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I am submitting herewith a dissertation written by Michael R. Ragsdale entitled "The Effect of Spatial Variability on Discrete Task Transfer." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Education, with a major in Physical Education.

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THE EFFECT OF SPATIAL VARIABILITY ON
DISCRETE TASK TRANSFER

A Dissertation
Presented for the
Doctor of Education
Degree
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Michael R. Ragsdale

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To My Wife

PATRICIA NEILL RAGSDALE

Without whose continued support and
endless encouragement the completion
of this work would have been highly
improbable if not impossible.

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ABSTRACT

The current study investigated Schmidt's (1975) schema theory as it relates to a discrete subject-paced task involving different patterns of spatial variability. Subjects performed a movement of 74.93 centimeters from a specified pushbutton location to a hinged barrier. The spatial pattern of the movement was designated by templates placed on the response platform between the pushbutton and the barrier. Subjects conformed their arm movement to the specified template designs as they attempted to complete the movement distance in 450 milliseconds.

During the experiment subjects (N=36) received 3 practice trials, 30 training trials, and 10 transfer trials. After each trial subjects received quantitative and qualitative knowledge of results regarding their movement time (milliseconds) relative to the desired movement time of 450 milliseconds. Two treatment groups received different training experiences. The high variability treatment group practiced using three different template patterns during the practice and training trials. Subjects in the low variability treatment group practiced and trained using only one of the template patterns. An equal number of males and females were assigned to each group. After training trials both groups transferred to a novel template pattern for the

transfer trials while attempting to hold movement time constant at 450 milliseconds.

Absolute error (AE), algebraic error (CE), and variable error (VE) were calculated on blocks of five trials for both the training and transfer trials. Spatial variability was the independent variable and movement time error (AE, CE, VE) the dependent variable. The AE measurement for the training trials was significantly lower for the low variability treatment group than the high variability group. The AE, CE, and VE measurements computed on the movement time data during the transfer trials indicated that the high variability group performed with significantly less error than the low variability group. This finding suggests that high spatial variability training is beneficial on spatial timing tasks when having to perform a novel movement of a related movement class. Perusal of the data revealed that females had significantly lower AE measurements as compared to males on the transfer trials.

The results of this study supported the variable practice prediction of Schmidt's schema theory. Discussion included how this information can be of benefit to the motor behavior theorist and to teaching practitioners.

TABLE OF CONTENTS

CHAPTER	PAGE
I. INTRODUCTION	1
Statement of Problem	2
Limitations of the Study	4
Assumptions	4
Definition of Terms	4
Significance of Study	8
II. REVIEW OF LITERATURE	10
Schema Theory	10
Tests of Schema Theory	13
Recall Schema	13
Recognition Schema	16
Research With Children	18
The Lordahl and Archer Study	20
Subject Gender	21
Summary	23
III. PROCEDURES	25
Selection of Subjects	25
Selection of Apparatus	25
Methods of Testing	26
Data Collections	31
IV. RESULTS	32
Analysis of Data	32
Results of Analysis	33
Training Trials	33
Transfer Trials	43
Initial Transfer Trial	51
Discussion of Results	56
Training Trials	56
Transfer Trials	58
Initial Transfer Trial	60
Gender Differences	60
Practical Implications	62
V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS	65
Summary	65
Conclusions	67
Recommendations	68

	vii	PAGE
BIBLIOGRAPHY		69
APPENDICES		72
A. INFORMED CONSENT		73
B. MEAN DATA TRAINING TRIALS		75
C. MEAN DATA TRANSFER TRIALS		79
D. MEAN DATA INITIAL TRANSFER TRIAL		82
E. ERROR MEASUREMENT CORRELATIONS FOR TRAINING TRIALS		84
F. ERROR MEASUREMENT CORRELATIONS FOR TRANSFER TRIALS		93
G. ERROR MEASUREMENT CORRELATIONS INITIAL TRANSFER TRIAL		96
VITA		98

LIST OF TABLES

TABLE	PAGE
1. Descriptive Statistics For Absolute Error During Blocks Of Training Trials.....	34
2. Analysis Of Variance For Absolute Error During Training Trials.....	35
3. Descriptive Statistics For Algebraic Error During Blocks Of Training Trials.....	38
4. Analysis Of Variance For Algebraic Error During Training Trials.....	39
5. Descriptive Statistics For Variable Error During Blocks Of Training Trials.....	41
6. Analysis Of Variance For Variable Error During Training Trials.....	42
7. Descriptive Statistics For Absolute Error For Blocks Of Training Trials.....	45
8. Analysis Of Variance For Absolute Error During Transfer Trials.....	46
9. Descriptive Statistics For Algebraic Error For Blocks Of Training Trials.....	49
10. Analysis Of Variance For Algebraic Error During Training Trials.....	50
11. Descriptive Statistics For Variable Error For Blocks Of Transfer Trials.....	52
12. Analysis Of Variance For Variable Error During Training Trials.....	53
13. Descriptive Statistics For Absolute Error For Initial Transfer Trial.....	54
14. Analysis Of Variance For Absolute Error During Initial Transfer Trial.....	55

15.	Descriptive Statistics For Algebraic Error For Initial Transfer Trial.....	55
16.	Analysis Of Variance For Algebraic Error During Initial Training Trials.....	56

LIST OF FIGURES

FIGURE	PAGE
1. Patterns Of The Templates Which Connected The Start Pushbutton To The Barrier During Training Trials.....	27
2. Pattern Of The Template Used To Connect The Start Pushbutton To The Barrier During The Transfer Trials.....	30
3. Groups x Blocks Interaction For Absolute Error During Training Blocks.....	37
4. Groups x Blocks Interaction For Algebraic Error During Training Blocks.....	40
5. Groups x Blocks Interaction For Variable Error During Training Blocks.....	44
6. Groups x Blocks Interaction For Absolute Error During Transfer Blocks.....	47

CHAPTER I

INTRODUCTION

It was the purpose of this study to examine two distinct types of learning situations and the effect of these situations on motor skill acquisition. The performance of both simple and complex motor skills plays an important role in our everyday activities. Regardless of whether we are working, playing, or simply relaxing, it is difficult to do any type of activity which does not involve some type of movement.

An integral part of most physical education programs involves the teaching of motor skills to students. Rarely does a day pass when the physical educator or coach does not provide information to individuals concerning motor skill development and improvement. With the teaching of motor skills being such an important aspect of human performance, it is surprising to find that there are many aspects of teaching and learning taken for granted by the teacher of motor skills. In many instances, physical educators use teaching methods which are based on past traditions rather than on current research findings. This phenomenon is not entirely the fault of the practitioner for much of the current completed research is often difficult to understand and to apply in actual teaching situations.

Recent theorizing in the field of motor behavior offers a refreshing exception to this problem. Of particular

note is Schmidt's (1975) schema theory of discrete motor skill learning. Schmidt has proposed that general motor programs are stored in memory and specific alterations are made to these general programs to meet the demands of any specific movement situation. An important prediction of Schmidt's theory is that variability of practice experiences enhances the learning and performance of motor skills. The current study tested this prediction by varying the spatial demands of a discrete subject paced task during acquisition in order to determine whether higher levels of variability enhanced transfer to a "new" (i.e., previously unpracticed) spatial pattern.

The results of an early study by Lordahl and Archer (1958) using a continuous tracking task suggested that spatial variability may be more important during training than temporal variability. The present investigation attempted to determine the effect of spatial variability during the acquisition of a discrete subject-paced task. Since recent evidence (Kimura, 1973) has revealed that males and females differ in performance on tasks with visual-spatial demands, an equal number of males and females were assigned to each group to additionally determine whether such differences existed in the present situation.

I. STATEMENT OF PROBLEM

The primary purpose of the present study was to determine whether increasing the variability of spatial

patterns experienced during acquisition of a visual-spatial timing task would facilitate transfer to a novel spatial variation of the task. In order to hold temporal factors constant, a fixed movement distance was used for all spatial patterns used in the study. Moreover, subjects were instructed to attempt to make all movements in a time of 450 milliseconds. A secondary purpose was to determine whether differences existed in the training and transfer performance of males and females.

The following research hypotheses were tested:

1. There will be no significant difference for absolute error, algebraic error, or variable error during the training phase of performance by the group who received high spatial variability and the group which received low variability.

2. There will be no significant difference for absolute error, algebraic error, or variable error during transfer performance for the group which received high spatial variability and the group which received low spatial variability during training.

3. There will be no significant difference for absolute error, algebraic error, or variable error during training trials for female subjects and male subjects.

4. There will be no significant difference for absolute error, algebraic error, or variable error during transfer trials for female subjects and male subjects.

5. There will be no significant interactions (i.e.,

blocks, groups, gender) for absolute error, algebraic error, or variable error on the training trials.

6. There will be no significant interactions (i.e., blocks, groups, gender) for absolute error, algebraic error, or variable error on the transfer trials.

II. LIMITATIONS OF THE STUDY

The study was limited to right handed adult male and female subjects living in Knoxville, Tennessee.

III. ASSUMPTIONS

It was assumed that subjects who participated in the study were naive to the task used in the experiment. Also, it was assumed that subjects attempted the task to the best of their ability.

IV. DEFINITION OF TERMS

Absolute Error (AE) - The difference in time (milliseconds) between a desired and an obtained response regardless of the direction of the error (Schmidt, 1975 b). In the present study AE on each trial was the difference between the desired movement time of 450 milliseconds and the actual movement time regardless of the error direction.

Algebraic or Constant Error (CE) - The difference in time (milliseconds) between an obtained and a desired response with respect to the algebraic direction of the error (i.e., positive or negative) (Schmidt, 1975 b). In the present

experiment CE on each trial was the difference between the desired response time of 450 milliseconds and the actual response with respect to the direction of the error.

Movements completed in less than 450 milliseconds were given a negative value while those completed in greater than 450 milliseconds were assigned a positive value.

Block - A specified number of individual trial scores which are grouped together for statistical purposes (Schmidt, 1975 b). In this study individual trial scores were blocked in groups of five for both the training and transfer trials. Absolute error, algebraic error, and variable error were calculated for blocks of five trials.

Cognition - Mental process by which knowledge is acquired (Houston, 1976).

Criterion Task - The standard requirement, skill, or task (Houston, 1976).

High Variability - Describes treatment where a performer receives a variety of experiences on the criterion task during training (Schmidt, 1975 b). In the present study spatial variability of the task was independently manipulated with the high variability group receiving three different spatial versions of the criterion task.

Interstimulus Interval (ISI) - The amount of time available between corresponding stimuli (Cratty, 1973). In the present study a twenty-five second ISI separated the flash of a light which signaled the subject to begin a trial.

Knowledge of Results (KR) - Information given to the performer by the experimenter regarding the extent to which a desired outcome was achieved (Schmidt, 1975 b). In the present study KR was reported as algebraic error (i.e., amount and direction of timing error) in millisecond units.

Low Variability - Describes a treatment condition where subjects during training receive constant exposure to the same practice conditions (Schmidt, 1975 b). In the present study an equal number of low variability subjects were assigned to each of the spatial versions of the training task. Each subject practiced only the version to which they had been assigned throughout the training phase.

Motor Skill - A task which requires the performer to move accurately and requires strength and/or power in various combinations (Cratty, 1973).

Movement Time (MT) - Time from response initiation to response completion (Schmidt, 1975 b). In this study MT was the amount of time between the release of the pushbutton and the dislodging of the barrier.

Reaction Time (RT) - The time between an unanticipated stimulus and the initiation of a response to the stimulus (Schmidt, 1975 b).

Spatial - Pertaining to or limited by space (Guralnik, 1968). In the present study this referred to any of the spatial template patterns which were used during the training or transfer trials.

Template - A pattern or gauge used to make something accurate (Guralnik, 1968). In this experiment a cardboard guide was placed on the response platform between the start switch and the hinged barrier which provided visual and tactile assistance to subjects in making the correct spatial movement.

Temporal - Pertaining to or limited by time (Guralnik, 1968). In the task used in the present study temporal demands were confined to the MT (i.e., 450 milliseconds) in which subjects attempted to perform the response.

Training Scores - Scores or values obtained on the training task (Cratty, 1973). In the current study this referred to the six-five trial blocks which preceded the transfer trials.

Transfer Scores - Scores or values obtained on the transfer task (Cratty, 1973). In the present study this referred to the respective error scores (i.e., AE, CE, VE) calculated on each of the two-five trial blocks which followed the training trials.

Transfer Task - A task performed after the practicing of, or completion of, some previous task (Cratty, 1973). In the current study a novel spatial pattern was employed while the 450 millisecond MT requirement remained unchanged.

Variable Error (VE) - The extent to which a subject fails to repeat his/her responses; one's response in-

consistency (Schmidt, 1975 b). In the current study VE was calculated as the standard deviation of each subject's CE scores for each block of five trials.

Visual-Spatial Timing Task - A task which involves both spatial and temporal components (Cratty, 1973). In the present study subjects were required to visually guide their arm movement along a defined spatial pattern, completing the movement in 450 milliseconds.

IV. SIGNIFICANCE OF STUDY

Schmidt's (1975 a) theory of discrete motor skill learning is one of the few motor learning theories which attempts to explain how motor programs may be stored in memory. Although professional physical education involves the teaching of motor skills, relatively few motor control theories have addressed the issue of how skills are acquired. The majority of studies in the field of motor behavior have centered on the exploration of isolated sport skills (e.g., free throw shooting) and have therefore failed to contribute to a general understanding of the mechanisms of skill acquisition (Cratty, 1973).

Schmidt (1975 a) contends that variability of practice is an important factor for physical educators to consider during the teaching of motor skills. Therefore, the generalizability of the notion of variability of practice has become a very provocative topic for both researchers and practitioners of motor behavior.

Recent research has provided moderate support for Schmidt's theory (e.g., Williams and Rodney, 1978; Moxley, 1979), however, there exists a paucity of information when one considers the potential importance of the theory to the discipline of motor behavior and to the profession of physical education. The majority of studies testing predictions of schema theory have employed either timing tasks or linear positioning tasks (e.g., Newell & Shapiro, 1976; Wrisberg & Ragsdale, 1979). Research with timing tasks have to date varied only the temporal demands of the task, holding spatial variability constant. In light of the fact that many sport and work skills require both spatial and temporal adjustments of the limbs in order to accomplish specific goals (e.g., hitting a baseball), research is needed to determine the role of spatial variability as well as temporal variability in the acquisition of rapid timing tasks. The present study manipulated the spatial variability of a visual-spatial timing task in order to determine whether increasing the variety of spatial experiences during training, facilitated transfer to a novel spatial version of the task.

CHAPTER II

REVIEW OF LITERATURE

This review of literature addressed the topics of (a) schema theory and (b) gender differences as related to motor skill performance. The discussion of schema theory included two broad sections. The first section discusses the principles and concepts upon which the schema theory was developed. The second section includes a review of the experimental research and is subdivided into four categories; (a) recall schema, (b) recognition schema, (c) applied research with children as subjects, and (d) the Lordahl and Archer (1958) study.

The discussion of schema theory is followed by a review of the research which compared the motor skill abilities of females and males. The review of literature concludes with a summary of important research findings addressed in the chapter.

I. SCHEMA THEORY

Bartlett (1932) describes a schema as a collection of information from a particular group of events which leads to the development of a rule governing membership into a particular group. Schmidt's (1975 a) schema theory of discrete motor skill learning borrows heavily from the principles of Bartlett's early schema theory. Schmidt theorized that over practice general motor programs are

stored in memory and specific adjustments are made to these general programs to meet the demands of particular situations.

Schmidt contends that when an individual makes a particular movement in an attempt to satisfy some goal, four types of information are stored in memory: (a) the initial conditions (e.g., information received by the senses prior to the actual response); (b) response specifications (i.e., the specific adjustments which are made to the general motor program); (c) sensory consequences (i.e., afferent feedback received from the senses about the movement); (d) response outcomes (i.e., success of the response in relation to the original goal). These four sources of information are collectively stored after the movement is completed. Schmidt hypothesizes that once a number of movements of a particular movement class (e.g., throwing a ball) have been produced, the individual begins to abstract information about the relationship between the four categories. This relationship essentially becomes the "schema" for generalized movement (e.g., throwing patterns which can be adjusted to meet the demands of a wide variety of situations)(e.g., side arm or overhand throws).

Schmidt elaborates on his theory by stating that movements lasting less than 200 milliseconds in duration cannot rely on peripheral feedback to adjust the movement

once it has been initiated (Keele, 1968; Schmidt, 1972). Two types of memory stores are therefore discussed in the theory to account for the discrepancies which exist when comparing the control of very rapid movements to that of slower self paced responses.

The "recognition memory" is postulated to have primary control of movements lasting in excess of 200 milliseconds, while the "recall memory" is assumed to control movements lasting less than 200 milliseconds. Both recognition and recall memories are predicted to be a function of initial conditions and response outcomes information. However, they differ in that recognition memory is also dependent on "sensory consequences" while recall memory also relies on "response specifications" (Schmidt, 1975 a).

The golf swing provides an example of a task which calls into play both recognition memory and recall memory. The take-away or backswing is a relatively slow movement which would be primarily controlled by the recognition memory. However, the rapid, ballistic downswing takes place in much less time and is controlled primarily by the recall memory. Thus, it should be obvious that the two control systems may not operate independently of each other in all situations. Certain movements, like the golf swing, rely heavily on both recognition and recall memory.

An important prediction of Schmidt's schema theory is that variability of practice facilitates skill acquisition.

Schmidt suggests that a wide variety of experiences leads to increased schema strength and this allows the subject to perform more effectively on subsequent novel forms of the task (i.e., hitting a tennis ball from a position never previously experienced). Schmidt describes schema strength as being a positive function of (a) the number of prior trials on a task, and (b) the variability of experiences during those trials (Schmidt, 1976). This idea of schema strength is applicable when referring to movements under the control of either recall memory or recognition memory. This suggests that the variability of response specifications is of primary importance in developing the recall schema while variability of sensory consequences is important to the development of the recognition schema.

Due in large part to Schmidt's work, the notion of variability of practice has become a popular topic among motor behaviorists and physical educators. Recently, many researchers have tested Schmidt's theory in an attempt to determine the validity of the schema notion.

II. TESTS OF SCHEMA THEORY

Recall Schema

Newell and Shapiro (1976, Experiment 1) conducted an experiment which examined variability of practice as it relates to transfer of training. A lever positioning task was utilized in which subjects attempted to move a lever a

specified distance (10.16 cm) in different periods of time (all less than 200 msec). The experiment was structured so that recall memory could be examined by analyzing the absolute timing error involved in the movement. Perusal of the data indicated that variable practice facilitated transfer to another task only when the response parameters of the transfer task were moderately different from those of the training task. This finding suggests that the degree of transfer between two tasks is not necessarily dependent upon how closely the tasks are related.

In the Newell and Shapiro (1976) study the performance of subjects in the variable practice group was superior to that of the constant practice group when knowledge of results was removed during the transfer trials. This finding supported Schmidt's (1975 a) idea that schema strength is increased by variable practice.

Zelaznik (1977) employed a rapid timing task where movement time was held constant and movement distance was varied. In this study the low variability treatment group trained at one movement distance while the high variability treatment group trained at three movement distances. After training, the two experimental groups transferred to a novel movement distance with movement time remaining constant. The results of the Zelaznik study were in contrast to the schema prediction. However, it should be noted that the low variability group trained closer to the actual transfer movement

distance than did the high variability group. Zelaznik suggested that the findings could be a result of the high variability group developing three distinct schema's for each of the training variations. However, schema theory suggests that variability of practice is effective only in the development of generalized motor programs which presumably are able to accommodate modest variations.

Wrisberg and Ragsdale (1979) tested the schema theory as it relates to coincidence anticipation tasks. The Bassin Anticipation Timing apparatus was used and subjects attempted to make a preferred hand button press response coincident with the lighting of the last of a series of runway lights. Prior to performance with a criterion transfer velocity, subjects received forty training trials in which they either watched or responded with their non-preferred hand to a stimulus moving at either the same speed on each trial or at different speeds from trial to trial. The transfer data revealed that the group which trained with high stimulus-response requirements (i.e., responded with the nonpreferred hand to a variety of stimulus velocities) anticipated and timed the criterion velocity with greater accuracy than any of the other groups. These findings suggest that Schmidt's schema theory may apply to situations in which variability (in this case temporal variations) is imposed by dynamic characteristics of the performance environment.

Recognition Schema

Predating the theorizing of Schmidt, Duncan (1958) conducted a schema type experiment in which a highly cognitive lever positioning task was used. Adult subjects received different degrees of training variability during learning trials. Variability was manipulated by having groups of subjects train at either one, two, five or ten movement pattern variations of the criterion task. The total number of trials was held constant for each of the groups. Duncan discovered that the degree of transfer to novel variations of the same task was positively related to the amount of variability during training. It could be argued, however, that what was learned and transferred were cognitive-conceptual relationships about the task. Therefore, Duncan's results do not necessarily support the schema notion for movement production. Although it should be noted that Duncan's study was not designed as a test of Schmidt's theory, it does, however, concur with Schmidt's schema predictions.

Newell and Shapiro (1976, Experiment 2) utilized a lever positioning task in which subjects moved a lever a specified distance (10.16 cm) in different periods of time. Although the movement times were all less than 200 milliseconds, recognition memory was explored by analyzing the absolute estimated error for each trial (difference between movement time and estimated movement time) and by the correlation of movement time and estimated movement time within

subjects over a series of trials. The results were similar to those of Newell and Shapiro's (1976) first experiment which examined recall memory. During the transfer trials (in which no KR was given) both measures of recognition memory were significantly better for the high variability group than for the low variability group. The results revealed that individuals who transferred outside the range of times were significantly more accurate in estimating their errors than the group who transferred within the practice range. This supports Schmidt's schema theory and counters the argument that the schema may simply represent a range effect (Poulton, 1957). The study also demonstrated that the development of the recognition memory paralleled that of the recall memory and therefore indicated that the two memory systems may not necessarily develop independently of each other.

Research by Williams and Rodney (1978) provided the initial support for Schmidt's Theory, although the study was not designed specifically to test the schema notion. These researchers utilized a linear positioning task which required blindfolded adult subjects to move to defined target locations. One group practiced by moving to the criterion target during training while a second group received randomly arranged targets around the transfer target. After a brief retention interval the "stop" which originally defined the targets was removed and subjects were asked to move the

slide to the criterion location (which for the random group was centrally located among the targets they moved to during training). Of particular significance was the finding that the random condition performed with greater accuracy than the control condition which had been presented the criterion target throughout training. These results suggested that variable practice of a task controlled by the recognition schema is superior to constant repetition of the response. Moreover, the results indicated that subjects need not experience the exact movement previously in order to produce it accurately.

Magill and Reeve (1978) used a lever positioning apparatus where subjects were trained at moving a lever to various physical "stops." The subjects were aware in advance of the distance that the lever would be moved. The adult subjects were divided into three groups; two high variability groups, one trained with more variation from the criterion task than the other, and a low variability group which trained at only one movement distance. Performance on the transfer trials revealed that the group receiving the highest variability performed with significantly less error than did the two other groups. This superiority appearing on the initial transfer trials, offered additional support for Schmidt's (1975 a) variability of practice prediction.

Research With Children

Several studies involving children as subjects

have been conducted which tested the variability of practice hypothesis as it relates to schema development. It was suggested that the motor skills of children are more affected than those of adults in variability of practice experiments (Schmidt, 1976). This could be a result of adults already having well developed schema's for numerous motor programs and children having yet to acquire generalized schema for motor skills.

Kerr and Booth (1977) found that children (age seven through nine) who practiced throwing both long and short distances around a criterion target during training performed significantly better when transferred to the criterion target than children who practiced throwing at the criterion target throughout. These results strongly coincide with those of Williams and Rodney (1978) which were discussed earlier except the task used by Kerr and Booth (i.e., throwing) is presumably under recall memory control while that used by Williams and Rodney (i.e., lever positioning) is under recognition memory control.

In a similar experiment involving children (ages six through eight), Moxley (1979) found that subjects who practiced throwing a shuttlecock from four different locations to a stationary target during training performed significantly better than individuals in a constant location training group when all transferred to a novel location. There was, however, no support for the suggestion that practice variability would stimulate the rate of acquisition

of the criterion task. This fact is illustrated when comparing the error scores of the high and low variability groups during training trials. An interesting point which should be made about both the Kerr and Booth (1977), and the Moxley (1979) study is that the same spatial requirements could be used in all training movements. The amount of force needed to propel the object different distances was the only actual limb variation involved.

The Lordahl and Archer Study

While the previously mentioned studies support Schmidt's theory as it relates to lever positioning and rapid timing tasks, it is clear that no attempts have been made to manipulate spatial variability in the tasks used. One early study which suggests support for the notion that spatial variability might contribute to schema development was conducted by Lordahl and Archer (1958). In an experiment which employed a rotary pursuit apparatus subjects were required to keep a stylus in touch with a revolving metal disk. During training, two groups practiced with a turntable speed which was either faster or slower than the criterion transfer speed (i.e., temporal variability). For these groups the radius of the revolving disk was the same as that used on transfer trials. Two other conditions practiced the criterion transfer speed but attempted to track a moving disk which had a radius which was either larger or smaller than the transfer radius (i.e., spatial

variability). When the performance of each of these groups was compared with that of a control condition which received only the criterion transfer task, higher transfer was found for the spatial component (51% transfer) than for the temporal component (31% transfer).

The Lordahl and Archer (1958) findings suggest that variations in the spatial component of visual-motor tasks may be more beneficial to learning than variations in the temporal components. However, it should be noted that these findings do not directly apply to Schmidt's schema theory. Schmidt (1975) states that tracking tasks (e.g., pursuit rotor) which require a continuous and simultaneous interaction between sensory input and motor output may not be relevant to his theory which addresses primarily discrete movements (i.e., those with a distinct beginning and end). Therefore, there remains a need for additional research testing Schmidt's theory which systematically varies the spatial component during acquisition of a discrete motor skill.

III. SUBJECT GENDER

Subject gender is one of the major individual difference variables affecting human motor performance (Hodgkins, 1963). Although a large amount of research has been conducted in this area, there still remains many unanswered questions as to the contribution of gender to motor performance.

Hodgkins (1963) used a sample of 930 males and females between the ages of 6 and 84 years of age, in a study which explored reaction time and movement time differences between the two genders. Reaction time was measured as the time between a given stimulus and the release of a telegraph key. Movement time was defined as the time between the moment of release of a telegraph key and the moment of contact with a padded rod 23.5 centimeters away. Hodgkins found that after the age of 12 the reaction time and movement time was significantly faster in males than in females.

Broverman, Klaiber, Kobayashi, and Vogel (1968) observed the performance of subjects on a variety of perceptual motor tasks and concluded that (a) females performed superior to males on tasks involving fine manual dexterity, and (b) suggests that females should perform better than their male counterparts on tasks that involve the fine coordination of small muscle groups in conjunction with the perceptual motor process. Examples of these types of tasks would be typing or the drop shot in badminton. These skills require the effective use of small muscle groups. On the other hand, these researchers found that the performance of males is typically superior on tasks involving the large muscle groups. This would mean that males would have an advantage when performing activities like high jumping where the large muscle masses are involved to a greater degree.

Kimura (1973) conducted a series of neurological and visual-spatial tests which revealed several gender differences. Of particular significance to the present study was the discovery that males performed significantly better than females on certain visual spatial tasks. This finding was attributed to the fact that the brain's right hemisphere's specialization which controls visual-spatial activity is more pronounced in males than females. By contrast, females appear to have greater left hemisphere development than males, resulting in greater verbal fluency for females.

Wrisberg, Paul, and Ragsdale (1979) tested male and female subjects on a receptor anticipation task by using a Bassin Anticipation Timer. Subjects responded with a preferred hand button press response coincident with the lighting of the last of a series of runway lights. The results of the study indicated that receptor anticipation of males was more accurate and less variable than that of females. Taken together, the available literature seems to offer inconsistent findings with the only firm fact appearing to be that there are distinct differences in motor performance capabilities of males and females in many types of skills.

IV. SUMMARY

While the majority of the recent research provides at least moderate support for Schmidt's theory, there remains

a paucity of information pertaining to the affects of variations of spatial components during acquisition of discrete motor skills. The majority of the completed research using timing tasks have explored variable practice from the dimension of temporal factors. While there have been studies which explore spatial variability using linear positioning tasks, little research has been conducted which explores how varying spatial aspects of a timing movement affects subsequent task transfer. This is particularly true of rapid subject controlled timing movements. This apparent gap in the schema literature is particularly noteworthy in light of the many sport and work skills which depend upon variable limb movement in accomplishing specific goals (e.g., hitting a baseball).

The present study was specifically concerned with the role of spatial variability in the schema development of a rapid visual-spatial timing task. In addition, an attempt was made to determine whether variations in the spatial components of a timing task during its acquisition differentially influenced the schema development of males and females.

CHAPTER III

PROCEDURES

The procedure used in this study involved the following four areas: (a) selection of subjects, (b) selection of performance apparatus, (c) methods of testing, and (d) data collection.

I. SELECTION OF SUBJECTS

The subjects for this experiment were 36 right handed students and faculty members from the State Technical Institute at Knoxville and the University of Tennessee at Knoxville. All subjects were randomly selected from a pool of volunteers, and then randomly assigned to two treatment groups. Half of the subjects in each condition were males and half females so that this factor could be studied experimentally. Individuals were not included as subjects if they had previous experience with the testing apparatus. None of the subjects were paid for their participation in the experiment. Each subject was asked to sign an informed consent statement upon their decision to participate in the study (Appendix A). The consent form was retained by the researcher.

II. SELECTION OF APPARATUS

A closed-system timing apparatus was utilized in the present study. Subjects placed their right hand on a start pushbutton which, upon release, initiated a digital timing

apparatus (Lafayette Instruments, #63017; Lafayette, Indiana). Time accumulated on the digital display unit until the moment the subject dislodged a hinged barrier which opened an electronic switch attached to the timing apparatus. The pushbutton was located to the right of the barrier and both were mounted on a response platform which was fixed at a height of 137.16 centimeters. Three different pushbutton locations were used in the experiment with each location having a different shaped, 5.04 centimeter wide template "connecting" the pushbutton to the barrier (see Figure 1). There was a constant movement distance of 74.93 centimeters from the pushbutton location to the barrier for each spatial movement pattern used in the experiment.

III. METHODS OF TESTING

Subjects were instructed to stand at a specified location which was marked at the foot of the testing apparatus, so that the barrier was located to the left of center of their body and the pushbutton to the right of center. Each participant was told that the experiment was designed to determine how well they could follow the design of the template with their arm motion and at the same time complete the movement (i.e., pushbutton to barrier following template) in 450 milliseconds. Touch pads were placed on the template to assist the subjects in following the proper motion. The subjects were told that their score on a trial

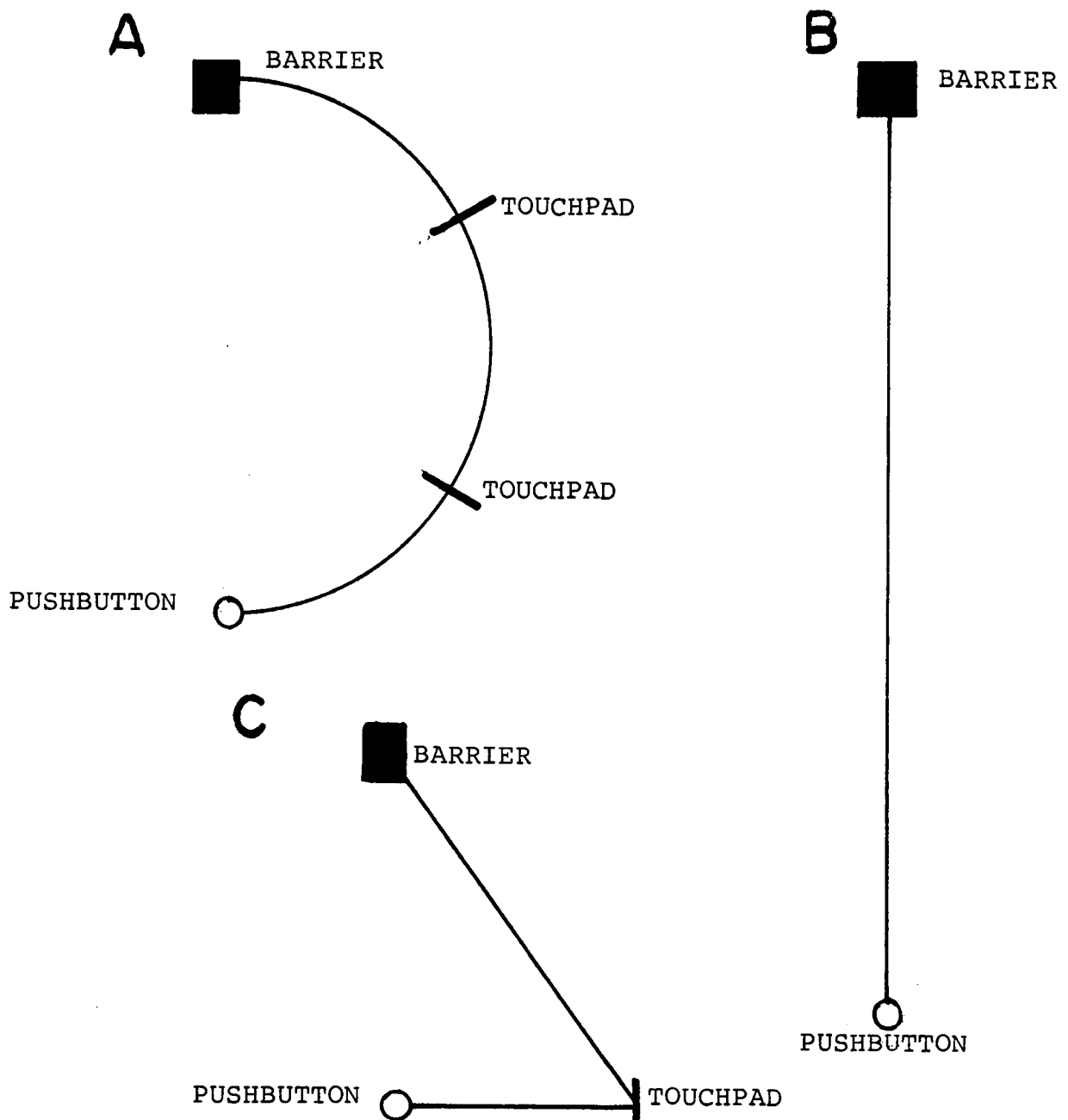


Figure 1. Patterns of the templates which connected the start pushbutton to the barrier during training trials. Each template defined a movement distance of 137.16 centimeters.

would not be counted if the movement was judged by the experimenter to depart from the defined spatial pattern. Subjects who failed to meet spatial requirements on a particular trial were reminded of the task demands and were encouraged to try to remain within the defined pattern. Error trials were repeated at the end of the block.

A combination of quantitative and qualitative knowledge of results pertaining to timing error was given to the subjects after each trial. For example, a movement lasting 460 milliseconds evoked knowledge of results given by the experimenter of "10 milliseconds too slow". Before the testing period the subjects were told that there would be three phases to the experiment: (a) three practice trials, (b) 30 training trials, and (c) 10 transfer trials. Following the three practice trials subjects were reminded of the task requirements and given the opportunity to ask any final questions. If there were no questions, the testing was begun.

A twenty-five second interstimulus interval was used throughout the experiment. This interval was controlled by a program timer (Lafayette Instruments #52020; Lafayette, Indiana) which illuminated a stimulus light for a period of one second at twenty-five second intervals. Subjects were instructed not to react to the light but rather to use the light as a signal for them to produce the movement when ready.

The 36 subjects were randomly divided into two treatment conditions with an equal number of male and female

participants in each group. Individuals in the high spatial variability group received one practice trial with each of three template patterns. Individuals in this group then received ten trials with each of the three spatial movement patterns during the training period. These patterns were distributed randomly with the sole restriction that each pattern be given 10 times in the total of 30 trials. This permitted the group to practice three different arm motions: (a) inside-out, swinging motion, (b) a straight arm motion, and (c) a diagonal motion, (see Figure 1). In order to assure fidelity to each spatial pattern, subjects were required to touch a small foam pad attached at different points on the templates.

Low spatial variability subjects received three practice trials with the spatial pattern which they later experienced during the training trials. Six subjects in this group were randomly assigned to each of the three spatial patterns with the stipulation that an equal number of male and female subjects be assigned to each pattern.

After the thirty training trials all subjects received ten transfer trials on a related, but novel (i.e., previously unpracticed) task (Figure 2). On the novel task subjects were required to touch a pad located to the right of the pushbutton then reverse their movement and proceed to the barrier. Both the timing requirements (450 milliseconds) and total movement distance (74.93 centimeters)

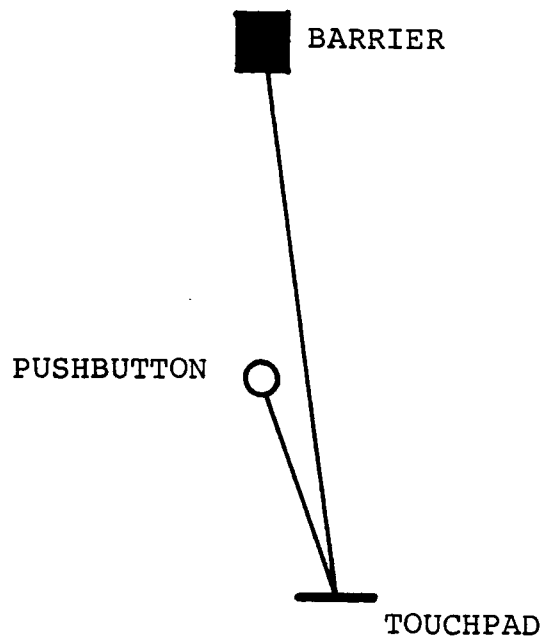


Figure 2. Pattern of the template used to connect the start pushbutton to the barrier during the transfer trials. The template defined a total movement distance of 137.16 centimeters.

remained constant for the training and transfer tasks. These restrictions were made to insure that the novel movement had a similar temporal requirement as the training movements yet differed in spatial demands (Posner and Keele, 1970).

IV. DATA COLLECTIONS

During each of the 43 trials the participants' score for each individual trial was recorded in terms of absolute timing error (AE) and algebraic timing error (CE). Mean absolute error, mean algebraic error and variable error (VE) were calculated on blocks of five trials for the training and transfer scores.

CHAPTER IV

RESULTS

The data were collected and analyzed to determine whether increasing the variability of spatial patterns during the acquisition of a visual-spatial timing task would effect the rate of learning of the task and facilitate transfer to novel spatial variations of the task. Another purpose was to determine whether gender differences existed during the training and transfer segments of the experiment. This chapter includes (a) the methods of data analysis, (b) results of the analyses, and (c) discussion of the results.

I. ANALYSIS OF DATA

A summary of the results gathered in this experiment can be found in Appendices B, C, and D. A three-factor (groups x gender x blocks) repeated measures design Analysis of Variance (ANOVA) was conducted on the six blocks of training scores and the two blocks of transfer scores. Subjects were nested within groups and gender. Separate three-way ANOVAs were conducted on mean absolute error (AE), mean algebraic error (CE) and variable error (VE) for both the training and transfer segments of the experiment. The initial transfer score (Trial 1) was also analyzed using a two-way (groups x gender) ANOVA. Separate ANOVAs were conducted for AE and CE measurements. A Newman-Keuls post-hoc

test was used to locate the source of significant ($p < .05$) differences.

It is well known that AE, CE, and VE are inter-related (Roy, 1976). In order to determine the strength and direction of these relationships during the various phases of this experiment a Pearson product moment correlation test was used to analyze the three error measurements. The results of these computations, while not included in the text of the paper, are provided for the information of the interested reader in Appendices E, F and G.

II. RESULTS OF ANALYSES

Training Trials

Absolute error. Descriptive statistics for the training trials are presented in Table 1. The ANOVA summary table for AE during the training trials is presented in Table 2. When analyzing the scores of the high and low variability groups for the training trials the AE measurement revealed a significant groups effect, $F(1,32)=8.2$, $p < .01$. Subjects assigned to the low variability group had significantly lower AE than subjects in the high variability group.

The AE measurement for blocks was also significant, $F(5,160)=28.3$, $p < .01$. Post-hoc analysis revealed that AE on the initial block (Block 1) was significantly higher than that on the remaining blocks of trials. In addition, the

TABLE 1
DESCRIPTIVE STATISTICS FOR ABSOLUTE ERROR (MSEC)
DURING BLOCKS OF TRAINING TRIALS

BLOCKS

GROUPS	1		2		3		4		5		6		TOTAL	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
High Variability	72	23	61	20	61	18	54	24	40	20	43	24	55	22
Males	69	27	56	22	64	23	56	26	33	16	46	25	54	23
Females	74	18	66	19	58	14	52	23	46	23	38	23	56	20
Low Variability	74	16	57	20	39	17	31	13	34	14	27	13	43	16
Males	73	21	53	27	41	21	34	15	34	15	26	15	43	19
Females	74	10	60	13	36	12	27	11	33	14	27	11	43	10
Total	73	19	59	21	50	21	42	23	37	17	35	20	49	18

TABLE 2
ANALYSIS OF VARIANCE FOR ABSOLUTE ERROR
DURING TRAINING TRIALS

SOURCE	df	SS	MS	F	p
Groups	1	7309	7309	8.2	.001
Gender	1	17	17	.01	.89
Groups x Gender	1	37	37	.04	.83
S (Groups x Gender)	32	28399	887	-	-
Blocks	5	38095	7619	28.3	.001
Groups x Blocks	5	4790	958	3.6	.01
Gender x Blocks	5	1721	344	1.3	.27
Groups x Gender x Blocks	5	591	118	.4	.82
S x Blocks (Groups x Gender)	160	43083	269	-	-
Total	215	124,042	-	-	-

second block of AE scores was significantly higher than the remaining four blocks of scores. The groups x blocks interaction for AE revealed numerous significant differences, $F(5,160)=3.6$, $p<.01$. The majority of these differences can be attributed to the fact that the scores of the low variability group improved more rapidly with practice. The groups x blocks interaction for AE is presented in Figure 3.

Algebraic error. Descriptive statistics and the ANOVA summary table for CE for the training trials are presented in Tables 3 and 4 respectively. The CE measurement revealed no significant groups effect. The same trend of scores improving with training was not as apparent with CE as it was with AE. For CE, there was a significant blocks effect, $F(5,160)=6.0$, $p<.001$, with significantly more overshooting of the criterion movement time occurring on Block 1 than on Block 3 and Block 6. Block 3 also showed significantly less overshooting than Block 5.

There was also a significant groups x blocks interaction for CE, $F(5,160)=2.5$, $p<.05$, (Figure 4). This interaction revealed several significant differences as CE gradually approached zero in both groups over practice.

Variable error. Descriptive statistics for VE are presented in Table 5. The VE ANOVA summary table for the training trials is presented in Table 6. There was no significant groups effect for VE during the training trials. There was, however, a significant effect of blocks, $F(5,160)=$

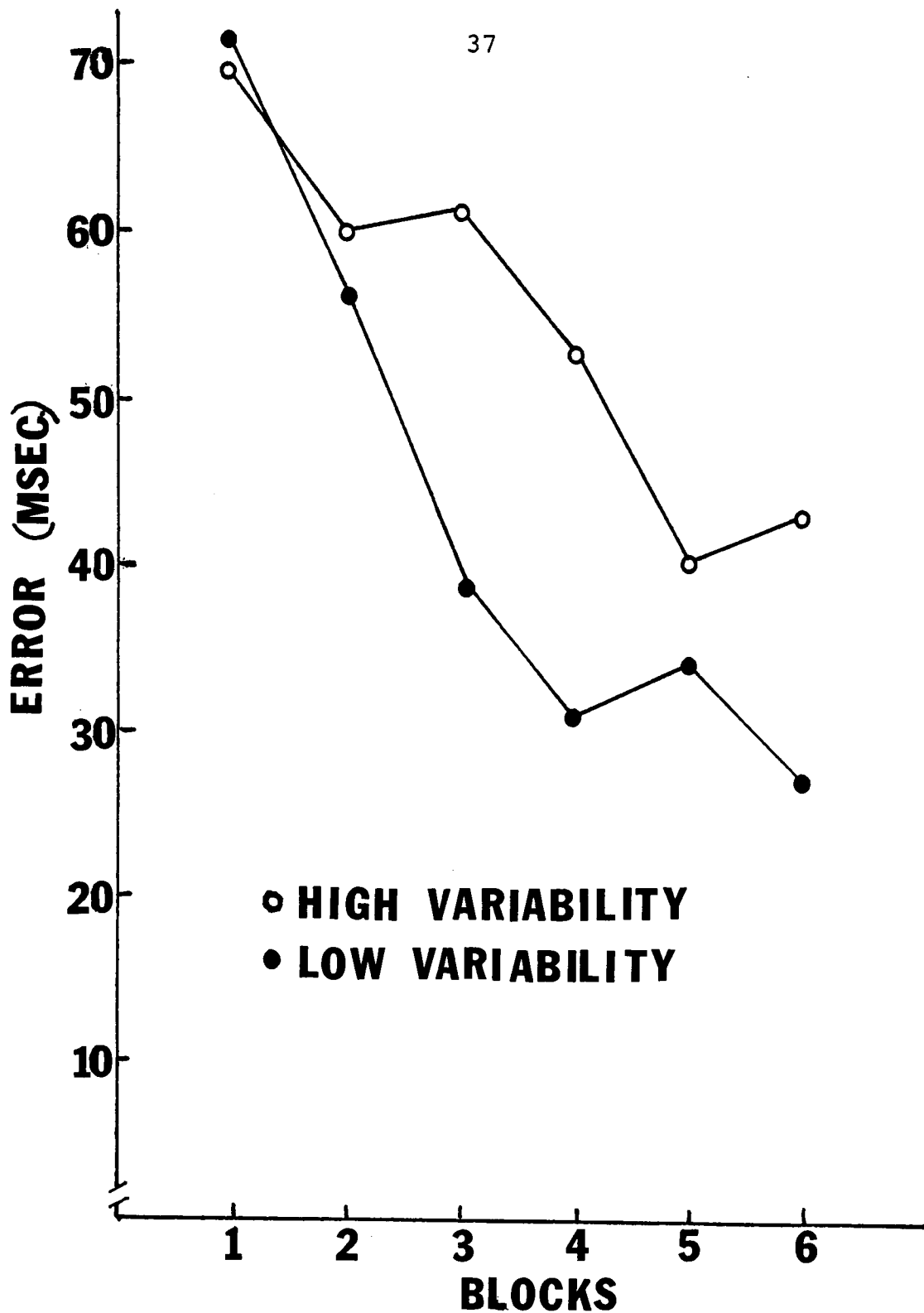


Figure 3. Groups x Blocks interaction for Absolute error (AE) during training blocks.

TABLE 3

DESCRIPTIVE STATISTICS FOR ALGEBRAIC ERROR(MSEC)
DURING BLOCKS OF TRAINING TRIALS

BLOCKS														
GROUPS	1		2		3		4		5		6		TOTAL	
	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD
High Variability	22	48	18	37	-23	38	0	32	15	16	-17	31	2	34
Males	10	47	5	27	-33	36	-4	32	8	16	-14	33	-5	32
Females	33	51	31	47	-13	39	4	33	22	32	-21	28	9	38
Low Variability	17	40	8	29	1	19	11	10	1	10	0	16	6	21
Males	20	39	15	28	8	16	11	15	4	14	-7	16	9	21
Females	15	42	2	30	-6	21	12	5	-3	11	7	17	4	21
TOTAL	20	44	13	35	-11	32	6	24	8	22	-9	26	4	28

TABLE 4
ANALYSIS OF VARIANCE FOR ALGEBRAIC ERROR
DURING TRAINING TRIALS

SOURCE	df	SS	MS	F	p
Groups	1	925	925	.7	.40
Gender	1	1372	1372	1.0	.31
Groups x Gender	1	4507	4507	3.4	.07
S (Groups x Gender)	32	42005	1313	-	-
Blocks	5	26459	5292	6.0	.001
Groups x Blocks	5	10910	2182	2.5	.05
Gender x Blocks	5	224	45	.05	.99
Groups x Gender x Blocks	5	5672	1134	1.3	.26
S x Blocks (Groups x Gender)	160	139953	875	-	-
Total	215	232027	-	-	-

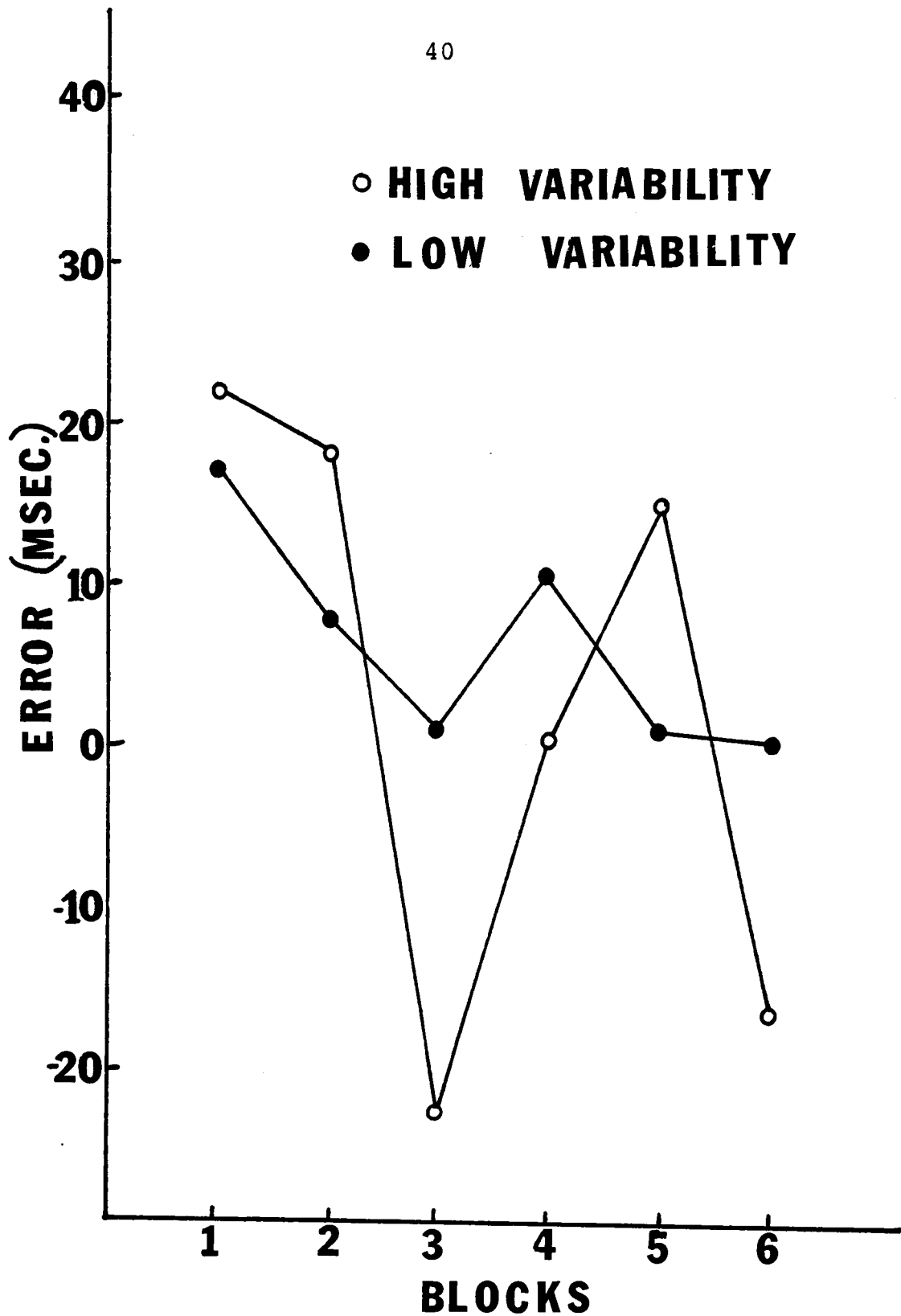


Figure 4. Groups x Blocks interaction for algebraic error (CE) during training blocks.

TABLE 5

DESCRIPTIVE STATISTICS FOR VARIABLE ERROR (MSEC)
DURING BLOCKS OF TRAINING TRIALS

BLOCKS														
GROUPS	1		2		3		4		5		6		TOTAL	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
High Variability	59	24	51	21	56	17	51	21	39	17	43	24	50	21
Males	61	29	58	24	62	15	54	21	35	16	48	29	53	22
Females	58	19	46	18	51	19	49	21	42	19	38	19	41	19
Low Variability	71	21	54	21	40	19	33	15	35	17	28	13	43	16
Males	68	22	48	29	41	27	36	17	32	17	27	15	42	21
Females	73	20	61	13	38	12	29	12	37	17	29	10	45	14
TOTAL	65	23	53	22	48	20	42	17	37	20	35	18	46	19

TABLE 6
ANALYSIS OF VARIANCE FOR VARIABLE ERROR
DURING BLOCKS OF TRAINING TRIALS

SOURCE	df	SS	MS	F	p
Groups	1	2385	2385	2.4	.13
Gender	1	148	148	.1	.70
Groups x Gender	1	890	890	.9	.35
S(Groups x Gender)	32	31664	990	-	-
Blocks	5	22549	4510	16.2	.001
Groups x Blocks	5	6457	1291	4.6	.001
Gender x Blocks	5	1099	220	.8	.56
Groups x Gender x Blocks	5	1091	218	.8	.56
S x Blocks (Group x Gender)	160	44428	278	-	-
Total	215	110711	-	-	-

16.2, $p < .001$. The VE for Block 1 was significantly higher than that for the remaining blocks of trials. In addition, VE for Block 2 was significantly higher than for Blocks 4, 5, and 6. The groups x blocks interaction was significant, $F(5,160) = 4.6$, $p < .001$. This interaction is presented in Figure 5.

No other main or interaction effects proved to be significant for the training scores. The Pearson product moment technique revealed numerous significant correlations between the three error measurements for both main and interaction effects. Correlations for the training phase of the experiment are presented in Appendix E.

Transfer Trials

Absolute error. Descriptive statistics for AE performance during the transfer trials are presented in Table 7. The AE ANOVA summary table for the transfer trials is presented in Table 8. The AE measurement revealed a significant groups effect, $F(1,32) = 29.5$, $p < .001$, with the high variability group having a lower AE than the low variability group. The block scores for the transfer trials followed a similar pattern as that observed during training trial blocks. There was a significant blocks effect for AE, $F(1,32) = 17.8$, $p < .001$, with AE on Block 1 being significantly lower than Block 2.

There was also a significant groups x blocks interaction, $F(1,32) = 5.6$, $p < .05$, (Figure 6). The AE for low

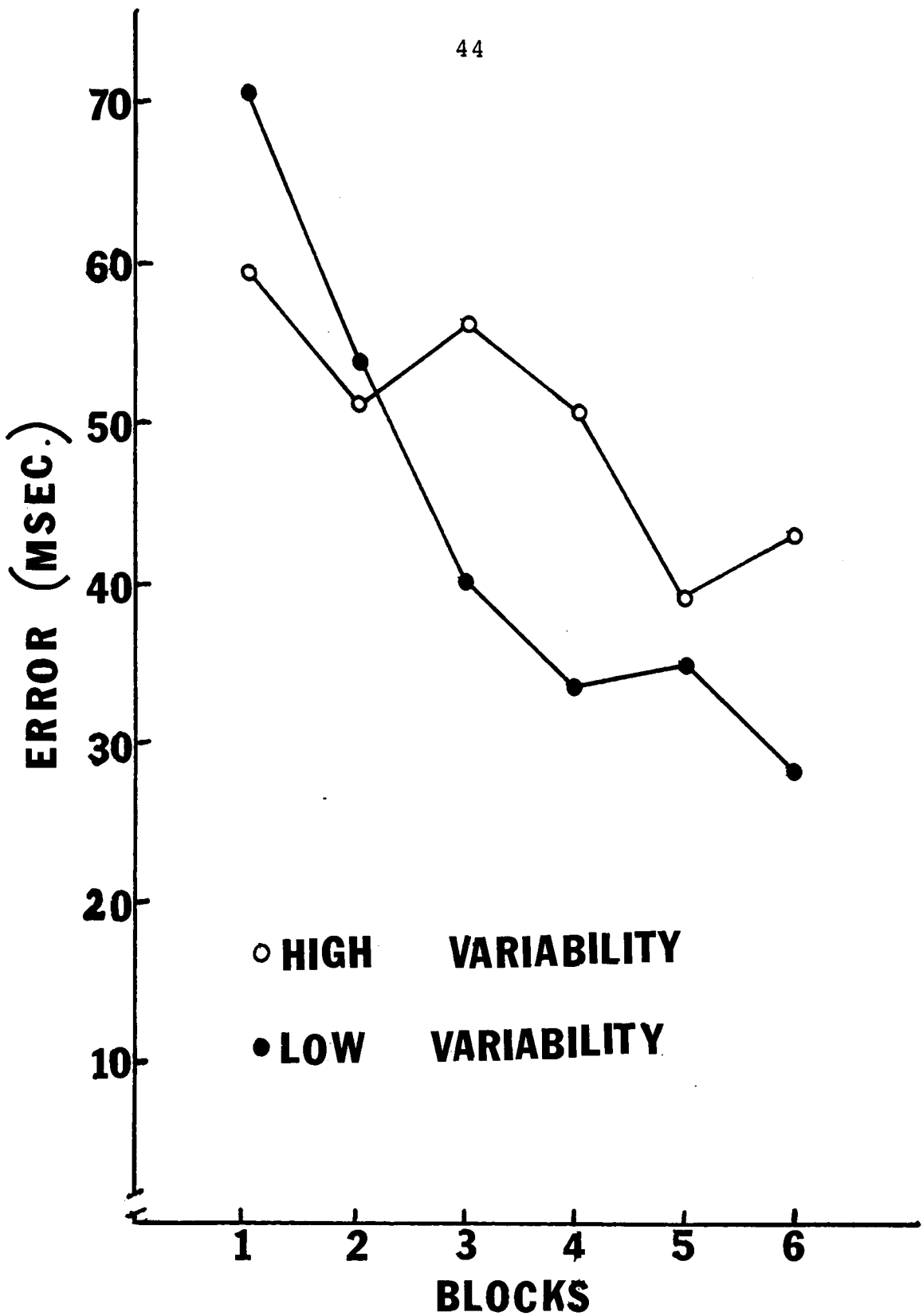


Figure 5. Groups x Blocks interaction for Variable error (VE) during training blocks.

TABLE 7
DESCRIPTIVE STATISTICS FOR ABSOLUTE ERROR (MSEC)
FOR BLOCKS OF TRAINING TRIALS

BLOCKS

GROUPS	1		2		TOTAL	
	X	SD	X	SD	X	SD
High Variability	28	11	24	8	26	10
Males	26	9	21	9	23	9
Females	30	13	27	7	28	10
Low Variability	58	22	42	13	50	8
Males	63	25	49	20	56	23
Females	52	19	36	5	44	12
TOTAL	43	23	33	16	38	12

TABLE 8
ANALYSIS OF VARIANCE FOR ABSOLUTE ERROR
DURING TRANSFER TRIALS

SOURCE	df	SS	MS	F	p
Groups	1	10337	10337	29.5	.001
Gender	1	204	204	.6	.45
Groups x Gender	1	1341	1341	3.8	.05
S (Groups x Gender)	32	11237	351	-	-
Blocks	1	1693	1693	17.8	.001
Groups x Blocks	1	535	535	5.6	.02
Gender x Blocks	1	2	2	.02	.89
Groups x Gender x Blocks	1	19	19	.2	.66
S x Blocks (Groups x Gender)	32	3039	95	-	-
Total	71	28407	-	-	-

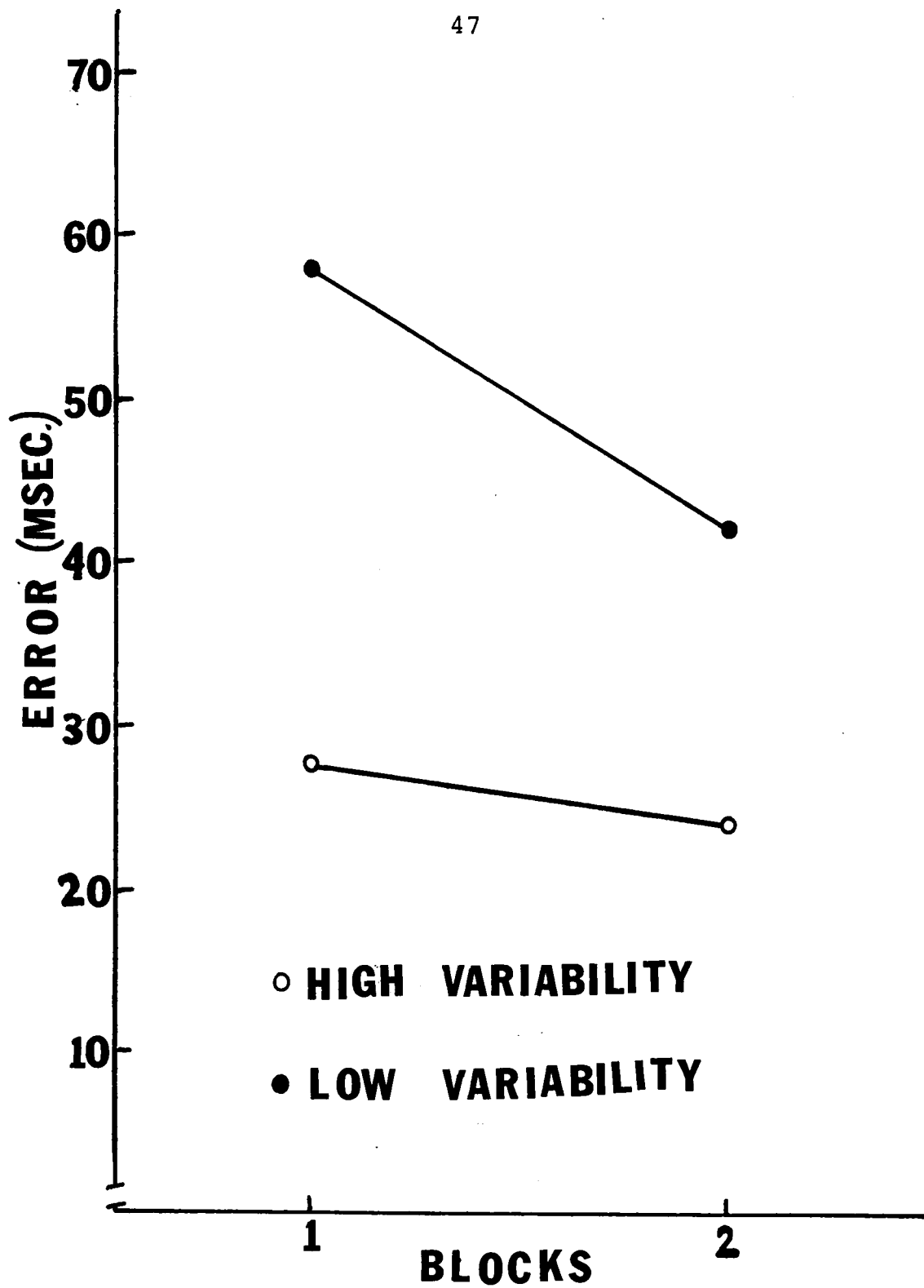


Figure 6. Groups x Blocks interaction for absolute error (AE) during transfer blocks.

variability subjects in Block 1 was significantly higher than that for the other group x block combinations. Although the AE scores of the low variability group improved significantly over blocks, both Block 1 and Block 2 scores of this group were significantly higher than that on both blocks for high variability subjects.

The groups x gender interaction was also significant, $F(1,32)=3.8$, $p<.05$. Low variability males had significantly higher AE than did any of the other group x block combinations. Moreover, low variability females had significantly higher AE than both high variability females and high variability males.

Algebraic error. Descriptive statistics for CE on the transfer blocks are presented in Table 9. The ANOVA summary table for CE is given in Table 10. There was a significant groups effect, $F(1,32)=7.6$, $p<.01$, with the high variability group performing with significantly less error than the low variability group. The CE scores for the transfer blocks followed a similar pattern as that of the AE scores. There was also a significant blocks effect, $F(1,32)=3.8$, $p<.05$, with CE on Block 1 being significantly higher than on Block 2. More specifically, there was significantly less overshooting of the criterion movement time on Block 2 than Block 1. There was no significant groups x blocks interaction for CE.

There was, however, a significant groups x gender interaction for the transfer blocks, $F(1,32)=5.8$, $p<.05$. Low variability males had significantly more positive CE

TABLE 9
 DESCRIPTIVE STATISTICS FOR ALGEBRAIC ERROR (MSEC)
 FOR BLOCKS OF TRAINING TRIALS

GROUPS	BLOCKS					
	1		2		TOTAL	
	X	SD	X	SD	X	SD
High Variability	8	16	6	9	7	13
Males	4	12	4	8	4	10
Females	12	20	9	10	10	10
Low Variability	30	34	16	20	23	26
Males	42	29	26	22	34	24
Females	18	35	6	18	12	18
TOTAL	19	28	11	18	15	17

TABLE 10
ANALYSIS OF VARIANCE FOR ALGEBRAIC ERROR
DURING TRAINING TRIALS

SOURCE	df	SS	MS	F	p
Groups	1	4756	4756	7.6	.01
Gender	1	1040	1040	1.7	.20
Groups x Gender	1	3630	3630	5.8	.05
S (Groups x Gender)	32	19951	623	-	-
Blocks	1	1070	1070	3.8	.05
Groups x Blocks	1	687	687	2.4	.07
Gender x Blocks	1	.5	.5	0	.97
Groups x Gender x Blocks	1	47	47	.2	.69
Sx Blocks (Groups x Gender)	32	8995	281	-	-
Total	71	40176.5	-	-	-

(i.e., greater overshooting) than did any of the other groups x gender combinations.

Variable error. Descriptive statistics and the ANOVA summary table for VE are presented in Tables 11 and 12, respectively. The variable error measurement showed a significant difference between groups, $F(1,32)=23.0$, $p<.001$, with the high variability group having lower VE than the low variability group. The effect of blocks was also significant, $F(1,32)=4.7$, $p<.05$, with VE improving from Block 1 to Block 2. Results of the Pearson product moment correlation calculations are presented in Appendix F.

Initial Transfer Trial

The initial transfer trial, in addition to being analyzed as a part of Block 1, was also analyzed separately. This analysis was conducted because the initial transfer trial represented the "purest" transfer measure, not being influenced by knowledge of results as were the other transfer trials.

Absolute error. Descriptive statistics for AE are given in Table 13. The ANOVA performed on this measure (Table 14) revealed a significant effect of groups, $F(1,32)=32.7$, $p<.001$, with AE for the high variability group having significantly lower error than the low variability group. Female subjects had lower AE than males. In addition, a significant groups x gender interaction, $F(1,32)=5.7$, $p<.05$, indicated that low variability males had significantly higher AE than did any of the other group x gender combinations. In

TABLE 11
 DESCRIPTIVE STATISTICS FOR VARIABLE ERROR (MSEC)
 FOR BLOCKS OF TRANSFER TRIALS

GROUPS	BLOCKS					
	1		2		TOTAL	
	X	SD	X	SD	X	SD
High Variability	28	11	28	11	28	11
Males	27	11	23	10	31	11
Females	30	12	33	12	25	12
Low Variability	52	20	52	10	47	15
Males	54	21	46	12	50	17
Females	50	19	37	8	43	13
TOTAL	40	20	35	13	37	13

TABLE 12
ANALYSIS OF VARIANCE FOR VARIABLE ERROR
DURING TRAINING TRIALS

SOURCE	df	SS	MS	F	P
Groups	1	6309	6309	23.0	.001
Gender	1	.1	.1	0	.98
Groups x Gender	1	789	789	2.9	.10
S (Groups x Gender)	32	8776	274	-	-
Blocks	1	508	508	4.7	.05
Groups x Blocks	1	392	392	3.6	.07
Gender x Blocks	1	3	3	.03	.87
Groups x Gender x Blocks	1	127	127	1.2	.29
S x Blocks (Groups x Gender)	32	3467	108	-	-
Total	71	20371.1	-	-	-

TABLE 13
 DESCRIPTIVE STATISTICS FOR ABSOLUTE ERROR (MSEC)
 FOR INITIAL TRANSFER TRIAL

GROUPS	$\bar{X}$	SD
High Variability	29	29
Males	28	13
Females	31	15
Low Variability	83	34
Males	104	34
Females	62	34
TOTAL	56	24

TABLE 14
ANALYSIS OF VARIANCE FOR ABSOLUTE ERROR
DURING INITIAL TRANSFER TRIAL

SOURCE	df	SS	MS	F	p
Groups	1	25814	25814	32.7	.001
Gender	1	3481	3481	4.4	.05
Groups x Gender	1	4489	4489	5.7	.05
S (Groups x Gender)	32	25268	790	-	-
Total	35	59052	-	-	-

TABLE 15
DESCRIPTIVE STATISTICS FOR ALGEBRAIC ERROR (MSEC)
FOR INITIAL TRANSFER TRIAL

GROUPS	$\bar{X}$	SD
High Variability	3	14
Males	2	13
Females	4	15
Low Variability	60	34
Males	83	34
Females	37	34
TOTAL	32	24

addition, the low variability female group had significantly higher AE than did the high variability groups of either gender.

Algebraic error. Descriptive statistics and the ANOVA summary table for CE on the transfer trial are presented in Tables 15 and 16, respectively. There was a significant effect of groups, $F(1,32)=9.9$, $p<.01$, with the high variability group having significantly lower CE than the low variability group. The results of the Pearson correlation test for the three error measurements on the transfer trial are presented in Appendix G.

III. DISCUSSION OF RESULTS

Training Trials

This study provided no support for the suggestion that practice variability during the training trials would facilitate performance on those trials. The AE for the low variability group was superior to that of high variability subjects during the training trials. The CE scores were generally cancelled out due to contrasting positive and negative scores with only a slight positive CE obtained during training trials. These results are not unexpected due primarily to the fact that the low variability group did not vary their spatial movement patterns during the training trials. While the low variability groups' AE was lower on the training trials, these subjects were not experiencing

TABLE 16
ANALYSIS OF VARIANCE FOR ALGEBRAIC ERROR
DURING INITIAL TRAINING TRIALS

SOURCE	df	SS	MS	F	p
Group	1	30034	30034	9.9	.01
Gender	1	4312	4312	1.4	.24
Group x Gender	1	5136	5136	1.7	.20
S (Group x Gender)	32	97506	3047	-	-
Total	35	136988	-	-	-

the variability necessary, in Schmidt's (1975 a) terms, to acquire schema strength on the task. This present finding corresponds with the previously discussed research of Moxley (1979) who found that the low variability treatment group performed with less error on the training trials than did the high variability group. If an individual's goal is to perform only one well-defined movement, then variable practice may not be of benefit. However, many tasks and games often involve the performance of variations of some original task (e.g., shooting a basketball). In these cases variable practice might be expected to be more beneficial in the learning of the skill.

Transfer Trials

The most noteworthy finding in this study was the significantly lower error measurements (AE, CE, VE) for the high variability treatment group as compared to the low variability group on the transfer trials. The AE of the high variability group was significantly lower than that of the low variability group on both transfer blocks. While the scores of the low variability subjects improved with practice over the two transfer blocks, their AE performance never reached the level obtained by the high variability subjects.

Both CE and VE measurements also revealed significant differences favoring the high variability subjects. While there was no significant groups x blocks interaction on the transfer scores for these two error measurements, there was

a significant effect of groups, indicating a consistent superiority of performance by the high variability group across these blocks. This finding conflicts with the results of the Moxley (1979) study in which subjects receiving high variability treatment performed superior only on the initial transfer trial. One reason for the discrepancy between results of the two experiments might be due to the different types of tasks employed. Moxley used a simple throwing task while the present study employed a more complex visual-motor timing task. It seems that task complexity may be an important variable determining the extent to which schema strength acquired during high variability training provides assistance on subsequent trials of a novel task. Therefore, it might be predicted that the more complex the task, the longer it would take a low variability group to reach the performance level of a high variability group upon transfer to a new version of the task.

Another important difference in the present study and that of Moxley (1979) pertained to the age of the subjects used. It is possible that adult subjects benefit to a greater extent from spatial variation during the acquisition of a motor skill. However, an age x task complexity interaction could also be possible.

Individuals who receive low variability training may have difficulty in establishing well-defined boundaries in which to perform movements never before experienced.

Results of the present study as well as those of other research (Newell and Shapiro, 1976; Wrisberg and Ragsdale, 1979) suggest the possibility that subjects who receive low variability training may in Schmidt's (1975 a) terms never achieve the schema strength necessary to perform as well on novel tasks as high variability subjects. Of course, practice on any novel task will, in time, override any type of prior experience.

The results of this study coincide with the previously discussed research of Lordahl and Archer (1958) who found a higher transfer of spatial components than of temporal components in a visual-spatial tracking task. Therefore, it might be argued that the temporal components of a variety of motor skills are more invariant (i.e., benefit less from variability of practice) than the spatial components.

Initial Transfer Trial

Support for schema theory was best illustrated on the initial transfer trial. Subjects receiving the high variability treatment had significantly lower AE and less positive CE than did the low variability group. Previously discussed research by Moxley (1979) and Williams and Rodney (1978) also reported lower error on the initial transfer trial.

Gender Differences

A second objective of this study was to evaluate

the interaction of gender differences with training schedules on the performance of a discrete subject-paced task. In this regard there was evidence of a difference in performance as a function of subject gender, albeit mild. While no significant effect of gender was found during training trials there was a significant gender effect for AE on the initial transfer trial. On this trial female subjects performed with lower AE than male subjects. In addition, there was a significant groups x gender interaction for both AE and CE measurements on the transfer blocks. In each case the low variability male group had higher error than the other three groups x gender combinations. Moreover, the low variability female group performed with significantly higher error than did the high variability groups of either gender. Thus, it might be argued that high spatial variability training benefited males more than it did females.

Admittedly, gender differences in performance are often difficult to interpret. The research of Broverman (1968) and others provides information suggesting the superiority of females on perceptual-motor tasks involving manual dexterity and the small muscle groups. The visual-motor timing task used in the present study involved the use of the small muscle groups in the arm and hand and this could possibly be the reason for the higher performance of females on the transfer trial. On the other hand, females did not perform with less error than

males on the training trials. Therefore, it is difficult to explain the gender difference on the transfer trial. However, it is possible that the particular spatial variation of the task used during transfer performance was the only one with sufficient manual dexterity to differentiate the performance of males and females.

The results of the present study are in conflict with the findings of Kimura (1973) who reported that males were superior to females on various types of visual-spatial tasks. Kimura offered a neurological explanation for her findings, noting that males possess more pronounced right-hemisphere brain specialization than females. In summarizing these gender differences it becomes apparent that there is a need for more basic psychological research examining differences in performance as a function of subject gender. One important difference in the nature of the visual-spatial task used in this and Kimura's studies was the requirement of a limb movement in conjunction with a timing demands in the present study.

Practical Implications

The principles of schema theory in conjunction with this research provide interesting possibilities for physical education teachers and for coaches. Schmidt (1976) suggests that it is important to develop a general base of motor skills prior to developing more specific sports skills. For example, it might be important to learn to

effectively hit a tennis ball in a variety of spatial locations before attempting to play tennis. Traditionally when teaching a person to play tennis the instructor continually provides opportunities for the student to make contact with the ball at basically the same spatial location. This practice continues until the student can perform this task in a proficient manner. This type of training allows the student to achieve a relatively fast measure of success, however, it is difficult to adapt the swing to meet the various spatial demands necessary to play the game successfully.

Instead of using the traditional teaching method it might be better to use a teaching plan based on schema principles. The instructor could provide increased spatial variability during the students' initial training. This could be accomplished by either tossing or hitting the ball to the student at a variety of spatial locations (e.g., high, low) and allowing the performer to swing at the ball at various spatial points. This type of practice would result in an initial performance which would be less than if the student practiced hitting the ball at only one primary location (e.g., waist height). However while the initial performance level may be lower in high variability practice situations, the student would be receiving experience in hitting the ball at various spatial points. According to Schmidt (1975 a) this type of practice would

promote the development of schema strength. This would enable the individual to perform more proficiently on a variety of tennis type responses when playing an actual game of tennis which among other things requires contact with the ball at a variety of spatial locations.

The underlying thought behind this method of teaching is based on research which suggests that schema strength is developed through variable practice and this strength enables individuals to perform better on novel variations of some original task (e.g., hitting a tennis ball from a position never before experienced). The goal of tennis instruction is to teach individuals to play the game of tennis, not to be able to successfully make racket contact with the ball at one spatial position. Tennis is a game involving high degrees of spatial variability, so naturally the spatial variability component should be included in practice sessions.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

I. SUMMARY

It was the primary intent of this study to determine whether increasing the variability of spatial patterns experienced during acquisition of a visual-spatial timing task would enhance transfer to a novel spatial variation of the task. A secondary objective of the study was to determine whether differences existed in the training and transfer performance of males and females.

Thirty-six right-handed students and faculty members from the State Technical Institute at Knoxville and the University of Tennessee served as subjects for the study. All subjects were randomly selected from a pool of volunteers.

A closed-system timing apparatus was used in the study. Subjects placed their right hand on a start pushbutton which preset the system. Upon initiation of the movement (i.e., lifting the finger from the pushbutton) time accumulated on a digital clock until the subject dislodged a hinged barrier. A spatial template defined the movement path between the pushbutton and barrier on each trial with a constant movement distance of 74.93 centimeters being used throughout the study.

Subjects were instructed to follow the design of the specified template and complete the movement (i.e., pushbutton to barrier following template) in 450 milliseconds. A combination of quantitative and qualitative knowledge of results pertaining to timing error (in milliseconds) was given to the subjects after each trial. There were three phases to the experiment: (a) three practice trials, (b) 30 training trials, and (c) 10 transfer trials. An interstimulus interval of twenty-five seconds was used throughout the experiment.

The subjects were randomly divided into two treatment groups with an equal number of male and female participants in each group. Subjects assigned to the high spatial variability group experienced three distinct spatial patterns during the practice and training trials while the low variability spatial group experienced only one of the three spatial patterns during these trials. An equal number of subjects in this group were assigned to each of the three possible spatial patterns. After completion of the training trials all subjects received ten transfer trials on a novel, but related spatial variation of the task.

Mean absolute error (AE), mean algebraic error (CE), and variable error (VE) were calculated on the training and transfer data. Separate three-way analyses of variance (groups x gender x blocks) were conducted for each error measurement on five-trial blocks for both the training and transfer sections. In addition, a two-way ANOVA (group x

gender) was performed on AE and CE scores for the initial transfer trial. Newman-Keuls post-hoc tests were used to determine the location of significant differences. A Pearson Product-Moment correlation technique was utilized to determine the strength and direction of relationships between the error measurements during the training and transfer trials.

The most noteworthy finding in the study was the significantly lower error measurements (AE, CE, VE) for the high variability treatment group as compared to the low variability group on the transfer trials. The results also indicated evidence of gender differences favoring female subjects on transfer trials. The Pearson correlation technique revealed numerous significant correlations between the error measurements during the training and transfer trials. These correlations appear in Appendices E, F, and G.

II. CONCLUSIONS

Based on this study the following conclusions were drawn:

1. Low spatial variability training is more beneficial than high spatial variability training when it is the goal of the performer to learn only one well-defined spatial movement.

2. High spatial variability training results in

higher transfer to a novel spatial variation of a visual-spatial, timing task than does low spatial variability training.

3. On a visual-spatial timing task involving complex, fine-motor movements females perform more effectively than males.

III. RECOMMENDATIONS

1. There is a need for additional research which tests the validity of Schmidt's (1975) schema theory of discrete motor skill learning. Of particular importance will be experiments which systematically vary both the spatial and temporal components of a visual-spatial timing task. Research of this nature could provide evidence as to whether spatial or temporal variability is most important in the learning of visual-spatial timing tasks. This type of investigation could more accurately determine whether the results of Lordahl and Archer (1958) apply to tasks other than tracking tasks.

2. There is a need for continued neurological, behavior, and neuropsychological research investigating the factors which cause gender differences in the performance of motor tasks. Numerous studies have reported gender differences on various types of motor skills, however few viable theories have been proposed to explain these differences.

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APPENDICES

APPENDIX A
INFORMED CONSENT

CONSENT FORM

I, _____, hereby volunteer to participate in a research study examining the effect of spacial variability on discrete task transfer. I understand that the motor task involved will include a simple arm motion from a pushbutton to a hinged barrier.

I understand that there will be 43 trials involved in the experiment, and the testing period will last approximately 30 minutes.

Other details of the project have been explained and I have had an opportunity to have my questions answered. I understand that I can expect to have further questions answered before continuing participation and I am free to withdraw my consent and to discontinue participation in the project at any time without penalty.

Participant's Signature: _____

Date: _____

Experimenter's Name: Michael R. Ragsdale

Experimenter's Phone number: 584-6103

APPENDIX B
MEAN DATA TRAINING TRIALS

Training Trials Data Listing the Means Scores for each Main Effect and Interaction Involved in the Analysis. Measurements for Absolute Error (AE), Algebraic Error (CE), and Variable Error (VE) are given in Milliseconds.

MEANS								
GROUPS		AE	CE	VE	GENDER	AE	CE	VE
High Variability (HV)		54.9	2.3	50.0	Female	49.3	6.9	45.9
Low Variability (LV)		43.2	6.4	43.3	Male	48.8	1.9	47.5
GROUPS X GENDER		AE	CE	VE	BLOCKS	AE	CE	VE
HV - Females		55.6	9.4	41.2	1	72.6	19.7	65.0
HV - Males		54.2	-4.8	52.8	2	58.7	13.1	53.1
LV - Females		43.1	4.4	44.6	3	49.9	-11.0	47.9
LV - Males		43.4	8.5	42.2	4	42.2	5.6	42.0
					5	36.7	7.7	36.8
					6	34.5	-8.8	35.3

MEANS

GROUPS X BLOCKS	AE	CE	VE	GENDER X BLOCKS	AE	CE	VE
HV - 1	71.8	22.8	59.4	FEMALE (F) - 1	74.2	24.1	65.5
HV - 2	60.8	17.8	51.7	F - 2	62.9	16.3	53.2
HV - 3	61.1	-23.1	56.1	F - 3	47.0	-9.6	44.3
HV - 4	53.7	-.1	51.4	F - 4	39.4	7.9	38.9
HV - 5	39.7	14.6	38.6	F - 5	39.7	9.5	39.7
HV - 6	42.5	-17.3	42.6	F - 6	32.9	-6.9	33.4
LV - 1	73.5	17.4	70.5	MALE (M) - 1	70.9	15.3	64.4
LV - 2	56.5	8.3	54.4	M - 2	54.4	9.8	52.9
LV - 3	38.7	1.1	39.6	M - 3	52.7	-12.3	51.4
LV - 4	30.6	11.4	32.6	M - 4	44.9	3.3	45.1
LV - 5	33.7	.7	34.8	M - 5	33.7	5.8	33.8
LV - 6	26.5	-.3	28.0	M - 6	36.1	-10.7	37.3

MEANS

GROUPS X GENDER X BLOCKS				AE	CE	VE
HV	-	F	- 1	74.0	33.7	58.1
HV	-	F	- 2	65.5	31.0	45.7
HV	-	F	- 3	57.8	-13.0	50.6
HV	-	F	- 4	51.6	3.6	48.8
HV	-	F	- 5	46.0	21.6	42.0
HV	-	F	- 6	38.6	-20.5	37.5
HV	-	M	- 1	69.2	10.4	60.7
HV	-	M	- 2	56.1	4.6	57.7
HV	-	M	- 3	64.4	-33.1	61.6
HV	-	M	- 4	55.7	-4.0	54.0
HV	-	M	- 5	33.4	7.5	35.3
HV	-	M	- 6	46.3	-14.0	47.7
LV	-	F	- 1	74.3	14.5	72.9
LV	-	F	- 2	60.4	1.7	60.7
LV	-	F	- 3	36.3	-6.1	38.1
LV	-	F	- 4	27.2	12.2	29.0
LV	-	F	- 5	33.4	-2.6	37.3
LV	-	F	- 6	27.1	6.7	29.2
LV	-	M	- 1	72.7	20.3	68.1
LV	-	M	- 2	52.6	15.0	48.2
LV	-	M	- 3	41.0	8.3	41.2
LV	-	M	- 4	34.1	10.6	36.1
LV	-	M	- 5	34.0	4.0	32.3
LV	-	M	- 6	25.8	-7.4	26.8

APPENDIX C
MEAN DATA TRANSFER TRIALS

Transfer Trial Data Listing the Mean Scores for each Main Effect and Interaction Involved in the Analysis. Measurements for Absolute Error (AE), Algebraic Error (CE) and Variable Error (VE) are given in Milliseconds.

MEANS						
GROUPS	AE	CE	VE	GENDER	AE	CE VE
High Variability (HV)	26.0	7.0	28.0	Female	36.3	11.3 37.3
Low Variability (LV)	50.0	23.2	46.7	Male	39.7	18.9 37.4
GROUPS X GENDER	AE	CE	VE	BLOCKS	AE	CE VE
HV Females	28.7	10.3	31.3	1	42.9	18.9 40.0
HV Males	23.4	3.7	24.7	2	33.2	11.2 34.7
LV Females	44.0	12.3	43.4			
LV Males	56.0	34.1	50.1			
GROUPS X BLOCKS	AE	CE	VE	GENDER X BLOCKS	AE	CE VE
HV - 1	28.2	7.7	28.3	Female 1	41.3	15.1 39.8
HV - 2	23.9	6.2	27.7	Female 2	31.3	7.5 34.9
LV - 1	57.6	30.2	51.7	Male 1	44.4	22.8 40.3
LV - 2	42.4	16.3	41.7	Male 2	35.0	15.0 34.6

MEANS

GROUPS X GENDER X BLOCKS				AE	CE	VE	
HV	-	F	-	1	30.4	11.8	30.1
HV	-	F	-	2	26.9	8.8	32.5
HV	-	M	-	1	25.9	3.7	26.6
HV	-	M	-	2	20.9	3.6	22.9
LV	-	F	-	1	52.2	18.4	49.5
LV	-	F	-	2	35.8	6.3	37.3
LV	-	M	-	1	62.9	42.0	53.9
LV	-	M	-	2	49.1	26.3	46.2

APPENDIX D

MEAN DATA INITIAL TRAINING TRIAL

Initial Transfer Trial (Trial One) Data Listing the Mean Scores for each Main Effect and Interaction Involved in the Analysis. Measurements for Absolute Error (AE) and Algebraic Error (CE) are given in Milliseconds.

MEANS

GROUPS	AE	CE	GENDER	AE	CE
High Variability (HV)	29.4	2.6	Female (F)	46.3	20.6
Low Variability (LV)	83.0	60.4	Male (M)	66.0	42.5

GROUPS X GENDER	AE	CE
HV - F	30.7	3.6
HV - M	28.1	1.6
LV - F	62.0	37.5
LV - M	104.0	83.3

APPENDIX E

ERROR MEASUREMENT CORRELATIONS
FOR TRAINING TRIALS

Error Measurement Correlations are Presented with Significance Values

85

<u>HIGH VARIABILITY (HV)</u>			<u>LOW VARIABILITY (LV)</u>			<u>HVB1</u>	
	CE	VE		CE	VE	CE	VE
AE	.80	.75					
	.40	.001	AE	.20	.93	.56	.55
				.42	.001	.05	.05
CE		.01	CE		.11		.17
		.84			.25		.49
<u>HVB2</u>			<u>HVB3</u>			<u>HVB4</u>	
	CE	VE		CE	VE	CE	VE
AE	.52	.60					
	.05	.01	AE	-.65	.51	-.45	.92
		.11		.05	.05	.06	.001
CE		.66	CE		-.37		-.47
					.88		.05
<u>HVB5</u>			<u>HVB6</u>			<u>LVB1</u>	
	CE	VE		CE	VE	CE	VE
AE	.73	.92					
	.01	.001	AE	-.72	.82	.37	.78
				.001	.001	.14	.001
CE		.59	CE		-.28		.13
		.01			.27		.60

<u>LVB2</u>		<u>LVB3</u>		<u>LVB4</u>	
	CE	VE		CE	VE
AE	-.06	.90			
	.81	.001	AE	-.42	.93
CE		.20		.08	.001
		.42	CE		.37
					.13
<u>LVB5</u>		<u>LVB6</u>		<u>Females (F)</u>	
	CE	VE		CE	VE
AE	-.18	.90			
	.47	.001	AE	.20	.78
CE		-.30		.06	.001
		.22	CE		.09
					.35
<u>Males (M)</u>		<u>FB1</u>		<u>FB2</u>	
	CE	VE		CE	VE
AE	-.01	.89			
	.97	.001	AE	.50	.36
CE		.01		.05	.14
		.96	CE		-.03
					.89

MB6

	CE	VE
AE	-.58	.87
	.01	.001
CE		-.17
		.48

HVFB1

	CE	VE
AE	.56	.40
	.11	.28
CE		.41
		.27

HVFB2

	CE	VE
AE	.73	.33
	.05	.38
CE		.26
		.49

HVFB3

	CE	VE
AE	-.31	.30
	.42	.43
CE		.46
		.21

HVFB4

	CE	VE
AE	-.45	.92
	.06	.001
CE		-.47
		.05

HVFB5

	CE	VE
AE	.83	.89
	.01	.01
CE		.67
		.05

HVFB6

	CE	VE
AE	-.88	.88
	.01	.01
CE		-.66
		.05

HVMB1

	CE	VE
AE	.58	.63
	.10	.07
CE		.05
		.90

HVMB2

	CE	VE
AE	.18	.96
	.64	.001
CE		.23
		.56

HVMB3

	CE	VE
AE	-.90	.70
CE	.001	.03
		-.53
		.14

HVMB4

	CE	VE
AE	-.45	.98
CE	.22	.001
		-.34
		.37

HVMB5

	CE	VE
AE	.36	.98
CE	.34	.001
		.37
		.33

HVMB6

	CE	VE
AE	-.66	.80
CE	.05	.01
		-.12
		.75

LVFB1

	CE	VE
AE	-.43	.62
CE	.25	.07
		-.44
		.24

LVFB2

	CE	VE
AE	-.08	.81
CE	.83	.01
		-.09
		.81

LVFB3

	CE	VE
AE	.64	.92
CE	.06	.001
		.53
		.14

LVFB4

	CE	VE
AE	.28	.96
CE	.46	.001
		.06
		.87

LVFB5

	CE	VE
AE	-.12	.91
CE	.75	.001
		-.19
		.62

LVFB6

	CE	VE
AE	.32	.90
	.39	.001
CE		-.02
		.96

LVMB1

	CE	VE
AE	.81	.91
	.01	.001
CE		.72
		.05

LVMB2

	CE	VE
AE	.02	.92
	.96	.001
CE		-.19
		.61

LVMB3

	CE	VE
AE	.64	.92
	.06	.001
CE		.53
		.14

LVMB4

	CE	VE
AE	-.62	.90
	.07	.001
CE		-.49
		.18

LVMB5

	CE	VE
AE	-.24	.92
	.52	.001
CE		-.34
		.36

LVMB6

	CE	VE
AE	-.36	.95
	.34	.001
CE		-.16
		.67

APPENDIX F

ERROR MEASUREMENT CORRELATIONS
FOR TRANSFER TRIALS

Error Measurement Correlations are Presented with Significance Levels.

<u>BLOCK 1</u>		<u>BLOCK 2</u>		<u>HIGH VARIABILITY (HV)</u>	
	CE		VE	CE	VE
AE	.66		.85		
	.001		.001		
CE		AE	.88	AE	.86
			.001		.001
		CE	.68	CE	.27
			.001		.11

<u>LOW VARIABILITY (LV)</u>		<u>HVB1</u>		<u>HVB2</u>	
	CE		VE	CE	VE
AE	.71		.79		.91
	.001		.001		.001
CE		AE	.86	AE	.50
			.001		.05
		CE	.06	CE	.66
			.82		.01

<u>LVB1</u>		<u>LVB2</u>		<u>FEMALES (F)</u>	
	CE		VE	CE	VE
AE	.62		.85		.79
	.05		.001		.001
CE		AE	.73	AE	.50
			.001		.01
		CE	.001	CE	.39
					.05

MALES (M)

FBI

FB2

	CE	VE		CE	VE		CE	VE
AE	.82	.91	AE	.52	.81	AE	.28	.75
CE	.001	.001	CE	.05	.001	CE	.27	.001
		.59			.34			.47
		.001			.16			.05

MB1

MB2

HVFB1

	CE	VE		CE	VE		CE	VE
AE	.77	.89	AE	.92	.94	AE	.59	.84
CE	.001	.001	CE	.001	.001	CE	.09	.01
		.47			.80			.23
		.05			.001			.54

HVFB2

HVMB1

HVMB2

	CE	VE		CE	VE		CE	VE
AE	.09	.85	AE	-.09	.91	AE	.79	.99
CE	.81	.05	CE	.82	.001	CE	.01	.001
		.47			-.41			.85
		.20			.28			.01

LVMB1

CE	VE
.64	.78
.06	.01
	.15
	.70

LVFB2

CE	VE
.73	.65
.05	.06
	.65
	.06

AE	.67
	.05
CE	.37
	.33

LVMB2

CE	VE
.89	.91
.001	.001
	.68
	.05

AE	
CE	

<u>LVFB1</u>		<u>LVFB2</u>		<u>LVMB1</u>	
	CE	VE	AE	CE	VE
AE	.55	.67	AE	.73	.65
	.12	.05		.05	.06
CE		.37	CE		.65
		.33			.06

<u>LVMB2</u>		VE
	CE	
AE	.89	.91
	.001	.001
CE		.68
		.05

AE	.64	.78
CE	.06	.01
		.15
		.70

APPENDIX G

ERROR MEASUREMENT CORRELATIONS
INITIAL TRANSFER TRIAL

Error Measurement Correlations are Presented with Significance Levels.

<u>HIGH VARIABILITY (HV)</u>		<u>LOW VARIABILITY (LV)</u>		<u>FEMALES (F)</u>	
AE	CE		CE		CE
	.15	AE	.62	AE	.48
	.55		.05		.05
<u>MALES (M)</u>					
AE	CE		<u>HVF</u>		<u>HVM</u>
	.74	AE	.21	AE	.07
	.001		.59		.85
AE	<u>LVF</u>		<u>LVM</u>		
	CE		CE		
	.42	AE	.63		
	.26		.07		

VITA

Michael Roy Ragsdale was born August 18, 1953, in Cleveland, Tennessee, to Mr. and Mrs. E. Roy Ragsdale.

He attended public schools in that city and graduated from Cleveland High School in June, 1971. The following September he entered the University of Tennessee, Knoxville, and in December of 1975 he received a Bachelor of Science degree in Physical Education. While at the University of Tennessee he received the Torchbearer Award, which is the highest honor given to a student, and was named the Outstanding Senior in the Department of Physical Education.

In the Fall of 1976 he enrolled in Auburn University, Auburn, Alabama, and graduated with a Master of Science degree in Summer of 1977. While at Auburn he served as an Instructor - Graduate Teaching Assistant in the Department of Physical Education. In the Fall of 1977 he accepted a Graduate Teaching Assistantship in the School of Health, Physical Education and Recreation at the University of Tennessee, Knoxville, and began study toward a Doctor of Education degree. In December of the same year he married Patricia Elizabeth Neill of Birmingham, Alabama.

He is currently employed as Director of Admissions and Records at the State Technical Institute at Knoxville. He expects to receive the Doctor of Education degree in August, 1981.