To the Graduate Council:

I am submitting herewith a dissertation written by Sharron Perkins Bilbrey entitled "The Relationship of Preferred Tempo and Intra-Subject Temporal Consistency to the Performance of a Serial Movement Task in a Stationary and Moving Environment." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Education, with a major in Physical Education.

Patricia A. Beitel

Patricia Beitel, Major Professor

We have read this dissertation
and recommend its acceptance:

Barbara J. Mead

Craig A. Wrisberg

Schuyler W. Huck

Accepted for the Council:

C.W. Minkel

Vice Provost
and Dean of The Graduate School

THE RELATIONSHIP OF PREFERRED TEMPO AND INTRA-SUBJECT TEMPORAL CONSISTENCY TO THE PERFORMANCE OF A SERIAL MOVEMENT TASK IN A STATIONARY AND MOVING ENVIRONMENT

A Dissertation

Presented for the

Doctor of Education

Degree

The University of Tennessee, Knoxville

Sharron Perkins Bilbrey

August 1988

ACKNOWLEDGMENTS

I wish to thank committee members, Drs. Barbara J. Mead, Craig A. Wrisburg, and Schuyler W. Huck, for their careful editing and scholarly input. I am especially grateful to Dr. Patricia A. Beitel, chairperson of my committee, for her wisdom, tireless effort, and encouragement. Dr. Beitel's help, guidance, and scholarly example have been invaluable throughout my graduate studies.

I would like to thank my friends and colleagues at Tennessee Technological University and in the Cookeville community for their assistance and cooperation in making this project possible. I would also like to express a special thanks to my husband, son, father, mother, and mother-in-law for their help and support.

ABSTRACT

The purpose of this study was to investigate the nature of the relationship between preferred tempo (PT), and intra-subject temporal consistency (TC), and the performance of a serial movement task requiring total body movement to project an object in a stationary and moving environment. The individual components in the serial task (moving to kick a soccer ball) were identified as: (a) continuous in the approach phase, and (b) discrete in the kicking phase.

Ss (female = 8, male = 12) were videotaped while kicking a stationary ball (closed), and a moving ball (open), to a stationary target with a numbered grid. Using frame by frame analysis, the time was recorded (.01 sec) to indicate total movement time, approach phase time, and kicking phase time for each kick. For each task, the means (to indicate PT) and standard deviations (to indicate intra-subject TC) were calculated for the three times. The total goal attainment score and standard deviation of each S's score were also recorded.

Each S performed the total and approach phase times, for both closed and open tasks, at a PT which was different than that of other individuals. However, Ss tended to perform the kicking phase in both environments at PTs which were not different from that of other individuals. Ss did not demonstrate a significant difference in intra-subject TC or PT between the approach phases of the two tasks. Although each subject performed the kicking phases at about the same PT, they tended to perform the kicking phase for the closed task more consistently than for the open task.

No significant relationships were found between intra-subject TC or PT and: (a) a higher total goal attainment score, or (b) the consistency of individual scoring. In the approach phase of the open task, Ss with faster PTs tended to be more consistent. In the kicking phase of the closed task, Ss with slower PTs tended to be more consistent. Significant sex differences were not found except that in the open task females tended to take more steps in the approach phase, and have slower PTs in the kicking phase. It was concluded that, although the environmental conditions did not alter a S's PT or TC in the approach phase (continuous), the environmental demands made a significant difference in the intra-subject TC of the kicking phase (discrete).

TABLE OF CONTENTS

PAGE

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Every movement task has a performance rhythm (Barsch, 1967) which is performed at a tempo that is unique to each individual. Preferred tempo, or personal tempo, has been defined as the "self-imposed preference of voluntary movement tempo" (Smoll, 1975a, p. 734), and it is part of the individual differences that make up one's "personal equation" (Cratty, 1973). Tempo implies a characteristic style of time and rhythm. Therefore, before preferred tempo can be understood, it is necessary to investigate the concepts of time, rhythm, and the spatial and temporal components of rhythm.

Time and Rhythm

Time

Barsch (1967) named four domains of time: (a) physiologic, (b) milieu, (c) physical, and (d) cognitive. Physiologic time is the internal time displayed by the working of the metabolic system and other bodily functions such as the heart rate, pulse rate and skin conductance. Milieu time involves the phases of development from infancy to adulthood. The physical and cognitive domains are the most important to the understanding of the relationship of time to movement. Physical time is divided into units of seconds, minutes, hours, days, weeks, months and years. The human being moves in physical time with distances being calculated in terms of time duration. Barsch (1967) defines Fast and Slow as two concepts referring to the duration of the time it takes to move from point to point in space. Physical time involves: (a) regulating the "speed of movement in keeping with the perceived need for variation" (Barsch, 1967, p. 157); and, (b) the sequence of muscular movements that occur rapidly, i.e., one discrete step following another. Cognitive time is the duration of time necessary to process stimuli, recognize, and attach meaning to the stimuli. It is the critical predeterminant of a person's actions and is essential to the efficiency of an individual's temporal orientation.

Rhythm

Barsch (1967) defined four aspects of rhythm relating to movement efficiency: (a) cosmic, (b) biologic, (c) perceived, and (d) performance rhythms. Cosmic and biologic rhythms contain invariant qualities. Cosmic rhythm is evident in the regulation of day and night, the seasons, the tide and hundreds of other examples in the universe. The biologic rhythm system: (a) includes the built-in regularities of respiration, heart beat, brain waves, etc., with each rhythmic element having a unique tempo; (b) contains patterns that are characteristic for all humans; and (c) contains elements which are individual difference variables. Using the language of a composer, the cosmic and biologic rhythms are the main theme of a symphony, therefore, the percieved and performance rhythms are variations upon the theme.

Perceived rhythm is the perception of the beat and tone in music and any other ordered patterns in the environment. It is recognizing the rhythm of recurrency and the regularity of an interval of time or movement according to some defined order. A combination of perceived and performance rhythms is required to keep the body in movement coincident with a musical rhythm, such as keeping step and playing in a marching band (Barsch, 1967).

Performance rhythm is acquired by the dynamic human organism. This rhythm is constructed into movement patterns of varying tempos, with some new temporal element being developed with each learning experience. The performance rhythm patterns can be: (a) postural, such as walking and running; (b) manipulative, such as throwing and striking; or (c) expressive, such as dancing. These patterns can be replicated consistently with movement efficiency (Barsch, 1967).

Spatial and Temporal Accuracy of Movement Tasks

It is recognized that the unique rhythmic experience of movement is a "space-time organization of events" (Mead, 1968, p. 156; Smoll, 1973, p. 233). A task demanding performance and perceived rhythm must require a consistency of spatial and temporal accuracy if movement is to be efficient. Keogh and Sugden (1985) described spatial and temporal accuracy of a movement task. For the task to have spatial accuracy the "whole body or certain body parts must be moved to a particular spatial location . . . in an appropriate direction and for an appropriate distance, often with an appropriate amount of force and speed" (p. 106). Temporal accuracy requirements of a task are created when the environment and/or the mover is moving and at a faster speed. Temporal accuracy means "coinciding the self with objects and other people to stay in unison or to intercept or avoid them" (Keogh & Sugden, 1985, p. 111). Considering tasks which require temporal accuracy, Keogh and Sugden (1985) distinguished between required changes in manual control and total body control tasks. Manual control of temporal accuracy in a task refers to controlling hand and arm movements either by: (a) keeping time, "maintaining a temporal pattern in a continuous set of movements" (Keogh & Sugden, 1985, p. 115), i.e., a perceived rhythm, or (b) coincidence timing, "matching a mover's position to the changing position of an object or another person" (Keogh & Sugden, 1985, p. 115), i.e., a performance rhythm. Body control tasks may also be considered as either tasks of: (a) keeping time, and/or (b) coincidence timing. These body control tasks, however, involve moving the entire body in a more moving environment. Further, coincidence timing may occur in two ways. First, the mover attempts to intercept, at one coincidence point, a moving object or another moving person. Second, the mover attempts to continuously match his or her movements to movements in the environment by maintaining a relatively consistent position to the changing spatial relationships of a moving object or another person, such as dancing with a partner. The requirements for the temporal accuracy of the task increase as the mover moves faster and/or the speed and path of object(s) and other person(s) in the environment become more complex and/or unpredictable. This leaves less time available for the mover to make changes in direction.

Every movement has temporal duration, with a beginning, middle, and end. For a movement to become efficient, it is "basically a matter of acquiring a more appropriate pattern of timing and intensity in the related time and stress values of the movement phase" (Barsch, 1967, p. 305). However, it is only after this pattern of timing is established in the movement skills of walking, running, hopping, skipping, manipulations, etc., that the human can explore multiple variations in tempo in any of these skills. It is suggested that from these multiple variations, an individual's preferred tempo will emerge.

Studies have demonstrated preferred tempo by illustrating high <u>intra</u>-subject consistency and high <u>inter</u>-subject variability using simple motor tasks in a stationary environment such as tapping (Frischeisen-Kohler, 1933; Harrison, 1941; Rimoldi, 1951; Wu, 1934), arm and leg swings (Harrison, 1941; Rimoldi, 1951), and typewriting skills (Harding, 1932). Even from the world of music, it has been shown that, over time, a musician will repeatedly perform a composition within the same time frame, yet the same piece of music will be performed by another musician within a different time frame (Clynes & Walker, 1982). Although some earlier studies supported the theory of an overall general preferred tempo (Frischeisen-Kohler, 1933; Harding, 1932), many of the studies (Harrison, 1941; Rimoldi, 1951; Wu, 1934) supported the theory that a preferred tempo exists within an individual for specific kinds of movement and seems to be consistent over time. The tasks used for these studies were performed in a stationary evironment with the emphasis only on the temporal element of rhythm, with the spatial accuracy requirements being minimal.

Using an apparatus to assess rhythmic ability involving both spatial and temporal accuracy requirements, Smoll (1975b) reported high intra-subject consistency and high inter-subject variability with subjects performing an arm swing task at their preferred tempo. Smoll and Schutz (1982) reported that when adult subjects were asked to perform the arm swing task at imposed tempos that were similar to, greater than, and less than their own preferred tempo, their optimum performance (in terms of spatial and temporal accuracy) was at the tempo close to their own preferred tempo. Walters (1983) made a similar discovery with children performing a simple tapping task. Further, Smoll (1975b, 1975c) and Smoll and Schutz (1978) found no sex differences in the preferred tempo or in the intra-subject temporal consistency of the arm swing task. Also, Smoll and Schutz (1978) found that subject's performing at a faster preferred tempo were more temporally consistent in their performance than those performing at slower tempos.

In a different framework, various researchers in engineering psychology have shown that a self-paced work rate is: (a) more efficient, both mechanically and physiologically (Conrad, 1960; Corlett & Mahadeva, 1970; DeJong, 1960; Salvendy, 1972); and (b) more psychologically satisfying than externally imposed work rates (Salvendy, 1974; Salvendy & Pilitsis, 1971). It has also been shown that subjects performing at different work loads on a bicycle ergometer would: (a) select a pace most comfortable to them, and (b) maintain the pace for the duration of the task. Some subjects were shown to maintain the same pace, no matter what the work load (McCann & Gliner, 1982; Taguchi, Gliner, Horvath, & Nakamura, 1981).

Generally, the literature indicates that preferred tempo is an important component of an individual's "personal equation" of movement. This is especially true if one is performing simple motor tasks in a stationary environment with minimal spatial accuracy problems as in the engineering psychology studies (using continuous tasks) and the tapping experiments. The studies by Smoll demonstrated preferred tempo as a factor in the successful performance of a rhythmic, repetitive discrete task requiring both spatial and temporal accuracy. However, the spatial and temporal accuracy requirements were limited to making one-directional movements of a single body part in a stationary environment. Walters' (1983) demonstration of preferred tempo only involved the element of "keeping time" with no spatial requirements.

If preferred tempo is such an important part of a person's rhythmic ability and is a factor in the performance of continuous and repetitive discrete tasks, it follows that preferred tempo might also be a factor in the performance of a single discrete task or serial movement task requiring total body control of coincidence timing. One study (Hubbard & Seng, 1954) reported the temporal consistency of baseball batters performing the discrete skill of swinging a baseball bat. Another study (Jones & Hanson, 1961) reported high intra-subject consistency and high inter-subject variability in the spatial and temporal patterns of subjects performing the discrete task of rising from a chair. However, no research was found where preferred tempo was studied in relationship to the performance of a single discrete task or serial movement task.

Statement of the Problem

The present study extended the research of Smoll (1975b, 1975c) and Smoll and Schutz (1978) on the concepts of preferred tempo and intra-subject consistency in the performance of a repetitive discrete task. The purpose of this investigation was to determine if preferred tempo and intra-subject consistency were factors in the performance of a serial movement task (with continuous and discrete components) requiring total body movement to project an object in stationary and moving environments.

The research of Smoll (1975b, 1975c) and Smoll and Schutz (1978) influenced the following hypotheses which were statistically tested with $\underline{p} \leqq .05$.

1. The average intra-subject temporal consistency of preferred tempo would be proportionately smaller than the inter-subject temporal consistency for the performance of a serial movement task requiring total body movement: (a) executed in a stationary environment, and (b) involving coincidence timing with the temporal accuracy requirements of the task being increased by creating a moving environment.

2. Subjects would demonstrate less intra-subject temporal consistency of preferred tempo performing a serial movement task,

requiring total body movement of coincidence timing in the moving environment (moving to kick a moving ball), than when performing a serial movement task in the stationary environment (moving to kick a stationary ball).

3. In both the stationary and moving environments, subjects displaying greater intra-subject temporal consistency of preferred tempo would demonstrate: (a) higher quality of goal attainment, and (b) greater consistency of goal attainment than subjects displaying a less consistent preferred tempo when meeting the temporal accuracy requirements of a serial movement task.

4. In both the stationary and moving environments, there would be no significant relationship between a subject's preferred tempo and: (a) the quality of goal attainment, and (b) the consistency of goal attainment when meeting the temporal acuracy requirements of a serial movement task.

5. In both the stationary and moving environments, there would be a significant positive relationship between preferred tempo and intra-subject temporal consistency, i.e., subjects displaying greater intra-subject temporal consistency would demonstrate faster preferred tempos than subjects displaying less temporal consistency when meeting the temporal accuracy requirements of a serial movement task.

6. In both the stationary and moving environments, there would be no sex differences in: (a) the intra-subject temporal consistency of preferred tempo, or (b) the preferred tempo when meeting the temporal accuracy requirements of a serial movement task.

Definitions of Terms

The following theoretical and operational definitions were used consistently throughout the text. The terms are listed in sequence for the purpose of comprehension of the related definitions.

1. Preferred tempo. Preferred tempo is the "self-imposed preference of voluntary movement tempo" (Smoll, 1975a, p. 734). Preferred tempo is how a person chooses to move and is part of the individual differences that make up one's "personal equation" (Cratty, 1973). Through the use of video tape and the video camera's automatic timer appearing in the picture, preferred tempo of the kicking motion was determined by calculating the mean movement times for the following: (a) the total kicking motion, the time between the initial contact of the first step and the actual contact with the ball, (b) the approach phase, the time between the initial contact of the first step and the point where the subject makes initial contact of the nonkicking foot immediately preceding the kick; (c) the kicking phase, the time between the initial contact of the nonkicking foot and the actual contact of the ball by the kicking foot. These movement times, recorded in the nearest hundredths of seconds, were represented by eight out of ten trials (dropping the highest and lowest total times for each subject) for the two environmental conditions, i.e., stationary and moving.

2. Intra-subject temporal consistency. The intra-subject temporal consistency indicates the degree of variation of the subject's movement times about his/her own preferred tempo. In this study the

intra-subject temporal consistency of an individual's performance was measured by calculating the standard deviation of the subject's movement times about his or her own mean movement time (preferred tempo) for the following: (a) total kicking times, (b) approach phase times, and (c) kicking phase times in the stationary and moving environments.

3. Inter-subject temporal consistency. Inter-subject temporal consistency is the degree of variation among the group of subjects in regard to the group's individual preferred tempo scores. The inter-subject temporal consistency was measured by calculating the standard deviation of all subjects' mean movement times, i.e., their preferred tempos.

4. Temporal/spatial accuracy demands of the environment. Movements are performed in stationary environmental conditions or in moving environmental conditions. Based on the temporal/spatial requirements, the movement tasks can be classified along a continuum between closed and open (Robb, 1972). If the environment is not changing and the performer can plan a movement in advance without the possibility of the situation changing, the task is termed closed. If the environment is unpredictable and the performer must match the changing situation, the task is termed open. As the environment becomes more variable, the temporal/spatial accuracy demands in the environment increase. "The temporal and spatial organization characteristics of the movement have a direct relationship to the temporal and spatial characteristics of the environment" (Higgins, 1972, p. 333). A subject's preferred tempo and intra-subject temporal consistency in the

task of kicking a soccer ball was determined in the following environmental conditions: (a) the ball was stationary, with the subject moving to kick the ball to a stationary target (closed task); and (b) the ball was moving, with the subject moving to kick the ball to the same stationary target (open task).

5. Goal attainment. Goal attainment is the result achieved when executing a movement task requiring the projection of an object to a target. In the present study, the degree of success in goal attainment was evaluated by scores achieved when a subject kicked a soccer ball for ten trials to a target grid (Appendix C). There were two types of goal attainment: (a) qualitative goal attainment, i.e., the subject's individual total score for the performance of the ten trials of the closed or open task; and (b) consistency of goal attainment, i.e., the standard deviation of the subject's score obtained for the closed or open task.

6. Performance rhythm. The spatial and temporal movement pattern of a task that can be replicated consistently by an individual (Barsch, 1967). Performance rhythm is consistently being in the right place at the right time in order to perform a movement task successfully. In the present study, performance rhythm was evidenced by the ability of the subjects to time their movement through space in order to kick: (a) a stationary ball, and (b) a moving ball.

7. Discrete, continuous, and serial movement tasks. A single discrete movement task contains one unit, with a distinct beginning and end, such as a baseball throw. "Some discrete tasks are repetitive and

are performed in a specified rhythmic tempo" (Singer, 1980, p. 20). An example of this repetitive discrete task is the arm swing task in the Smoll (e.g., Smoll, 1975b) studies. In the present study, the single discrete movement task is the kicking phase of moving to kick the soccer ball. For each subject, the preferred tempo of the kicking phase was represented by the mean kicking time. The intra-subject temporal consistency was represented by the standard deviation of the kicking phase time.

A continuous movement task (e.g., riding a bicycle) has no distinct beginning or end and could continue for an indefinite amount of time (Singer, 1980). In the present study, the continuous movement task is the approach phase of moving to kick the soccer ball. For each subject, the preferred tempo of the approach phase was represented by the mean approach phase time. The intra-subject temporal consistency was represented by the standard deviation of the approach phase time.

A serial movement task contains a series of specified events put together to form an apparent continuous performance with emphasis being placed on the sequence of the distinct elements, such as moving to kick a ball. The movement task performed in the present study was the instep kick used in the sport of soccer. The total kicking motion was a serial task formed by running (i.e., continuous) in order to gain momentum and attain position for kicking (i.e., discrete) to a stationary target. The preferred tempo of the total movement time was represented by the mean total movement time. The intra-subject temporal consistency was represented by the standard deviation of the total movement time.

8. Spatial accuracy requirements of a movement task. For executing a serial task requiring the projection of an object to a stationary target the nature of spatial accuracy is combining the path of a body part (e.g., an arm or leg) with the point of the projection of the object in order to determine the direction of the object's flight (Keogh & Sugden, 1985). In the present study, the degree of spatial accuracy was measured by the degree of goal attainment (see Definition #5).

9. Temporal accuracy requirements of a movement task. For executing a serial task requiring the projection of an object to a stationary target the nature of temporal accuracy is to time the completion of the sequence of the body movements to coincide with the projection of the object in order to produce a successful performance. In the present study, the temporal accuracy requirements for the closed task were minimal, limited only by successfully completing the sequence of body movements that was required for moving to kick a stationary soccer ball. Temporal accuracy requirements of the task are greater if the performer, target, or object are no longer stationary. In this case, coincidence timing becomes an important factor to the success of the performer (Keogh & Sugden, 1985). In the present study, temporal accuracy was represented by the type of task, because requirements for the open task (i.e., the ball was moving) were greater than for the closed task (i.e., the ball was stationary).

10. Total body control tasks. These tasks involve moving the entire body in a moving environment and may be considered as either tasks of: (a) keeping time, or (b) coincidence timing. Moving to kick

a rolling ball is a total body control task of coincidence timing involving the projection of an object (Keogh & Sugden, 1985).

11. Coincidence timing. The total body control task in which the mover attempts to intercept, at one coincidence point, a moving object. In the present study, the coincidence timing task was demonstrated by the subject moving to kick a moving soccer ball as it crossed a specific spot on the floor for the purpose of hitting a stationary target.

Scope of the Study

Subjects were undergraduate students who had completed a physical education soccer activity class at Tennessee Technological University. Because the study addresses the problem of intra-subject consistency or variability of preferred tempo, no control was made to exclude experienced soccer players. The study specifically addresses the hypotheses that for individuals with faster and more consistent preferred tempos, the higher the quality and greater the consistency of goal attainment will be. However, it was recognized that skill level could have been a factor in the consistency of movement and the degree of goal attainment.

Significance of the Study

Preferred tempo is an allusive part of the individual differences that make up one's characteristic style of movement. When athletes are not particularly successful during a game or match, one might say they "lost their timing" or were "out of rhythm." On the other hand, coaches might say, that in order to win, their teams must "control the tempo" of the game. Timing, rhythm, and tempo are universal phenomena that athletes and coaches deal with constantly throughout their sport careers.

This study attempted to demonstrate the importance of preferred tempo and the intra-subject consistency of preferred tempo in the performance of a sport skill. Preferred tempo has been identified as an important factor in the performance of: (a) continuous tasks (e.g., Rimoldi, 1951), and (b) simple, repetitive discrete tasks (e.g., Smoll and Schutz, 1978) in a predictable environment. This study, a follow-up to the Smoll (1975b, 1975c) and Smoll and Schutz (1978) research, attempted to identify the concept of preferred tempo as an important factor in the successful performance of a serial task (with continuous and discrete components) both in stationary and moving environments. This study could also prove to be a springboard for further research dealing with the influence of preferred tempo on the efficiency of movement, as demonstrated through biomechanical analysis.

CHAPTER II

REVIEW OF LITERATURE

The purpose of this review was to expand the concept of preferred tempo and explore the relationship of preferred tempo to the performance of various types of movement tasks. First, the idea of preferred tempo was investigated in studies using: (a) simple motor tasks, (b) repetitive discrete tasks requiring rhythmic ability, and (c) continuous tasks. Second, preferred tempo was related to the performance of a single discrete motor task.

Preferred Tempo and Simple Motor Tasks

Investigations that have demonstrated preferred tempo, or personal tempo, used simple tasks such as tapping (Frischeisen-Kohler, 1933; Harrison, 1941; Rimoldi, 1951; Wu, 1934), and leg and arm swings (Harrison, 1941; Rimoldi, 1951; Smoll, 1975b, 1975c). Most of the preferred tempo studies have shown a high intra-subject consistency and a high inter-subject variability. Some of the earlier studies (Frischeisen-Kohler, 1933; Harding, 1932) supported the theory of an overall general preferred tempo which is unique to each individual. Other studies (Harrison, 1941; Rimoldi, 1951; Wu, 1934) supported the theory that a preferred tempo exists for specific kinds of movement within an individual.

Frischeisen-Kohler (1933) defined personal tempo as the individual tempo of personality which is expressed in acts of perception and volitional processes. To demonstrate the existence of personal tempo, the author summarized several finger tapping and metronome experiments that used the same subjects. In the tapping experiments, subjects were asked to tap against a table with a spontaneously chosen position of the hand or fingers, tap on the floor with the foot, and tap on the edge of a table with an outstretched forefinger. In each tapping experiment the subject was asked to tap in a tempo that was most agreeable to him or her. The number of taps in a specific time interval (ten seconds) was recorded. In the metronome experiments, the same subjects listened to several tempos and were required to indicate if each tempo was too slow, too fast or precisely agreeable for their personal taste. The group of tapping experiments was repeated on four different days with a one or two day interval between the second and third session. The metronome experiments were repeated twice, with a two month interval between sessions. By calculating the mean index of variability for all subjects in each experiment, Frischeisen-Kohler (1933) concluded the results showed a definite intra-individual consistency of the subject's tempo.

Wu (1934) investigated the possibility of a general speed factor with studies of the relationship between personal tempo and maximum speed. In studying personal tempo, nine subjects were tested over a period of ten weeks and 26 subjects were tested in a single sitting on each of the six rate tests of: (a) foot tapping, (b) counting numerals, (c) finger tapping, (d) poetry reading, (e) observing octagon, and

(f) word writing. Although details of experimental and statistical techniques were not available, the author reported positive *phi* correlations of the tempo tests (except for word writing), and positive *phi* correlations for all combinations of the six tests. He concluded that each subject worked at his or her own characteristic rate or "personal tempo" on each of the tasks. The same subjects used in the ten week study were timed on the six speed tests of: (a) finger tapping, (b) number naming, (c) foot tapping, (d) packing blocks, (e) word writing, and (f) triangular tapping. Again, Wu (1934) reported all *phi* intercorrelations of the six speed tests were positive, demonstrating that subjects who were comparatively fast in one task were comparatively fast in others. In comparing the personal tempo tests with the speed tests, the finger tapping tests and word writing tests were both positively correlated (*phi* = .51 + .10; *phi* = .56 + .09), and the intercorrelation among all six tempo tests and all six speed tests was positive, but weak (*phi* = .19 + .13). From this, Wu (1934) concluded that if certain tasks had more or less similar content, an individual's "personal tempo" could be somewhat related to his or her maximum speed. However, no general speed factor was determined.

Harrison and Dorcus (1938) were concerned with studying an individual's consistency of usual movements of everyday life without the expectancy to respond at maximum speed. Fifty male undergraduates were timed: (a) in turning a crank ten revolutions while reading, (b) tapping while reading, (c) tracing an irregular pathway on paper, (d) drawing a straight line, (e) raising the right arm, (f) turning the head through a constant angle, (g) bending over from a sitting position, and (h) walking. Subjects were instructed to proceed at their chosen rate. The intercorrelation of speed measurements indicated no unitary speed trait that could be characteristic of an individual. The authors also concluded that the tendency of individuals was to perform at a fairly consistent rate from one time to another, suggesting some kind of personal tempo within tasks (Harrison & Dorcus, 1938). However, the authors gave no indication of the time interval between testing sessions.

Recognizing questions left unanswered from the previous study (Harrison & Dorcus, 1938), Harrison (1941) attempted to discover: (a) if a voluntary rate of movement was a unitary personal speed factor possessing intra-personal consistency; (b) if the same applied to maximal tempo; and (c) whether habituation resulting from repetition of performances had any effect on specificity or generality of voluntary tempo. In the first experiment, 50 male undergraduates (Group A), average age of 19 years, were tested on 24 tasks within a one hour session. The first twelve tasks were carried out at the subject's chosen rate of speed. The subjects were timed on tasks ranging from simple motor tasks and locomotor tasks that used widely different muscle groups, to more complex and cognitive tasks. Motor and locomotor tasks included: (a) turning a hand-crank, (b) card sorting, (c) tapping, (d) head turn, (e) body bend, (f) arm raising, (g) patting, and (h) walking. The cognitive tasks included: (a) speed of decision demonstrated by the time it took for the subject to choose between descriptive terms that chartacterized personal qualities, (b) writing, (c) reading, and (d) counting. Following the twelve tasks performed at a chosen rate of speed, twelve different tasks were timed for maximal speed. The maximal speed tasks contained high-order cognitive functions, sensori-motor functions, and simple motor reactions. The cognitive performance tasks included: (a) solving a Rossolimo picture puzzle, (b) multiplication, (c) speed writing, (d) speed reading, and (e) finding omitted letters in columns of words. Sensori-motor tasks included: (a) a test for finger dexterity, (b) a symbol substitution test, and (c) speed card sorting. The simple motor tasks included: (a) speed patting, (b) speed tapping, (c) speed cranking, and (d) a test for auditory reaction time. In general, there were low correlations (average $\underline{r}$ = .16) between tasks of voluntary tempo, indicating tempo specificity within each task rather than a unitary personal speed factor. However, there were sixteen tasks with positive and statistically reliable correlations that could be explained on the basis of common elements. For example, Harrison (1941) reported significant interrelationships between head turning, arm raising, and body bending that were regarded as simple motor adjustments made in everyday life.

In the second part of Experiment I, Harrison (1941) investigated the possibility that some individuals could be consistent across tasks. The author took the twelve voluntary tempo scores of the same subjects in Group A and converted them into rank orders for each person. Only two subjects were found to be consistent, and nine subjects were found to be moderately consistent. All other subjects were found to have completely erratic rank-order profiles. For the maximal speed performances of the 50 male undergraduates in Group A, where the results were even more specific than for the voluntary rate performances (overall average $\underline{r}$ = .15 +.09), the same rank-order profiles were used to determine the consistency of individual speed performances. Three subjects were found to be highly consistent at an individualized speed level, while three other subjects performed fairly consistently. Harrison (1941) concluded that some individuals displayed an overall unitary, or general, personal tempo across tasks, despite the specificity findings.

In the second experiment, Harrison (1941) studied the effect of repetition of performances, or habituation, on voluntary speed in relation to the theories of specificity-generality. The author hypothesized that the apparent generality of voluntary tempo in tasks of daily life could be attributed to habituation. Experiment II was composed of two groups. (Group B, $\underline{N}$ = 20, males and females with average age of 21.0 years; Group C, $\underline{N}$ = 20, males and females with average age of 20.6 years.) Ten tasks were chosen from the voluntary speed tasks performed by Group A (cranking, tapping, head turn, arm raising, body bend, writing, reading, counting, patting, and walking). The instructions and methods were the same as in Experiment I except Group B repeated the tasks for six consecutive days and Group C repeated the tasks over a period of six weeks on the same day of the week. The hypothesis that generality could be due to habituation was studied by comparing the daily and weekly groups for the first and final practice days (B-I and C-I with B-VI and C-VI). For the hypothesis to be correct the majority of correlations in B-VI and C-VI should have been much closer to 1.0 than the same correlations in B-I and C-I. However, this was not the case. "Habituation, which would be expected to result from repetition of performances, failed uniformly to augment intercorrelations to a sufficient extent to yield results that would favor the theory of a generalized personal speed trait" (Harrison, 1941, p. 374). In general, the author concluded that no unitary, or general, speed factor was present across tasks, but subjects did, however, display intertrial consistency of speed for specific tasks.

To determine the factors that could make up personal tempo, Rimoldi (1951) tested 91 male college students (ages: 19-25 years) on 59 different tests. These tests included: (a) motor activities (large and small movements, proximal and distal, symmetric and parallel, left and right side movements, upper and lower limbs, etc.); (b) reaction time measurements; (c) complex processes such as judgments and recognition of designs; (d) expressive movements such as drawing; (e) intellectual processes, as tested with the Primary Mental Abilities (PMA) tests; (f) preferred metronome rate; and, (g) speed of walking. All tests except for the reaction time tests were performed in the most "natural, congenial way." The battery of tests was completed in a single three hour session. Seventeen of the subjects repeated the battery within a period of two to four weeks.

Through extensive factor analysis, nine factors were identified in the following order:

1. Factor A included large movements of the limbs or trunk, independent of side of the body, muscular group concerned (shoulder, hips and trunk), or function (abduction, adduction, flexion, etc.); and probably related to gait and gesture of an individual.

2. Factor B included small movements, performed by the distal muscles of the limbs, requiring a finer coordination and precision of movements than found in Factor A. Because of the moderate correlation between Factors A and B (r = .51), Rimoldi (1951) suggested the possibility of interpreting these factors as independent and concluded "some sort of generality of speed for many varied muscular activities" (p. 291).

3. Factor E dealt with tests relating to speed of making simple drawings with the feet. Because these tests involved some large movements, the correlation between Factors A and E was positive (r = .29).

4. Factor H dealt with speed drawing with the hands, including handwriting. Factor E, speed of drawing with the feet, and Factor H were correlated to certain degree (r = .19), with an average intercorrelation of right and left foot drawings to right and left hand drawings also being positive (r = .36).

5. Factor C identified speed of perception, involving verbal ability, speed of reading, three of the PMA's (verbal meaning, reasoning, and number) and the speed with which the subject perceived visually presented material. Factor C positively correlated with Factor

F, the metronome doublet (r = .26); and with Factor G, reaction time (r = .24).

6. Factor G included tests dealing with reaction time. Factor G related positively with Factor C, speed of perception (r = .24). Both Factors G and C, relating to the sensory field, correlated low and negative with Factors A and B, motor speed factors (A and C, r = -.13; A and G, r = -.18; B and C, r = -.03; B and G, r = -.08). This indicated that preferred speed of perception and speed of reaction time could not be used to predict preferred speed of motor movements. Also, Rimoldi (1951) used coefficients of variation as a measure of variability of movement time and plotted it against mean reaction time. It seemed that the speedier the individual, the more consistent, at least for a definite activity. On the other hand, individuals with slow or medium speed showed a variability that was either very high or at other times consistent.

7. Factor I dealt with tests for speed of cognition, involving recognizing figures, reasoning and judgment. There were low, positive correlations between Factor I and Factor C, speed of perception (r = .13); and between Factor G, reaction time (r = .12). There was a negative correlation between Factor I and Factor A, large motor movements (r = -.12); and between Factor I and Factor B, small motor movements (r = -.27). These negative correlations indicated a split in speed of performance for motor versus nonmotor activities.

8. Factor D was a marbles doublet without a clear interpretation. Marble tests necessitated transferring marbles from one tray from right

or left to another tray. Factor D correlated with A and B, motor speed factors, (r's = .26, .28) favoring the possibility that Factor D would be interpreted as some kind of motor activity.

9. Factor F was a metronome doublet. Preferred metronome rates as used by Frischeisen-Kohler (1933) were included. This factor showed a positive correlation with all factors except: Factor D, the marbles doublet ($r = -.19$); Factor E, speed of drawing with the feet ($r = .12$); and Factor H, speed of drawing with the hands ($r = -.12$).

Raw scores were converted to standard scores and profiles were graphed for each individual, showing each subject's relative position in the different factors. Of the 91 subjects, only three were consistently above or below average on all factors (excluding Factor D). If a general tempo factor were to be defined, more individuals would have to be consistently above or below average in all factors. However, this was not the case and, as in the Harrison (1941) study, Rimoldi (1951) determined that a general speed or tempo factor was not present.

After a second order analysis by Rimoldi (1951), four variables were isolated: Speed of all motor activities (Factors A, B, D, and E); Speed of perception (Factors C and F); Speed of cognition (Factor I); and reaction time (Factors C, E, and G). In summary, Rimoldi (1951) concluded that it was not possible to predict speed of psychological functions on the basis of one or two isolated speeds. Nonmotor speeds could not be predicted from motor speeds. Roughly, motor speeds could be the best indicators of other speeds, provided activities implied by Factor G, reaction time, and Factor I, speed of cognition, were omitted.

In general, Rimoldi (1951) believed it was safer to accept the existence of different tempos within an individual rather than to expect a single universal tempo. Previous research defining a general personal tempo by using only tapping tests would be unsatisfactory, its influence being very limited due to the existence of definite clusters of speed as described. Rimoldi's (1951) best definition of personal tempo was that through long periods of time individuals seem to be constant in their characteristic tempos by adopting a certain temporal pattern for a particular group of activities.

Rimoldi (1951) referred to his study in ergographic work (Rimoldi, 1946) and offered a possible explanation for the temporal consistency of performances:

> Each individual performs a particular act following a certain specific temporal pattern which he keeps constant. This pattern seems to be the most economical for the individual, since others externally imposed usually have a detrimental effect. If the problem is envisaged from the point of view of energy expenditure, these temporal patterns are of interest in explaining the characteristics of certain psychobiological systems. (p. 302)

The tasks used in the previous preferred tempo studies, such as tapping at the subject's chosen rate (Frischeisen-Kohler, 1933; Harrison, 1941; Harrison & Dorcus, 1938; Rimoldi, 1951; Wu, 1934), leg and arm swings, and walking (Harrison, 1941; Harrison & Dorcus; Rimoldi, 1951), required: (a) perceived rhythm, and (b) simple performance rhythm with a regulation of physical time. Rimoldi's (1951) tasks of Reaction Time also involved cognitive time. The idea of preferred tempo was further developed in a series of studies by Smoll and his associates (1973, 1974a, 1974b, 1975a, 1975b, 1975c, 1975d; Smoll & Schutz, 1978,

1982) by using a manual control motor task. This task required: (a) perceived rhythm, and (b) complex performance rhythm that involved both physical and cognitive time.

Preferred Tempo and Rhythmic Ability

In studying the relationship of rhythmic abilities and motor patterns, Smoll (1973) found that the tests of motor rhythm used by earlier investigators involved motor responses to auditory or visual stimuli and were only concerned with assessing the temporal accuracy of the performer's rhythmic response. Some of the tests used motor responses such as finger tapping (Buck, 1936; Seashore, 1926), foot tapping (McCristal, 1933), and locomotor patterns (Ashton, 1953; Haight, 1944; Lemon & Sherbon, 1934; Simpson, 1958). However, the unique rhythmic experience of movement is recognized to be a "space-time organization of events" (Mead, 1968, p. 156; Smoll, 1973, p. 233), and earlier tests were concerned with only a portion of the phenomenon of rhythmic ability (Smoll, 1973). To deal with the assessment of motor responses to auditory rhythmic stimuli which required both spatial and temporal accuracy, Smoll (1973) developed the rhythmic ability analysis system. With this system, individuals were tested on their ability to move an arm to a specific point in space at a specific point in time.

The system consisted of an electric metronome, a target, and a series of electrical-mechanical components that transmitted anterior-posterior movements of the performer'a arm to a recording instrument.

The performer, in a standing position, held a lever with a sighting rod next to his or her side. The motion was to move the lever from a vertical starting position, forward and upward, stopping when the sighting rod was in line with the target line, approximately at a horizontal position. The performer tried: (a) to move the arm to hit the target with the lever at a time coincident with the auditory stimulus, and (b) to return to the starting position on the alternate beat. A potentiometer recorded the oscillating motion of the lever arm on a paper read-out indicating: (a) where each movement deviated from the target line (the measure of spatial accuracy), and (b) the time each movement deviated from the stimulus (the measure of temporal accuracy). For the purpose of analysis, data were derived from the deviation measures expressed in absolute or arithmetic terms (Smoll, 1973).

Smoll (1974b) used the rhythmic ability analysis system apparatus to study the development of rhythmic ability in children. Boys and girls (n = 20 each, ranging from 5.0 to 11.11 years of age) performed 16 consecutive arm swing responses in time with constant auditory stimuli of 0.50-msec. duration, emitted at 0.9-sec. intervals. Algebraic error scores (with regard to sign) for spatial and temporal accuracy were obtained for each response, and the subject's score for each element was the mean algebraic error for the 16 responses. A significant positive linear relationship was found between age and both spatial and temporal accuracy, indicating that, as the age of the subjects increased, there was a reduction in both the spatial and temporal response errors. Smoll

(1974b) also found that there were no sex differences in the performance scores for any of the age levels tested.

To study the children's consistency or inconsistency of successive performance scores, Smoll (1975d) reanalyzed the data of the latter study (Smoll, 1974b). In this second study Smoll (1975d) found that a reduction of variable error in both spatial and temporal accuracy occurred as age increased, showing that the number of errors and the variability of those errors decreased with age.

Smoll (1974a) used the rhythmic ability analysis system apparatus to investigate further the development of the space-time characteristics of children's motor responses. Children ($\underline{N}$ = 20, ranging from 6.0 to 11.11 years of age) were tested with auditory stimuli presented at three selected tempos, with signals emitted at 1.4-, 1.1-, and 0.8-sec intervals. He found that children: (a) tended to undershoot in spatial accuracy, (b) responded late to the imposed stimuli, and (c) had a significant reduction of response error in spatial and temporal accuracy at each age level, for each tempo. However, a nonsignificant Tempo X Age interaction showed no general change in the differences between tempos at any age level. Smoll explained this lack of interaction by suggesting that, in spite of task requisites, an individual's motor ability was biased by how he or she chose to move according to self-instructions given prior to and during the execution of the motor task. Smoll described this individualized influence as being the variable of personal rhythm or preferred tempo.

To further investigate the idea of preferred tempo, Smoll (1975b) cited research studies that found intra-individual consistencies and inter-individual differences in tempos involving various body actions such as arm and leg swinging, foot circling, and body bending (Rimoldi, 1951; Sloan, 1958); typewriting (Harding, 1932); and finger, hand and foot tapping (Frischeisen-Kohler, 1933; Tisserand & Guilhot, 1949; Wu, 1934). Smoll (1975b) suggested the shortcoming of these former studies was that the subjects were required to perform tasks in a specific time interval, a procedure that did not permit the assessment of a performance time for each response. In other words, although the subjects were instructed to move in a way that was most comfortable and natural, as in 43 of the 51 tests conducted by Rimoldi (1951) and the personal tempo tests used by Harrison (1941), data were determined by the number of responses within a specific time period, rather than by determining the amount of time it took for each individual response within the task.

Using a slightly modified version of the rhythmic ability analysis system, Smoll (1975b) studied the differences in the within- and between-subject variability in the performance of repetitive discrete movements at a self-paced tempo. Subjects (75 males, mean age: 23.9 years; 75 females, mean age: 23.0 years) were instructed to use their preferred arm to move the lever of the apparatus from a vertical starting position forward and upward, until the sighting rod was in line with the target line, then return to the starting position. They were told to repeat the movement at a tempo that was most comfortable, convenient and natural. It was emphasized to the subjects not to perform at their fastest tempo. Thirty-six consecutive arm oscillations were recorded, and by measuring the differences between the apices, a conversion was made to temporal units (accurate to 0.01 second) to determine the time of each arm swing. Mean response times were recorded for males and females and within-subject variance, standard deviation of the subject's response times about his or her own mean response time, was calculated for each subject. Sex differences were not found in the consistency of individual performances. Combining data for the males and females, the differences of between-subject selected tempos of performance were considerably greater than the amount of variation within each subject's response times. This indicated that each individual had a preference of moving that was different from other individuals. Although the study demonstrated there were individual differences in movement times, Smoll (1975b) did not determine if these individual times would be consistent over a period of days or weeks.

Using further statistical analysis on data from the previous study (Smoll, 1975b), Smoll (1975c) calculated the magnitude of within-subject individual differences in variability for each subject performing the repetitive movements at their self-paced tempo. Using odd-even and serial half techniques, reliability coefficients were used to estimate the relative amounts of individual differences in the subject's mean response times ($\underline{r}$ = .99 for both) and within subject variances ($\underline{r}$ = .72 for odd-even; $\underline{r}$ = .66 for serial half). Smoll (1975c) concluded that there were substantial differences in each subject's preferred tempo, making preferred tempo a systematic and biological component of individual differences. With further statistical analysis, he discovered that subjects with faster preferred tempos were more consistent from response to response than were those subjects with slower preferred tempos. The specific preferred tempo was a factor that affected the consistency or inconsistency of the subject's performance on the repetitive discrete task. It is suggested that one's biologic rhythm could have an effect on one's performance rhythm of a task.

To investigate the nature of within-subject variability and between-days performance, Smoll (1975a) used testing procedures with the rhythmic analysis system similar to the format of the earlier study (Smoll, 1975b). Sixty college students (23 males, 36 females, mean age = 21.7 years) performed the arm swing task on two consecutive days. A mean response time was calculated for each subject for each day as well as the within-subject variance for each subject for each day. Supporting the earlier analysis (Smoll, 1975c), marked inter-individual differences and intra-individual consistency were found over the two day period. The correlation of the subject's performance on Day 1 with those on Day 2 ($p < .01$) and between-day correlation for within-subject variances ($p < .05$) indicated that the preferred tempo and consistency of response times were at least moderately stable over a period of time.

Using the rhythmic ability analysis system apparatus (Smoll & Palmatier, 1977), Smoll and Schutz (1978) replicated Smoll's studies (1975a, 1975b, 1975c) and investigated how subjects responded to rhythmic stimuli presented at a tempo similar to their own preferred tempo. In the first phase of the experiment, male and female subjects ($\underline{n}$'s = 100 each) performed 35 consecutive trials of the arm swing task. For the first part of the study, the task was self-paced. Smoll's earlier findings (1975a, 1975b, 1975c) were supported by the facts that: (a) within-subject variability of spatial and temporal performance were found to be unique to each individual, and (b) there were no sex differences for either preferred tempo or consistency of performance. Smoll and Schutz (1978) also found that subjects performing at a faster preferred tempo were more temporally consistent from cycle to cycle of arm swings than those performing at slower perferred tempos. This supported findings of other investigators, i.e., Rimoldi (1951), and Tisserand and Guilhot (1949).

In the second phase of the experiment (Smoll & Schutz, 1978), the subject's spatial and temporal accuracy were measured while performing the arm swing task in cadence to the simulation of the subject's own preferred tempo. This tempo was not a predetermined tempo as in the other Smoll studies (1974a, 1974b), but rather the preferred tempo was determined in the first experiment by calculating the mean time of the arm swing cycles made at the self-paced tempo. Using constant error as the measure of accuracy of performance and variable error as the measure of consistency in performance, Smoll and Schutz (1978) reported that subjects with greater spatial accuracy were more spatially consistent in their trial-to-trial performance. Using the same measurements of temporal accuracy, the authors reported that temporal accuracy performance was unrelated to the consistency of temporal performance.

The correlation between the variable errors for spatial and temporal consistency (*r* = .33) indicated that these two components of rhythmic accuracy were independent. There was an overall high correlation (*r* = .68) between constant errors for spatial and temporal accuracy which was due primarily to those subjects (*N* = 113) having constant errors less than zero (indicating late responses) for temporal accuracy. For the subjects with late responses, the correlation between temporal and spatial accuracy was high (*r* = .88). However, for subjects (*N* = 87) with constant errors greater than zero (early responses), the correlation between temporal and spatial accuracy was low (*r* = .10), indicating no interdependence of the spatial and temporal elements. Also, subjects responding late tended to undershoot the target. On the other hand, for subjects responding early, there was no significant relationship between their temporal response and the spatial accuracy of their response. The low correlations between subject's preferred tempo and constant and variable errors for spatial performance (*r*'s = .14 and -.12, respectively), along with corresponding values for temporal performance (*r*'s = .48 and .42) suggested that each measure reflected an independent performance attribute. An individual's preferred tempo (whether fast, moderate, or slow) was not found to be "appreciably related to rhythmic accuracy or consistency of performance" (Smoll & Schutz, 1978, p. 892.)

Smoll and Schutz (1982) studied the influence of preferred tempo on rhythmic ability in two experiments. They investigated the effects on spatial and temporal accuracy of performing a motor rhythm task at a tempo that was faster or slower than the individual's own preferred tempo. Using the same apparatus and arm swing task as the earlier study (Smoll & Schutz, 1978), the authors determined the preferred tempo of 240 male and female undergraduates (N = 120 for each experiment, mean age = 19.5 years) by calculating the mean time of the arm swing cycles performed at a self-paced tempo. In each experiment, the subject's spatial and temporal accuracy was assessed under three experimental conditions using the arm swing task, keeping in cadence with three different tempos--faster than, slower than, and at preferred tempo. The time differential in Experiment One was 0.4 seconds faster or slower that the subject's preferred tempo. In Experiment Two, the time differential was plus or minus 0.6 seconds.

To investigate the group's performance under the three experimental conditions, the means and standard deviations were calculated for three dependent variable measures: constant error, absolute error, and variable error. For the spatial component of rhythmic accuracy, a faster tempo (relative to the preferred tempo) caused more performance errors and detrimentally affected the trial-to-trial spatial consistency. Greater decrements in spatial accuracy and consistency occurred as the magnitude of the tempo was increased (i.e., the tempos were even faster in relation to the preferred tempo). However, performance at tempos slower than the preferred tempos did not detrimentally affect either spatial accuracy or consistency. For the temporal component of rhythmic performance, a tempo faster than preferred tempo detrimentally affected the temporal accuracy scores. However, the temporal consistency of performance was actually better in this faster condition. Temporal accuracy or consistency of performance was not detrimentally affected when there was an increase in the magnitude of faster tempos in relation to the preferred tempo. With the slower tempos, both mean performance errors and consistency of temporal performance were negatively affected. When the magnitude of the differential was increased (i.e., the tempos were even slower in relation to the preferred tempo), the detrimental effects of the slower tempos on the performance errors and temporal consistency likewise increased.

Walters (1983) made a similar discovery with children. He measured 96 males and females, Grade K-3, for personal tempo by asking them to pat both hands on their lap in a steady, comfortable beat. Personal tempo measurements ranged from M.M40 (M.M = metronome marking, an expression of tempo in beats per minute) to M.M210 between subjects. Subjects were measured for personal tempo four times over a three week period, with 78 of the 96 children having a coefficient of variation below .17. Only data for the 78 children were used in the analysis. In general, both inter-individual variability and intra-individual consistency of personal tempo were found with these children.

When subjects were administered the Froseth's Primary Measure of Kinesthetic Response to Tempo in Music (a 14-item synchronization test ranging in tempo from M.M57 to M.M130), it was found that the highest mean synchronization score across all subjects was achieved for the test time at or nearest each subject's personal tempo. Scores generally decreased as items diverged from personal tempo. If the divergence was to the slow side of personal tempo, the scores were more consistent with a more severe decrement of scores than if the divergence was to the fast side. Errors were consistently in the direction of the subject's personal tempo. Also, a comparison of mean synchronization scores for the 78 subjects of consistent personal tempo with the 18 subjects of inconsistent personal tempo revealed significantly higher scores for the ones with the inconsistent personal tempos. Although this was an interesting comparison, no explanation of the higher scores was mentioned. In general, Smoll and Schutz (1982) and Walters (1983) concluded that while performing a motor rhythm task at an externally paced tempo, optimum performance accuracy and consistency were achieved at the tempo most closely corresponding to the performer's preferred tempo.

Preferred Tempo and Continuous Tasks

Returning to their study, Smoll and Schutz (1982) compared their conclusions to a related line of research from the engineering psychology-industrial setting. Various researchers (Conrad, 1960; Corlett & Mahadeva, 1970; DeJong, 1960; Salvendy, 1972) have found that when individuals were allowed to determine their own work pace, the energy expenditure, as well as errors per unit of external work, was minimized, while human efficiency was maximized. Further, performance either above or below self-pace maximized the psychological cost per unit of work and minimized physiological efficiency. This could, however, be a function of age. Salvendy and Pilitsis (1971) and Salvendy (1974) reported younger subjects (ages 20-45 years) working at a freely chosen rate had a higher efficiency and greater psychological satisfaction than older subjects (ages 45-65 years) who, in contrast, exhibited their highest psychophysiological efficiency during external paced performance. Smoll and Schutz (1982) suggested information mentioned in the engineering-psychology research along with the findings of their study (Smoll & Schutz, 1982) have practical implications for the industrial setting where machines or conveyors dictate the work tempo and to motor learning researchers and sport scientists interested in achieving optimum performance on tasks in response to externally imposed rhythms. However, in these studies, the motor task was performed at a constant resistance, not considered to be a pertinent factor.

To determine the relationship between preferred tempo, mechanical efficiency, and increasing work resistance, Taguchi, Gliner, Horvath, and Nakamura (1981) tested subjects using the continuous task of riding a bicycle ergometer. In the first of two experiments, subjects ($\underline{N}$ = 5) were timed at a self-paced work rate measured in rpm's, on seven consecutive days using a workload of 0.0 Newtons for ten minutes. To infer that preferred tempo was established, the authors used analysis of variance to estimate reliability. The results showed the individual work rates to be consistent within sessions ($\underline{r}$ = .99 for all subjects) and for between sessions ($\underline{r}$ = .73 to .96). More specifically, from day to day, the subjects generally maintained a constant tempo for the duration of the task.

In the second experiment, four of the same five subjects were tested on three days, working for ten minutes at each of four workloads: 0.0, 4.9, 14.7, and 24.5 Newtons. Only two of the four subjects maintained a consistent perferred tempo for all workloads. However, this could have been caused by differences in physical conditioning. For all four subjects, there was a minimal change in tempo after the first minute of cycling, then each subject maintained a consistent tempo within the different workloads. Taguchi et al. (1981) suggested that subjective comfort and perceived exertion were the determining factors in setting a preferred tempo. McCann and Gliner (1982) reported similar results, finding that increasing workloads on a bicycle ergometer did not change the subjects' preferred tempo or temporal variability.

Preferred Tempo and Single Discrete Tasks

In all of the previously mentioned studies dealing with preferred tempo, there was a regulation of physical time using: (a) continuous tasks, and (b) repetitive discrete tasks of perceived rhythm and simple performance rhythm. Only the Smoll studies dealt with: (a) perceived rhythm, and (b) performance rhythm of a repetitive discrete task as a space-time phenomenon involving physical and cognitive time. However, none of the research studied the preferred tempo of performing a single discrete task or a serial task, with an emphasis on performance rhythm.

Although preferred tempo was not the target of research, two studies may relate preferred tempo with the performance of a single discrete task. In a classic study, Hubbard and Seng (1954) filmed 29 professional baseball players during batting practice. Although the primary purpose of the research was to determine how batters visually track a pitched ball, timing of the step and speed of the swing was also determined. The investigators used a filming (35 mm) set-up that included mirrors which enabled them to film a simultaneous view of the pitcher, ball flight, and the batter's motions (step and swing) from start to finish. Data were obtained from the film by using the number of frames from the point of release of the ball by the pitcher to the time the ball either crossed the plate or was hit. The authors reported temporal relations of the start of the step, finish of the step, and start of the swing with the different ball speeds. They concluded, in general, that "the batter tended to start his step with the pitch, to delay the finish of the step and the start of the swing progressively as ball speed decreased, [the start of the swing tended to occur in a uniform number of frames before the hit], but not to alter the duration of the swing or probably the speed of the swing" (Hubbard & Seng, 1954, p. 49). This suggests support for the idea of preferred tempo within a single discrete skill. The variability of the individual batter's speed of swing, important information to infer intra-subject temporal consistency of preferred tempo, was not investigated by Hubbard and Seng (1954).

Jones and Hanson (1961) studied the single discrete task of rising from a chair. They analyzed the individual differences in time-space patterns of two groups of male undergraduates ($\underline{N}$ = 25), classified as "well-coordinated" and "poorly coordinated" on the basis of five tests for gross motor performance previously administered by the Department of Physical Education. The subjects were asked to sit in a standardized position. On signal, they rose to a standing position as quickly as possible. The movements were recorded by color-coded multiple-image photography. Profiles of the time-space patterns of each movement were obtained by plotting the angular displacements of the neck, head, leg, and arm. The profiles were found to be highly characteristic for each individual but markedly different from subject to subject. The two groups were significantly distinguished ($\underline{p}$ < .001) by the fact the "well coordinated" group showed a greater efficiency than the low group by following a simpler and more direct path in reaching their goal in a shorter time without wasted effort. However, as in the Hubbard and Seng (1954) study, data were not provided that could demonstrate individual differences in: (a) preferred tempo, nor (b) intra-subject temporal consistency.

Summary

In the literature, preferred tempo has been investigated using: (a) simple motor tasks, (b) repetitive discrete tasks, and (c) continuous tasks. Although some earlier studies supported the theory of an overall general preferred tempo (e.g., Frischeisen-Kohler, 1933), many of the studies (e.g., Rimoldi, 1951) supported the theory that a preferred tempo: (a) exists within an individual for specific kinds of movement, and (b) seems to be consistent over time. The earlier studies were limited in two ways. First, the subjects were required to perform tasks in a specific time interval, not permitting the assessment of a performance time for each response. Second, the tasks were either: (a) simple, continuous tasks, or (b) repetitive discrete tasks of perceived rhythm and simple performance rhythm in a predictable environment with minimal spatial accuracy demands.

Smoll's research (e.g., Smoll, 1975b) demonstrated preferred tempo as a factor in the performance rhythm of a repetitive discrete task requiring both spatial and temporal accuracy. Smoll demonstrated the influence of preferred tempo by illustrating high intra-subject consistency and high inter-subject variability with subjects performing a self-paced arm swing task. The general findings of these preferred tempo studies (Smoll, 1975b, 1975c; Smoll & Schutz, 1978, 1982) were: (a) there were substantial differences in each subject's preferred tempo, i.e., subjects had a preference of moving that was different from other individuals; (b) subjects with faster preferred tempos were more consistent from response to response than were those with slower preferred tempos (agreeing with Rimoldi, 1951); (c) preferred tempo and consistency of response times were moderately stable over a period of time; (d) there were no sex differences for either preferred tempo or consistency of performance; (e) temporal accuracy of performance was unrelated to the consistency of temporal performance; (f) an individual's select tempo, whether fast, moderate, or slow, was not found to be related to rhythmic accuracy or consistency of performance; (g) while performing the rhythmic repetitive discrete task at an externally paced tempo, optimum performance accuracy and consistency were achieved at a tempo most closely corresponding to the performer's preferred tempo (also agreeing with Walters, 1983). However, one major limitation of the Smoll studies (e.g., Smoll, 1975b) was that the spatial and temporal accuracy requirements were limited to making one-directional repetitive movements of single body parts in a stationary environment. Similarily, Walters (1983) demonstration of preferred tempo involved only the element of "keeping time" with no spatial requirements.

In studies where preferred tempo was demonstrated using a continuous movement task (Taguchi et al., 1981; McCann & Gliner, 1982) of riding a bicycle ergometer subjects maintained a constant tempo for a self-paced work rate. These tempos were consistent: (a) over time, and (b) at different workloads. However, the tasks: (a) did not require spatial nor temporal accuracy, and (b) as in the Smoll studies (e.g., Smoll, 1975b), were performed in a stationary environment.

Two studies inferred that preferred tempo could be a factor in the performance of a single discrete task. One study (Hubbard & Seng, 1954) a temporal consistency of baseball batters performing the discrete task of swinging a baseball bat. Another study (Jones & Hanson, 1961) reported high intra-subject consistency and high inter-subject variability in the spatial and temporal patterns of subjects performing the discrete task of rising from a chair. However, no research was found where preferred tempo was specifically studied in relationship to the performance of a single discrete task or serial task.

Because many sports demand the execution of discrete and serial tasks involving performance rhythm and perceived rhythm with control of physical and cognitive time, the importance of knowing the relationship of preferred tempo to performance becomes apparent. It seems essential that teachers of motor skills should be aware of this individual difference when teaching a discrete or serial task, especially if the task deals with the spatial and temporal elements of performance rhythm involved in coincidence timing tasks, such as throwing a ball to a moving target, striking, and kicking a rolling ball.

CHAPTER III

PROCEDURES FOR THE STUDY

The purpose of this study was to investigate the nature of the relationship between preferred tempo and the performance of a serial movement task (with continuous and discrete components) requiring total body movement to project an object in stationary and moving environments. Chapter III describes: (a) the subjects used, (b) the motor task, (c) administrative procedures, (d) method of data recording, and (e) analysis of data.

Subjects

The subjects for this study were 20 right-footed, male and female students who had completed a physical education soccer class at Tennessee Tech University. The decision to use students who had completed a soccer class was based on the apparent need for the subjects in the study: (a) to have a general knowledge of the sport of soccer, and (b) to have had previous experience with the instep pass kick. Because the present study addressed the problem of intra-subject consistency of preferred tempo, no control was made for the subjects' experience in soccer other than that they had completed the soccer class. The subjects were informed of the nature of the investigation and were asked to sign an informed consent (Appendix A). Subjects were also asked to indicate: (a) the number of years they had participated in soccer, and (b) the levels of their competitive experience (Appendix B).

The Motor Task

The motor task for this study was the basic instep pass kick used in the sport of soccer. The kick was selected for this study based on the need for the skill to be a serial task: (a) with a specific beginning and end, (b) which required basically the same movement in either a stationary or open environment, and (c) that was one of the fundamental movement skills.

The present investigation required each subject to be filmed while moving to kick a stationary ball to a target, a closed task; and moving to kick a moving ball to a target, an open task. The target grid used to measure the degree of success in goal attainment was the same for both environmental conditions. A regulation soccer ball, inflated to 9 pounds of pressure, was used for all kicks.

The target was 5 feet (1.52 m) high and 10 (3.05 m) feet wide. There were five equal spaces perpendicular to the floor, with point values assigned to each space. The value of the spaces, from right to left, was 1 point, 3 points, 5 points, 3 points, and 1 point (Appendix C). The ball was kicked from a spot on the floor 20 feet 10 inches (6.35 m) from the middle of the target area. This set-up was a modification of a valid and reliable skills test devised by Johnson

(1962). The subject's starting point, for both closed and open tasks, was 8 feet (2.44 m) from the spot on the floor, at approximately a 28 degree angle to the wall, and at a 90 degree angle to the view of the camera. The camera was 46 feet 5 inches (14.15 m) away from the kicking spot (Appendix D).

For the closed task, the subjects moved to kick the stationary ball, placed on the kicking spot on the floor, for the purpose of aiming at the target grid. For the open task, subjects moved to kick the ball rolling across the kicking spot on the floor, for the purpose of aiming at the target grid. The open task was created by rolling the ball down a wooden trough.

The trough was made of two 1 inch (2.54 cm) by 6 feet (1.83 m) pine boards, held together at a 90 degree angle with three hinges. A board 2 feet 8 inches (.81 m) high kept the trough at approximately a 27 degree angle to the floor. A board 6 feet (1.83 m) long was used on the bottom to provide support and stability to the trough (Appendix E).

The ball was placed at the top of the trough and held there by the examiner. When the subject and camera were ready, the examiner simply released the ball, providing no impetus to it, allowing only the pull of gravity to create the speed of the ball. The ball came to the end of the trough at a point 13 feet 1 inch (3.99 m) from the kicking spot, moving in a direction perpendicular to the line created from the kicking spot to the center of the target grid (Appendix C). It crossed the spot traveling approximately 7.79 feet (2.38 m) per second. Through pilot work, the speed of the ball and the direction of the ball were found to be consistent over trials. Also, the condition was found to be realistic to the sport of soccer as determined by the subjective judgement of an experienced soccer player.

Administrative Procedures

Each subject was taken through a brief two minute warm-up of stretching exercises, followed by two practice kicks of the stationary ball and two practice kicks of the rolling ball. Following the warm-up, the subject was given these instructions: "Move to kick the ball in a manner that is comfortable and natural to you. At the same time, try to hit the target grid attempting to score as many points as possible. Begin your movement from the mark indicated on the floor. You will kick the stationary ball 10 times from the kicking spot on the floor. You will have 10 more times to kick the rolling ball as it crosses the same spot on the floor. You may begin each kick any time after I indicate to you the camera is ready. You will be given approximately 15 seconds between kicks."

After each kick, the ball was either replaced on the kicking spot or put on the trough. The numbers on the portable scoreboard indicating the subject number and trial number were changed to indicate the appropriate trial. The examiner then indicated to the subject to begin the next trial at any time.

Method of Data Recording

The video camera used in this study was a Panasonic WV-3230 NewVicon. The speed of the recording was set on Extended Play, the slowest possible speed. There was a timer in the picture, recording in hundredths of seconds. Data were obtained through the use of stop-action, frame by frame analysis of the video tape for the purpose of recording the time values shown by the timer in the picture. Also in the set-up there was a portable, plastic scoreboard device, indicating the subject number and trial number. The camera and timer were allowed to keep recording throughout each testing session.

Data for each trial were obtained by recording the time, as indicated on the timer in the video, (a) when the initial contact of the first step occurred, (b) the point where the subject made initial contact with the floor with the nonkicking foot immediately preceding the kick, and (c) the actual contact of the ball. Also recorded were: (a) if the first step was made with the right or left foot, and (b) the number of steps from the first step to the point where the subject made contact with the nonkicking foot immediately preceding the kick (Appendix F).

As a test of rater reliability four subjects were randomly selected and the video tape of each subject was analyzed by the present investigator in an identical manner as the first viewing. Pearson product-moment correlations were used to determine the relationship between the original analysis and the second analysis for the:

(a) total time (r = .94), (b) approach phase (r = .96), (c) kicking phase (r = .76), and (d) score (r = .93). All correlations were significant (p < .001).

Analysis of the Data

For each subject the mean and standard deviation were calculated for: (a) the total time of the kicking motion, the time between the initial contact of the first step and the actual contact of the ball; (b) the approach phase, the time between the initial contact of the first step and the point where the subject made initial contact with the floor with the nonkicking foot immediately preceding the kick; and (c) the kicking phase, the time between the point when the subject made initial contact with the floor with the nonkicking foot and the actual contact of the ball by the kicking foot. These calculations were made for eight out of the ten trials for both the closed and open tasks. The highest and lowest total times for the closed and open tasks were not considered in the data analysis in order to give a more accurate picture of each subject's preferred tempo. The decision was based on (a) Smoll's (1975b) similar control of performance variation, and (b) observation of subjects' performances of the specific tasks for the present study. By observing the raw data it was found that 18 of the 20 subjects had at least one total movement time in each task that was either extremely high or extremely low. These extreme scores were apparently the subject's adjustment to the task. By dropping the highest and lowest total times, extreme scores in either direction were avoided. For each subject, Appendix G lists: (a) the mean total time, (b) lowest score dropped, and (c) highest score dropped for both the closed and open task.

Goal attainment was determined by totaling the number of points scored in the eight trials of kicking the ball to the target grid, for both the closed and open tasks. There were two types of goal attainment: (a) qualitative goal attainment, i.e., the subject's individual total score for performance of the closed or open tasks; and (b) consistency of goal attainment, i.e., the standard deviation of the subject's score obtained in the closed or open tasks.

Data analyses were performed relative to each stated hypothesis (Chapter I, pp. 8-9) utilizing the following approaches.

Hypothesis 1 stated that the average intra-subject temporal consistency of preferred tempo would be proportionately smaller than the inter-subject temporal consistency for the performance of a serial movement task requiring total body movement: (a) executed in a stationary environment, and (b) involving coincidence timing with the temporal accuracy requirements of the task being increased by creating a moving environment. This hypothesis was tested by computing the value of the ratio: (inter-subject temporal consistency)/mean intra-subject temporal consistency) for both environments (Smoll, 1975b).

A. For the stationary environment this ratio was calculated for: (a) total movement time, (b) approach phase time, and (c) kicking phase time.

B. For the moving environment this ratio was calculated for: (a) total movement time, (b) approach phase time, and (c) kicking phase time.

Hypothesis 2 stated that subjects would demonstrate less intra-subject temporal consistency of preferred tempo performing a serial movement task, requiring total body movement of coincidence timing in the moving environment (moving to kick a moving ball), than when performing a serial task in the stationary environment (moving to kick a stationary ball). This hypothesis was tested by computing correlated t-tests between the means of the standard deviation of each subject's: (a) total movement time, (b) approach phase time, (c) kicking phase time in the stationary environment and the standard deviation of each subject's respective movement times in the moving environment.

Hypothesis 3 stated that in both the stationary and moving environments, subjects displaying greater intra-subject temporal consistency of preferred tempo would demonstrate: (a) higher quality of goal attainment, and (b) greater consistency of goal attainment than subjects displaying a less consistent preferred tempo when meeting the temporal accuracy requirements of a serial movement task. This hypothesis was tested by computing Pearson product-moment correlations between the following:

A. The standard deviation of each subject's: (a) total movement time, (b) approach phase time, and (c) kicking phase time in the stationary environment and the total goal attainment score obtained in the stationary environment.

deviation of each subject's: (a) total movement
hase time, and (c) kicking phase time in the
t and the standard deviation of each subject's
score obtained in the stationary environment.

deviation of each subject's: (a) total movement
ase time, and (c) kicking phase time in the moving
otal goal attainment score obtained in the moving

deviation of each subject's: (a) total movement
ase time, and (c) kicking phase time in the moving
tandard deviation of each subject's goal attainment
moving environment.

tated that in both the stationary and moving
would be no significant relationship between a
empo and: (a) the quality of goal attainment, and
of goal attainment when meeting the temporal
s of a serial movement task. This hypothesis was tested by computing Pearson product-moment correlations between the following:

A. The mean of each subject's: (a) total movement time, (b) approach phase time, and (c) kicking phase time in the stationary environment and the total goal attainment score obtained in the stationary environment.

B. The mean of each subject's: (a) total movement time, (b) approach phase time, and (c) kicking phase time in the stationary environment and the standard deviation of each subject's goal attainment score obtained in the stationary environment.

C. The mean of each subject's: (a) total movement time, (b) approach phase time, and (c) kicking phase time in the moving environment and the total goal attainment score obtained in the moving environment.

D. The mean of each subject's: (a) total movement time, (b) approach phase time, and (c) kicking phase time in the moving environment and the standard deviation of each subject's goal attainment score obtained in the moving environment.

Hypothesis 5 stated that in both the stationary and moving environments, there would be a significant positive relationship between preferred tempo and the intra-subject temporal consistency, i.e., subjects displaying greater intra-subject temporal consistency would demonstrate faster preferred tempos than subjects displaying less temporal consistency when meeting the temporal accuracy requirements of a serial movement task. The hypothesis was tested by computing Pearson product-moment correlations between the following:

A. The standard deviation of each subject's: (a) total movement time, (b) approach phase time, and (c) kicking phase time in the stationary environment and the corresponding mean movement times for each subject's performances in the stationary environment.

B. The standard deviation of each subject's: (a) total movement time, (b) approach phase time, and (c) kicking phase time in the moving environment and the corresponding mean movement times for each subject's performances in the moving environment.

Hypothesis 6 stated that in both the stationary and moving environments, there would be no sex differences in: (a) the intra-subject consistency of preferred tempo, or (b) the preferred tempo when meeting the temporal accuracy requirements of a serial movement task. The hypothesis was tested by computing t-tests between the following:

A. The means of the standard deviations of the: (a) total movement times, (b) approach phase times, and (c) kicking phase times for female and male subjects performing the serial movement task in the stationary environment.

B. The means of the preferred tempos for the: (a) total movement times, (b) approach phase times, and (c) kicking phase times for female and male subjects performing the serial movement task in the stationary environment.

C. The means of the standard deviations of the: (a) total movement times, (b) approach phase times, and (c) kicking phase times for female and male subjects performing the serial movement task in the moving environment.

D. The means of the preferred tempos for the: (a) total movement times, (b) approach phase times, and (c) kicking phase times for female and male subjects performing the serial movement task in the moving environment.

CHAPTER IV

RESULTS OF DATA ANALYSIS

Chapter IV contains the results of data analysis for the study, which sought to extend the work of Smoll (1975b, 1975c) and Smoll and Schutz (1978) and test their findings by investigating the nature of the relationship between preferred tempo and the quality and consistency of performance in a serial movement task. Twenty subjects were video taped while kicking a soccer ball to a target, both in a stationary and a moving environment. This was followed by a stop-action, frame by frame analysis of the video tape. Major findings of the study were based on data obtained by calculating the means and standard deviations for: (a) the total movement time of the kicking motion, (b) the approach phase time, and (c) the kicking phase time in both environments. Additional important factors used in the study included: (a) subject's years of soccer experience, (b) the sex of the subject, (c) the number of steps taken in the approach phase, (d) the standard deviation of the number of steps, (e) the total goal attainment score obtained, and (f) the standard deviation of the goal attainment score.

The organization of the chapter follows the order of the stated hypotheses which were statistically tested with $p \leq .05$. Descriptive statistics are listed in Appendix H.

Hypothesis 1 stated that the average intra-subject temporal consistency of preferred tempo would be proportionately smaller than the inter-subject temporal consistency for the performance of a serial movement task requiring total body movement: (a) executed in a stationary environment, and (b) involving coincidence timing with the temporal accuracy requirements of the task being increased by creating a moving environment. To test this hypothesis, the ratio of (inter-subject temporal consistency)/(mean intra-subject temporal consistency) was calculated for: (a) total movement time, (b) approach phase time, and (c) kicking phase time in the stationary and moving environment. By dividing the standard deviation of each subject's mean movement time by the mean of all subjects' standard deviation of movement time, the difference between the subjects' preferred tempos was compared to the amount of variation in all of the subjects' response times.

In the stationary environment, the mean of the standard deviation of the subjects' total movement times (.0763 sec) was 3.90 times less than the standard deviation of the mean total movement times (.2978 sec). The mean of the standard deviation of the subjects' approach phase times (.0754 sec) was 4.01 times less than the standard deviation of the mean approach phase times (.3026 sec). The mean of the standard deviation of the subjects' kicking phase times (.1510 sec) was 1.45 times less than the standard deviation of the mean kicking phase times (.0218 sec) (Table 1).

In the moving environment, the mean of the standard deviation of the subjects' total movement times (.1138 sec) was 2.91 times less than the standard deviation of the mean total movement times (.3316 sec). The mean of the standard deviation of the subjects' approach phase times (.1116 sec) was 2.90 times less than the standard deviation of the mean approach phase times (.3237 sec). The mean of the standard deviation

Table 1

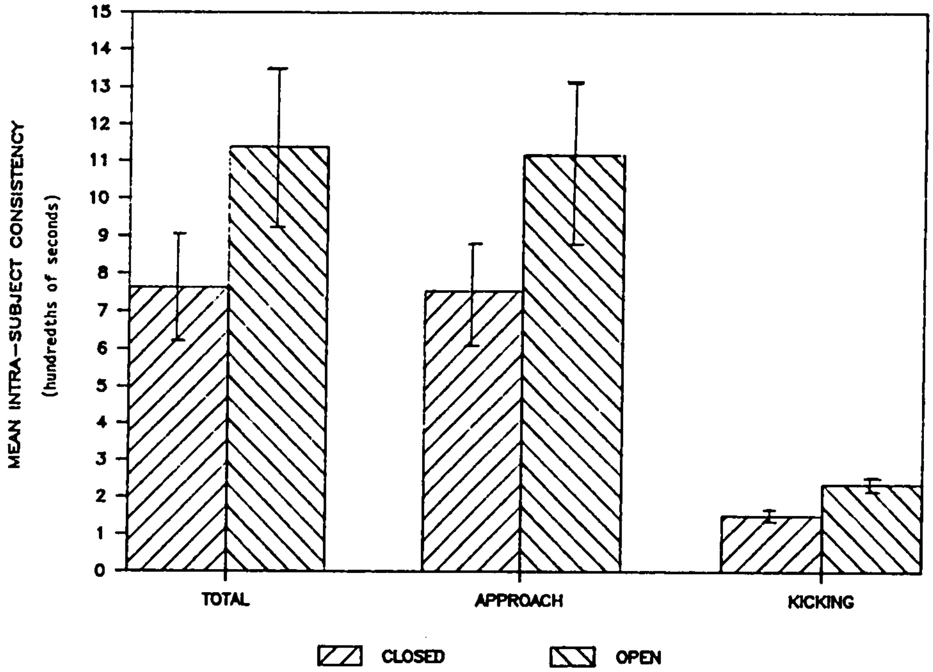
The ratios of inter-subject temporal consistency (SD of MTs) and mean intra-subject temporal consistency (Mean of SD of MTs) for the total movement times, approach phase times, and kicking phase times in the closed and open tasks. Table values are in hundreths of seconds.*

		Total	Ratio	Approach	Ratio	Kicking	Ratio
	SD OF MTs*	29.778		30.265		2.185	
CLOSED			3.903		4.014		1.447
	MEAN OF SD OF MTs*	7.630		7.540		1.510	
	SD OF MTs*	33.159		32.373		2.664	
OPEN			2.914		2.901		1.134
	MEAN OF SD OF MTs*	11.380		11.160		2.350	

* Example: Table value 29.778 = .2978 seconds

of the subjects' kicking phase times (.0235 sec) was 1.13 times less than the standard deviation of the mean kicking phase times (.0266 sec). The hypothesis was supported for all three variables in both the stationary and moving environments. However, the ratios for the kicking phase times were not as large as the ratios for the total movement times and approach phase times for either environment (Table 1).

Hypothesis 2 stated that subjects would demonstrate less intra-subject temporal consistency performing a serial movement task, requiring total body movement of coincidence timing in the moving environment (moving to kick a moving ball), than when performing a serial task in the stationary environment (moving to kick a stationary ball). To test this hypothesis correlated t-tests were computed between the means of the standard deviations of each subject's: (a) total movement time, (b) approach phase time, and (c) kicking phase time in the stationary environment, and the respective standard deviation of each subject's movement times in the moving environment (Figure 1). A significant difference was not found between the means of the standard deviations of the total movement times ($t(19) = -1.43$, $p = .17$) or the means of the standard deviations of the approach phase times ($t(19) = -1.34$, $p = .20$). However, a significant difference was found between the means of the standard deviations of the kicking phase times ($t(19) = -3.99$, $p < .001$). This indicates that subjects were significantly more consistent in the kicking phase times in the closed task than in the open task. Therefore, the hypothesis was supported for the kicking phase times, but not for the total movement times nor the approach phase times.



MOVEMENT TIMES

	TOTAL		APPROACH		KICKING	
	Closed	Open	Closed	Open	Closed	Open
mean	7.63	11.38	7.54	11.16	1.51	2.35
standard deviation	6.23	9.54	6.35	9.74	.46	.77
standard error of mean	1.39	2.13	1.41	2.18	.10	.17
t=	-1.43		-1.34		-3.99	
p=	.17		.20		.0008	
df=	19.0		19.0		19.0	

N = 20

Figure 1. Differences between the mean intra-subject temporal consistency (standard deviation of movement times) when subjects performed the total movement times, approach phase times, and kicking phase times of the closed and open tasks

Hypothesis 3 stated that in both the stationary and moving environments, subjects displaying greater intra-subject temporal consistency of preferred tempo would demonstrate: (a) a higher quality of goal attainment, and (b) greater consistency of goal attainment than subjects displaying a less consistent preferred tempo when meeting the temporal accuracy requirements of a serial movement task. To test this hypothesis Pearson product-moment correlations were calculated between the following:

A. Each subject's total goal attainment score obtained in the stationary environment and the standard deviation of each subject's: (a) total movement time (r = -.05, p = .83), (b) approach phase time, (r = -.04, p = .87), and (c) kicking phase time, (r = .14, p = .56). These correlations were not significant, therefore, this part of the directional hypothesis was not supported.

B. The standard deviation of each subject's goal attainment score obtained in the stationary environment and the standard deviation of each subject's: (a) total movement time (r = .11, p = .65), (b) approach phase time, (r = .10, p = .66), and (c) kicking phase time, (r = .001, p = .99). These correlations were not significant, therefore, this part of the directional hypothesis was not supported.

C. Each subject's total goal attainment score obtained in the moving environment and the standard deviation of each subject's: (a) total movement time (r = -.15, p = .54), (b) approach phase time, (r = -.13, p = .58), and (c) kicking phase time, (r = .09, p = .71).

These correlations were not significant, therefore, this part of the directional hypothesis was not supported.

D. The standard deviation of each subject's goal attainment score obtained in the moving environment and the standard deviation of each subject's: (a) total movement time ($\underline{r}$ = .13, $\underline{p}$ = .58), (b) approach phase time, ($\underline{r}$ = .14, $\underline{p}$ = .56), and (c) kicking phase time, ($\underline{r}$ = −.15, $\underline{p}$ = .54). These correlations were not significant, therefore, this part of the directional hypothesis was not supported.

Hypothesis 4 stated that in both the stationary and moving environments, there would be no significant relationship between a subject's preferred tempo and: (a) the quality of goal attainment, and (b) the consistency of goal attainment when meeting the temporal accuracy requirements of a serial movement task. To test this hypothesis Pearson product-moment correlations were calculated between the following:

A. Each subject's total goal attainment score obtained in the stationary environment and the mean of each subject's: (a) total movement time ($\underline{r}$ = −.35, $\underline{p}$ = .13) (b) approach phase time ($\underline{r}$ = −.34, $\underline{p}$ = .17), (c) kicking phase time ($\underline{r}$ = −.30, $\underline{p}$ = .20). The null hypothesis could not be rejected for the total movement time, approach phase time and the kicking phase time in the stationary environment; thus, there was support for this part of the hypothesis.

B. The standard deviation of each subjects goal attainment score obtained in the stationary environment and the mean of each subject's: (a) total movement time ($\underline{r}$ = .15, $\underline{p}$ = .52), (b) approach phase time

($\underline{r}$ = .15, $\underline{p}$ = .53), and (c) kicking phase time ($\underline{r}$ = .05, $\underline{p}$ = .8453) in the stationary environment. The null hypothesis could not be rejected for the total movement time, approach phase time and the kicking phase time in the stationary environment; thus, there was support for this part of the hypothesis.

C. Each subject's total goal attainment score obtained in the moving environment and the mean of each subject's: (a) total movement time ($\underline{r}$ = .11, $\underline{p}$ = .64), (b) approach phase time ($\underline{r}$ = .13, $\underline{p}$ = .60), and (c) kicking phase time ($\underline{r}$ = −.15, $\underline{p}$ = .52) in the moving environment. The null hypothesis could not be rejected for the total movement time, approach phase time and the kicking phase time in the moving environment; thus, there was support for this part of the hypothesis.

D. The standard deviation of each subjects goal attainment score obtained in the moving environment and the mean of each subject's: (a) total movement time ($\underline{r}$ = .15, $\underline{p}$ = .53), (b) approach phase time ($\underline{r}$ = .15, $\underline{p}$ = .52), and (c) kicking phase time ($\underline{r}$ = .01, $\underline{p}$ = .97) in the moving environment. The null hypothesis could not be rejected for the total movement time, approach phase time and the kicking phase time in the moving environment; thus, there was support for this part of the hypothesis.

<u>Hypothesis 5</u> stated that in both the stationary and moving environments, there would be a significant positive relationship between preferred tempo and the intra-subject temporal consistency, i.e., subjects displaying greater intra-subject temporal consistency would demonstrate faster preferred tempos than subjects displaying less

temporal consistency when meeting the temporal accuracy requirements of a serial movement task. To test this hypothesis Pearson product-moment correlations were computed between the following:

A. The standard deviation of each subject's three movement times (total, approach, and kicking) in the stationary environment and the mean movement times for each subject's: (a) total movement time $\underline{r}$ = .44, $\underline{p}$ = .05), (b) approach phase time ($\underline{r}$ = .41, $\underline{p}$ = .07), and (c) kicking phase time ($\underline{r}$ = -.50, $\underline{p}$ = .03) in the stationary environment. This means that in the stationary environment, subjects with faster preferred tempos in the total movement time were significantly more consistent in their performance than the subjects with slower preferred tempos. On the other hand, subjects with slower preferred tempos in the kicking phase were significantly more consistent in their performance than the subjects with faster preferred tempos. Therefore, this part of the directional hypothesis was supported for the total movement time, but was not supported for the approach phase nor the kicking phase in the stationary environment.

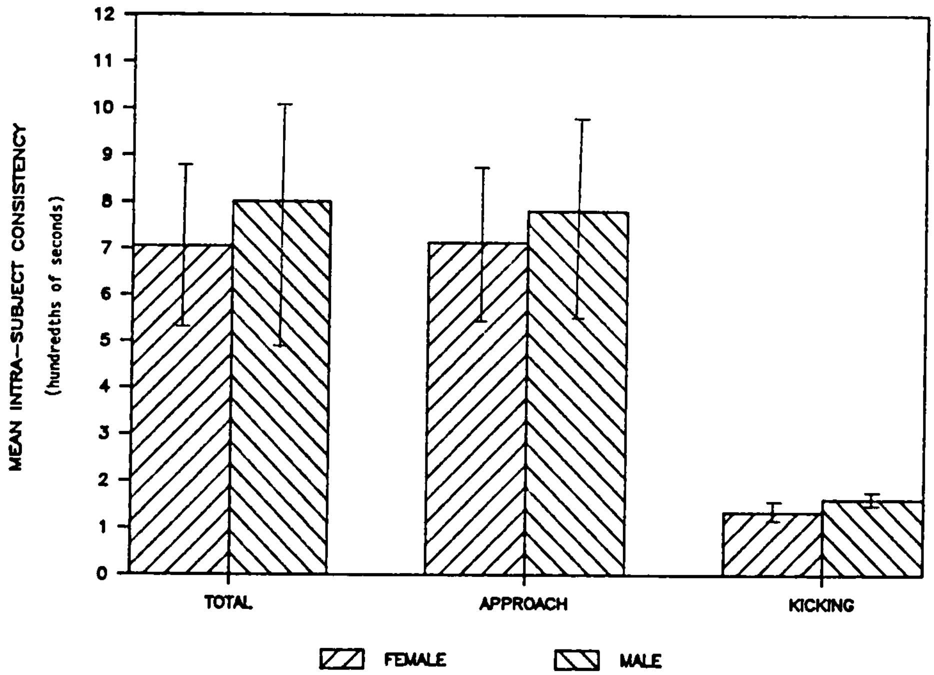
B. The standard deviation of the subject's three movement times (total, approach, and kicking) in the moving environment and the mean movement times for each subject's: (a) total movement time ($\underline{r}$ = .40, $\underline{p}$ = .08), (b) approach phase time ($\underline{r}$ = .45, $\underline{p}$ = .05), and (c) kicking phase time ($\underline{r}$ = .36, $\underline{p}$ = .12), in the moving environment. This means that in the moving environment, subjects with faster preferred tempos in the approach phase were significantly more consistent in their performance than subjects with slower preferred tempos. Therefore, this part of the directional hypothesis was supported for the approach phase time, but was not supported for the kicking phase nor the total movement times in the moving environment.

<u>Hypothesis 6</u> stated that in both the stationary and moving environments, there would be no sex differences in: (a) the intra-subject consistency of preferred tempo, or (b) the preferred tempo when meeting the temporal accuracy requirements of a serial movement task in a stationary environment. To test this hypothesis t-tests were computed between the following:

A. The means of the standard deviations of the: (a) total movement time ($\underline{t}(17.9) = .35$, $\underline{p} = .73$), (b) approach phase time ($\underline{t}(18) = -.25$, $\underline{p} = .81$), and (c) kicking phase time ($\underline{t}(8.2) = -1.14$, $\underline{p} = .28$) for female and male subjects performing the serial movement task in the stationary environment. The null hypothesis could not be rejected, thus, there was support for this part of the hypothesis for all three variables (Figure 2).

B. The means of the preferred tempos for the: (a) total movement times ($\underline{t}(11.4) = .76$, $\underline{p} = .46$), (b) approach phase times ($\underline{t}(11) = .65$, $\underline{p} = .53$), and (c) kicking phase times ($\underline{t}(13) = 1.34$, $\underline{p} = .20$) for female and male subjects performing the serial movement task in the stationary environment. The null hypothesis could not be rejected, thus, there was support for this part of the hypothesis for all three variables (Figure 3).

C. The means of the standard deviations of the: (a) total movement times ($\underline{t}(18) = .36$, $\underline{p} = .72$), (b) approach phase times ($\underline{t}(17.9)$



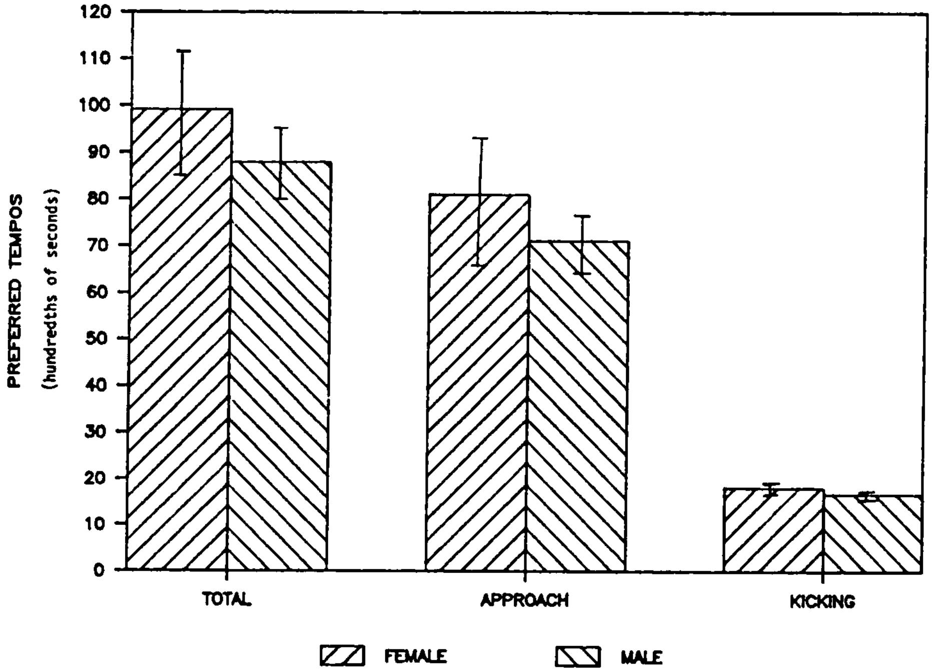
MOVEMENT TIMES

	TOTAL		APPROACH		KICKING	
	Females	Males	Females	Males	Females	Males
mean	7.06	8.01	7.13	7.81	1.34	1.62
standard deviation	5.06	7.10	4.92	7.35	.66	.24
standard error of mean	1.79	2.05	1.74	2.12	.23	.07
t=	.35		-.25		-1.14	
p=	.73		.81		.28	
df=	17.9		18.0		8.2	

Female N = 8

Male N = 12

Figure 2. Sex differences between the intra-subject temporal consistency (standard deviation) of the total movement times, approach phase times, and the kicking phase times in the performance of the closed task.



MOVEMENT TIMES

	TOTAL		APPROACH		KICKING	
	Females	Males	Females	Males	Females	Males
mean	99.21	87.99	81.02	71.17	18.19	16.83
standard deviation	36.46	25.18	37.96	24.96	2.39	1.95
standard error of mean	12.89	7.25	13.42	7.20	.85	.56
t=	.76		.65		1.34	
p=	.46		.53		.20	
df=	11.4		11.0		13.0	

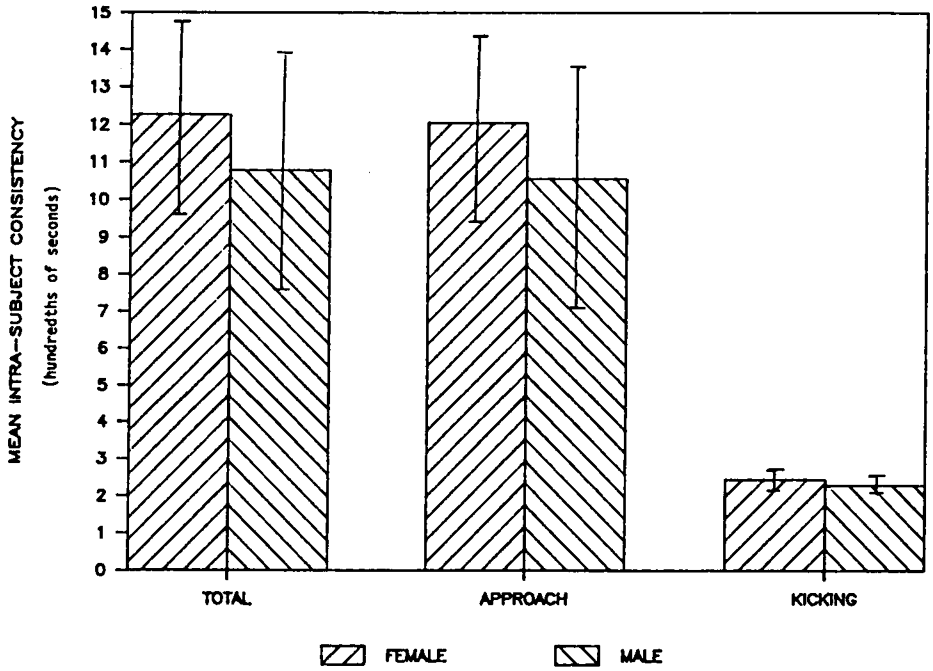
Female N = 8

Male N = 12

Figure 3. Sex differences between the preferred tempos (mean movement times) of the total movement times, approach phase times, and the kicking phase times in the performance of the closed task.

= .36, p = .72), and (c) kicking phase times ($t(11)$ = .39, p = .70) for female and male subjects performing the serial movement task in the moving environment. The null hypothesis could not be rejected, thus, there was support for this part of the hypothesis for all three variables (Figure 4).

D. The means of the preferred tempos for the: (a) total movement times ($t(11.8)$ = 1.95, p = .08), (b) approach phase times ($t(12)$ = 1.78, p = .10), and (c) kicking phase times ($t(10.4)$ = 2.34, p = .04) for female and male subjects performing the serial movement task in the moving environment. The results indicate that males were significantly faster than females in the kicking phase of the serial task in the moving environment. Therefore, the null hypothesis could not be rejected for the total movement times and approach phase times, but was rejected for the kicking phase times (Figure 5). Thus, there was support for this part of the hypothesis for the total movement time and approach phase time, but not for the kicking phase time.



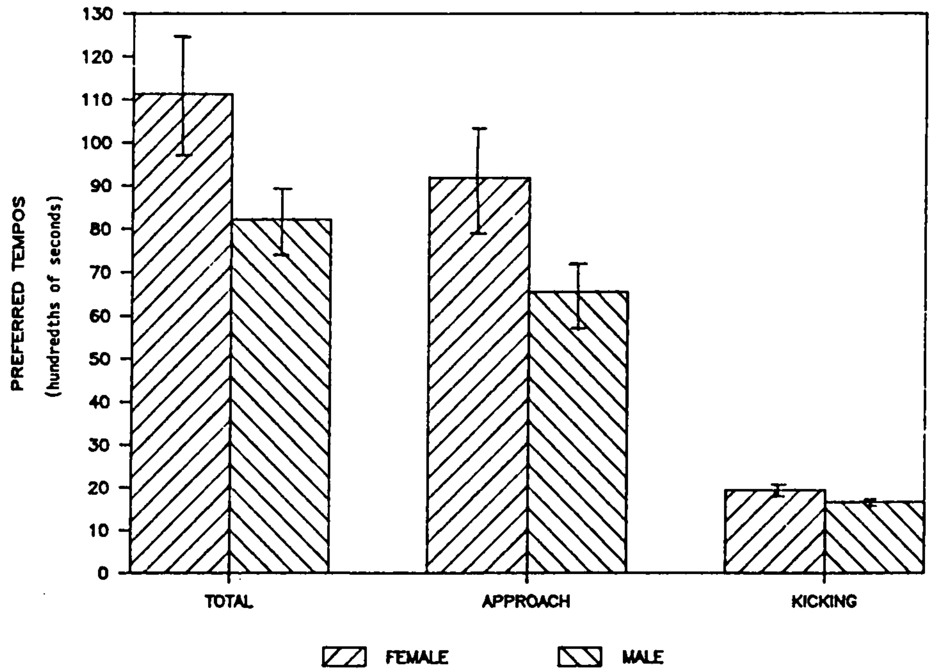
MOVEMENT TIMES

	TOTAL		APPROACH		KICKING	
	Females	Males	Females	Males	Females	Males
mean	12.27	10.79	12.05	10.56	2.45	2.29
standard deviation	7.22	11.09	6.85	11.53	.98	.64
standard error of mean	2.55	3.20	2.42	3.33	.35	.18
t=	.36		.36		.39	
p=	.72		.72		.70	
df=	18.0		17.9		11.0	

Female N = 8

Male N = 12

Figure 4. Sex differences between the intra-subject temporal consistency (standard deviation) of the total movement times, approach phase times, and the kicking phase times in the performance of the open task.



MOVEMENT TIMES

	TOTAL		APPROACH		KICKING	
	Females	Males	Females	Males	Females	Males
mean	111.25	82.26	91.91	65.59	19.44	16.68
standard deviation	36.41	26.20	35.74	26.37	3.00	1.79
standard error of mean	12.87	7.56	12.63	7.61	1.06	.52
t=	1.95		1.78		2.34	
p=	.08		.10		.04	
df=	11.8		12.0		10.4	

Female N = 8

Male N = 12

Figure 5. Sex differences between the preferred tempos (mean movement times) of the total movement times, approach phase times, and the kicking phase times in the performance of the open task.

CHAPTER V

DISCUSSION OF THE RESULTS

The present study was designed to extend the research of Smoll (1975b, 1975c) and Smoll and Schutz (1978) on the concepts of preferred tempo and intra-subject consistency of performance. The results of the study are discussed in relation to how: (a) support was given, (b) distinctions were made from, and (c) additions were made to the existent literature dealing with the relationship between preferred tempo and the performance of a serial movement task in a stationary and/or moving environment.

Hypothesis 1 stated that the average intra-subject temporal consistency of preferred tempo would be proportionately smaller than the inter-subject temporal consistency for the performance of a serial movement task requiring total body movement: (a) executed in a stationary environment, and (b) involving coincidence timing with the temporal accuracy requirements of the task being increased by creating a moving environment. This hypothesis was tested by computing the ratio of (inter-subject temporal consistency)/(mean intra-subject temporal consistency) for the: (a) total movement times, (b) approach phase times, and (b) kicking phase times in the stationary and moving environments. By dividing the standard deviation of each subject's mean movement time by the mean of all subjects' standard deviation of movement time, the difference between the subjects' preferred tempos was compared to the amount of variation in all of the subjects' response times. Using this ratio, Smoll (1975b) discovered that subjects had a preference of moving that was different from other individuals when performing a repetitive arm swing task. In the Smoll (1975b) study the mean within-subject variance (.0025 sec) was 72 times less than the between-subject variance (.18 sec). However, to compare Smoll's ratio to the ratios of the present study, it was necessary to convert Smoll's ratio from "squared seconds" (his ratio used variances) to "seconds" in order to have the measure of variability in terms of the original units of measurement. In other words, since the variances were in squared units, by taking the square root to convert the figures to standard deviations, a return was made to the original unit of measurement, i.e., seconds (McCall, 1970). Therefore, using standard deviations from the Smoll (1975b) study, the mean within-subject variation (.05 sec) would only be 8.48 times less than the between-subject variation (.42 sec). In the present study the amount of variation of tempo within each individual subject was less than the amount of variation of different tempos between subjects in the serial task of kicking a soccer ball. This was not as large a ratio as in the Smoll (1975b) study.

For the present study, specifically, the ratios (Table 1, p. 59) indicated that when performing the serial task in the stationary and moving environments subjects had a preferred tempo in the total movement time which was approximately 4 times and 3 times, respectively, different from that of other subjects, primarily due to the manner in which each subject chose to perform the approach phase. For the closed and open task the ratio for the kicking phase was practically one-to-one indicating each subject performed this element of the soccer kick at about the same temporal consistency as the other subjects. This was probably due to the fact that because the kicking phase was a quick, reaction-type movement, individual variation was limited. This somewhat supports the findings of Hubbard and Seng (1954) that when performing the single discrete task of swinging a bat to hit a pitched baseball, subjects tended not to alter the duration of their swing. Rather, all subjects tended: (a) to gear the swing of the bat to the speed of the pitched ball, and (b) to perform the swing (a reaction-type movement) with uniform duration and similar temporal consistency as that of other subjects.

For both the total movement time and the approach phase times the individual differences in the variation of tempos were slightly more for the closed task (4 times) than for the open task (3 times). A probable explanation for this would be that when a subject performed the task in the stationary environment, there were no temporal demands of a rolling ball, making it possible for individuals to perform with more freedom of choice in tempos. Gentile (1972) suggested that, when performing a closed task, "the regulatory conditions in the environment are stationary, [the subject] is quite free to select from a wide range of temporal organizations for the patterning of his motor outflow" (p. 6). A similar explanation may be made concerning the greater degree of individual differences when subjects performed the repetitive discrete arm swing task in Smoll's (1975b) study as compared to the performance of the serial tasks of the present study. Although both the repetitive discrete task and serial tasks were performed at a chosen tempo, more time was available for subjects to select a preferred tempo for performing the repetitive discrete task. Whereas the mean performance time of the arm swing task was 1.79 sec, the mean total time of moving to kick the soccer ball was only .93 sec in the stationary environment and .94 sec in the moving environment. When performing the closed and open serial tasks, although individual subjects performed the approach phase of both tasks at preferred tempos which were different than that of other subjects, all subjects were running in the approach phase in order to generate speed and power to kick the soccer ball. Because each subject chose to run in the approach phase of the tasks, this probably created the situation where there was a more limited opportunity for individual differences in the closed and open serial task as compared to the slower performance of the repetitive discrete task.

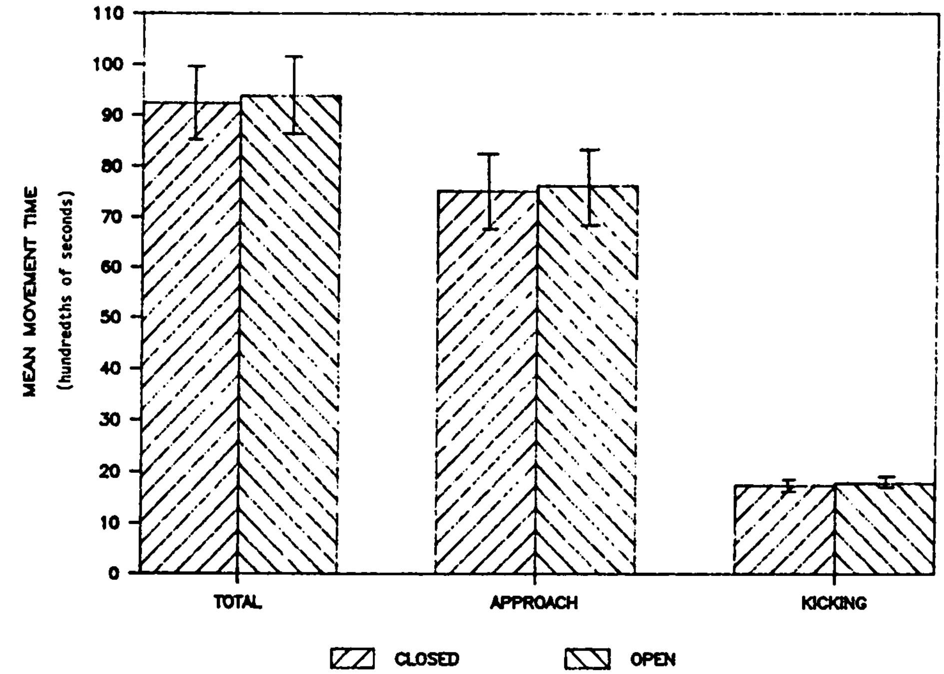
A further contrast between the Smoll (1975b) task and the task of the present study may lead to other possible explanations for this greater degree of individual differences found in the repetitive discrete task than in the serial task. The serial task of kicking a soccer ball requires a higher degree of gross motor movement than the repetitive discrete arm swing task. Referring to the terms used by Keogh and Sugden (1985), the arm swing task would be considered a manual control task whereas the soccer kick would be considered a body control task involving the integration of multiple body segments. Further, referring to the terms used by Barsch (1967), the arm swing task would be mainly one of perceived rhythm, with emphasis on recurrency and a regularity of movement. The soccer kick task would be a pattern of performance rhythm involving the projection of an object, i.e., the ball. The results of the present study would indicate that when individuals perform movements at a self-paced tempo the type of task might determine the amount of individual variation. One explanation of the difference between the results of the present study and Smoll's (1975b) results is that it may be more possible for a subject to perform the repetitive discrete arm swing task 8 times (Smoll, 1975b) faster or slower than the overall mean preferred tempo than it would be possible for a subject to perform the serial kicking task at a time that would be more than 4 times (present study) faster or slower than the overall mean preferred tempo. For example, it would not be humanly possible to perform the total movement time of the soccer kick 8 times faster than .93 sec, the mean preferred tempo in the stationary environment. However, it would be possible to move the arm 8 times faster than the 1.79 sec mean preferred tempo of the arm swing task. This would also explain why there was virtually no variation in the kicking phase of the soccer task. The purpose of the kicking phase was the same for each subject, i.e., to kick with enough force to hit the target. If a subject would try to make the kick 4 or 8 times slower, the ball would not successfully reach the target. Further, it would not be humanly possible to kick at the ball with leg movement much faster than the average tempo of .17 sec. Therefore, it seems it would be necessary to have greater individual variation in the performance of repetitive discrete tasks requiring manual control than when performing serial movements which are body control tasks.

One further point needs to be made. In the present study all subjects were experienced with the serial task of kicking the soccer ball. Although some subjects may have been more skilled than others, none of the subjects were novice. It is suggested that experience level might also explain the lesser degree of individual variation in the serial task than was found in the repetitive discrete task.

Hypothesis 2 stated that subjects would demonstrate less intra-subject temporal consistency of preferred tempo performing a serial movement task requiring total body movement of coincidence timing in the moving environment than when performing a serial movement task in the stationary environment. A significant difference was not found between the means of the standard deviations of the closed and open task total movement times or the approach phase times. A significant difference was found between the means of the standard deviations of kicking phase times in the closed and open tasks, i.e., subjects were significantly more consistent in the kicking phase time in the closed task than in the open task (Figure 1, p. 61).

It might be assumed that when performing the serial task of kicking a soccer ball in the two environmental conditions that the individual's most preferred tempo for the task would likely be in the stationary environment rather than the moving environment where the temporal accuracy demands increase. In the moving environment the subject could possibly be forced to move: (a) with less consistency than preferred, and (b) at different tempos than their preferred tempo. This would correspond with Higgens and Spaeth's (1972) conclusions that "open skills move toward a diversity of patterns of movement matched to environmental conditions and that closed skills move toward consistency in patterns of movement" (p. 65). Similarily, Gentile (1972) concluded that the "temporal and spatial characteristics of open motor patterns are concomitantly contolled by the temporal/spatial characteristics of the variable regulation conditions in the environment" (p. 6).

However, according to the results of the test of Hypothesis 2, within each individual there was no difference between consistency of performance in the total movement time in the stationary and moving environments primarily due to the fact there was no difference in the consistency of the approach phase times in the two environments (Figure 1, p. 61). Further, additional information was obtained by computing a correlated t-test between the mean time of the total movement in the stationary environment and the mean time of the total movement in the moving environment. Similar additional correlated t-tests were computed for: (a) the approach phase times, and (b) kicking phase times (Figure 6). No difference was found between the means of the total movement times ($\underline{t}(19) = -.26$, $\underline{p} = .79$) or between the means of the approach phase times ($\underline{t}(19) = .19$, $\underline{p} = .85$). Therefore, not only did individual subjects perform the total movement with similar temporal consistency, they also performed the total movement and approach phase of the closed and open task in approximately the same amount of time.



MOVEMENT TIMES

	TOTAL		APPROACH		KICKING	
	Closed	Open	Closed	Open	Closed	Open
mean	92.48	93.90	75.11	76.11	17.37	17.78
standard deviation	29.78	33.16	30.26	32.37	2.18	2.66
standard error of mean	6.66	7.41	6.77	7.24	.49	.60
t=	-.26		-.19		-.94	
p=	.79		.85		.63	
df=	19.0		19.0		19.0	

N = 20

Figure 6. Differences between the preferred tempos (mean movement times) when subjects performed the total movement times, approach phase times, and kicking phase times of the closed and open tasks. Times are in hundreths of seconds.

The additional correlated t-test indicated there was no difference between the mean kicking phase time in the stationary environment and the mean kicking phase time of the moving environment ($\underline{t}(19) = -.94$, $\underline{p} = .66$), i.e., a subject tended to perform the kicking phase in approximately the same time for both environmental conditions (Figure 6). In contrast, a significant difference was found between the consistency of the kicking phase of the closed and open tasks ($\underline{t}(19) = -3.99$, $p < .001$) indicating that a subject performed this element of the soccer kick with less consistency in the moving environment than in the stationary environment (Figure 1, p. 61). This difference in consistency was probably due to the added temporal demand created by the moving environment, i.e., the rolling ball, as indicated by Gentile (1972) and Higgens and Spaeth (1972).

The finding of the present study that subjects performed the total movement time of the serial task with the same consistency in both environments is not consistent with the related literature (e.g., Gentile, 1972). The definition of a serial task may be the source of a possible explanation for this inconsistency with the literature. The serial task of moving to kick a soccer ball has been described as running (i.e., a continuous task) in order to gain momentum and attain position for kicking (i.e., a discrete task) to a stationary target (Chapter I, p. 13). The running, i.e., the approach phase, is classified as a continuous task. The fact that subjects performed the approach phase element of the serial task at the same tempo and consistency in both environmental conditions lends support for the literature in which subjects were found to have a consistent preferred tempo in the continuous task of: (a) walking (Harrison, 1943; Rimoldi, 1951), and (b) riding a bicycle ergometer, regardless of the workload (Taguchi et al., 1981). However, the literature does not indicate if a change in the environmental conditions for the continuous task would also change the consistency of preferred tempo. The kicking phase of the serial task has been described as discrete. The only literature on the preferred tempo of a single discrete task is limited to the implication of studies in which temporal consistency was noted in the: (a) single discrete open task of swinging a bat to hit a baseball (Hubbard & Seng, 1954), and (b) single discrete closed task of rising from a chair (Jones & Hanson, 1961). Again, no comparison was made to the performance of the Hubbard and Seng (1954) task or the Jones and Hanson (1961) task in different environmental conditions.

Only a limited comparison may be made between the single discrete task of the kicking phase element of the soccer kick and the repetitive discrete task used in the Smoll and Schutz (1982) study. Smoll and Schutz (1982) discovered that when subjects performed the repetitive discrete arm swing task at a tempo faster than their preferred tempo there were detrimental effects in: (a) spatial accuracy, (b) spatial consistency, and (c) temporal accuracy, but the faster than preferred tempo condition actually enhanced the temporal consistency. While the arm swing task was in response to an externally imposed tempo, the soccer kick, a ballistic movement, was performed at a self-imposed tempo. Any changes in temporal consistency of the repetitive discrete task were probably in the form of perceived rhythm and not performance rhythm, as might be the case in a single discrete task.

Because of the complex nature of the serial task, it is difficult for the individual findings (Hubbard & Seng, 1954; Jones & Hanson, 1961; Smoll & Schutz, 1982) to be related to the performance of a dynamic task such as moving to kick a soccer ball. Therefore, when analyzing closed and open serial tasks as to the influence of the environment on the consistency of the task as a whole, the component parts of the task must be examined to determine individual demands on each part.

If this is indeed the case, however, another explanation may be offered as to why there was no difference in the consistency of the approach phase in the stationary versus moving environment. It is possible that the nature of the task used in the present study did not allow for the duration of the approach phase to last long enough so that a difference in consistency could be evidenced. The continuous task (i.e., running) might require a longer amount of time than is needed in a discrete task before a difference in consistencies could be demonstrated. Again, the types of component tasks of the skill would make a difference in the individual consistency when performing in the stationary or moving environment.

Another explanation concerning the nature of the serial task used in the present study must be considered as to why there was no difference in the consistency of the approach phase times. It is possible that because of the high predictability of the open task (i.e., the ball was rolling the same speed for each trial), subjects were able to estimate the time they needed to make contact with the moving ball. Therefore, subjects performing the open task could simulate the tempo of the closed task with consistency.

Hypothesis 3 stated that in both the stationary and moving environments, subjects displaying greater intra-subject temporal consistency of preferred tempo would demonstrate: (a) higher quality of goal attainment, and (b) greater consistency of goal attainment, than subjects displaying a less consistent preferred tempo when meeting the temporal accuracy requirements of a serial movement task. Also dealing with goal attainment, Hypothesis 4 stated that in both the stationary and moving environments, there would be no significant relationship between a subjects preferred tempo and: (a) quality of goal attainment, and (b) consistency of goal attainment when meeting the temporal accuracy requirements of a serial movement task in a stationary environment. In the present study in both the stationary and moving environments, no significant relationships were found between intra-subject temporal consistency or preferred tempo and: (a) a higher score on the kicking task, or (b) the consistency of the scores achieved when performing the kicking task.

In comparison, Smoll and Schutz (1978) found that an individual's preferred tempo (whether fast, moderate, or slow) was not "appreciably related to rhythmic accuracy or consistency of performance" (p. 892). In other words, a subject's preferred tempo was found not to be significantly related to being in the right place at the right time when performing a repetitive discrete task. When subjects were made to perform the repetitive discrete task at speeds other than their preferred tempo detrimental effects were noted in: (a) spatial accuracy, (b) temporal accuracy, and (c) spatial consistency (Smoll and Schutz, 1982). The fact that no relationships were found between preferred tempo or the consistency of preferred tempo and: (a) the quality of goal attainment, and (b) consistency of goal attainment in the serial task of kicking a soccer ball is consistent with Smoll and Schutz (1978).

It is suspected that the primary factor in the quality and consistency of goal attainment of a sport skill such as kicking a soccer ball might be the skill level of the subjects and their years of playing experience. Although a significant relationship was not found between years of experience and total goal attainment score for the closed task ($\underline{r} = -.08$, $\underline{p} = .72$), a significant relationship was found between the years of experience and the total goal attainment score achieved when performing the open task ($\underline{r} = .46$, $\underline{p} = .04$). However, a significant relationship was not found between years of experience and consistency of goal attainment.

Hypothesis 5 stated that in both the stationary and moving environments, there would be a significant positive relationship between preferred tempo and the intra-subject temporal consistency, i.e., subjects displaying greater intra-subject temporal consistency would demonstrate faster preferred tempos than subjects displaying less temporal consistency when meeting the temporal accuracy requirements of a serial movement task. In other words, the hypothesis suggested that subjects with the faster preferred tempo should have the more consistent movement times and vice versa.

According to the results of the test of Hypothesis 5 a low, but nonsignificant, positive relationship ($\underline{r}$ = .40, $\underline{p}$ = .08) was found between the consistency of preferred tempo and the total movement time in the open task, with a significant positive correlation found in the approach phase time ($\underline{r}$ = .45, $\underline{p}$ = .05). Therefore, subjects with the faster approach times in the open task tended to be more consistent in their preferred tempos. The same might be said for the closed task. Even though a nonsignificant correlation ($\underline{r}$ = .41, $\underline{p}$ = .07) was found for the approach phase, a marginally significant relationship ($\underline{r}$ = .44, $\underline{p}$ = .05) was found for the total movement time in the closed task. These findings correspond with the related literature dealing with maximal-speed tasks and repetitive tasks (e.g., Rimoldi, 1951; Smoll, 1975c). The literature suggests that the speedier the individual on tasks requiring reaction time and maximal speed performances, the more consistent their performance (e.g., Rimoldi, 1951). In dealing with repetitive discrete tasks requiring self-pacing Smoll (1975c) and Smoll and Schutz (1978) discovered that subjects with the faster preferred tempos were more consistent from response to response than subjects with slower preferred tempos.

However, in the present study, the findings were not completely consistent with the related literature. A contradicting significant, moderate negative relationship ($\underline{r}$ = -.50, $\underline{p}$ = .03) was found in the kicking phase of the closed task, i.e., the slower the kicking phase time, the more consistent the preferred tempo. In contrast, a nonsignificant, but positive, correlation (r = .336, p = .12) was found for the kicking phase of the open task. This somewhat supports the Smoll and Schutz (1978) findings that the faster movement times were more consistent than the slower times. In Hypothesis 1 it was noted that for the closed and open tasks individual subjects performed the kicking phase at approximately the same tempo as other subjects. In Hypothesis 2, however, individuals were found to have a significant difference between the consistency of kicking phase times of the closed task and open task, with individuals performing the closed task kicking phase more consistently than the open task kicking phase. The suggestion was made that without the demands of a moving environment more time was available in the performance of the closed task for subjects to select a tempo with which to kick the ball (Gentile, 1972).

Since individuals performed the approach phase of both the closed task and open task with no significant difference in the consistency of tempo, the closed and open tasks seemed to differ because of the relationship between the consistency of preferred tempo of the kicking phase times. In the closed task the slower kicking times were more consistent. In the open task, the faster kicking times were slightly (although not significantly) more consistent. This supports the explanation that in the serial task of kicking a soccer ball the approach phase and the kicking phase are independent elements, i.e., the approach phase is a continuous task and the kicking phase is a discrete task. The environmental conditions did not alter an individual's preference or consistency of tempo in the approach phase. However, the difference in the environmental demands made a difference in the consistency of the kicking phase times for the open and closed task. Again, the types of component tasks in the skill made a difference in consistency of performance.

Hypotheses 6 stated that in both the stationary and moving environments, there would be no sex differences in: (a) the intra-subject temporal consistency of preferred tempo, or (b) the preferred tempo when meeting the temporal accuracy requirements of a serial movement task. t-Tests were computed between the means of the standard deviations and of the preferred tempos for the closed and open task variables of: (a) the total movement time of the task, (b) the approach phase time, and (c) the kicking phase time (Figures 2, 3, 4, and 5, pp. 67, 68, 70 and 71, respectively). Additional t-tests were computed for: (a) the number of steps taken in the approach phase, (b) the standard deviation of the number of steps, (c) the total goal attainment score obtained, and (d) the standard deviation of the goal attainment score. Sex differences were found only for: (a) the number of steps taken in the approach phase of the open task ($t(10.3) = 2.35$, $p = .04$) (Table 2), and (b) the mean kicking phase time when subjects performed the soccer kick in the moving environment ($t(10.4) = 2.34$, $p = .04$) (Figure 5). Females tended to take more steps in the approach phase of the open task and tended to have slower times in the kicking phase of the open task.

In the studies using males and females (Smoll, 1974b, 1975b; Smoll & Schutz, 1978) sex differences were not found when subjects performed a

Table 2

Sex differences between the number of steps taken in the open task.

	FEMALE		MALE
Mean	3.14		2.41
Standard Deviation	.81		.48
Standard Error of Mean	.29		.14
t=		2.35	
p=		.04	
df=		10.30	

Female N = 8

Male N = 12

repetitive discrete task. Most of the findings of the present study were consistent with the literature. The fact that females differed from males in the number of steps could be explained by suggesting that: (a) the females might have needed extra steps in order to generate more power with which to kick the ball; or (b) the males may have tended to have a longer leg length and, thus, have needed fewer steps than the females. Similarily, the females' slower kicking time might be explained by suggesting that: (a) the males were more powerful and could perform the kicking movement phase faster than the females, or (b) the males chose to kick the ball with more speed because of a desire to demonstrate their power.

CHAPTER VI

SUMMARY, CONCLUSIONS, AND IMPLICATIONS FOR FURTHER RESEARCH

Chapter VI contains a summary of the study, significant conclusions, and a list of implications and suggestions for further research.

Summary

In the literature, preferred tempo has been investigated using: (a) simple motor tasks, (b) repetitive discrete tasks, and (c) continuous tasks. Although some earlier studies supported the theory of an overall general preferred tempo (e.g., Frischeisen-Kohler, 1933), many of the studies (e.g., Rimoldi, 1951) supported the theory that a preferred tempo exists within an individual for specific kinds of movement and seems to be consistent over time. The earlier studies were limited in two ways. First, the subjects were required to perform tasks in a specific time interval, not permitting the assessment of a performance time for each response. Second, the tasks were either: (a) simple, continuous tasks, or (b) repetitive discrete tasks in a predictable environment with minimal spatial accuracy demands.

Smoll's research (e.g., Smoll, 1975b) demonstrated preferred tempo as a factor in the performance of a rhythmic, repetitive discrete task requiring both spatial and temporal accuracy. Smoll demonstrated the influence of preferred tempo by illustrating high intra-subject consistency and high inter-subject variability with subjects performing the self-paced arm swing task. Some of the general findings of these preferred tempo studies were as follows: (a) there were substantial differences in each subject's preferred tempo, i.e., subjects had a preference of moving that was different from other individuals; (b) subjects with faster preferred tempos were more consistent from response to response than were those with slower preferred tempos (agreeing with Rimoldi, 1951); (c) there were no sex differences for either preferred tempo or consistency of performance; and (d) an individual's preferred tempo, whether fast, moderate, or slow, was not found to be related to rhythmic accuracy or consistency of performance.

In studies where preferred tempo was demonstrated using a continuous task of riding a bicycle ergometer (Taguchi et al., 1981; McCann & Gliner, 1982) subjects maintained a constant tempo for a self-paced work rate. These tempos were consistent: (a) over time, and (b) at different workloads.

Two studies inferred that preferred tempo could be a factor in the performance of a single discrete task. One study (Hubbard & Seng, 1954) reported the temporal consistency of baseball batters performing a discrete skill of swinging a baseball bat. Another study (Jones & Hanson, 1961) reported high intra-subject consistency and high inter-subject variability in the spatial and temporal patterns of subjects performing the discrete task of rising from a chair. However, no research was found where preferred tempo was studied in relationship to the performance of a single discrete or serial task.

The present study extended the research of Smoll (1975b) and Smoll and Schutz (1978) on the concepts of preferred tempo and intra-subject temporal consistency in the performance of a repetitive discrete task. The purpose of the present study was to investigate the nature of the relationship between: (a) preferred tempo, and (b) intra-subject temporal consistency and the performance of a serial movement task requiring total body movement involving the projection of an object in a stationary and moving environment.

Twenty right-footed male and female college students who had completed a physical education soccer class were video taped while: (a) kicking a stationary soccer ball to a stationary target (closed task), and (b) kicking a moving soccer ball to the same target (open task). Subjects were instructed to kick the ball in a manner that was comfortable and natural. Each subject was given 10 trials for the closed task and 10 trials for the open task. Data were obtained through the use of stop-action, frame-by-frame analysis of the video tape. The investigator recorded the time in hundredths of seconds, as indicated on a timer in the video display, when: (a) the initial contact of the first step occurred, (b) the point where the subject made initial contact with the floor with the nonkicking foot immediately preceeding the kick, and (c) the actual contact of the ball. For each subject the means (to indicate preferred tempo) and standard deviations (to indicate intra-subject temporal consistency) were calculated for: (a) total movement times, the time between the initial contact of the first step and the actual contact of the ball; (b) approach phase time, the time between the initial contact of the first step and the point where the subject made initial contact with the floor with the nonkicking foot immediately preceeding the kick; and (c) kicking phase time, the time between the point when the subject made initial contact with the floor with the nonkicking foot and the actual contact of the ball by the kicking foot, for the closed and open tasks. Also recorded were: (a) the subject's total score obtained by kicking the ball to a target grid, and (b) the standard deviation of their score in the closed and open tasks.

In the present study moving to kick a soccer ball was defined as a serial task. The individual units of the task were identified as: (a) continuous in the approach phase, and (b) discrete in the kicking phase. Because of the complex nature of the serial task, each hypothesis was tested for the approach phase and kicking phase, as well as for the total movement time.

In the present study the amount of variation of tempo within each individual subject (intra-subject) was less than the amount of variation of different tempos between subjects (inter-subject) in the total serial task (in both stationary and moving environments) of kicking a soccer ball. This was also true for the approach phase of the task. However, this difference was approximately half as large a ratio as that indicated by Smoll (1975b) for the performance of the repetitive discrete arm swing task. On the other hand, in the present study individual subjects tended to perform the kicking phase in approximately the same amount of time and consistency as other subjects.

In the present study subjects did not demonstrate a difference in the intra-subject temporal consistency between the approach phase of the closed task and the approach phase of the open task. Further, each subject tended to perform the approach phase of the closed task at about the same preferred tempo as he/she performed the approach phase of the open task. On the other hand, each subject tended to perform the kicking phase of the closed task at a more consistent tempo than he/she performed the kicking phase of the open task. The finding of the present study that subjects performed the total kicking movement (and approach phase) with the same consistency for both closed and open tasks is not consistent with the related literature (e.g., Gentile, 1972). However, the finding that the kicking phase was more consistent in the closed task than in the open task supports the related literature. The comparison of the findings of the present study with the literature was explained in relation to the differences between: (a) continuous, and (b) discrete tasks.

In the present study no significant relationships were found between intra-subject temporal consistency or preferred tempo and: (a) a higher score on the kicking task, or (b) the consistency of the scores achieved when performing the kicking task in the stationary or moving environments. This is basically in agreement with Smoll and Schutz (1978) in that an individual's preferred tempo in the performance of a repetitive discrete task (whether fast, moderate or slow) was not significantly related to rhythmic accuracy or consistency of performance. In the present study it was concluded that the primary factor in the quality and consistency of goal attainment was probably the skill level of the subjects.

In the studies using males and females (Smoll, 1974b, 1975b; Smoll & Schutz, 1978) sex differences were not found when subjects performed a repetitive discrete task. Most of the findings of the present study were consistent with the literature. However, there were two exceptions: (a) females tended to take more steps than males in the approach phase, and (b) females tended to have slower times than males in the kicking phase of the open task. The fact that females differed from males in the number of steps could be explained by suggesting that: (a) the females might have needed extra steps in order to generate more power with which to kick the ball, or (b) the males may have tended to have a longer leg length and, thus, have needed fewer steps than the females. Similarily, the females' slower kicking time might be explained by suggesting that: (a) the males were more powerful and could perform the kicking movement phase faster than the females, or (b) the males chose to kick the ball with more speed because of a desire to demonstrate their power.

Since individuals performed the approach phase of both the closed task and open task with no significant difference in the consistency of tempo, the closed and open tasks seemed to differ because of the relationship between the consistency of preferred tempo of the kicking phase times. In the closed task the slower kicking times were more consistent. In the open task, the faster kicking times were slightly (although not significantly) more consistent. This supports the explanation that in the serial task of kicking a soccer ball the approach phase and the kicking phase are independent elements, i.e., the approach phase is a continuous task and the kicking phase is a discrete task. The environmental conditions did not alter an individual's preference or consistency of tempo in the approach phase. However, the difference in the environmental demands made a significant difference in the consistency of the kicking phase times for the open and closed task. Again, the types of component tasks in the skill made a difference in consistency of performance.

Conclusions

The following conclusions are based on the findings of the present study:

1. The average intra-subject temporal consistency of the total movement time and approach phase of the closed task and the total movement time and approach phase time of the open task were proportionately smaller, in relation to Smoll's (1975b) findings, than the inter-subject temporal consistency; i.e., subjects performed the total movement times and approach phase times at a preferred tempo which was different from that of other individuals.

2. The average intra-subject temporal consistency of the kicking phase of the closed task and the kicking phase of the open task were not

different from the inter-subject temporal consistency, i.e., subjects tended to perform the kicking phase of the closed task and the kicking phase of the open task at preferred tempos which were not different from that of other individuals.

3. There was greater individual variation of tempos when performing repetitive discrete tasks (Smoll, 1975b) than when performing the serial movement tasks involving the projection of an object.

4. The component parts of a serial task, e.g., continuous and discrete components, in addition to the task as a whole, should be examined to determine individual environmental influences on the consistency of performance.

5. Subjects did not demonstrate a significant difference between the intra-subject temporal consistency in: (a) the total movement time and the approach phase time of the closed task, and (b) the total movement time and approach phase time of the open task. In other words, each subject tended to perform the total kicking motion, and the approach phase of the closed task at about the same consistency of tempo as he/she performed the total kicking motion and approach phase of the open task.

6. Subjects demonstrated a significant difference between the intra-subject temporal consistency in the kicking phase of the closed task and the open task, i.e., each subject tended to perform the kicking phase of the closed task at a more consistent tempo than he/she performed the kicking phase of the open task.

7. In the performance of the closed and open tasks there was no relationship between the temporal consistency of the: (a) total

movement time, (b) approach phase time, or (c) kicking phase time and the total goal attainment score achieved or the consistency of goal attainment.

8. In the performance of the closed and open tasks there was no relationship between preferred tempo of the: (a) total movement times, (b) approach phase times, or (b) kicking phase times, and the total goal attainment score achieved or the consistency of goal attainment.

9. Subjects displaying greater intra-subject temporal consistency in the total movement time of the closed task tended to have slightly faster preferred tempos in the total movement time than subjects displaying less temporal consistency.

10. Subjects displaying greater intra-subject temporal consistency in the approach phase of the open task tended to have slightly faster preferred tempos in the approach phase than subjects displaying less temporal consistency.

11. Subjects displaying greater intra-subject temporal consistency in the kicking phase of the closed task tended to have slower preferred tempos in the kicking phase than subjects displaying less temporal consistency.

12. There was no significant relationship between intra-subject temporal consistency and the preferred tempo of the kicking phase in the open task.

13. Sex differences were not found in the performance of the serial task of kicking a soccer ball except for: (a) the number of steps taken in the approach phase of the open task, and (b) the mean kicking phase time of the open task.

Implications for Further Research

Suggestions for future research include:

1. the addition of different skill levels to determine at what level of skill proficiency a preferred tempo occurs;

2. the addition of different age groups, to determine if preferred tempo is evident at younger ages;

3. further refinement of movement analysis to determine if preferred tempo is a factor in the efficiency of performance;

4. the determination of the nature of the consistency of preferred tempo over time.

LIST OF REFERENCES

LIST OF REFERENCES

Ashton, D. (1953). A gross motor rhythm test. Research Quarterly, 24(3), 253-260.

Barsch, R. H. (1967). Achieving perceptual-motor efficiency. Seattle, WA: Special Child Publications.

Buck, N. (1936). A comparison of two methods of testing response to auditory rhythms. Research Quarterly, 7(3), 36-45.

Clynes, M., & Walker, J. (1982). Neurobiologic functions of rhythm, time, and pulse in music. In M. Clynes (Ed.) Music, mind, and brain: The neuropsychology of music (pp. 171-216). New York: Plenum Press.

Conrad, R. (1960). Letter sorting machines -paced, "lagged" or unpaced? Ergonomics, 3, 149-157.

Corlett, E. N., & Mahadeva, K. (1970). A relationship between a freely chosen working pace and energy consumption curves. Ergonomics, 13, 517-524.

Cratty, B. J. (1973). Movement behavior and motor learning (3rd ed.). Philadelphia: Lea and Febiger.

DeJong, J. R. (1962). Speed of work and machines: ergonomical aspects. Ergonomics, 5, 15-23.

Frischeisen-Kohler, I. (1933). The personal tempo and its inheritance. Character and Personality, 1(4), 301-313.

Gentile, A. M. (1972). A working model of skill acqusition with application to teaching. Quest, 17(1), 3-23.

Haight, E. C. (1944). Individual differences in motor adaptions to rhythmic stimuli. Research Quarterly, 15(2), 38-43.

Harding, D. W. (1932). Rhythmization and speed of work. British Journal of Psychology, 23, 262-278.

Harrison, R. (1941). Personal tempo and the interrelationships of voluntary and maximal rates of movement. The Journal of Genetic Psychology, 24, 343-379.

Harrison, R., & Dorcus, R. M. (1938). Is rate of voluntary bodily movement unitary? The Journal of Genetic Psychology, 18, 31-39.

Higgins, J. R. (1972). Movements to match environmental demands. Research Quarterly, 43(3), 312-226.

Higgins, J. R., & Spaeth, R. K. (1972). Relationship between consistency of movement and environmental condition. Quest, 17(1), 61-69.

Hubbard, A. W., & Seng, C. N. (1954). Visual movements of batters. Research Quarterly, 25(1), 42-57.

Johnson, R. D. (1962). Measurements of achievement in fundamental skills of elementary school children. Research Quarterly, 33(1), 94-103.

Jones, F. P., & Hanson, J. A. (1961). Time-space pattern in a gross body movement. Perceptual and Motor Skills, 12, 35-41.

Keogh, J., & Sugden, D. (1985). Movement skill development. New York: Macmillan.

Lemon, E., & Sherbon, E. (1934). A study of the relationships of certain measures of rhythmic ability and motor ability in girls and women. Research Quarterly, 5(2), 82-85.

Mead, B. J. (1968). Movement and rhythm. In H. M. Smith (Ed.), Introduction to human movement (pp. 154-168). Reading, MA: Addison-Wesley.

McCall, R. B. (1970). Fundamental statistics for psychology. New York: Harcourt, Brace & World.

McCann, D., & Gliner, J. A. (1982). Preferred and imposed work rates: tempo variability and mechanical efficiency. Ergonomics, 25(3), 255-258.

McCristal, K. J. (1933). Experimental study of rhythm in gymnastic and tap dancing. Research Quarterly, 4(3), 63-75.

Rimoldi, H. J. (1946). Ritmo y fatiga. Buenos Aires: El Ateneo.

Rimoldi, H. J. (1951). Personal tempo. Journal of Abnormal and Social Psychology, 46(3), 283-303.

Robb, M. D. (1972). Task analysis: A consideration for teachers of skills. Research Quarterly, 43(3), 362-373.

Salvendy, G. (1972). Physiological and psychological aspects of paced and unpaced performance. Acta Physiological Academiae Scientiarum Hungarical, 42, 267-275.

Slavendy, G. (1974). Discrimination in performance assessments against the aged. Perceptual and Motor Skills, 39, 1087-1099.

Salvendy, G., & Pilitsis, J. (1971). Psychophysiological aspects of paced and unpaced performance as influenced by age. Ergonomics, 14, 703-711.

Seashore, R. H. (1926). Studies in motor rhythm. Psychological Monographs, 36, 142-189.

Simpson, S. E. (1958). Development and validation of an objective measure of locomotor response to auditory rhythmic stimuli. Research Quarterly, 29(4), 342-348.

Singer, R. N. (1980). Motor learning and human performance. New York: Macmillan.

Sloan, M. R. (1958). A comparison of group responses to auditory, visual and kinesthetic rhythms. (Doctoral dissertation, University of Wisconsin, Madison) Ann Arbor, Michigan. University Microfilms (No. 58-2576).

Smoll, F. L. (1973). A rhythmic ability analysis system. Research Quarterly, 44(2), 232-236.

Smoll, F. L. (1974a). Development of rhythmic ability in response to selected tempos. Perceptual and Motor Skills, 39, 767-772.

Smoll, F. L. (1974b). Development of spatial and temporal elements of rhythmic ability. Journal of Motor Behavior, 6(1), 53-58.

Smoll, F. L. (1975a). Between-days consistency in personal tempo. Perceptual and Motor Skills, 41, 731-734.

Smoll, F. L. (1975b). Preferred tempo in performance of repetitive movements. Perceptual and Motor Skills, 40, 439-442.

Smoll, F. L. (1975c). Preferred tempo of motor performance: Individual differences in within-individual variability. Journal of Motor Behavior, 7(4), 259-263.

Smoll, F. L. (1975d). Variability in development of spatial and temporal elements of rhythmic ability. Perceptual and Motor Skills, 40, 140.

Smoll, F. L., & Palmatier, R. A. (1977). A second-generation motor rhythm analysis system. Behavior Research Methods and Instrumentation, 9(6), 508-510.

Smoll, F. L., & Schutz, R. W. (1978). Relationships among measures of preferred tempo and motor rhythm. Perceptual and Motor Skills, 46, 883-894.

Smoll, F. L., & Schutz, R. W. (1982). Accuracy or rhythmic motor behavior in response to preferred and nonpreferred tempos. Journal of Human Movement Studies, 8, 123-138.

Taguchi, S., Gliner, J. A., Horvath, S. M., & Nakamura, E. (1981). Preferred tempo, work intensity and mechanical efficiency. Perceptual and Motor Skills, 52, 443-451.

Tisserand, M., & Guilhot, J. (1949). Etude du tempo de 335 sujets masculins de la region Parisienne. Biotypologic, 50, 89-94.

Walters, D. L. (1983). The relationship between personal tempo in primary-aged children and their ability to synchronize movement with music (Doctoral dissertation, University of Michigan, 1983). Dissertation Abstracts International, 44, 423A.

Wu, C. F. (1934). Personal tempo and speed in some rate tests. Journal of Testing (Chinese), 2, 85-94. (From Psychological Abstracts, 1935, 9, Abstract No. 1709).

APPENDIXES

APPENDIX A

CONSENT FORM

INFORMED CONSENT

I understand that the purpose of this study is to determine the relationship of task demands to elements of performance in two similar, but different, soccer tasks.

I confirm that my participation as a subject is entirely voluntary. No coercion of any kind has been used to obtain my cooperation. I understand that no portion of my grades or academic standing is dependent upon participation in this experiment.

I understand that I may withdraw my consent and terminate my participation without penalty at any time during the investigation.

I understand that I will be asked to perform 2 tasks, 12 trials for each. I understand that the tasks consist of: (a) running a short distance and kicking a stationary soccer ball to a target for accuracy, and (b) running a short distance and kicking a rolling soccer ball to a target for accuracy.

I understand that all of my soccer task trials will be videotaped; that only numbers will be used to match the tapes with the other recording sheets; that only the experimenter(s) will view the videotapes later to score the task; and that only group data will be utilized in reporting the results of the study.

I understand that all my responses, tapes, and scores will remain completely confidential. I also understand that: (a) all videotapes, score sheets, and demographic data will be stored in a locked office and available for review only by the researchers; and (b) that the videotapes will be erased following the study.

I understand what is expected of me as a subject. I also understand that any further questions I might have will be answered to my satisfaction by the experimenter.

I wish to give my cooperation as a subject.

DATE ____________________ Signed ____________________

Witness ____________________

Campus Address: ____

Local phone number: ________________

Sharron P. Bilbrey
Box 5057, TTU
372-3924

APPENDIX B

SUBJECT QUESTIONNAIRE

Subject number _________

Age______ Date of Birth_______________

Sex______

Please indicate how many years of soccer experience you have had:

____1 - 2 years

____3 - 4 years

____5 - 6 years

____Over 7 years

Please indicate what type of soccer experience you have had.
Check all appropriate answers:

____Physical Education activity class in college

____Intramural Soccer - High School

____Intramural soccer - College

____Club soccer - Elementary School

____Club soccer - High School

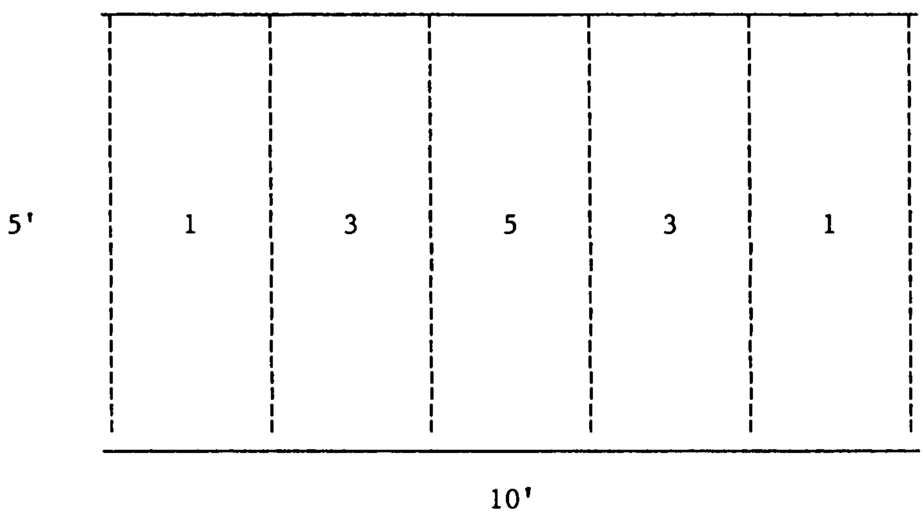
____Club soccer - College

____Varsity Soccer - High School

____Varsity Soccer - College

APPENDIX C

DIAGRAM OF THE TARGET GRID



<u>Figure C-1</u>. Diagram of the target grid.

APPENDIX D

THE TESTING SETTING

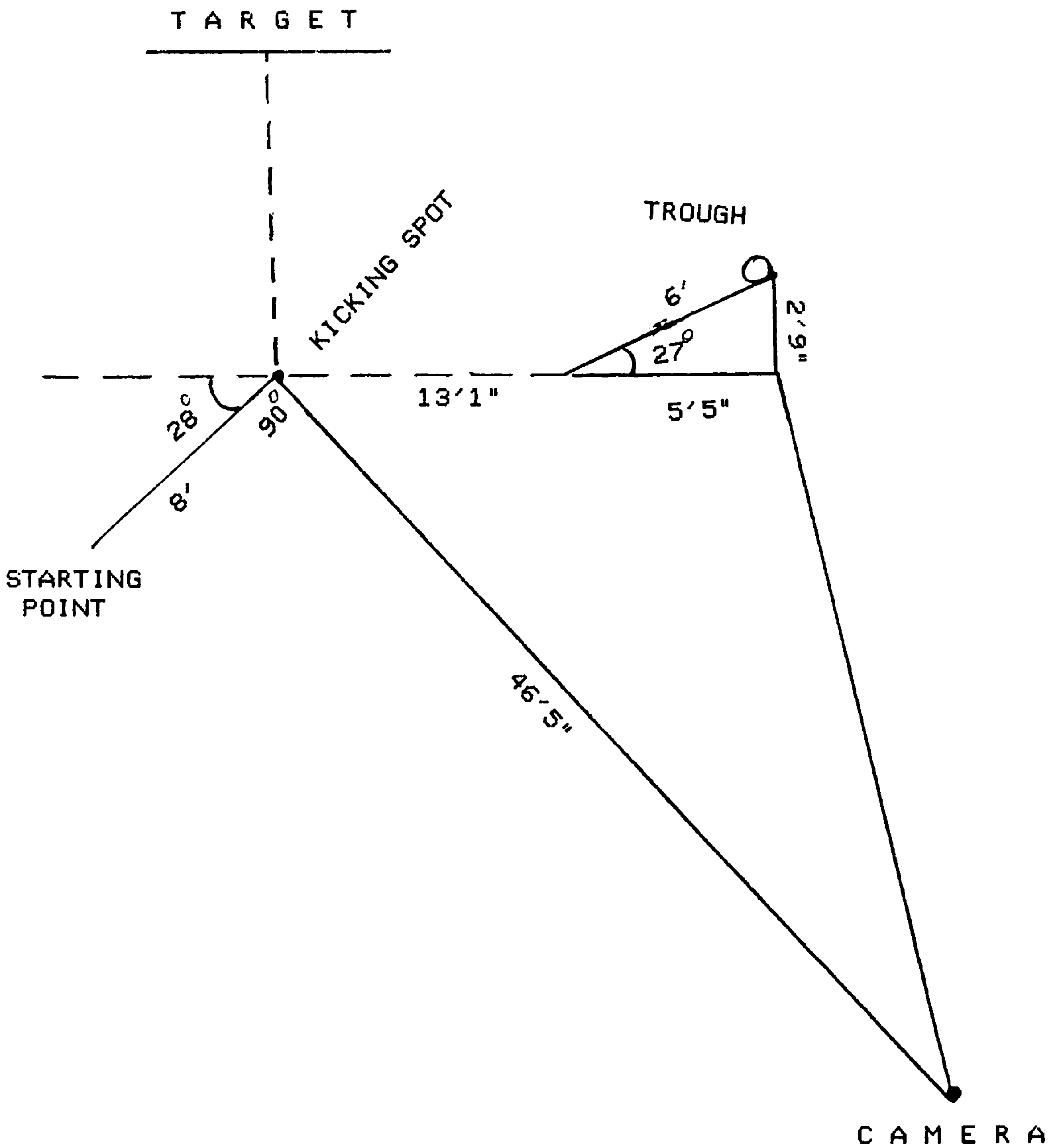


Figure D-1. Diagram of the testing setting.

Figure D-2. Testing setting.

APPENDIX E

WOODEN TROUGH

Figure E-1. Wooden trough.

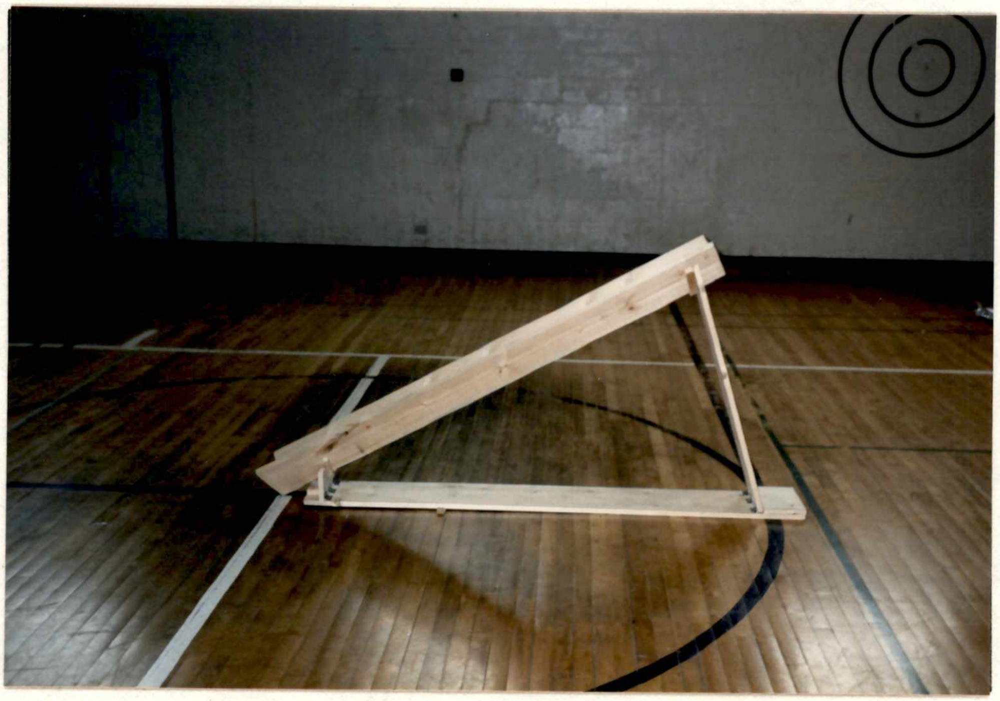


Figure E-2. Wooden trough (side view).

APPENDIX F

FORMS FOR RECORDING DATA

SUBJECT #_____
SEX_____

CLOSED TASK

TRIAL		CONTACT		TIMES IN MOVEMENT PHASES		
#1	C._____ B._____ A._____	START L OR R #STEPS_____ A TO B	SCORE_____	1ST_____ B − A	2ND_____ C − B	TOTAL_____ C − A
#2	C._____ B._____ A._____	START L OR R #STEPS_____ A TO B	SCORE_____	1ST_____ B − A	2ND_____ C − B	TOTAL_____ C − A
#3	C._____ B._____ A._____	START L OR R #STEPS_____ A TO B	SCORE_____	1ST_____ B − A	2ND_____ C − B	TOTAL_____ C − A
#4	C._____ B._____ A._____	START L OR R #STEPS_____ A TO B	SCORE_____	1ST_____ B − A	2ND_____ C − B	TOTAL_____ C − A
#5	C._____ B._____ A._____	START L OR R #STEPS_____ A TO B	SCORE_____	1ST_____ B − A	2ND_____ C − B	TOTAL_____ C − A
#6	C._____ B._____ A._____	START L OR R #STEPS_____ A TO B	SCORE_____	1ST_____ B − A	2ND_____ C − B	TOTAL_____ C − A
#7	C._____ B._____ A._____	START L OR R #STEPS_____ A TO B	SCORE_____	1ST_____ B − A	2ND_____ C − B	TOTAL_____ C − A
#8	C._____ B._____ A._____	START L OR R #STEPS_____ A TO B	SCORE_____	1ST_____ B − A	2ND_____ C − B	TOTAL_____ C − A
#9	C._____ B._____ A._____	START L OR R #STEPS_____ A TO B	SCORE_____	1ST_____ B − A	2ND_____ C − B	TOTAL_____ C − A
#10	C._____ B._____ A._____	START L OR R #STEPS_____ A TO B	SCORE_____	1ST_____ B − A	2ND_____ C − B	TOTAL_____ C − A
		$\underline{X}$=_____ SD_____	TOTAL_____	$\underline{X}$=_____ SD_____	$\underline{X}$=_____ SD_____	$\underline{X}$=_____ SD_____

SUBJECT #_____
SEX_____

OPEN TASK

TRIAL		CONTACT		TIMES IN MOVEMENT PHASES		
	C._____	START L OR R				
#1	B._____	#STEPS_____	SCORE_____	1ST_____	2ND_____	TOTAL_____
	A._____	A TO B		B - A	C - B	C - A
	C._____	START L OR R				
#2	B._____	#STEPS_____	SCORE_____	1ST_____	2ND_____	TOTAL_____
	A._____	A TO B		B - A	C - B	C - A
	C._____	START L OR R				
#3	B._____	#STEPS_____	SCORE_____	1ST_____	2ND_____	TOTAL_____
	A._____	A TO B		B - A	C - B	C - A
	C._____	START L OR R				
#4	B._____	#STEPS_____	SCORE_____	1ST_____	2ND_____	TOTAL_____
	A._____	A TO B		B - A	C - B	C - A
	C._____	START L OR R				
#5	B._____	#STEPS_____	SCORE_____	1ST_____	2ND_____	TOTAL_____
	A._____	A TO B		B - A	C - B	C - A
	C._____	START L OR R				
#6	B._____	#STEPS_____	SCORE_____	1ST_____	2ND_____	TOTAL_____
	A._____	A TO B		B - A	C - B	C - A
	C._____	START L OR R				
#7	B._____	#STEPS_____	SCORE_____	1ST_____	2ND_____	TOTAL_____
	A._____	A TO B		B - A	C - B	C - A
	C._____	START L OR R				
#8	B._____	#STEPS_____	SCORE_____	1ST_____	2ND_____	TOTAL_____
	A._____	A TO B		B - A	C - B	C - A
	C._____	START L OR R				
#9	B._____	#STEPS_____	SCORE_____	1ST_____	2ND_____	TOTAL_____
	A._____	A TO B		B - A	C - B	C - A
	C._____	START L OR R				
#10	B._____	#STEPS_____	SCORE_____	1ST_____	2ND_____	TOTAL_____
	A._____	A TO B		B - A	C - B	C - A
		X=_____	TOTAL_____	X=_____	X=_____	X=_____
		SD_____		SD_____	SD_____	SD_____

APPENDIX G

TABLE OF SUBJECTS' MEAN TOTAL TIMES, LOWEST SCORES DROPPED, AND HIGHEST SCORES DROPPED FOR THE CLOSED AND OPEN TASK

Table G-1

Table of subjects' mean total times, lowest scores dropped, and highest scores dropped for the closed and open task

	Closed Task			Open Task		
Subject	Mean Total Time	Low Time Dropped	High Time Dropped	Mean Total Time	Low Time Dropped	High Time Dropped
1	105.88	67	120	117.13	97	124
2	76.25	67	90	141.88	80	173
3	65.50	60	71	62.88	47	96
4	117.00	104	137	109.75	100	117
5	96.25	53	116	49.63	46	60
6	101.88	93	113	98.38	87	106
7	74.13	60	140	56.50	46	70
8	62.50	60	110	86.38	54	170
9	56.00	56	120	54.25	43	106
10	60.88	56	66	65.13	53	110
11	163.38	127	217	137.75	80	170
12	99.63	90	106	103.63	77	153
13	123.88	117	133	79.75	60	144
14	58.75	56	60	60.88	60	64
15	105.88	78	123	116.25	100	130
16	96.75	87	113	114.00	80	127
17	58.75	56	64	56.50	50	76
18	72.75	66	77	81.63	70	87
19	134.88	117	194	157.88	143	174
20	118.63	70	141	127.75	43	185

* All table values are in hundreths of seconds.
Example: Table value 105.88 = 1.0588 seconds.

APPENDIX H

TABLE OF DESCRIPTIVE STATISTICS

Table H-1

Table of descriptive statistics*

	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	RANGE	STD ERROR OF MEAN
CLOSED TASK						
Mean Total	92.48	29.78	56.00	163.38	107.38	6.66
SD of Total	7.63	6.23	1.64	24.44	22.80	1.39
Mean Approach	75.11	30.27	39.25	150.13	110.88	6.77
SD of Approach	7.54	6.35	1.06	25.27	24.21	1.42
Mean Kicking	17.37	2.18	13.25	20.75	7.50	0.49
SD of Kicking	1.51	0.46	0.00	2.10	2.10	0.10
Total Score	28.75	5.66	17.00	36.00	10.00	1.26
SD of Score	.77	.29	0.46	1.30	0.84	0.06
OPEN TASK						
Mean Total	93.90	33.16	49.63	157.88	108.25	7.41
SD of Total	11.38	9.54	2.29	34.82	32.53	2.13
Mean Approach	76.11	32.37	34.75	138.88	104.13	7.24
SD of Approach	11.16	9.74	2.45	36.44	33.99	2.18
Mean Kicking	17.78	2.66	14.00	24.63	10.63	0.60
SD of Kicking	2.35	0.77	0.52	3.65	3.14	0.17
Total Score	19.95	7.25	7.00	30.00	23.00	1.62
SD of Score	1.59	0.44	0.71	2.33	1.62	0.10

* All table values are in hundreths of seconds.
Example: Table Value 92.48 = .9248 seconds

VITA

Sharron Perkins Bilbrey was born in Knoxville, Tennessee, on June 9, 1951. She attended Blowing Springs Elementary School in Clinton, Tennessee, and was graduated from Clinton Senior High School in June 1969. The following September she entered Emory and Henry College in Emory, Virginia, and in June 1973 she received a Bachelor of Arts degree in physical education. In the fall of 1973 she accepted a teaching assistantship at the University of Tennessee, Knoxville, and began study toward a Master's degree in physical education. This degree was awarded in August 1974.

While employed by Tennessee Technological University in Cookeville, Tennessee, Mrs. Bilbrey re-entered the Graduate School of the University of Tennessee, Knoxville, in September 1983. She received the Doctor of Education degree with a major in physical education in August 1988.

The author is a member of the American Alliance for Health, Physical Education, Recreation and Dance. Mrs. Bilbrey teaches in the Physical Education department and is the head volleyball coach at Tennessee Tech.