of the movement. A series of 35 reaction-time and 35 movement-time trials were recorded for 122 female college subjects who had been subdivided into two nominal categories of athletes and nonathletes. Athletes were faster than nonathletes in both reaction time and movement time. Youngen suggested these differences might be caused in part by intrinsic motivation due to the competitive attitudes of the athletes.

Knapp (1961) projected that highly-skilled players of racquet sports would have a faster simple reaction time response to a visual stimulus as compared to non-playing students who were members of a research class. The task was to release a key following a varying foreperiod of one to four seconds. Two blocks of 25 trials each were spaced by a one-minute rest period. Using the split-parallel technique to assess reliability of the mean of each block of trials, a high coefficient of $\underline{r} = .846$ was obtained when all subject data were pooled. When the scores of only the highly-skilled performers were considered, a higher estimate of reliability $\underline{r} = .95$ was obtained. When the 50 responses were used to compute the average reaction time for each subject, the skilled (.207 seconds mean reaction time) were faster to respond than the non-playing subjects (.235 seconds reaction time).

Because the estimate of the variance for each group of 25 trials for each subject was not normally distributed, transformation was made to $\underline{z} = \frac{1}{2} \log_e s^2$. The transformed $\underline{z}$ scores showed no difference between the first and second block of 25 trials for members of either group. Using the $\underline{z}$ scores it was found that the variation in simple reaction time of the highly-skilled was less than the non-playing subjects.

Definition of the Task

The length of the foreperiod and the temporal sequence at which the stimulus is presented to the person contribute to performance. Some preparatory intervals have been found to induce faster reaction times than others. Information compiled by Woodworth and Schlosberg (1954) relating to early studies concerning the effects of the length of the foreperiod on the ensuing response indicated that the prevalent theory of readiness or set which governed the relationship of the length of the foreperiod and reaction time was that the two factors were interrelated in a curvilinear manner. Consensus was that a series of foreperiods of standard length would elicit a faster response than would a series of foreperiods of varying lengths. Later theories have considered the probability of stimulus occurrence in relation to time decadence within the interval and the ordinal length of the foreperiods preceding the measured response. Effects of the pattern of variance were postulated to cause differing lengths of response.

Optimal foreperiod. Early studies by Woodrow (1914) and Telford (1931) form the base for the theory that set and optimal reaction time form a curvilinear graphic pattern. Woodrow (1941) used auditory stimuli in his laboratory to test simple reaction time of three well-trained subjects in a key-release task. All were given only motor set, for the direction to each subject was to focus his attention on the motor act of releasing the key rather than on the sensory act of listening for the stimulus. By extending the foreperiod in intervals of 1, 2, 4, 8, 12, 16, 20, and 24 seconds, Woodrow found there were differences in the length of response time depending on whether the foreperiod remained the same for a series of trials or was varied irregularly and without warning. By controlling the length of the foreperiod and presenting the stimuli in a consistently rhythmic pattern, thereby aiding the subject to anticipate the arrival of the stimulus, the optimal length of the foreperiod was two to four seconds. Longer or shorter foreperiods than the optimal interval elicited slower reaction times. When the foreperiod was varied in an irregular temporal pattern, there was no clear optimal length of the foreperiod. Reaction time definitely was faster in the group receiving constant foreperiod length as compared to the group receiving varying foreperiod intervals.

Telford (1931) studied the effects of foreperiods presented at intervals of .5, 1, 2, and 4 seconds on simple reaction time to an auditory stimulus. The 8- and 12-second intervals had the same effect as the 4-second interval in a pilot study and had been discarded due to their redundant contribution. The one- and two-second foreperiod intervals were most favorable for fast reaction time indicating a possible curvilinear relationship between the length of the foreperiod and simple reaction time. Telford found marked deterioration in reaction time when the foreperiod interval was shortened to .5 seconds as opposed to the leveling effects found at the longer intervals.

Klemmer (1956) concurred with the general consensus that the use of constant foreperiods initiated faster reaction time when the order of presentation was mixed randomly. He found that individual foreperiods of trials had less effect on reaction time compared to the breadth of the range in which the foreperiod was positioned.

Rothstein (1973) studied reaction time to a visual stimulus when a 2.5-second common foreperiod was placed in one of three consecutive, overlapping two-second ranges of foreperiods. The influence of position within the range on temporal expectancy of the subject was assessed. Results indicated that when the 2.5-second foreperiod was positioned at the faster edge of the .5 to 2.5-second interval and at the midpoint of the 1.5 to 3.5-second interval, reaction time was fastest within each respective range. However, when the common foreperiod was positioned at the lower edge of the 2.5 to 4.5-second interval, reaction time was slowest within that particular range. Rothstein projected that a swimming coach might train a swimmer to react to a shorter foreperiod than would be utilized in competition. The actual foreperiod in competition would position later in the range of expectancy of the swimmer and should elicit a faster reaction time.

Interval order. Two additional theories have been suggested regarding the effect of the length of the foreperiod upon the reaction time response. One theory involves the "information reduction effect" which infers that the subject realizes that as time passes the stimulus is more imminent. The ability of the subject to be aware subconsciously of orderly time passage depends upon his knowledge of the probability of occurrence of the stimulus and his own individual sense of timing.

Proponents of this theory state that as time within the expected range increases, the probability of occurrence increases as does the subject's sense of anticipation and consequent set.

The "previous foreperiod effect" is a second theory used to explain the interrelationship between length of the foreperiod and simple reaction time response. The subject is assumed to predict the length of a given foreperiod based on his knowledge of the length of the previous foreperiod. Therefore, the influence of the relative length of foreperiods preceding the measured response is of importance, and sequential effects of order would not be expected necessarily to be equal for intervals of varying lengths.

Klemmer (1956) further studied the effects of order of foreperiod signal intervals on simple reaction time and found that the slowest reaction times resulted from a short foreperiod preceded by a long period. To the contrary, a long foreperiod preceded by a short foreperiod obtained the fastest reaction time. Two long or two short foreperiods in sequence elicited reaction time equal to the mean at that interval. The foreperiod occurring three trials before the reaction time being evaluated had no effect on that response.

Karlin (1959) investigated the effect upon simple reaction time of the length of the foreperiod immediately previous to the response. Specifically, he was concerned with a careful examination of Woodrow's (1914) findings, and therefore, he inspected responses within the two to four second optimal length of the foreperiod according to the theory of curvilinear relationship. Foreperiods of .5, 1, 2, and 3.5 seconds were presented in ascending or descending order or in blocks at 1, 2, and 3.5

second intervals. In each block, the median foreperiod was presented as were two additional times, one 20% slower than the median time and one 20% faster. Trend analysis showed that the median times in each block elicited the fastest reaction times. Results indicated that whether treatments were presented in blocked or sequential order there was no difference in reaction time and that foreperiods of .5, 1, 2, and 3.5 seconds elicited a linear path of reaction time scores from fastest to slowest time without inflection. These results clearly were in opposition to the curvilinear theory.

Using two college students as subjects, Drazin (1961) set a mean foreperiod of 1.5 seconds within a series of ranges of varying widths. The reaction time and foreperiod relationship was found to be affected when the range width of the foreperiod was .5 seconds or less. Reaction time decreased initially tracing a negatively accelerated curve in relation to the foreperiod length. The length of the foreperiod preceding the measured response influenced reaction time to a greater extent than the length of the second foreperiod before the measured response. Long reaction times tended to follow short foreperiods to a large degree while short reaction times tended to follow long foreperiods to a lesser extent.

Botwinick and Brinley (1962) presented foreperiods of .5, 1, 3, 6, and 15 seconds in both regular and irregular series with combined audio and visual stimuli as well as in two separate sets of stimuli in two auditory ranges. Women were slower than men in reaction time at all intervals under both treatments. Except at the 15-second interval, presentation of the foreperiod in regular series elicited faster reaction time than presentation in irregular series.

Data were subjected to principal components factor analysis to ascertain if length of the foreperiod could be identified as an independent factor. The primary component, labeled general reaction time, accounted for 63% of the variance for regular presentation and either 73% or 84% for the irregular presentation. The difference in loadings occurred because two separate ranges were utilized in the irregular presentation of the stimulus. High positive factor loadings were obtained for short foreperiods and negative factor loadings for long intervals within each range. Due to the polarity, rotation of axes was conducted to attempt to reflect the independent variance of the shortest foreperiods. The principal component, general reaction time, accounted for 58% or 81% of the variance. The second component was identified as the short preparatory interval, for there were high positive loads on the short interval and zero loads on the long intervals. Results of the factor analysis were tenable regardless of whether the foreperiod was controlled or randomized, or, in the case of the two special auditory stimuli, the breadth of the range was standard. When data from regular and irregular series were pooled, the principal component, general reaction time, accommodated 50% of the variance. Subsequent components could not be identified, and rotation of the axes did not clarify classification.

McCormack (1961) had subjects complete a fine-motor task which involved hitting a microswitch as fast as possible after a stimulus which arrived from 30 to 90 seconds after the previous one. The task continued for a 35-minute period. A linear relation between the length of the reaction time and duration of the task was found; that is, as the duration of the experimental period was extended the reaction time of the subject became slower.

Henry (1960a) in explaining his "Memory Drum" theory found when trials were blocked at the same level of task complexity reaction time at all ages was faster than when task complexity was varied from trial-to-trial. This, Henry indicated, could be due in part to practice effects of having the same subjects in both experimental blocks and always completing the blocked trials before the randomly varied trials.

Thompson, Nagle, and Dobias (1958) studied the effect of varying lengths and rhythms of the foreperiod upon a gross motor skill. Football offensive signals were presented at even and uneven cadence to find which presentation elicited the faster reaction time among football linemen. The quarterback called the cadence rhythmically or arhythmically having told each subject previously on which number he was to charge. The quarterback pressed a button to activate the clock on the predetermined "hut." When the lineman stepped on a contact plate 18 inches ahead of the starting line, the clock was stopped, and movement time was indicated. Five trials were given on the pretest, but the number of trials was shortened to three when the correlation between the mean scores of five trials and three trials was $\underline{r} = .86$. Reliability coefficients of the test-retest situation were $\underline{r} = .71$ for rhythmic presentation and $\underline{r} = .52$ for nonrhythmic presentation. Rhythmic signals elicited faster reaction time and movement time for both college and high school males than nonrhythmic signals.

To clarify the potential for fast starts in football to offensive cadence signals, Wilson (1959) studied the relationship of reaction time and movement time to a visual stimulus presented within a series of visual cue lights which was presented at a rhythmical or arhythmical tempo. The laboratory-oriented task involved removing the forefinger from a key to enact an arm movement to hit a tennis ball placed 12 inches in front of the subject. A large light was illuminated in a random order within a series of eight smaller lamps arranged horizontally. The smaller lamps were lit in a display of one every second in the rhythmical presentation and one every .5, 1, or 1.5 seconds in the arhythmical presentation.

The nonrhythmic presentation of the display resulted in a mean reaction time of .210 seconds and the rhythmic presentation in a mean time of .198 seconds. The rhythmic presentation elicited significantly faster responses. When the shorter irregular interval times and corresponding trials for regular stimuli were discarded, the mean foreperiod was one second for each group. Reaction time to irregular tempo of presentation still was slower. There was no difference in movement time regardless of the method of stimulus presentation. The correlation coefficient of $\underline{r} = .308$ indicated little relationship existed between reaction time and movement time so that they were interpreted as independent factors.

Simon and Slaviero (1975) used a lamp display to count down the foreperiod. Eight lights: a warning light, six "count-down" lights, and the stimulus light were mounted on a panel. The countdown lights were lit every .280 seconds during a constant two-second foreperiod for the experimental group. The lights were not activated for the control group; hence, the control group received less time-reducing information than the experimental group. Simple and choice reaction time tasks were presented to see if time-pacing would help lower choice reaction time more than simple reaction time. Experimental group trial times were faster than control group times, and simple reaction time was faster than choice reaction time for both groups. Interaction effects indicated that although countdown shortened both simple reaction time and choice reaction time, the effects were greater on choice reaction time. It was suggested that readiness affects both peripheral and central processes of discrimination and choice tasks.

Nature of the Skill

Armbruster, Allen, and Billingsley (1973) described the mechanics of the grab racing swimming start. The swimmer steps up to the blocks and places his feet six to ten inches apart with his toes over the edge of the blocks. His attention is directed to the starter. Upon the command, "Take your mark," the swimmer immediately gets into starting position by bending forward and grasping the front of the block with both hands for balance and support. The entire set of the swimmer is on the pistol shot. Since the attention of the swimmer occurs in waves, the length of time the swimmer is held on the mark is crucial to the effectiveness of the start. When the pistol is fired, the swimmer pulls forward with his hands and arms as he extends his knees forcefully. Gambril (1969), a national-level coach, suggests that since the grab start gets the person into the water faster than the traditional forward start, the grab start should be used by swimmers who have poor reaction time. He concluded that fast swimmers are those who react to the pistol shot more quickly than other swimmers.

Walker and Hayden (1933) performed the first recorded experiment to determine the optimal time between the set signal and the sound of the gun in relation to the effectiveness of track performers in the sprint start. They assumed that the certain optimal time necessary for a performer's attention and the gun sound should coincide. They noted that attention tended to fluctuate in that it peaked, subsided, and peaked again. They used a gun and attached a chronoscope from the gun to the rear foot of the runner on the starting block. The apparatus was used to measure temporal factors. A stopwatch was used to measure six different intervals between the commands and the gun: 1, 1.2, 1.4, 1.6, 1.8, and 2 seconds. Each of the 27 subjects completed 168 starts, four in each interval, daily for seven days. In order to eliminate fatigue, four starts were completed for each interval during each test period, and this was a limiting condition. The optimal mean time was 1.6 seconds. A foreperiod of 1.0 to 1.2 seconds was found to be too short; 1.4 to 1.6 seconds was optimal; and 1.8 to 2.0 seconds was too long. Walker and Hayden concluded that if the sprinter was held about 1.5 seconds on the mark, the changes were significantly greater that he would get an optimal start.

Nakamura's (1934) work on track starts substantiated the inference that 1.5 seconds was the optimal length of the foreperiod. He noted that in 1934 Japanese track sprinters were held at set position for at least two seconds before the gun. Runners were complaining that the long wait was distressing. Nakamura tested three time intervals: 1, 1.5, and 2 seconds. Subjects were assigned by random to groups for 36 starts. Time intervals were established by using a metronome. The starter was trained and experienced. There was a five-minute rest between the trials, and after the tenth trial an additional 10-minute rest was provided if necessary. Apparently not all subjects were afforded a 10-minute rest, which is a limitation of the study. Each of the 10 subjects was asked to write his thoughts after the experiment. Subjects reported that when the foreperiod was 1 second, their attention was directed to getting into the set position. The time was not long enough for them to organize this attention as they were still in the process of getting poised. When the foreperiod was extended to 2 seconds their attention began to fluctuate. To the sprinters, the interval of 1.5 seconds felt optimal.

Tuttle, Morehouse, and Armbruster (1939) studied response time (reaction time plus movement time) in the conventional forward swimming racing start and the length of foreperiod as controlled by an experienced starter. The starter had practiced controlling the length of the foreperiod against a stopwatch. The response times for 10 male varsity swimmers was obtained with randomly ordered foreperiods of 1, 1.2, 1.4, 1.6, 1.8, 2, and 2.2 seconds. The range of 1.6 to 2.2 seconds was found to be optimal.

Tuttle, Morehouse, and Armbruster (1940) considered differences in techniques used to initiate the foreperiod in their previous study on the swimming start and the results of the study of the track start by Walker and Hayden (1933). Techniques of measurement were analyzed to see if they accounted for the .5 second difference in the range of optimal holding time of the foreperiod for the two gross tasks. Thirty swimmers, 15 of whom had swum competitively for three or more years and

15 of whom were untrained, completed five trials at each of three intervals: 1, 1.5, and 2 seconds. Swimmers received the same treatment as the track runners had in the Walker and Hayden study. After the command, "Get set," the foreperiod was measured on a stopwatch and the gun was fired after the designated interval. In the previous swimming start study, the time the swimmer moved from the vertical to the crouched position on the blocks was included in the foreperiod. Conclusions were that for trained swimmers the optimal interval was 1.5 seconds, and for the untrained swimmers the optimal time was 1 second. Unfortunately, only raw mean scores were presented, and the data were not subjected to statistical analysis.

Slater-Hammel (1953) suggested that the initial position of the knees and distribution of weight could affect total body reaction time. The gross task he studied was similar in starting position to the racing dive. Slater-Hammel devised a choice reaction time task for gross body response by embedding microswitches in the surface of a low platform in front of a two-light visual display. The subject placed each foot on a microswitch and assumed a specified position relative to bending or straightening knees and distributing the body weight over the whole of both feet or concentrating the weight on the balls of the feet. When one of the lights on the display was illuminated, the subject moved his corresponding foot diagonally forward. Analysis through Latin squares indicated that knee position was of no consequence. College men reacted faster when their weight was evenly distributed as compared to when their weight was concentrated on the balls of the feet. A subsequent experiment indicated that when weight was distributed over the balls of the feet, subjects rocked on their heels before removing their feet from the platform thereby extending response time.

Mechanical factors. Several studies have been conducted which emphasize mechanical aspects of various styles of racing dives. Recently the grab start has been gaining popularity. Research has been conducted which is designed to compare the effectiveness of the grab start and the conventional starts.

Heusner (1959) prepared mathematical specifications for the racing dive. His problem was to minimize total time needed to dive, glide, and swim 75 feet. When using cinematographical analysis to establish validity, he found the optimal angle of take-off from the blocks at the required height of 2.5 feet to be at an angle 13 degrees above the horizontal. By lowering the blocks to 1.5 feet above the surface, the optimal angle decreased one degree. Standing height and weight of the swimmer affected the optimal angle of take-off. Variance in standing height from 71 to 64 inches raised the optimal angle one degree. That is, the shorter person performed better from a starting block set at a 14 degree angle to the water surface. The optimal angle of take-off of a 110-pound swimmer was 2 degrees less than for a 160-pound swimmer.

Groves and Roberts (1972) investigated in depth the optimum angle of projection for the generation of horizontal velocity for the forward start. Using a film analysis of 16 college men, they measured the path of a black circle sewn on the swimmer's trunks in a position to coincide with the center of gravity. A background grid was provided to indicate units of distance. The center of gravity was plotted at the instant when the feet left the starting block and subsequently was plotted when the center of gravity entered the water. The horizontal distance between these two points was called the range. By multiplying the range by the number of frames per second, the time needed to pass the horizontal distance was calculated. The vertical velocity was determined by the formula:

$$V_{yo} = \frac{1}{2} g t^2 - \frac{yo}{ta}$$

when "yo" is the distance the center of gravity fell while the subject was a free-falling body and "ta" was the time the student remained in the air while acting as a freely-falling body. The horizontal velocity was calculated by dividing the horizontal range by the time spent in the air as a freely falling body. The angle of projection was the tangent to the vertical velocity divided by the horizontal velocity.

Heusner (1959) contended that heavier competitors should project themselves at a higher angle than competitors with less mass. The results of Groves and Roberts contradict that contention. They found that each subject, regardless of weight, had an optimal angle of projection of -13 degrees. Groves and Roberts concluded that any angle which does not deviate greatly from -13 degrees results in a dive of greater horizontal distance than any angle above the horizontal.

Comparing three styles of conventional forward dives, Maglischo and Maglischo (1968) studied 10 varsity male swimmers. Each of the starts: (a) straight backswing, (b) circular backswing, (c) arms-back, was compared to the time with which the competitor reached a point in the water 15 feet from the block. Subjects were trained in each start until, to an observer, every swimmer could perform each style equally well. During the test, every swimmer completed 10 dives of each style in rotated order. A Dekan automatic performance analyzer which recorded times to .01 seconds was used. A 15-foot control line was attached to each swimmer's suit with clips. As the swimmer started, the switch was closed manually. When the swimmer reached a point 15 feet from the starting block, the control line was pulled from the analyzer which stopped the timer. Use of the sign test for the middle six scores indicated that the circular backswing and the arms-back starts were both better than the straight backswing start. There was no difference in the effectiveness of the circular and arms-back swings.

Cinematographical analyses. Film analyses have been a source of information regarding the differences in performance when the same swimmer uses a grab start or a conventional start. Many of the studies are purely descriptive in nature while other data are subjected to statistical analysis.

Groves (1973) used cinematographical analysis of 16-mm films of 16 male intercollegiate swimmers. The average age was 20, and the average years of competitive swimming experience was eight. The diving style was not specified. After 20 training sessions of 15 minutes duration each, a film including the sequence from the flash of the gun through the feet leaving the blocks was taken for five trials per man. Using a film analyzer, reaction time was measured from the flash of the gun until the start of the first movement of any part of the body. Movement time was described from the first movement of any part of the body until the feet left the blocks. Results were as follows:

Table 1

Reaction Time and Movement Time Scores

	n	Range	$\overline{X}$	SD	$SE_{\overline{X}}$
Reaction Time (sec)	16	.151-.293	.214	.036	.009
Movement Time (sec)	16	.760-.888	.811	.041	.010

A Pearson correlation between reaction time and movement time yielded a coefficient of $\underline{r} = -.231$ indicating no relationship between these factors. The r^2, coefficient of determination, indicated that 5% of the variance of reaction time was associated with movement time.

Roffer (1972) used nine swimmers, eight males and one female, to compare the grab start and the conventional start. The time of each swimmer from his leaving the block to his reaching a point 12 feet distant was measured. Because the swimmers were not familiar with the grab start, a three-week training period consisting of 15 periods of 30 minutes was initiated. During the test, each swimmer completed 90 trials, alternating five trials of each style. Roffer used sophisticated cinematographical equipment. Filming was done at 100-feet-per-second, and timing marks from a signal generator were used for calibration. Analysis was completed with a Vanguard Motion Analyzer with an x-y coordinate system. This enabled efficient calculation of distance and velocity. When the data were analyzed, the start time was divided into segments: (a) the start time or the time from the gun to when the feet leave the block, and (b) the flight time or the time from when the feet leave the block until a point is reached 12 feet from the blocks. Results indicated that the grab start elicited a faster start time than the conventional start although there was no difference in flight time. The conclusion was drawn that the grab start was faster than the traditional start.

Hanauer (1972) also conducted a cinematographical study to compare the grab start to the conventional start. Only one subject, an accomplished varsity male sprinter who had adopted the grab start successfully the previous year, was studied. Only one trial of each type of start was filmed. Crucial frames which were analyzed included: (a) starting position, (b) release of hands for the grab start, (c) upper body parallel to the surface, (d) toes leaving the blocks, (e) full flight, and (f) hand entry. Tracings made of crucial frames for each diving style were superimposed. A drawing was made of the trajectory on each start from the frame when the toes left the block to the frame when the hips entered the water. The top of the swimmer's trunks was used as the landmark. The parameter of time was measured by counting the frames elapsed during the movement. Reaction time was determined by counting the number of frames from the flash of the gun until the initiation of movement. Frames also were counted for the following sequence: (a) toes leaving the block, (b) hands hitting the water, (c) feet disappearing into the water, (d) hands passing the edge of the picture frame which indicates the horizontal distance of the body at entry.

Hanauer's study was intended to be descriptive in nature. No statistical evidence was offered. Hanauer did indicate that the swimmer traveled a greater horizontal distance with the conventional start. However, the swimmer left the block faster with the grab start.

Michaels (1973) used the observational conclusions of Hanauer to set his hypothesis that the advantage of the time saved between leaving the blocks and entering the water from the grab start would outweigh the distance lost when comparing the conventional start and the grab start. Subjects were six male varsity college athletes. None had attempted the grab start previous to the test. Each was allowed one practice start on each type of forward racing dive. Then each subject completed 10 trials, alternating grab and conventional starts with half of the subjects starting with the conventional start on their first trial and the other half beginning with the grab start. An electronic timing device which was activated by a starting gun and was stopped by a hand button was used. The timer and the operator stood 25 feet from the starting block even with a line painted on the pool bottom. At the gunshot, the swimmer did the assigned start and held his extended position for 25 feet. When his hands passed the line, the clock was stopped.

Results of Michaels' study indicated that there were fewer (virtually no) false starts for the grab position. The data were not treated statistically. The time from the gunshot to the body entering the water was shorter for the grab start than for the conventional start. However, the conventional start projected the swimmer further over the water. This might be due to the fact that in the grab start, the center of gravity is further forward over the feet during the set position. The movement of the arms and legs has immediate effect without having to drop the position of the center of gravity forward first. In the conventional start, the first movement is to lean forward to move the center of gravity forward. This delay would affect the time span of the body leaving the blocks. There is time, however, for a greater summation of forces using the conventional start. The arms describe a more circular and wider pattern which produces greater force in the summation process.

Van Slooten (1973) filmed one varsity college male swimmer who had never used the grab start before the testing. The path of the center of gravity was traced for both the grab and traditional starts. He found that the grab start produced greater velocity, faster take-off, and a faster time to the water entry. The traditional start produced a greater angle of take-off, greater acceleration, and a greater distance into the water.

Summary

Detailed investigation of the relationship of reaction time and movement time in the grab racing start in swimming and interaction of those variables with the length of the foreperiod before the gun sounds necessitates examination of several factors. The attributes the performer brings to the task must be considered. The task itself must be clearly defined. This involves analysis of the nature of the foreperiod and the effects differing methods of stimulus presentation have upon the task. Inspection must be made of those previous investigations which have dealt specifically with the swimming start so that techniques and methodology may be reviewed.

The two factors, reaction time and movement time, have been shown to be independent variables. Henry's series of experiments indicate virtually no relationship between the variables. Subsequent studies indicate this lack of relationship is not changed by maturational influences of age or by the inherent characteristic of sex. Members of highly-skilled groups tend to aggregate faster reaction times and movement times than lesser-skilled persons. Higher correlations between reaction time and movement time occur when heterogeneous groups are compared.

Reaction time has been shown to vary with age, primarily in a curvilinear pattern peaking at age 19. Throughout the teenage years an extremely slight, yet apparent, decrease in reaction time occurs. Movement time decrements follow basically the same pattern. Men are faster in both variables than women. More differences seem to exist due to maturational and sex characteristics in movement time as compared to reaction time. Movement time changes more with practice and should be measured reliably in highly-skilled groups.

Use of electric shock as a motivator has produced decreases in reaction time. The mild shock is administered when a given response endures longer than the average response for the specific subject. Presentation of shock in this manner is called motivational in that some time-keeping knowledge and reinforcement is presented. Levels of manifest anxiety did not affect simple reaction time.

The cue to which the subject attends has been shown to affect simple reaction time to a lesser degree than choice reaction time. However, even in simple reaction time, a sensory set has been shown to elicit a faster response than a motor set.

Several theories exist regarding the relation of the length of the optimal foreperiod for fast response time. Early studies clearly supported the theory that the graphic relation between the preparatory interval and the optimal response was curvilinear. Competitors found they could not position themselves physically if the foreperiod was too short, and they would lose their keen edge of concentration if the foreperiod was too long. From the earliest studies, regular presentation of foreperiods has elicited consistently faster responses than irregular presentation of foreperiods.

In recent studies attempts have been made to examine the effect of the length of preceding foreperiod intervals on the given response. There is agreement that the third interval previous to the response does not affect the response time. There is disagreement about the precise interrelationship of preceding order of more immediate foreperiods upon the response.

Investigations have included inspection of the foreperiod embedded within a given range. Placement toward the middle or higher end of the range seems to elicit the optimal result, although this finding is not conclusive.

As indicated by the review of literature, study of the optimal foreperiod for an effective swimming or track start was most pronounced in the 1930's. Results of early investigations agreed that the optimal length of foreperiod was approximately 1.5 to 2 seconds. Attention was found to be related to the length of the foreperiod in a curvilinear pattern.

Several studies have been conducted to compare the grab start with the conventional start. It has been found that the grab start allows the competitor to leave the blocks faster than the traditional start. Certainly the grab start eliminates false starts due to the unstable starting position of the conventional start. Studies have not been completed to evaluate the effect of varying the foreperiod between the command and the sound of the gun on starting time by the skilled performer of the grab start.

CHAPTER III

EXPERIMENTAL PROCEDURES

Within this chapter a description of the apparatus and its use in measurement is given. Methods of selecting and testing subjects for both the pilot study and the experimental study are presented as well as projected statistical treatments of the data.

Description of the Apparatus

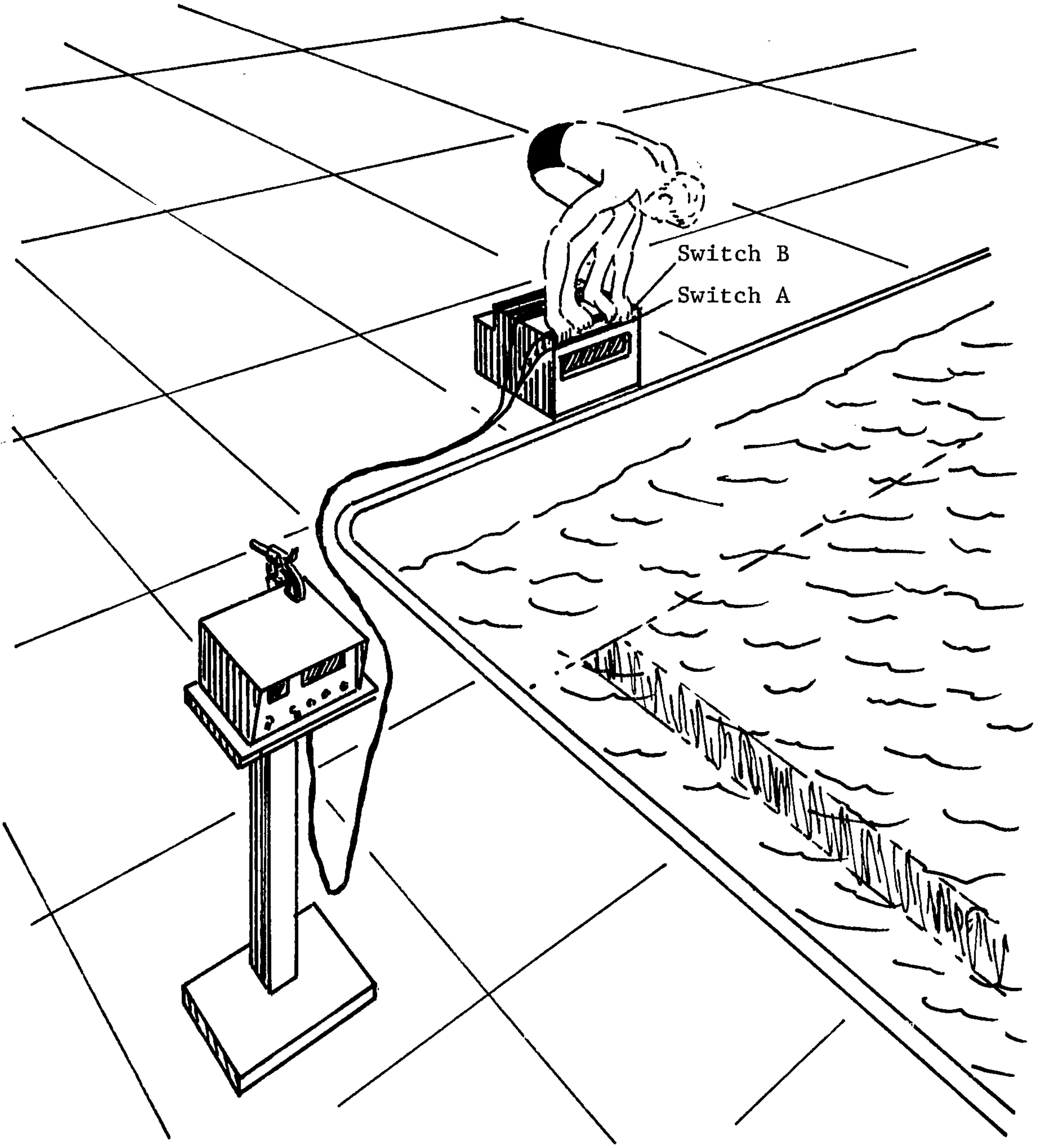
Speed of response was measured by a specially-designed timing device. The portable unit (4 inches x 9 inches x 9 inches) contained a 6-volt battery as its power source. The device was programmed to control the length of the foreperiod, to activate a solenoid which fired the gun, and to display times at which two pressure-sensitive ribbon switches mounted at the hand and foot positions of the swimmer on the block were opened. The foreperiod switch either could be activated manually by the starter or automatically by the swimmer when he first placed his hands on the ribbon switch. For both methods of activating the device, the starter held the "start" button down until the gun fired. This protective procedure was necessary so that children could not play with the switches on the block and make the gun fire.

On the face of the chassis of the timing device was a foreperiod indicator which could be set within the range of .1 to 9.9 seconds in intervals of .1 seconds. A digital display which recorded time from .001 to 9.999 seconds in .001 second intervals was on the panel. A standard 22-calibre starter's pistol containing a 9-blank cylinder was mounted on the chassis. The gun was modified by the addition of a hair-trigger which provided sufficient sensitivity for the trigger to be pulled automatically by a solenoid which exerted 25 ounces of force. A 15-foot plastic-covered cord was attached to the chassis and to two ribbon switches (5/32 inches x 9/16 inches x 24 inches) which were activated by application of 8 ounces of pressure (Tapeswitch Type 121 BP). One of the switches was mounted on the upper edge of the starting block, and the other switch was attached on the hand grip so the wire within the switch was placed precisely on the lower horizontal edge of the grip (see Figure 1).

The logic of the timing circuit was programmed to count down the foreperiod and to reverse at the gun to count up. The starter selected the foreperiod. When the unit was activated, the length of the selected foreperiod was printed on the digital display, and as the logic program of the timer counted down, the display numbers decreased proportionately in .1 second intervals. When the foreperiod ended, the gun was activated automatically, and the timer simultaneously began counting up. When the hands of the swimmer first moved on the ribbon switch, a split time was recorded on the display. When the feet left the ribbon switch on the block, the timing circuit terminated its program of counting up. If the hands left the ribbon switch before the gun was activated, a false start was indicated by the digital readout of 8.888. If the feet left the block before the hands, such as when a subject rocked back on his heels, the foreperiod switch was reactivated so that the error in technique produced obviously unuseable data.

Figure 1

Testing Apparatus



Pilot Study

A pilot study was conducted in order to verify the mechanical efficiency of the timing instrument, to test for subject reliability, and to smooth operational and clerical techniques. The study was completed July 2, 1975, at the Cedar Rapids, Iowa, YMCA indoor swimming pool.

Selection of subjects. Swimmers, ages 12 to 17, from a Cedar Rapids Amateur Athletic Union team volunteered as subjects. Five swimmers, three girls and two boys, participated. The subjects were selected because they were familiar with the grab start and because they were among the most highly skilled swimmers on the team. One girl was the national YMCA 12-year-old champion in the freestyle sprints; one girl was an Iowa high school state champion, and both boys had placed in the Iowa high school state swimming championships.

Testing procedure. All subjects were tested at one session and performed individually in successive rotation. Each subject completed a block of five dives at the .5 and 1.5 second foreperiod intervals and three dives at the 1 and 2 second intervals and at varied foreperiod intervals. Order of presentation of the blocks of trials was assigned at random.

Initially, several operational errors of the starter caused the subjects to commit false starts. Once the procedures were standardized two subjects continually committed false starts and were eliminated from the study. The remaining three subjects did not commit a false start on any of their trials at the .5, 1, or 1.5 second or varied foreperiod intervals. Numerous false starts occurred at the 2 second interval.

Trials in which false starts occurred were repeated at the end of each sequence. The starting platforms were placed horizontal to the water throughout the testing session. An informal study had indicated that an unduly larger number of false starts occurred when the platform was tilted to -13 degrees. Informal trials had shown also that one strong girl could perform 22 starts in succession without fatigue. Therefore, in the pilot study when the subjects were rotated in a group of three, fatigue was not considered to be a contaminating variable.

The entire group of five subjects was given the following instructions:

> You will each complete 20 short-course starts, rotating one person after the other. When the starter says, "Take your mark," drop immediately into position. Try to concentrate on the start as you would in a race. You want to get a good start and to avoid any false starts. Are there any questions?

The starter cocked the gun before initiating his commands. He selected the assigned foreperiod for the subject, and he pushed the "reset" button to clear the timing device. The instrument was placed 12 feet to the front of the swimmer and to the side of the block on a ledge 4.5 feet above the deck where the starter is positioned during meets at the YMCA pool. The starter gave the command and pushed the "start" button. The device was activated for the set foreperiods by having the swimmer touch the hand switch; for the varied foreperiods, the gunshot was initiated by the starter who pushed the "start" button. When the swimmer left the blocks, a recorder wrote on the data sheet the time the hands first moved. The recorder then pushed the "foot" button and recorded the time at which the feet left the blocks. After each eight trials, the starter reloaded the gun.

Analysis of data. Two subjects' scores were not used. One girl consistently committed a false start and one boy rocked back onto his heels continuously. Neither subject yielded useable data, and both were dropped from the study after five attempts to get acceptable data.

The data from the remaining three subjects were analyzed to determine reliability of the trials. Using the Pearson Product Moment Method of linear correlation to compare the odd and even trials, scores from the first four trials at the .5 and 1.5 second intervals were analyzed to establish reliability coefficients. The resulting range of coefficients was from .92 to .99 (see Table 2). The subjects were highly reliable.

Table 2

Correlation Coefficients For Hand Movement Time and Starting Time in the Pilot Study

		Foreperiod Intervals in Seconds	
Correlational Technique	*n*	.5	1.5
Hand Movement Time	3		
Pearson Correlation		.80	.97
Spearman-Brown Prophecy Formula		.92	.99
Starting Time	3		
Pearson Correlation		.93	.89
Spearman-Brown Prophecy Formula		.98	.96

Experimental Study

The experimental study was completed July 15, 16, and 17, 1975, at the Scottsdale Swim and Tennis Club in Walnut Creek, California. Data were collected at swim practices between 7:00 and 9:00 a.m. at the outdoor pool.

Selection of subjects. Twenty-four swimmers, 12 boys and 12 girls, were selected from the members of the senior swim team. All swimmers had achieved Pacific Association Amateur Athletic Union "AA" times. Ages ranged from 12 to 17. Each subject had been a team member for a minimum of one season, and each swimmer used the grab start exclusively in swimming meets (see Table 3).

Table 3

Distribution of Subjects By Age and Sex

	Age in Years					
Sex	12	13	14	15	16	17
Male	3	1	3	2	2	1
Female	3	3	2	3	1	0

Testing procedure. Use of the equipment and the procedures followed were similar to the methods utilized in the pilot study. The timing device was placed 10 feet to the side of the starting block on a table raised four feet above the deck. The top surface of the starting block was horizontal to 30 inches above the water level. The pressure switches were mounted on the upper horizontal edge of the block and on the hand grip precisely over the center of the grip.

Four trials were blocked for each of the four foreperiods: .5, 1, 1.5 seconds and varied foreperiods. The 2-second foreperiod interval was eliminated after the pilot study results indicated that a substantial number of false starts occurred at that interval. Each block of trials was presented in random order to each swimmer. Blocked trials presented in random intervals minimize the effects of order of presentation of intervals and the effects of order of presentation of trials.

Subjects were tested in groups of four. A rotation order was used so that one subject was tested at a time, but the swimmer always remained in the same order of rotation with respect to other members of the group. One trial was initiated each 30 seconds. After each eight trials, the gun was reloaded during a 30 second interval. The length of each interval was measured from the pace clock utilized by the swimmers in the workout. This sequence allowed four swimmers to complete a testing period in 40 minutes if there were no false starts. In the case of a false start, that trial was repeated at the end of the block of trials at that interval.

Three testing personnel were used. The starter was experienced in starting AAU meets. A member of the parents' club volunteered to be recorder. Both the recorder and the starter followed the same procedure outlined in the pilot study. Another person watched for rolling starts which were counted as false starts and for swimmers falling into the water rather than diving out over the water. Those "fall-in's" also were recorded as false starts.

Treatment of the Data

All subjects received randomly ordered treatments of four blocked trials at foreperiod intervals of .5, 1, and 1.5 seconds and at one interval of varied foreperiods. Subject reliability at each interval was assessed through use of reliability coefficients derived from Pearson Product Moment Method of linear correlation between odd and even trials. Resulting coefficients were stepped up through use of the Spearman-Brown Prophecy Formula to establish the reliability coefficients for the total of four trials at each interval.

The dependent variables of hand movement time and starting time were analyzed in separate 2 x 4 analyses of variance (ANOVA) with sex as one independent variable and with repeated measures on the last independent variable, the foreperiod interval, to determine if there were an optimal length of foreperiod for effective performance in the grab start.

The main advantage of the repeated measure design as compared to ANOVA for independent groups is that some control is established over the effects of individual subject differences. When the same subject is given several treatments, differences among treatment means do not contain the differences between members of the independent groups. Therefore, the error term for the repeated measure design is smaller than for the ANOVA for independent groups.

Certain assumptions concerning the distribution of scores must be met in order to utilize values listed in the _F_ table which are based upon the theoretical _F_ distribution. The two critical assumptions for the repeated measures design are the homogeneity of within treatment variances and the homogeneity of covariance between pairs of treatment conditions.

The assumption relating to homogeneity of within treatment variances considers both subjects within groups and treatment times subjects within groups. Equal variability of scores in each treatment population is expected. The F-Max test (Winer, 1971) was used to assess if this assumption were tenable.

The second assumption for the repeated measures design is homogeneity of covariance between pairs of treatment conditions. The ability of subjects to maintain their relative ranking in each repeated measure is tested by establishing a variance-covariance matrix for each group of subjects, male and female, and testing by X^2 analysis to see if the matrices are homogeneous and symmetrical (Winer, 1971). If the matrices are homogeneous and symmetrical, a pooled matrix can be used in the error term thereby increasing the degrees of freedom.

ANOVA with repeated measures has been found to be relatively robust to deviations from normality particularly if equal sample sizes are used (Winer, 1971; Keppel, 1973). If the assumptions are violated and the regular error term is used to calculate the F ratio, a positively biased F is obtained. Therefore, an F ratio which appears to be significant $p<.05$ would in effect be significant at approximately $p<.08$ or .10 level. Greenhouse and Geisser (Winer, 1971) suggest using a conservative test of significance when the assumptions are violated. The degrees of freedom used in selecting the critical value of F are reduced so that the ensuing test is made assuming maximum departure from the assumptions.

Results of the ANOVA were analyzed. Significant main effects were isolated by use of the Newman-Keuls procedure to find where the differences among the treatment means occurred. If there were interaction, examination was made of simple effects. Analysis of power was conducted to determine how sensitive the test was to rejecting the null hypothesis when the hypothesis should be rejected. A Pearson correlation was utilized to assess the relationship between hand movement time and starting time at each interval.

CHAPTER IV

RESULTS AND DISCUSSION

Results

Reliability Scores

Swimmers completed four successive trials blocked at each of four foreperiod intervals: .5, 1, 1.5 seconds and varied foreperiods. Subject reliability was assessed by correlating the odd and even trials at each level using the Pearson Product Moment Method of linear correlation. The Spearman-Brown Prophecy Formula was applied to find subject reliability for all four trials at each interval (see Table 4). The stepped-up reliability coefficients of .88, .84, .87, and .82 for hand movement time and .87, .92, .88, and .71 for starting time indicated that the subjects performed in a highly consistent pattern for each foreperiod interval.

Analyses of Variance

Separate analyses were conducted for the hand movement time and the starting time scores. Data were subjected to a 2 x 4 analysis of variance with repeated measures on the second factor, foreperiod interval.

Hand movement time. Homogeneity assumptions for hand movement scores were tested. Homogeneity of variance was measured by the F-Max test. The resulting within subjects F-Max (2, 33) of 3.2549 indicated that the two groups were not homogeneous with regard to the variance assumption (see Table 5). When the assumption of covariance was tested, the resulting $\underline{X}^2$ of 28.7 was significant at the .05 level, indicating that the variance-covariance matrices were not homogeneous (see Table 6).

Table 4

Reliability Coefficients For Hand Movement Time and Starting Time

Correlational Technique	n	Foreperiod (in seconds) .5	1.0	1.5	Varied
Hand Movement Times					
Pearson Correlation Odd-Even Trials	24	.78*	.73*	.77*	.69*
Spearman-Brown Prophecy Formula	24	.88*	.84*	.87*	.82*
Starting Times					
Pearson Correlation Odd-Even Trials	24	.77*	.84*	.79*	.56*
Spearman-Brown Prophecy Formula	24	.87*	.92*	.88*	.71*

*p <.01.

Table 5

Homogeneity Tests For Hand Movement Time

Source	SS	F-Max df	F
Between Subjects			
Error	.0202		
Female	.0064	2, 11	2.1562
Male	.0138		
Within Subjects			
Error	.0217		
Female	.0051	2, 33	3.2549*
Male	.0166		

*p <.05.

Table 6

Variance-Covariance Matrices

For Hand Movement Time

Females:	b_1	b_2	b_3	b_4
b_1	.0002	.0003	.00009	.0003
b_2		.0001	.0002	0
b_3			.0003	.0003
b_4				.0003
	Determinant: /52/			

Males:	b_1	b_2	b_3	b_4
b_1	.0006	.00009	.0005	.0003
b_2		.0004	.00009	.00009
b_3			.001	.0005
b_4				.0003
	Determinant: /63/			

Pooled:	b_1	b_2	b_3	b_4
b_1	.0004	.0002	.00005	.0003
b_2		.0002	.0001	0
b_3			.0006	.0004
b_4				.0003
	Determinant: /134/			

$\underline{X}^2 = 28.7$, $\underline{p} < .05$.

Mean scores for hand movement time at each interval were calculated (see Table 7). Measures of hand movement time were subjected to a 2 x 4 analysis of variance with sex as the first independent variable, and the length of the foreperiod as the independent variable having repeated measures. An alpha level of .05 was established as necessary for statistical significance (see Table 8).

Table 7

Mean Scores For Hand Movement Time

Foreperiod	n	$\overline{X}$	SD	$SE_{\overline{X}}$
.5	24	.5207	.0234	.0048
1.0	24	.5214	.0167	.0034
1.5	24	.5397	.0276	.0056
Varied	24	.5217	.0211	.0043

Table 8

Summary of Analysis of Variance

For Hand Movement Time

Source	SS	df	MS	F
Between Subjects				
Sex	.0015	1	.0015	1.67
Error	.0202	22	.0009	
Total		23		
Within Subjects				
Treatments	.0061	3	.0020	6.67*
Interaction	.0018	3	.0006	2.00
Error	.0218	66	.0003	
Total		72		

*$p < .05$.

Because the homogeneity assumptions were not tenable, results of the ANOVA were evaluated by using the Greenhouse-Geisser (Kepler, 1973) approximation of the *F*-ratio. Therefore, when the foreperiod treatment yielded a normal *F* (3, 66) of 6.67 which was significant beyond the .05 level, the conservative Greenhouse-Geisser standard of *F* (1, 46) was applied. The treatment *F* of 6.67 was still significant at the .05 level. None of the other *F* ratios were significant.

Subsequently, all treatment means were compared by the Newman-Keuls procedure to find where the difference in treatments existed. Treatment means were ordered from fastest to slowest. The standard error of the mean of all treatment effects was computed. The degrees of freedom were 66, the same as for the within subject error term in the ANOVA. Distances between ranked means (r) were calculated, and the appropriate terms were selected from a table of critical values for the .05 level of significance for the Newman-Keuls test. The standard of comparison to determine significance ($S_{\bar{B}}qr$) was computed by multiplying the standard error of the mean by the appropriate factor for each distance. Results indicated that the 1.5 second interval elicited times which were slower than at any of the other intervals and that the varied foreperiod interval elicited slower responses than the .5 second foreperiod interval period (see Table 9).

Hand movement data were subjected to power tests as described by Keppel (1973) and Cohen (1969) (see Table 10). A high degree of sensitivity was indicated, and because power indicates the probability of rejecting the null hypothesis when the null is in fact true, the effects due to sex or interaction should have been evident had they existed.

Table 9

Newman-Keuls Analysis

For Hand Movement Time

Intervals Means	.5 (.5207)	1.0 (.5214)	Varied (.5217)	1.5 (.5397)	r	$S_{\bar{B}}qr^{a}$ (r, 66)
.5		.0007	.001*	.0190*	4	.0131
1.0			.0003	.0193*	3	.0119
Varied				.0180*	2	.0099

[a] $S_{\bar{B}} = .0035$.

*$p < .05$.

Table 10

Power For Analysis of Variance

For Hand Movement Time

Source	df_{num}	n/cell	ϕ	Power (.05)
Sex	1	48	1.8	.74
Treatment	3	24	3.6	.99
Interaction	3	12	3.6	.99

Starting time. The time elapsed between the sound of the gun and the swimmer's feet leaving the block was the dependent measure of starting time. The mean starting time for each interval was calculated (see Table 11).

Table 11

Mean Scores For Starting Time

Foreperiod	n	$\overline{X}$	SD	$SE_{\overline{X}}$
.5	24	.8236	.0328	.0067
1.0	24	.8282	.0322	.0066
1.5	24	.8335	.0334	.0068
Varied	24	.8274	.0371	.0076

When the data were subjected to tests for the assumption of homogeneity of variance, the F-Max tests indicated that the assumption was tenable (see Table 12). When the variance-covariance matrices were inspected, a X^2 of 46.0 was significant beyond the .05 level of confidence, indicating that the matrices were not homogeneous and could not be pooled (see Table 13).

Table 12

Homogeneity Tests For Starting Time

Source	SS	F-Max df	F
Between Subjects			
Error	.0576		
Female	.0207	2, 11	1.7971
Male	.0372		
Within Subjects			
Error	.0428		
Female	.0158	2, 33	1.7089
Male	.0270		

Table 13

Variance-Covariance Matrices

For Starting Time

Females:	b_1	b_2	b_3	b_4
b_1	.0003	.00001	.0001	.0003
b_2		.0015	.0003	.0006
b_3			.0004	.0004
b_4				.0011

Determinant: /64/

Males:	b_1	b_2	b_3	b_4
b_1	.0019	.0007	.0009	.0009
b_2		.0007	-.0001	.0008
b_3			.0018	.0003
b_4				.0017

Determinant: /177/

Pooled:	b_1	b_2	b_3	b_4
b_1	.0011	.0004	.0005	.0006
b_2		.0011	.0001	.0007
b_3			.0011	.0004
b_4				.0014

Determinant: /725/

$X^2 = 46.0$, $p < .05$.

A repeated measures analysis of variance was completed with sex as one independent variable and the length of the foreperiod as the independent variable having repeated measures. Results of the analysis indicated that no significant effects existed at the established .05 alpha level. There was no difference in starting time due to sex, foreperiod interval, or the interaction between the two variables (see Table 14).

Table 14

Summary of Analysis of Variance

For Starting Time

Source	SS	df	MS	*F*
Between Subjects				
Sex	.0002	1	.0002	.0769
Error	.0579	22	.0026	
Total		23		
Within Subjects				
Treatments	.0028	3	.0009	1.5
Interaction	.0024	3	.0008	1.33
Error	.0428	66	.0006	
Total		72		

When the power was calculated, the ANOVA was fairly sensitive to interaction as indicated by a power rating of .60. The power of treatment effects was .34 which was low and the statistical power of sex was .07 which was quite poor (see Table 15).

Correlation Between Variables

Using Pearson Product Moment Method of linear correlation, the relationship between the variables of hand movement time and starting time was assessed. Coefficients were determined for males, females, and for all swimmers for performances at each foreperiod interval of .5, 1, 1.5 seconds and varied foreperiods. Coefficients of .20, .28, -.20, and .31 were computed for all swimmers at intervals of .5, 1, 1.5 seconds and varied foreperiods, respectively. For males, at the corresponding intervals, coefficients of .24, .02, -.34, and .34 were obtained. When females' scores were considered, coefficients of .10, .54 ($p < .05$), .24, and .24 were calculated (see Table 16).

Table 15

Power For Analysis of Variance For Starting Time

Source	df_{num}	n/cell	ϕ	Power (.05)
Sex	1	48	.3	.07
Treatment	3	24	1.0	.34
Interaction	3	36	1.5	.60

Table 16

Correlation Coefficients For Hand Movement and Starting Times

		Foreperiod Intervals (in seconds)			
	n	.5	1	1.5	Varied
Pooled	24	.20	.28	-.20	.31
Males	12	.24	.02	-.34	.34
Females	12	.10	.54*	.24	.24

*$p < .05$.

Discussion

Reliability Scores

Reliability coefficients ranging from .71 to .92 indicated that the subjects were extremely reliable in performance of the grab swimming start. This high reliability would be expected since all the swimmers met criteria of having used the grab start exclusively in meets for one year and having been a senior level club swimmer for at least one year. Each swimmer had practiced the grab dive over a period of time, and each had developed a high level of skill.

In performance of any gross skill some inconsistency of performance would be expected. Thompson, Nagle, and Dobias (1958) found a reliability coefficient of $\underline{r} = .71$ for college football players responding to a rhythmical signal cadence with gross body movements. The reliability of the swimmers' performances compared favorably to Thompson's findings. However, Knapp (1961) found that adults who were highly skilled racquet sport performers had a reliability coefficient of .95 in a fine-motor skill reaction time task. The lower reliability coefficients of the swimmers would be expected primarily because the complexity of the task of performing the grab racing start is greater than enacting the fine movement task required in Knapp's experiment. Henry (1961) indicated that consistency of performance is reduced as the complexity of the task is increased. Also, although the movement time of the 12- to 17-year-old age group can be expected to be relatively equal, peak efficiency in movement time is achieved in the 15 to 17 year age range (Hodgkins, 1963). Some of the swimmers would not have reached their peak in this variable. Adults who had reached their full level of movement time efficiency could be expected to be more reliable than younger performers.

Sex Effects

When data from the starting time and the hand movement times were subjected to separate analyses of variance with repeated measures on the foreperiod variable, no differences were found between the performance of members of the sexes. The hand movement time and the starting times were in effect two movement times. The hand movement would be a less complex skill than the starting movement which was a result of several contributing movements. Henry (1961) found no difference in movement time in arm movement skills between members of both sexes. Hodgkins (1963) found women to be slower than men in movement time. However, her sample was drawn from a general population. Swimmers in this study were a highly select group basically homogeneous in composition. Less difference in scores between males and females would be predicted in this select group as compared to the general population.

Treatment Effects

The four foreperiods of .5, 1, 1.5 seconds and varied foreperiods all produced equal starting times. These results conflict with early studies of both track and swimming starts (Walker & Hayden, 1933; Nakamura, 1934; Tuttle, Morehouse & Armbruster, 1940) who found 1.5 seconds to be the optimal foreperiod of time to hold the swimmer or track man on his mark between the command and the sound of the gun. Tuttle, Morehouse, and Armbruster (1940) found an interval of .5 seconds to be the optimal time to hold untrained college male swimmers on the block. At least three plausible explanations for these differences exist:

First, the mechanical efficiency of timing devices used in the 1930's and the 1940's was not as exacting as the sophisticated electronic circuitry used to measure the foreperiod, to activate the gun, and to record the times of the swimmers in this study. The ability to measure accurately a foreperiod in .5 second intervals with a .10-second stopwatch or a chronoscope must be questioned. Statistical analysis of the data is more refined than the methods used for analysis in the 1940's.

Second, the swimming start used in early studies was a different skill than the grab start utilized throughout this study. The conventional starts of earlier swimmers were enacted from a relatively unstable position as compared to the grab start. Also the exact positioning for the start was less consistent in the traditional starts. When both the hands and the feet are placed in the same position for each dive as in the grab start, a more reliable starting position is achieved than when just the feet are placed securely on the blocks and the hands are positioned in the air. In the grab start, the balanced position is reached momentarily after the swimmer's hands grasp the block and the balanced position can be maintained easily.

Third, the swimmers used in this study may have become conditioned to shorter foreperiod intervals than 1.5 seconds. In northern California, starters in meets hold swimmers on the blocks less than 2 seconds and tend to produce a foreperiod of .5 to 1 seconds. Therefore, swimmers may have been conditioned to the .5 to 1.5 seconds range before the testing began. Informal preliminary studies showed a substantial number of false starts occurred when swimmers were held on the blocks for 2 seconds. Since suitable data could not be gathered at the 2 seconds foreperiod interval, that interval was eliminated in the experimental study. Partial explanation of increased number of false starts at the longer interval could be due to use of the information reduction theory. As the length of time within the expected range of foreperiods increased, the swimmer's sense of anticipation of the gunshot in relation to his own timing system increased until his personal limit of timing was reached at which point he completed his dive even though the gun had not been fired.

Results did not concur with Telford's (1931) conclusion that while the 1 and 2 second intervals were optimal for reaction time responses, a marked slowing in movement time was observed at the .5 second interval.

That there was no difference in the responses at the .5, 1, and 1.5 seconds foreperiod intervals was not in accord with Karlin's (1959) findings that reaction time was expressed in a linear relationship of decreasing speed from a .5, 1, 2, and 3.5 seconds series of intervals. Although reaction time and movement time are not the same variable and have been shown to not be related (Henry, 1952, 1960a; Slater-Hammel, 1952), the graphic increases at each variable due to maturational effects have been shown to be similar (Hodgkins, 1963).

When the hand movement time scores were analyzed, male and female scores did not differ. Since hand movement time represents a movement time measure similar to, although less complex than, the starting time, the lack of differentiation between the times of males and females on both of the two dependent measures is not unexpected.

The exact contribution of the hand movement time to the total performance of the grab start is not clear. The sequence of performance of the grab start seems to be dropping of the head simultaneous with rounding of the shoulders as the hands grasp more tightly to hold the body in position. This sequence is not in total agreement with Armbruster, Allen, and Billingsley (1973) who indicate that pulling with the hands is the initial movement in the grab start. The hands do appear to leave the block before the knees extend fully and the feet leave the block. It would be thought that the hand movement time would vary somewhat with the timing of an individual's own diving style. There was significantly slower hand movement time at the 1.5 second foreperiod interval compared to all other foreperiods and at the varied foreperiod interval as compared to the .5 second interval. One possible explanation is that as the diver's anticipation of the gunshot increases, he grasps more tightly with his hands to avoid a false start. Any tenseness in the grip could necessitate a slower hand release time. Although the hands left the blocks more slowly at the 1.5 second interval than at the other treatment levels, there was no difference in starting time at the 1.5 second interval as compared to the other starting forperiods. Somewhere in the timing sequence of the complete dive, the slower time of the hands leaving the blocks was balanced in the timing since the starting times were equal for all intervals. So the time to enact the start as a whole at the 1.5 second foreperiod was not slow.

Previous studies of fine movement and gross movement tasks seem to agree that signals presented in a rhythmic pattern elicit faster response times than signals presented in arhythmic patterns (Woodrow, 1914; Klemmer, 1956; Thompson, Nagle & Dobias, 1958; Wilson, 1959). For this reason, four trials were blocked in a series for each interval of .5, 1, and 1.5 seconds. The varied foreperiod treatment consisted of four trials conducted by the starter in his normal manner. That meant that the foreperiod intervals were presented in an arhythmical pattern for the varied foreperiod treatment. It was expected that the response time to the varied intervals might be slower than for the rhythmical presentations at all other intervals. This was not the case, as ANOVA results indicated that there was no difference due to treatments for starting time at any interval and that for hand movement time the varied foreperiod treatment was equal to or faster than the other foreperiods.

Studies which were reviewed used a much longer series of trials (20 to 50) when the experiments were conducted in the laboratory. Rhythmic series elicited faster results than arhythmical presentations conclusively. Thompson, Nagle, and Dobias (1958), however, used only three trials for reaction to football cadence signals and found faster movement time response to rhythmic presentations as compared to arhythmical series. Also, in this study, although the starter's foreperiod intervals were presented varied in sequence and at random, the starter used a starting range within the limits controlled in the experiment. Even though the starter was not familiar to the swimmers, his timing of the foreperiods was typical of AAU starters. In this sense his timing, although irregular, would be a comfortable pattern for the swimmer.

Correlation Between Variables

Only one significant correlation coefficient was found between the variables of hand movement time and starting time. A correlation of .54 was found at the 1 second foreperiod interval. All additional correlations were both low and not significant. Little information regarding the relationship between two movement time variables of differing complexity was available. The results seem to indicate that although both responses are movement responses, the hands moving and the feet leaving the blocks are separate skills. Henry (1960a) did note that in arm movement tasks, women more closely approximated men's response times as the complexity of the task increased. Since the correlations obtained in this study were not significant, that information could not be assessed.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

The speeds at which man reacts and at which man moves historically have been popular topics of concern. Some of the earliest recorded studies in track and swimming assess the speed at which a contestant leaves the starting blocks (Walker & Hayden, 1933; Nakamura, 1934; Tuttle, Morehouse & Armbruster, 1940). Logic would suggest that the variable of fast reaction time would have a high relationship with speed in running a race. Studies by Tuttle and Westerland (1931) confirmed this theory. However, later experiments conducted by Henry and Traft (1951) using more sophisticated measurement tools and research design refuted that theory. No relationship was found between reaction time and running time in a track race.

Concurrently, in the laboratory, exploration of the relationship of reaction time and movement time in finer movement skills was being initiated. When reaction time and movement time scores were compared by Henry (1952a, 1960), and Slater-Hammel (1952) little or no relationship was found between the two variables. Subsequent studies by Henry (1960b, 1961) revealed that sensory set produced faster reaction time than motor set. Christina (1973) extended those studies and found that sensory set elicited faster response than motor set regardless of the task complexity.

Hodgkins (1963) found that maturational changes affect reaction and movement times. Reaction time and movement time tended to peak between ages 18 to 21 and 15 to 17, respectively, for both males and females. Women (Henry, 1960a) tend to be slower in movement time tasks and slightly slower in reaction time than men (Henry, 1961).

Persons skilled in sports exhibited faster reaction time and movement time in both fine and gross skills when compared to average-skilled persons (Kelly, 1952; Beise & Preaseley, 1937; Olson, 1956; Youngen, 1959; Knapp, 1961). High reliability was found when scores from reaction and movement speed tasks were correlated for highly skilled adult performers (Knapp, 1961).

In formulating and testing the curvilinear theory of anticipation, Woodrow (1914) and Telford (1931) found that 1 to 2 second foreperiod intervals were optimal to elicit fast response in laboratory tasks. Early studies of the track and swimming starts (Walker & Hayden, 1933; Nakamura, 1934; Tuttle, Morehouse & Armbruster, 1940) found the optimal length of the foreperiod between when the starter gave the commands and the sound of the gun to be 1.6 to 1.8 seconds as measured by stopwatches and chronoscopes. Slower performances followed longer or shorter foreperiods.

Karlin (1959) refuted the curvilinear theory when he found a linear relationship from fast to slow response from foreperiods of .5, 1, 2, and 3.5 seconds. Simon and Slavenko (1975) completed a study related to the time-reduction theory of anticipation which is a conflicting theory to the curvilinear theory. Reaction time was decreased by using a lamp display to help subjects estimate the progressively decreasing time of the foreperiod.

All studies seem to agree that rhythmic presentation of a foreperiod or signal decreases reaction and movement times (Henry, 1960a; Klemmer, 1956; Woodrow, 1914). Thompson, Nagle, and Dobias (1958) and Wilson (1951) discovered that when total-body skills were enacted by football players, the rhythmical cadence of signal presentation effected faster response than arhythmical cadence.

Recently the grab start has become popular in competitive swimming. Not only has the grab style of dive been shown to project the swimmer off the blocks more quickly than the conventional starts (Hanauer, 1972; Roffer, 1972; Michaels, 1973; Van Slooten, 1973) but significantly fewer false starts have occurred when the grab start has been used (Michaels, 1973). The reduction in number of false starts probably has been because the starting position is more stable in the grab start than in the conventional start. Many studies have been conducted using cinematographical analysis of the grab start (Roffer, 1972; Groves, 1973; Hanauer, 1972; Michaels, 1973; Van Slooten, 1973). Since the 1940's no effort has been made to see if there is an optimal foreperiod time to hold the swimmers on the blocks in order for the swimmer to have his fastest starting time.

Therefore, it was the purpose of this study to determine if there is an optimal foreperiod between the commands given by the starter and the sound of the gun to elicit a fast response when the grab start is used in swimming competition. An electronic timer was designed to measure hand movement time and starting time and varied foreperiods. The equipment also standardized the foreperiod timed intervals of .5, 1, and 1.5 seconds. Four trials were blocked and presented at each foreperiod interval and presented in random order to 24 California AAU swimmers, 12 males and 12 females, between the ages of 12 and 17.

The dependent variables of hand movement time and starting time were subjected to separate analyses of variance with sex as one independent variable and the length of the foreperiod as the independent variable having repeated measures. Subject reliability was quite good as indicated by coefficients determined by correlating the odd and even trials using the Pearson technique and stepping up the results to the reliability coefficient of all four trials by use of the Spearman-Brown Prophecy Formula. The range of coefficients was $r = .56$ to .92.

Results indicated there was no optimal foreperiod within the range of .5, 1, and 1.5 seconds and varied foreperiod for starting time. For hand movement time an F (3, 66) of 6.67 was significant beyond the .05 level of confidence indicating a difference in treatment effects. Treatment means were analyzed further through the Newman-Keuls procedure and the 1.5 second foreperiod was shown to elicit a slower hand movement speed than all other intervals, and the varied foreperiod interval initiated slower hand responses than did the .5 second interval.

Findings

Within the limitations of this study, the following findings were accrued:

(a) There was no difference in starting time in the grab start after foreperiods of .5, 1, 1.5 seconds and varied foreperiods assigned in random order.

(b) There was no difference in hand movement time in the grab start after foreperiods of .5 second, 1 second, and varied foreperiods presented at random intervals. At the 1.5 second interval the hand movement times were slower than at the other treatment levels. Hand movement times after the varied foreperiod interval were slower than after the .5 second interval.

(c) There was no difference in starting time in the grab start due to the interaction between sex and the length of the foreperiod.

(d) There was no difference in hand movement time in the grab start due to the interaction between sex and the length of the foreperiod.

(e) For the total group, correlation between hand movement time and starting time was significant only at the 1 second interval where a substantial relationship was found.

(f) For subgroups of males and females no significant relationship existed between hand movement time and starting time at any foreperiod interval.

Conclusion

It was concluded that among the foreperiod intervals of .5, 1, and 1.5 seconds and varied foreperiod there was no optimal foreperiod interval which elicited a faster starting time in the grab start racing dive than any other interval.

Implications for Further Study

As a result of completing this study, investigation could be extended to the following topics:

(a) The study could be repeated with a larger sample to increase the power of the statistical analysis for starting time.

(b) An effort could be made to simulate actual competitive situations in the testing experience. Several swimmers could be started at once. Either all could be timed or, if equipment is unavailable, one could be timed and placebo pressure-switches could be placed on the alternate blocks so that all competitors would think they were being tested.

(c) Times could be charted in actual competitive situations. It might be expected that the starting times would be quicker when only one all-out effort is required.

(d) An accurate measure of reaction time could be incorporated into the electronic timing device. This might involve placing electronic devices on the shoulders or ears of the competitor. Or at least film analysis could be used to roughly estimate the reaction time so that it could be compared to starting time as registered on the electronic timing device.

(e) Sensory or motor set could be enforced to see if there were an effect by this variable on starting time.

(f) Speed leaving the blocks after the stimulus of a starter's pistol as used in the United States could be compared to starting time after the sound of a gong under each starting block as is used in international competition.

(g) Age as a variable affecting starting time could be assessed. In Master Level AAU swimming, ages range from 25 to 75. If older subjects could be found who performed the grab start in a reliable manner, comparative data could be gathered. Better, data could be gathered longitudinally at Master AAU national swim meets.

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APPENDIX A

Order of Presentation of Foreperiod Intervals

Group	Subject	Sex	1	2	3	4
01	01	M	1.0	Var	.5	1.5
01	02	M	.5	Var	1.0	1.5
01	03	M	1.5	1.0	Var	.5
01	04	M	Var	.5	1.0	1.5
02	05	F	1.5	.5	Var	1.0
02	06	F	1.5	1.0	Var	.5
02	07	M	1.5	.5	Var	1.0
02	08	M	1.5	1.0	Var	.5
03	09	M	1.5	1.0	.5	Var
03	10	M	.5	1.0	Var	1.5
03	11	F	Var	1.5	1.0	.5
03	12	F	.5	Var	1.0	1.5
04	13	M	1.0	Var	1.5	.5
04	14	M	1.5	.5	Var	1.0
04	15	M	Var	1.0	.5	1.5
04	16	F	1.0	Var	.5	1.5
05	17	F	Var	1.5	1.0	.5
05	18	F	Var	1.0	1.5	.5
05	19	F	Var	1.0	.5	1.5
05	20	F	1.5	.5	Var	1.0
06	21	M	Var	.5	1.5	1.0
06	22	F	.5	1.5	1.0	Var
06	23	F	.5	1.0	Var	1.5
06	24	F	1.0	1.5	.5	Var

APPENDIX B

Hand Movement Time Scores

Subject	Sex	Foreperiod Intervals (Seconds)			
		.5	1.0	1.5	Varied
05	F	.536[a]	.541	.528	.511
06	F	.553	.511	.536	.538
11	F	.538	.543	.535	.521
12	F	.508	.497	.516	.499
16	F	.517	.521	.501	.543
17	F	.551	.538	.537	.542
18	F	.527	.510	.546	.523
19	F	.529	.536	.571	.546
20	F	.501	.543	.545	.516
22	F	.542	.527	.561	.566
23	F	.522	.517	.532	.523
24	F	.535	.501	.542	.512
01	M	.488	.506	.497	.525
02	M	.516	.526	.510	.532
03	M	.526	.543	.501	.515
04	M	.492	.510	.566	.526
07	M	.537	.510	.558	.535
08	M	.511	.487	.526	.501
09	M	.478	.538	.546	.521
10	M	.523	.551	.516	.476
13	M	.466	.511	.549	.481
14	M	.499	.501	.545	.506
15	M	.554	.547	.620	.549
21	M	.548	.499	.571	.516

[a] mean (in seconds) of four trials.

APPENDIX C

Starting Time Scores

		Foreperiod Intervals (Seconds)			
Subject	Sex	.5	1.0	1.5	Varied
05	F	.800[a]	.894	.809	.831
06	F	.847	.864	.860	.876
11	F	.810	.862	.812	.829
12	F	.829	.752	.788	.790
16	F	.805	.794	.844	.805
17	F	.815	.806	.818	.789
18	F	.806	.812	.822	.844
19	F	.809	.836	.822	.814
20	F	.818	.831	.814	.799
22	F	.855	.876	.861	.877
23	F	.830	.810	.828	.882
24	F	.844	.817	.808	.835
01	M	.793	.813	.866	.793
02	M	.827	.794	.906	.853
03	M	.890	.873	.896	.888
04	M	.872	.829	.899	.792
07	M	.807	.870	.790	.890
08	M	.868	.847	.789	.824
09	M	.791	.819	.831	.836
10	M	.851	.838	.835	.822
13	M	.725	.784	.785	.745
14	M	.821	.812	.837	.802
15	M	.822	.820	.846	.812
21	M	.832	.824	.838	.831

[a] mean (in seconds) of four trials.