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The effects of variable practice and subjective estimation on error-detection capabilities

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THE EFFECTS OF VARIABLE PRACTICE AND SUBJECTIVE ESTIMATION ON
ERROR-DETECTION CAPABILITIES

By

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Thesis

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in partial fulfillment of the requirements

for the degree of

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in

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Ypsilanti, Michigan

DEDICATION

A dedication is made four times to those whose support made a tremendous impact on the completion of this thesis project:

To Mom (Pat) Ward. Your encouragement and belief in me gave me the courage to try.

To my husband, Doug. Your quiet support and long patience was certainly a gift of love.

To Murali Nair. The most positive, supportive, and patient professor. Thank you for picking up the pieces and then some.

To my Higher Power, with whom all things can happen.

ABSTRACT

Retention and transfer for ballistic open motor skills may best be achieved through specific + variable practice along with error estimation. Inconsistent support for the variability of practice hypothesis warrants a cross-testing of this hypothesis. Estimation had been used and found beneficial on ballistic closed motor skills, but what about ballistic open motor skills?

This study tests ballistic open motor skills on an anticipation timer. Specific and specific + variable practice groups coupled estimation and no-estimation conditions for testing purposes.

The results indicated that although there were no significant differences during acquisition, significant differences did exist for retention and transfer in support of the variability of practice hypothesis.

In conclusion, no particular practice condition aided learning during acquisition. Specific practice was more beneficial for retention, which did not support S+V-enhancing retention. And finally, estimation and S+V practice benefited transfer, which supports the variable of practice hypothesis.

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CHAPTER I: INTRODUCTION

Issues pertaining to learning a motor skill are general quantity of practice, variation of practice in terms of quantity and quality, and organization of practice sessions (Magill, 1993). Variability of practice is rehearsing the many possible variations of movement that make up the framework of a motor skill during the learning process (Schmidt, 1991). The use of this type of practice is said to increase the transfer of that skill to a variety of performance situations. In contrast to variable practice, studies have generally found that retention of a skill is enhanced by specific practice, or practice involving the repetition of only one variation of the skill.

The hypothesis experimenters use when comparing specific versus variable practice is the variability of practice hypothesis, derived from schema theory (Schmidt, 1975). The schema notion posits that variable practice is the reason for successful responses to a new skill variation. In recent studies it has been discovered that not only do variable experiences lead to better transfer to novel renditions of a skill, but that more variability is better. In other words, the use of more skill variations during acquisition has more successful transfer than that of less skill variations. Along with the variable practice's aiding transfer, studies also showed variable practice to be beneficial for retention of a skill (Magill, 1993).

The second hypothesis experimenters use when comparing practice types is the specificity of learning hypothesis. This hypothesis, seemingly formulated from exercise science's specificity of training principle, suggests that motor skills are unique and that the slightest change of the task requires the development of a new motor program. The development of a new motor program is thought to completely deviate from the learning of the original skill. Therefore, specific practice is simply practicing only one variation of a skill

at a time. Practice of a motor skill by means of the specificity of learning hypothesis postulates enhanced retention performance (Barnett, Ross, Schmidt, & Todd, 1973).

The paradigm used in studying variability and/or specificity of practice involves the use of two groups: one group that practices a specific task and another group that practices variations of the task during the acquisition phase. Following the acquisition phase is the testing phase. A retention test is given to see how well participants remember what they have learned. To gauge this test, the specificity of learning hypothesis is typically used. This hypothesis poses that the group practicing a task specific only to the retention test will perform better on that test than the variable group (Shea & Kohl, 1990). For instance, if a practice involved a timing task where a participant was to stop a moving object, the specific group would practice at one speed, whereas the variable group would practice at speeds above and below but not at the specific group's speed. The retention test therefore would test both groups by using the single speed of the specific group to see if concentration on only one aspect of a skill would lead to better performance learning. The transfer test, on the other hand, would test both groups using a speed variation that neither group had practiced. This testing standard is derived from the variability of practice hypothesis, which suggests that the variable group will outperform the specific group on the transfer to a new skill variation. The success of transfer is dependant upon the schema strength or set of learning parameters that has been developed for that skill.

Two recent experiments (Landin, Herbert, & Fairweather, 1993; Shea & Kohl 1990) examined specific and variable practice. Shea and Kohl (1990) used specific and specific + variable practice groups in experiment (a), whereas a specific + specific group was added for experiment (b). The task, for both experiments, used force production produced by the static

pull of a participant lying upon a table with the upper arm against the table and a 90° elbow bend, allowing for the lower arm to extend vertically. The measured force was converted to a voltage, which was then transmitted to a computer capable of reading and displaying the participant's target and actual forces. In experiment (a), the specific group practiced 85 trials, whereas the specific + variable group practiced 289 trials all in 17 blocks for each group. The 289 trials were made up of the 85 criterion trials plus 204 variable forces interpolated within the 17 blocks. A 24-hour retention test found that at the first trial, the specific + variable group performed better than the specific-only group. This did not give support for a strict interpretation of the specificity of learning hypothesis.

Experiment (b) used the same practice groups as experiment (a) with the addition of a specific + specific practice group. The purpose was to compare specific to specific + variable conditions in an equal amount of trials (298). Once again, according to the specificity of learning hypothesis, the specific + specific group should have performed best on the retention test. A 24-hour retention test followed the acquisition phase. It was found that the specific + variable practice conditions performed best on the initial retention trials and that performance error from the last acquisition trial to the first retention trial increased tremendously. This showed that during acquisition, the higher the amounts of contextual interference, or the confusion derived from practicing skill variations within the same practice session (Magill, 2001), produced more errors. However, the opposite result occurred in retention. These results were confirmed by another study by Landin et al. (1993).

Landin et al. (1993) used a basketball free throw as a real-world skill to be tested. Specific and specific + variable practice groups were utilized for 120 trials over a 3-day

period. The criterion distance was set at 12 ft (3.6 m) for the specific group. The criterion distance plus 8 ft and 15 ft (2.4 m and 4.5 m) were the distances used for the specific + variable group. The retention and transfer tests, each 10 trials, were administered 72 hours following acquisition. The retention test was made up of 10 trials from the criterion distance. Results indicated that initial retention trials showed specific + variable to be superior over specific. This suggests that specific + variable practice conditions can be generalized for real-world sports. Practice for games that utilize one-to-two skill attempts at a time, such as basketball free throws, would benefit from specific + variable practice. The 10-trial transfer test was made up of a new distance and a new location (13 ft, or 3.9 m, and 90° from the free-throw line to the right). The test resulted in negative effects for both practice groups because of the motor program/visual display's being completely altered. It was also noted that neither group was superior overall.

What makes these two experiments particularly noteworthy is that the results indicated that some form of variety or randomization is better for the retention of a motor skill. This conclusion is supported by the schema theory, which proposed that practice of any variation of a skill during acquisition leads to superior recall and recognition of those variations (Shea & Kohl, 1990). Ultimately, variable practice would lead to better retention. This interpretation contradicts former studies, which found that practicing a motor skill in a blocked (or specific) condition results in superior retention performance over a random (or variable) condition and that the reverse is true of transfer tests (variable practice enhances transfer but not retention).

Another variable used in some experiments (Hogan & Yanowitz, 1978; Schmidt &

White, 1972; Sherwood, 1996) with motor skill learning is error estimation. Error estimation is the combination of subjective error estimations (error estimated by the participant) with the objective error, or actual error. The stronger the correlation between the two, the stronger the schema is. A strong schema enables error detection. When error-detection capabilities are well formed, they can work independently of KR (knowledge of results) and allow the learner to remain at present accuracy levels or climb to improved performance (Hogan & Yanowitz, 1978). Error estimation is one form of task variation that may benefit transfer, according to the variability of practice hypothesis.

There are two issues at hand. One is whether error detection is beneficial in ballistic open motor skill learning. The other is a question of whether error detection is beneficial for ballistic open motor skills in conjunction with differing practice conditions. Because of the constant change in task variation during random practice, there is an increase in task difficulty, which has been demonstrated to be beneficial. The addition of higher contextual interference, such as error estimation, qualifies as variable practice. Error estimation, coupled with KR, allows the participant to compare errors to goal movements. This comparison ability will eventually lead to the participant's maintaining and improving skill performance without KR, as indicated by Schmidt and White (1972). Error estimation appears not to be beneficial during random practice (practice in which several variations of a task are rehearsed without any particular order). This is due to the inability to make corrections because the following trial will be a different variation of the task (Sherwood, 1996).

A concern raised about the importance of error estimation with KR is in the findings of Newell (1974). The task was a ballistic timing task using a slide to measure linear movement and error detection. Participants were to move a lever to the left a distance of

24.03 cm in 150 ms with their right hands. Four seconds later, participants received a command to estimate the movement time for the five initial trials, and then give the error direction without any KR. At 8 s, participants finally received KR of movement time.

Newell did find that participants receiving KR while estimating error on a ballistic task had less absolute difference between objective and subjective error estimation than those who did not receive KR. However, when the same data were analyzed by a different statistical procedure, conflicting results surfaced. Empirically, it is unclear whether verbal estimation is advantageous in motor skill learning, although, theoretically, it appears to be, as indicated by Adams (1971) and Schmidt (1975).

Throughout the many studies (Goodwin et al., 1998; Landin et al., 1993; Shea & Kohl, 1990; Sherwood, 1996) on the specificity of learning hypothesis, results frequently have been inconclusive. Some of these studies primarily focused on the retention tests and usually included either a specific-only condition or a random-only condition. With these two conditions, a conclusion has been made that some variability along with specific practice is conducive for skill retention. Little has been done to combine the two groups and compare specific with specific + variable practice conditions in addition to having experimenters use error detection as an independent variable. In addition to few specificity of learning hypothesis studies incorporating error detection, fewer yet have involved a ballistic open motor skill. And with the discrepancies in the findings for the reliability of the specificity of learning hypothesis, it may be wise to test it on transfer, in addition to retention.

Studies focusing on the specificity of learning hypothesis and the variability of practice hypothesis typically follow a set standard of variables to investigate. Studies are made unique by altering one of those variables. The following are elements included in such

a study: (a) a closed motor skill used possibly for the ease of investigational control, (b) two individual practice conditions--specific and variable, (c) error estimation, and (d) testing for one or both hypotheses. The uniqueness of the present study, as opposed to previous studies, was a peculiar combination of skill, practice type, error estimation, and tests. These differences as a foursome qualify for a distinct study. The skill type examined was open motor (the conditions of the skill may not be controlled by the participant, for example, receiving a tennis serve), the primary skill type physical educators and coaches teach. The practice conditions used were specific and specific + variable. Usually studies of this nature use the two conditions specific and variable individually. An added variable was error estimation. Frequently experimenters will only study error estimation on closed motor skills. The research design of the present study included retention tests--standard with the specificity of learning hypothesis and transfer tests--usually used only when searching for reliability of the variability of practice hypothesis. The present study used both retention and transfer tests to test and cross-test the reliability of the specificity of learning hypothesis.

Statement of the Problem

Two problems were examined in this investigation. First, the question of practice composition in motor skill learning was examined. Specifically, the roles of the specific practice condition and the specific + variable practice condition were examined on the performance and the learning of an anticipation timing task. Second, the efficacy of error detection capabilities in motor skill learning was examined. Specifically, the role of the 100% estimation condition and the 0% estimation condition was examined on the performance and learning of an anticipation timing task.

Purpose

The purpose of the study was to test the effects of variable practice and subjective estimation on error-detection capabilities, cross-test the variable of practice hypothesis, and determine if error detection could promote continued learning.

Significance of Study

Examining the effect of specific and specific plus variable practice on error-detection capabilities in ballistic open motor skill learning has theoretical implications. Specifically, practice under specific conditions offers enhanced retention, whereas practice under variable conditions offers enhanced transfer to a novel task. Both practice conditions give way to the testing of the specificity of learning hypothesis and the variability of practice hypothesis. Few studies testing these hypotheses have implemented tasks that included ballistic open motor skills. Typically, recall, which is associated with schema theory, is usually associated with ballistic skills. To separate recall (movement) from recognition, the ballistic task is appropriate, allowing for the observation of proximity effects. Findings from studies of the specificity of learning hypothesis contradicted the support for specific practice to enhance retention. Although the effects of variable practice on retention tests have not been widely addressed, several studies (Goodwin et al., 1998; Landin, Herbert, & Fairweather, 1993; Shea & Kohl, 1990) have indicated that variability aids in retention, although not significantly. These studies again did not implement ballistic open motor tasks.

Practical implications also apply to examining the effect of specific and specific + variable practice in ballistic open motor skill learning. The results could assist teachers and coaches in more appropriate use of time for skill acquisition. Specifically, with what quantity of specificity should a ballistic open motor task be taught? Most studies pertain to closed

motor skills, whereas most ballistic open motor skills are used in team and lifetime sports. The education field needs real-world studies that apply to teachers and coaches for updated instructional purposes, coinciding with time limitations in the classroom setting.

In addition, examining the effects of KR and error estimation on ballistic open motor skills has empirical limitations. Specifically, substantial practice of a motor skill with KR and subjective reinforcement during the KR-delay interval offers a means by which to measure error-detection capabilities on no-KR retention and transfer tests while also testing the prediction of the specificity of learning hypothesis. Schmidt and White (1972) concluded that error-detection capabilities develop when the learner can effectively correlate subjective errors with objective errors. This correlation offers a method by which the learner can continue learning without incessant KR from the instructor. Because KR cannot be supplied for every student about every error in a classroom, it is desirable that students learn to self-evaluate skill performance. When initial KR is given to students often enough for them to develop response guidelines for the desired movement outcome, the removal of KR will render the student the capability to self-detect errors and even continue learning, (Schmidt's study as cited in Hogan & Yanowitz, 1978).

Definitions and Explanation of Terms

The following definitions and explanations were established for use in this study:

1. *Absolute Constant Error (|CE|)*: The absolute value of an average amount of constant error, which measures the degree of response bias (too fast or too slow).

2. *Acquisition Phase*: Practice designed to enhance retention and or transfer performance.

3. *Error -Detection Capabilities*: Tuning in to response guidelines and outcomes,

which allows the participant to know the inaccuracy of the performed skill.

4. *Knowledge of Results (KR)*: Information the participant receives pertaining to the degree to which the movement outcome matches the movement goal.

5. *Mean Absolute Objective-Subjective Difference (|O-S|) Error*: The average of the difference between the objective (or actual error) and the subjective (or estimated error) without regard to the sign.

6. *Practice Composition*: Manipulation of the task number or variation within a practice session.

7. *Retention Test*: A test that measures the learning effects of a task performed during acquisition (Magill, 1993).

8. *Specific Practice*: The practice of a task that does not vary in condition or form and is exactly the task of a retention test.

9. *Specificity of Learning Hypothesis*: A hypothesis that predicts that when practice is specific to the retention test, the participant will perform better on the retention test.

10. *Specific + Variable Practice (Random Practice)*: The practice of a task in which the actual skill is practiced, as well as varying conditions of the task.

11. *Transfer Test*: A test that measures the learning effects of a skill performed under conditions other than those experienced during acquisition.

12. *Variable Error (VE)*: A measure of overall consistency for the variability of errors. VE is the calculation of the standard deviation of error scores.

13. *Variability of Practice Hypothesis*: A hypothesis that predicts that participants who practice a skill under varying conditions will perform better on a transfer test than those who practice under specific conditions.

Assumptions and Limitations

Assumptions. The following assumptions were made in the anticipation-timing task:

1. Participants understand the value of a numeral to the one-thousandth place.
2. Thought processes during the KR-delay interval typify thought processes encountered during KR-delay intervals for learning motor skills.

3. Schema for learning motor skills will develop with practice.
4. Specific practice is essential for developing motor learning schema.
5. Participants will make best efforts during testing.

Delimitations. The study was delimited to the following conditions:

1. Forty-eight college students who were in Department of Physical Education classes and aged 18-57.
2. The participants were randomly assigned to one of two practice conditions: specific + variable or specific. Estimation conditions were either 100% or 0%.
3. The estimation group verbally estimated errors after every acquisition trial during the KR-delay interval, and the no-estimation group did not.
4. Participants under the specific + variable practice condition performed 90 trials at three different velocities: 5, 7, and 9 mph for a total of 270 trials. The specific condition participants performed 270 trials at 7 mph.
5. The transfer test did not include the criterion speed practiced.
6. The study was conducted for 3 weeks in July 1997.

CHAPTER 2: REVIEW OF LITERATURE

Practice Conditions

The schema theory of motor skill learning was developed by Schmidt in 1975 (Schmidt, 1975). The theory holds that for a person to practice or master the technique of a skill, a Generalized Motor Program, or GMP, must be developed. A GMP is an image stored in memory of the desired class of actions necessary to perform a given skill. Along with the GMP are two schemas: the recall schema and the recognition schema. Based on the initial conditions with knowledge of the task goal, the recall schema helps a person select the force with which to carry out the task. The recognition schema allows the participant to make a comparison of how it feels to correctly execute the task and how it feels to incorrectly execute the task (feedback).

In detail, the breakdown for the components of both of the schemas is in four parts: (a) Initial conditions let the participant know where he/she is, where the target is located, and where the body is positioned; (b) components needed to perform the action such as force, speed, or direction make up the response specifications; (c) sensory consequences are obtained from feedback during and after the movement from the senses; and (d) comparison of actual results of the movement to the desired results is the response outcome (Magill, 1993).

Because much research had already been directed at the recognition schema, Schmidt wanted studies aimed toward gaining empirical support for the recall schema. The difference between the two schemas is that one initiates the movement, whereas the other alters it.

The recall schema uses the initial conditions along with the goal of the movement to determine the force. By changing the movement or context characteristics (Magill, 2001) of

the practice conditions, such as distance, force, speed, and trajectory, the recall schema is strengthened. A strong schema formed from variable practice allows the participant to determine the force to use for a new distance. The stronger the schema is, the more successful the participant will be in performing new variations of a skill. This is known as the variability of practice hypothesis.

Also using the initial conditions and the knowledge of the task goal is the recognition schema. The function of the recognition schema is not to start the movement but to determine how the movement feels through sensory feedback. Following the release of a softball throw, a participant could tell how good a throw was by how it felt coming off the fingers. The feedback from the eyes and ears allows the participant to alter aspects of the movement while performing it. After a skill is performed, all of the components are stored in memory as a schema, or system of knowledge, which organizes and semblances experiences (Van Rossum, 1990).

To be able to judge how correct a movement is, the participant needs to be able to draw on the GMP to compare the actual feedback with that of what is expected. This relationship makes up response guidelines (Schmidt, 1975), or a mental listing of steps for executing a given skill. Through practice, the learner matches the response outcome with the response guidelines for that outcome and stores this information. The stored information, or schema, is constantly added to and updated so that any given movement is a new construction from schema, not an exact reproduction of a previous movement. When participants seek the most correct response outcome and response guidelines during variable practice, their schema is then strengthened (Van Rossum, 1990) with the help of KR (Shea & Kohl, 1990).

The variability of practice hypothesis, derived from the schema theory, posits that variable practice leads to transfer of a novel variation and aids in the recall, recognition, and retention of a variation practiced in acquisition (Shea & Kohl, 1990). The stronger the schema strength is, the more the participant can generalize movements to meet other response outcomes within a motor program (Schmidt, 1975). Questions have been raised as to whether variable practice really is better than specific for learning a motor skill and whether initial practice with KR aids in schema strength when KR is removed.

Variable Practice

Jacques H. A. Van Rossum (1990) examined experiments done over a 12-year period that were aimed at validating the variability of practice hypothesis. This supposition, derived from schema theory, claimed that variable practice or practice in which some aspect of the skill is altered is better for the development of the schema than specific practice, or repetitious practice of one characteristic of a skill. The question of which practice type is better, variable or specific, was not completely confirmed.

This study examined all experiments from 1975 through 1987 that directly addressed the variability hypothesis. Of these experiments, half did not address the variability hypothesis directly because no learning took place during acquisition. Of the remaining studies, six pertained to timing task experiments using adult participants and had limited support for the variability of practice hypothesis, concluding that consistent empirical support for the hypothesis is still to come. Some of the studies in Van Rossum's analysis, which had significant results, are included in this chapter.

One such experiment was that of Newell and Shapiro (1976), who performed two studies on a rapid linear timing slide in order to analyze recall and recognition--two of the

four components for developing a schema, according to Schmidt's (1975) schema theory.

These separated components would demonstrate that those who practiced a specific task from the first trial would be less successful than those who practiced a variation of the task for the transfer to a new task within the same schema, as suggested by the variability of practice hypothesis (Newell & Shaprio, 1976).

The subjects were to slide a vertical handle, mounted upon a horizontal, tabletop trackway, across a given distance in a given amount of time. The trackway was made up of two stainless steel rods 91.44 cm long and 1.27 cm in diameter. Each rod, 3.81 cm apart, housed a ball-bearing sleeve connected by a slide with a vertical handle 12.70 cm long. The apparatus was placed in front of the participant with the trackway allowing left-to-right arm movements. The time clock was started when the slide had passed through a microswitch on the trackway and stopped when the slide had passed through a second microswitch located further down the trackway.

The first experiment (Newell & Shapiro, 1976) was composed of 96 male and female college students who were to move a slide, with their right hands, a distance of 10.16 cm at the signal of a beep. They were to return the slide to the start point with their left hands. The participants were equally divided into two constant groups separately assigned to specific task-completion goal times and one variable group assigned to two different goal times. One constant (specific) group practiced at 70 ms, whereas the other practiced at 130 ms, for group totals of 60 trials each. The variable group was split in half, forming two groups. Each group was labeled by the speeds practiced for the first 30 trails and for the second 30 trials: 70-130 ms and 130-70 ms. Trials 31-60 essentially served as retention trials for the constant groups, whereas the reversal in speeds counted as more acquisition for the variable group. After the

last trial, half of each practice group transferred to a no-KR, 100-ms, inside transfer test (a test in which the speed is different from those practiced during acquisition but within the range of the practiced speeds), whereas the other half transferred to a no-KR, 180-ms, outside transfer test (a test in which the speed is different from those practiced during acquisition and also outside of the range of the practiced speeds). The transfer design was a 3 (practice) x 2 (transfer) x 20 trial factorial grouping.

For recall, significant differences were found on the 180-ms test where the 70-130-ms variable group had the smallest mean error as compared to the 130-70 ms group, and the constant groups (130-130-ms, and 70-70 ms groups, respectively). There was a significant transfer main effect that indicated that inside transfer (target 100 ms) produced less mean error than did outside transfer (target 180 ms). Also, the training-order effect showed that the 70-130-ms variable group had transferred significantly better than the variable group that practiced in the reversed order (130-70 ms), indicating an order dependency for successful transfer on the 180-ms test. There was no difference between variable groups on the 100-ms transfer test.

For recognition, the same design was used for absolute error as was used for recall. Results were similar to recall for all practice groups. Estimated error was significantly smaller for 100-ms transfer test participants as opposed to the 180-ms test participants. In addition, the 70-130-ms group transferred significantly better than the 130-70-ms group on the 180-ms test, but no differences were found on the 100-ms test.

Overall, variable practice was beneficial only when practice was initiated in a certain order relative to the transfer criteria. If practice is too similar to the transfer task, there are no benefits for variable practice. The results for recall and recognition were comparable. This

similarity promoted a question about whether or not the effects of training and transfer were due to both phases of experimentations, using the same guidelines or whether these two aspects of learning simply reacted similarly.

The second experiment expanded the variability to determine if further manipulation would foster transfer to a new skill. This experiment consisted of five practice conditions, all of 60 trials each: (a) 60 trials at 130 ms; (b) 30 trials each at 70 ms and 130 ms; (c) 20 trials each at 70 ms, 100 ms, and 130 ms; (d) 60 trials in ascending order from 70 ms through 130 ms; (e) and a random order from 70 ms through 130 ms. All practice conditions transferred to a 180 ms target for 20 no-KR trials.

The absolute movement error results for recall showed the random practice condition to have the lowest group mean, followed by the other variable groups, and the specific group had the highest group mean. Even though the variable groups did not have significantly lower movement errors on the initial trial, the variable groups tended to have less errors over the first five trials; the 130-ms group increased in errors. In addition, the recognition schema helped to decrease movement error because the variable groups' estimated error was smaller than their movement error.

The absolute estimated error results for recognition were similar to those of the first experiment (Newell & Shapiro, 1976) with none of the interactions or the effects showing significance.

Overall, the results of these two experiments gave preliminary support to the variability of practice hypothesis and revealed that outside transfer was successful when there were only moderate parameter changes from the acquisition task. In addition, ascending practice order targeted toward the 180-ms transfer task was not necessary, as the random

practice group performed similarly. Finally, due to the estimated error scores' only being somewhat smaller than those of the movement error scores, it was still not clear as to whether the recall and recognition schemas developed from separate means but at the same rate or if they both developed from a single process (Newell, 1974).

Simulating the Newell and Shapiro (1976) study, Lee, Magill, and Weeks (1985) conducted a study with the transfer tests inside and outside of the practice range. The first experiment utilized 36 right-handed, physical education college students who performed two arm movements (including a reversal movement) in a rapid timing, barrier knock-down task. From a microswitch-timed starting point, each participant moved his/her arm to the left at a 15° angle to knock down an 8 x 1-cm, hinged, wooden barrier 43 cm away to trigger a timed-microswitch. From this point, each the participant reversed the movement toward the right and, at a 20° angle, knocked down a second barrier 43 cm away, stopping the timer.

The participants were assigned to one of three practice groups. The constant practice group performed all 60 acquisition trials at one of four criterion movement times: (a) three participants at 300 ms for the first movement and 700 ms for the second movement (“300-700”); (b) three participants at “400-600”; (c) three participants at “600-300”; (d) and three participants at “700-400.” The blocked practice condition practiced 4 different criterion times in groups of 15 consecutive trials. The order was consecutive and balanced across each participant: “300-700,” “400-600,” “600-300,” and “700-400.” The random practice condition practiced the same goal times as the blocked practice condition, but no more than twice in succession; each goal time was only practiced three times within the 12 trials.

For transfer, block 5 of five for the inside and outside transfer was analyzed by a

MANOVA and ANOVA, which involved 3 (groups) x 2 (movement segments) x 3 (blocks) models with repeated measures on the last two factors. The inside transfer test included new times but within the ranges practiced during acquisition: 12 trials at speeds of “500-500.” The outside transfer test (outside the practice boundaries) used 12 trials at speeds of “800-800.” Trial order was not counterbalanced, and no KR was given during either test. A 5-min rest period took place before the transfer tests.

In this first experiment, a significant difference was found in the (groups x blocks) interactions for absolute constant error, $|CE|$, and variable error, VE. Absolute constant error is a measure of accuracy without regard to signs (+/-), whereas variable error is a measure of consistency on individual scores around a mean. No inside transfer differences were noted for $|CE|$, but for the outside transfer, the random and blocked variable conditions had significantly more accurate scores than those for the constant condition. For VE, the random group significantly had the least amount of variability.

The second experiment comprised 48 right-handed, college physical education students who did not participate in the first experiment. The participants produced two left-to-right arm movements as accurately as possible to criterion times identical to those of the first experiment; the conditions and trials were also the same.

For the transfer analysis, the trial order within each practice group was counterbalanced. This counterbalanced order within practice groups was included as a separate factor in the analysis. The time after the acquisition phase, during which the inside and outside transfer took place, was not stated by the authors. The order of which was first, the inside or outside, was stated as either way. The MANOVA and ANOVAs involved 3

(groups) x 2 (order of transfer blocks) x 2 (movement segment) x 3 (blocks) models with repeated measures on the last two factors. Preresponse time ANOVA was a 3 (groups) x 2 (order) x 3 (blocks) model with repeated measures on the last factor. KR was given for all groups.

In this second experiment, although there was a (groups x block) significant interaction, the results could not verify the findings of the first experiment because random was not better than blocked. The mean error score for the blocked group was higher than for the specific group for |CE|, but the blocked group had a lower mean score for VE over the specific group. The support for the variability of practice hypothesis was only partial.

Another barrier-slide timing experiment was conducted in two-parts by McCracken and Stelmach (1977). The apparatus was a plywood platform (105 x 45 cm) with five lines of holes drilled 5.5 cm apart down the length of the board. Electrical contacts were mounted a given distance from each barrier; times were acquired by moving the slide from the microswitch through the barrier.

The first experiment, made up of 48 right-handed, college freshmen males, involved the specific task of moving a slide from a switch to a barrier, breaking contact within 200 ms. The 48 males made up three groups: a control group, a low-instance (variable) group, and a high-instance group. The control group performed 75 trials at one barrier. The low-instance group performed 300 trials at one barrier. And the high-instance group performed 75 trials on four different barriers in random order, repeating no distance, for a total of 300 trials. Both the control and low-instance groups had the participants, within groups of four, assigned to different barriers in a subject-rotating order so that all of the distances were equally used.

Each group was to estimate errors before KR. Barriers were randomly placed among the holes at distances of 15, 35, 60, and 65 cm for acquisition, whereas 50 cm marked the transfer barrier in the center line so as not to incur spatial bias. The results showed a significant AE (absolute error) interaction. Absolute error is the amount of error deviated from the criterion without regard to sign (Magill, 1993). For the interaction, variable practice improved from the final practice blocks to immediate transfer, and the constant condition decreased drastically. Both groups had similar scores on the 2-day transfer test. The other interaction involving VE showed that the outstanding performance by the constant group on the last acquisition blocks vanished on the transfer tests. Both groups were almost equal on scoring, which gives weak support for the variability of practice hypothesis.

On the second analysis, a main effect was found to be significant for AE, demonstrating the superiority of variable practice over constant practice and a strong support for the variability of practice hypothesis.

Wrisberg, Winter, and Kuhlman (1987) had a two-fold purpose for examining the efficacy of the variability of practice hypothesis. The first was to test the effects of different types of variable practices against different types of constant practices (distances and times). The second was to determine whether one type of increased variation is better at promoting transfer success than another or if a combination of transfer variations is better (distances and times).

The study consisted of 126 right-handed, male college students who performed on a closed-skilled Reaction-Movement Timer (Lafayette Instruments # 62017) for movement distance and movement time. The apparatus was a table-top platform with five microswitches 1.5 cm in diameter spaced 15 cm horizontally before the participant and 18 inches from the

table's edge. To the left of the microswitches was a vertically hinged target (11 x 13 cm). Each microswitch was a given distance from the target, with the closest first: 43, 58, 73, 88, and 103 cm. Starting with the right arm, the participants depressed a microswitch, made a ballistic right-to-left movement, crossed the predetermined distance in the stated movement time, and knocked down the target, which stopped the timer. Verbal KR, expressed in ms of either too long or too short of the goal time, followed each trial.

Participants were equally divided into three main groups: control, distance-varied, and time-varied. Each group practiced four blocks of 45 trials equaling 180 trials. In the acquisition phase, the control group was divided into four subgroups with different distances (in cm) and times (in ms) listed respectively for each group: 43-300, 58-300, 58-400, and 43-400. The distance-varied group performed within the time of 400 ms but at distances of 58, 73, and 103 cm. The time-varied/distance-varied group performed within time of 400, 600, or 700 ms and within the distance of 58, 73, or 103 cm. And finally, the time-varied group used the distance of 58 cm and the times of 400, 600, and 700 ms.

In the transfer analysis for AE, because of a significant interaction effect, a post hoc test was used. Results showed for the variable practice groups and the group specific to practice, the 20 no-KR trial transfer task had significantly better accuracy levels as compared to results for the other specific groups. The variable groups and the specific transfer group had significantly lower mean CE and VE scores than the specific (nontransfer) groups. Two considerations need to take place when pondering the authors' claim for supportive findings for the variability of practice hypothesis: There were nonidentical results for each dependant variable, and there may be no difference between variable practice and nontransfer task specific practice.

Another study manipulating the variable of practice hypothesis was that of Del Ray, Wughalter, and Whitehurst (1982). Female participants studied the effects of high and low levels of variable practice on an open motor timing task. This was to determine which type of variable set up was best for Schmidt's schema theory for enhanced transfer, as none had been stated.

The apparatus used was a Bassin Anticipation Timer (1475 mm long x 85 mm wide) (Lafayette Instrumentation Co.) equipped with two vertically connected sets of 16 lamps. After the illumination of an amber warning light, followed by a 1.5 s delay, the 16 lamps were successively illuminated toward the participant. The participant then depressed a button with the dominant index finger upon the exact arrival of the final runway light.

All participants received three pretest trials of 4 mph. Next, the three acquisition groups (constant, blocked, and random) began four blocks of 16 trials, for a total of 64 acquisition trials. The constant group used a 6-mph speed for all trials. The blocked group used 16 trials with block speeds of 13, 11, 5, and 7 mph. Finally, the random group performed each speed four times without succession in each block. Novice and experienced participants made up each of the three acquisition groups.

Ten minutes following the acquisition phase, the transfer task occurred. Six trials each of 6 and 12 mph, for a total of 12 inside transfer speed trials, made up the test. The order of the transfer task was counter balanced. Half of each acquisition group received the transfer trials in a blocked-random order, and the other half received the trials in a random-blocked order; the 6-mph speed preceded the 12-mph speed for the blocked portion of the transfer task. A 2 (experience) x 3 (acquisition group) x 2 (transfer interference order) x 2 (transfer task) four-way ANCOVA with repeated measures on the last factor was the analysis

used. For ICEI and VE, a significant interaction was found for each. It was noted for VE that the group practicing under a blocked variable condition at a slower speed showed significantly less variability when the transfer began with the blocked version.

For ICEI, novice participants performed significantly better after a random practice and at faster transfer speeds than did experienced participants. Although there was limited support for the variability of practice hypothesis, it was clearly shown that the variability of practice may greatly depend on a participant's proficiency level.

The results of these timing tasks showed limited support for the variability of practice hypothesis. It was determined that participants' experience levels require consideration in determining practice types and that transfer outside of the practice range was best performed under variable practice conditions. These findings examined one aspect of learning when participants performed a ballistic open motor skill. Another side, which needs to be addressed, is that of retention and the specificity of learning hypothesis.

The following experiments compared specific and variable practice conditions in two real world settings and three laboratory settings pertaining to the specificity of learning hypothesis as well as the variability of practice hypothesis.

A comparison of two experiments using real-world motor skills included Landin et al.'s (1993) basketball free throw and Goodwin et al.'s (1998) dart throw.

The free throw experiment included specific and specific plus variable practice conditions. This practice arrangement replicated that of Shea & Kohl's (1990) experiment with the intention of finding similar results (i.e., variable practice, including the criterion task, performing significantly better on retention).

Landin et al. (1993) separated 28 female students into two practice conditions for the

free throw study: specific and specific + variable. Both conditions used the criterion distance of 12 ft. with the specific + variable group also practicing at 8 and 15 ft. All participants completed 120 trials over a course of 3 nonconsecutive days. After participants read written directions for the task as well as viewed examples by video with key points verbalized, they were given five warm-up shots before starting each day of the 3-day, 120-KR trial experiment. Seventy-two hours following acquisition, a 10-trial retention test was administered, followed by a 10-trial transfer test.

The transfer test was based on the findings from Wrisberg, Winter, and Kuhlman (1987) that revealed that the more similar the transfer task is to what was practiced, the less likely superior transfer will take place for variable practice. Therefore, Landin, et al. (1993) differed the transfer task by changing the distance and position of the free throw to the side of the basket. For the free throw retention test, there was no significant difference between the two groups, although the specific + variable performed more accurately. These results demonstrated the generalizability of a varied practice set up for real-world sports, which contradicts the way most coaches and teachers approach a practice for game-like situations. For example, foul shots are taken in increments of one or two at a time during a game. Most coaches, however, have athletes practice well over two foul shots at a time. The results of the transfer test did not meet expectations of superior variable practice because of the fact that the visual display needed to have some type of familiarity.

In the dart throw experiment, Goodwin et al. (1998) wanted to test the generalizability of the variability of practice hypothesis for sports' practice routines using criterion skills, typically studied under laboratory conditions. Goodwin et al. used the same practice groups as had Landin et al. (1993) (specific and specific + variable) but took the

variable practice a step further and added a third group. The three practice groups consisted of specific, specific + variable (three variables), and specific + varplus (five variables). This practice set up was to determine whether specific practice supplemented with variable practice enhanced retention given that typically this practice set-up enhances transfer tests.

Sixty undergraduate students practiced throwing darts to the center ring of a dartboard. The specific group threw from 2.39 m for 75 trials. The specific + variable group threw from 1.47 m, 2.39 m, and 3.30 m for 25 trials each, repeating no distance more than two times consecutively. The specific + varplus threw from 1.47 m, 1.93 m, 2.39 m, 2.84 m, and 3.30 m for 15 trials each, repeating no distance more than two times consecutively.

The 24-hour retention test of 15 trials at 2.39 m showed no significant differences between all three groups. On the other hand, the 24-hour transfer test of 15 trials at 3.76 m showed a distinctive performance difference among groups: (a) specific + varplus performed the best, and (b) specific + varplus and specific + variable performed better than specific. For retention, the results generally but not entirely indicated specific + variable was as good as and somewhat better than specific for improving retention. The transfer results generally but not entirely indicated that specific + variable was better than specific in improving transfer. In other words, some variation was better than none, but more practice was not necessarily better.

The three lab experiments that compared specific and variable practice conditions pertaining to the specificity of learning and the variability of practice hypotheses are those of Shea and Kohl (1990) and Sherwood (1996).

To verify the notion that specific practice with added variable practice enhances retention of a force production task, Shea and Kohl (1990) performed two lab experiments.

The apparatus was a two-part system that first measured an exerted force and then changed it to a voltage. The voltage was then sent to a computer able to read it. From there, the results were displayed on a monitor for participants to view during the task.

The procedure called for the participant to lie upon a table with the monitor positioned directly above the eyes of the participant. The force transducer was adjusted to allow the participant, whose elbow rested on the table, to raise the forearm 90° in order to grip the transducer with the palm. After the participant pulled on the transducer in an attempt to exert a given force, the monitor displayed immediate KR in the form of a vertically ascending line in conjunction with a horizontal line, which represented the target force. This enabled the participant to view response bias, or the degree to which error was made.

The first experiment included 24 college students placed in specific and a specific + variable practice conditions. Each group experienced 85 practice trials at the criterion force of 175N. The specific group practiced the 85 trials in 17 blocks with a 16 s interval between each. The specific + variable group practiced the same five trials per block but also had three interpolating trials (at 25 and 50 N above and below the criterion force) in between each trial, yielding 17 trials per block, for a total of 289 trials. Experiment 2 used the previous conditions in addition to a specific + specific condition. The specific + specific condition practiced all 289 trials at the criterion force.

Two KR blocks at the criterion force of 175N with no interpolated trials made up the retention test, taken 24 hours after acquisition. The retention results of Shea and Kohl's first experiment showed that the specific + variable group performed significantly better than the specific alone, signifying that more practice was better and that variability was beneficial. On

the other hand, the retention results of Shea and Kohl's second experiment showed that the specific + variable was significantly better than the other two conditions, indicating that more is not necessarily better and that varying practice schedules aid in retention.

Sherwood (1996) conducted a rapid aiming task to determine whether the random practice groups' increased thought processes affected the way error detection and movement were carried out. Essentially, did one directly correlate to the other? For this discussion, only the motor task will be addressed.

A slotted Plexiglas platform, large enough for a 75° movement, resting upon a tabletop was the apparatus used. A 16-in. aluminum handle had a Beckman potentiometer (Model No. 3351, Beckman Instruments, Brea, CA) attached to it for recording spatial bias while it traveled through the slot. This bias was captured digitally and stored by a MINC 11/23 computer (Digital Equipment Corporation, Merrimack, NH).

The 24 student participants, with elbows fixed to the table, were to make a right-handed reversal movement to the degrees of either 20, 40, or 60 in 225 ms from a starting point of 0° (closest to the participant) and returning to the starting point. An opaque sheet eliminated potential visual feedback.

Participants were quasi-randomly divided into either a blocked or a random practice group. The blocked practice group moved 30 trials at each of the angles 20°, 40°, and 60°. The counterbalanced order of amplitudes allowed for the six possible block orders to have two participants practice at each. The random practice group practiced each of the amplitudes with no consecutive amplitudes repeated, creating the repeating measure of nine blocks of 10 trials.

For the no KR retention test, all participants were randomly divided into four groups (random/random, random/blocked, blocked/blocked, and blocked/random) to perform 10 trials at each of the three amplitudes 2 minutes after acquisition. Another retention test was administered 24 hours after the immediate retention test. Five seconds after each movement had stopped, participants guessed their finishing point for both tests. A counterbalance of amplitudes for the blocked group followed the same format as had acquisition. Both retention tests maintained the same set-up and conditions.

The author noted that in immediate retention there was a significant acquisition effect where the random condition performed better than the blocked condition. Only partial support was found in either study regarding the specificity of learning hypothesis. (The second study can be found listed first in the next section of study, error detection.)

Error-Detection Capabilities

Another area of the present study examined was error-detection capabilities. The capability of acquiring error-detection skills was interpreted from the increased correlation of objective and estimated error in a ballistic-timing task. Subjective reinforcement, or error estimation, during the KR-delay interval is assumed to lead to better internal feedback for movement guidelines to increase learning (Schmidt & White, 1972). It is also said to promote skill development and error-detection capabilities for similar skills (Liu & Wrisberg, 1997). If KR were given consistently during practice and then removed, the participant would continue to remain at current accuracy levels of performance or even exceed present levels (Schmidt, 1975) because subjective reinforcement had taken the place of KR (Hogan & Yanowitz, 1978).

Recent views hold that the learner is actively engaged in movement procedures and

error detection during KR-delay intervals (Swinnen, 1990). The participant, working on the schema for the particular goal movement, is engaged in intense thought processes. Extremely short KR-delay intervals or interpolated KR-delay interval activities disrupt learning and may slow down error-detection capabilities (Swinnen, Schmidt, Nickolson, & Shapiro, 1990). In addition, the more that KR is given to a performer, the more dependent on that information the participant is and the less able the participant will be to detect errors. This notion is termed the *guidance hypothesis*. The means by which error-detection capabilities are measured are the correlation of the objective (actual) and subjective (estimated) errors. When error-detection capabilities are strong, the difference between the objective and subjective errors is small. The following experiments looked at variable practice and subjective estimation on error-detection capabilities.

Sherwood (1996), as stated earlier, performed two experiments comparing blocked and random practice conditions for spatial accuracy and error detection in a rapid aiming task. The aim was to determine if higher levels of thinking and processing involved in random practice not only apply to movement thought processes, but also to error detection.

The task for the first experiment called for 24 right-handed participants to move a lever from a starting point of 0° to either 20, 40, or 60° with reversal movement in 225 ms. The blocked group practiced each amplitude (counterbalanced) for 30 trials, and the 90 total trials were measured in 10 repeated-measure trial blocks. KR was given in three different areas: (a) actual location; (b) time, which was qualitative; and (c) partial error, which was quantitative.

For retention, the groups were arranged in random/random, random/blocked,

blocked/blocked, or blocked/random conditions with six participants in each, in order to evaluate specificity of practice. The immediate retention took place 2 min following the acquisition with 10 no-KR trials at each of the three amplitudes, which was then followed by a 24-hr, delayed, no-KR, retention test. In each of the retention tests, reversal points were guessed 5 s after the reversal was made.

Although blocked had a smaller mean |O-S| error than did random for the acquisition trials in the first experiment, the random condition on immediate and delayed no-KR retention tests had a smaller mean |O-S| error. These findings indicated that when parameter variations (force or time) rather than the whole motor program were changed, random practice conditions with estimation were better for learning a motor skill.

In the second experiment by Sherwood (1996), methods that differed from the first were as follows: (a) 40 participants; (b) 24 trials per amplitude (72 total trials) analyzed in eight trial blocks with repeating measures; (c) two independent variables (estimation and no estimation for each blocked and random grouping) added at retention (40 trials, or 10 at each amplitude on the immediate retention test) and finally, (d) a 30° measure added during transfer as the novel transition. No groups estimated during the acquisition trials. Estimation only occurred at the no-KR retention test in order to determine if random practice was beneficial without the added contextual interference of estimation.

Although the overall results were insignificant, it was found that when participants guessed spatial errors on retention, the acquisition group practicing under random conditions demonstrated lower spatial |CE| than under blocked. The results also indicated that there were no significant differences between the random or blocked practice conditions that were not

required to guess their spatial errors on retention. As Sherwood pointed out, it is possible that the blocked condition performed more poorly than the random when required to begin estimating errors on the retention test because participants did not engage in the intense thought processes and the internal error detection that the random group experienced when changing responses from trial to trial during acquisition.

Another experiment using a reversal slide was that of Swinnen (1990). Participants were tested in three experiments to analyze the significance of the KR-delay and Post-KR interval for learning and retention. A comparison was made using the three following conditions: interpolated task estimation, no estimation, and estimation. The last group was added to determine if the general hypothesis of forced estimation benefited learning on a timing task.

The slide was a ball-bearing sleeve attached to a stainless-steel shaft approximately 1.3 m long. It was equipped with a handle grasped by the fingers and a pointer directly in front of the handle. The task was to move the slide in a three-part movement to the left. The first segment closed a switch on the right end while moving into a target zone of 65 cm. The second segment reversed the slide to a zone 45 cm away. The third and final segment was the follow-through to the left end, which triggered the stop-time switch. The target task time was to be 1,000 ms per trial. The interpolated task was for the participant to view two reversal slide movements performed by the experimenter. The movements were similar to that of the primary task but at a shorter total distance of 42 cm. A second apparatus placed 1 m in front of the participant was used for the interpolated reversals. The participant was to estimate error of this secondary task, taking away from the primary focus.

In the first experiment, 66 college undergraduates were assigned to the three practice

conditions (interpolated task estimation, no-estimation, and estimation) previously mentioned, with equity among gender for each group. The interpolated task estimation condition was to guess the reversal timing error during the KR delay interval of the primary task. The no estimation condition rested throughout the KR delay interval. And the estimation condition estimated errors of the primary task in milliseconds.

All conditions began with 80 KR trials in the acquisition phase. The retention phase consisted of 25 no-KR trials each in the immediate (10 min) and 2-day retention phases. In the first experiment it was noted that during acquisition, the no-estimation condition performed better than the estimation condition and was significantly better than the interpolated condition. However, during a delayed-retention test, the estimation group performed better than the no-estimation group.

The second experiment resulted similarly to the first, which led to the third experiment by Swinnen (1990). The results of this experiment revealed the detrimental effect of an interpolated task during the KR-delay interval, suggesting that important thought processes took place here. The researcher also found that although estimation during acquisition was beneficial in performing the criterion task on the retention test, results were not significant. The author suggested that forced estimation may not be useful in that estimation may automatically occur in motor-skill performance.

Fifty KR trials followed by 50 no KR trials were the means by which Hogan and Yanowitz (1978) examined estimation and no-estimation conditions on a ballistic linear task. The purpose of the study was to find empirical evidence of the role of error detection on a ballistic motor skill. The apparatus was a mounted, steel-based slide flush and fixed upon one end of a tabletop. On top of the base, two aluminum blocks were spaced 85 cm apart and

housed two steel rods .5 in. in diameter to make a trackway. Upon the rod of the trackway was an aluminum slide, 7.6 x 3.5 x 5.8 cm, functional by way of a 1-in. Thompson ball bushing. Projecting vertically from the center of the slide was a handle.

The slide was operated by an initial 4.5-v Hewlett Packard (Model 6216A) power supply. The slide started from the left aluminum block, which interrupted a beam of light directed at a photocell directly across from it. As the slide moved, the connected beam signaled a switch, which started the Beckman Universal Eput and Timer (Model 8350). When the slide passed through the second photocell and light source, the timer stopped.

Twenty right-handed, undergraduate students moved a slide from left to right, covering a distance of 47 cm in 200 ms with room to allow a follow-through from the momentum through the measured distance. The design for this experiment was a 2 (groups) x 2 (KR conditions) x 10 (blocks of 10 trials) repeated-measures formation. A 13-s interresponse interval was implemented. Whereas group one was to estimate movement time up to three digits, the other group was to repeat three nonsense letters. All participants were given verbal KR in milliseconds for the first 50 trials. Following a one-minute break, the second 50 trials were administered without KR. The absolute, constant, and variable error were measured from the dependent variable of movement time per trial.

The authors, Hogan and Yanowitz (1978), found that estimation showed no improvement with KR. However, when KR was withdrawn, the estimation group remained steady on AE and CE scores, which were significantly smaller in absolute errors than for the nonsense group. These findings show that increased correlation of objective and subjective errors occurring with practice led to error-detection capabilities; movement errors stated verbally served as KR when KR was removed.

Liu and Wrisberg (1997) devised a study to observe a possible correlation between subjective estimation of both movement form and movement error during immediate and delayed-KR conditions. The three-fold purpose was to confirm (a) the prediction that accuracy would not be affected by the KR delay, (b) movement form estimation would not enhance throwing accuracy during acquisition but would during retention, and (c) movement form estimation during acquisition would enhance performance estimation error during retention. The study used the task of an underhand throw.

The four practice groupings for acquisition were immediate KR, delayed KR, immediate KR + form estimation, and delayed KR + form estimation. Participants received immediate KR by turning their heads following the throw release, whereas the delayed KR group waited a period of 13 s. Groups required to estimate did so after viewing the placement of the landing.

Forty-eight college participants stood sideways to a target on the floor with the non-throwing side farthest away at a distance of 3 m. Sweeping across the body in an underhand fashion, participants tried to land a nonbouncing ball onto a target of point-valued circles whose center circle held the most value. Participants were blinded to peripheral vision via blinder glasses.

A five trial, no-visual-KR pretest was administered following a three trial visual practice session. Participants viewed a hand-held drawing of the target, guessed the direction, distance, and zone the throws landed, and thereby performed estimation practice. Acquisition consisted of six blocks of 10 trials with 1 min of rest between blocks. The retention tests were 5 min and 24 hr after acquisition, and each consisted of a five-trial block without KR but with verbal estimation.

Retention results showed that the estimation groups performed more accurately than the no-estimation groups. The estimation groups were superior for estimated error accuracy; the delayed-KR estimation condition performed slightly better than the immediate-KR estimation condition. These results once again support the conception that estimation enhances error-detection capabilities.

Finally, a ballistic linear task was the means by which Schmidt and White (1972) examined Adams's (1971) closed-loop theory. The theory states that participants should develop a perceptual trace over time (perceptual trace is stored feedback of a correct movement response that is compared to the feedback of a current movement). From this perceptual trace, error-detection capabilities formed could take the place of KR to guide skill execution. Other predictions following Adams's theory for this study include KR removal at the motor stage of learning. It is predicted that KR removal sustains response correctness and allows error-detection capabilities to take over correct responses and even learning. The KR removal also should have error detection demonstrated by a smaller difference between objective and subjective errors, leading to participant confidence.

The apparatus was a slide similar to the one used in the Hogan and Yanowitz (1978) study; the steels rods (0.5 in. in diameter) extended 36 in. and fixed to a wooden stand, which was attached to a tabletop. On top of the rods were two ball-bearing sleeves (Thompson Ball Bushing) connected by a slide with a 5-in. vertical handle (0.5 in. diameter). Moving the slide from right to left $\frac{1}{4}$ in. released a microswitch to start the timer (Standard Type S-1, 6-v. DC clutch), which was then stopped at the far left microswitch, 9.5 in. away. A stop enabled the mechanism to come to rest at the far right, which opened the last microswitch and allowed the timer to stop.

Ten right-handed, undergraduate and graduate (4 female and 6 male) students moved a slide for 170 trials from left to right, covering the 9.5 in. in 150 ms. KR was present on all trials except 11-20 and 141-170. For two days participants estimated after each trial for three conditions: (a) objective error confidence (how close the response was within 5 ms, as confidence is a sign of a strong perceptual trace), (b) subjective error (actual score, which would be used to subtract the objective error from and, again, shows strength in error detection), and (c) subjective error confidence (how confident the participant was that the subjective score was within 5 ms of the actual or objective score). These responses were given 5 s after the movement was completed as indicated by three lamps lit within 5 s intervals. After the responses, KR was given when the task called for KR.

The task took two days of practice. Day 1 of acquisition consisted of 10 KR trials, 10 no-KR trials, and 100 KR trials. Day 2 consisted of 20 KR trials followed by 30 no-KR trials. The supposition was that the first KR withdrawal segment would have a decline in performance because of its occurrence during the verbal motor stage, whereas the second KR withdrawal segment would allow for continued performance and improvement because of the action taking place in the motor stage of learning. After substantial practice with KR, the subjects were in fact able to substitute subjective estimation for KR when KR was withdrawn.

A second experiment conducted by Schmidt and White (1972) tested the notion that to withdraw KR before error-detection capabilities have been formed was detrimental to motor skill learning. In this study, 22 trials were performed, and KR was administered only for the first two trials. The findings fully supported the notion that early KR withdrawal was detrimental to learning.

In conclusion, the results of studies specific to the variability of practice hypothesis that used timing tasks ranged from no support to strong support and included limited and partial support. Results for the specificity of learning hypothesis also had little support. The studies utilizing specific conditions in addition to some variable conditions performed better than those utilizing specific-only conditions. A study using specific versus random condition showed that the random group outperformed the specific group on immediate retention. And a study that chose to include retention and transfer found no significant differences on the retention test between the practice conditions: specific, specific + variable, and specific + varplus. However, the specific + varplus performed better than the specific and the specific + variable conditions on the transfer test, showing some limited support for the variability of practice hypothesis. This poses the thought that neither specific nor variable practice conditions alone may be more beneficial for transfer than a condition of specific with many variable conditions.

Finally, from the studies addressing error detection, it was noted that variable practice with KR was better for retention over blocked practice conditions. Despite the suggestion of Swinnen (1990) that forced error estimation may not be useful because of the lack of significance in his findings and that error estimation may occur automatically, other studies showed benefits of subjective estimation. The benefits, however, may only be gained once enough trials of KR have been administered with adequate KR delay time to develop error-detection capabilities.

The studies previewed above used at most 150 trials, which may not be enough to allow for learning to take place. The studies were also specific to only one area of testing, such as specific versus variable practice conditions for retention, and only one author chose

to examine the retention and transfer tests together. No studies have been made examining two different types of variables, such as error detection and types of practice at the same time, while testing the two hypotheses, the specificity of learning hypothesis and the variability of practice hypothesis. In addition, only one study went so far as to cross test the specificity of learning hypothesis (test-specific practice conditions on a transfer test). This idea of testing specific practice with transfer tests may be worthy of investigation because many previous studies have found discrepancies in the claims of both the specificity of learning hypothesis and the variability of practice hypothesis.

With the discrepancies in support for former studies on the specificity of learning hypothesis, the following testing conditions are introduced in hopes of bringing new insight and clarification to the issue. Using a ballistic open motor skill with specific as well as specific + variable practice conditions is a combination unique to studies of this nature. Additionally, this experiment focused not only on retention, but also transfer for cross testing the specificity of learning and the variability of practice hypotheses. The experiment also used error-detection as an independent variable.

This study utilized 48 male and female college students for an anticipation timer study. Assigned to either a specific or specific + variable practice group were both 0% and 100% estimation conditions for a four-group total. The 3-day acquisition of 90 trial blocks for each day used speeds of 7, 5, and 9 mph for a 270-trial total. Each practice condition received Knowledge of Results (KR) at 10 or 5 s respective to the 0% estimation or 100% estimation conditions mentioned above. A 24-hour, no-KR, 10-trial retention test was held at 7 mph with a 10-s between-trial estimation. This was followed by an immediate no KR transfer test of two 10-trial blocks using speeds of 3 and 11 mph with a 5-s delay for

estimation. $|CE|$, VE, and $|O-S|$ served as dependent variables.

Hypotheses for the Investigation

The following hypotheses for the investigation were examined at the .05 level of significance:

1. There were no significant differences in the acquisition phase between specific and specific + variable practice conditions for ICEI.

2. There were no significant differences in the acquisition phase between the 100% and 0% estimation conditions for ICEI.

3. There were no significant interaction effects between practice x estimation conditions in the acquisition phase for ICEI.

4. There were no significant differences in the acquisition phase over time for ICEI.

5. There were no significant differences in the acquisition phase between specific and specific + variable practice conditions for VE.

6. There were no significant differences in the acquisition phase between the 100% and 0% estimation conditions for VE.

7. There were no significant interaction effects between practice and estimation conditions in the acquisition phase for VE.

8. There were no significant differences in the acquisition phase over time for VE.

9. There were no significant differences in the retention phase between specific and specific + variable practice conditions for ICEI.

10. There were no significant differences in the retention phase between the 100% and 0% estimation conditions for ICEI.

11. There were no significant interaction effects between practice x estimation conditions in the retention phase for ICEI.

12. There were no significant differences in the retention phase between the specific and specific + variable practice conditions for mean $|O-S|$ error.

13. There were no significant differences in the retention phase between the 100% and 0% estimation conditions for mean $|O-S|$ error.

14. There were no significant interaction effects between practice x estimation conditions in the retention phase for mean $|O-S|$ error.

15. There were no significant differences in the retention phase between specific and specific + variable practice conditions for VE.

16. There were no significant differences in the retention phase between 100% and 0% estimation conditions for VE.

17. There were no significant interaction effects between practice x estimation conditions in the retention phase for VE.

18. There were no significant differences in the transfer phase between specific and specific + variable practice conditions for ICEI.

19. There were no significant differences in the transfer phase between the 100% and 0% estimation conditions for ICEI.

20. There were no significant interaction effects between practice x estimation conditions in the transfer phase for ICEI.

21. There were no significant differences in the transfer phase between the specific and specific + variable practice conditions for mean $|O-S|$ error.

22. There were no significant differences in the transfer phase between the 100% and 0% estimation conditions for mean |O-S| error.

23. There were no significant interaction effects between practice x estimation conditions in the transfer phase for mean |O-S| error.

24. There were no significant differences in the transfer phase between specific and specific + variable practice conditions for VE.

25. There were no significant differences in the transfer phase between the 100% and 0% estimation conditions for VE.

26. There were no significant interaction effects between practice x estimation conditions in the transfer phase for VE.

CHAPTER 3: METHOD

This study was designed to test the effects of variable practice and subjective estimation on error-detection capabilities. The purpose was twofold. The first was whether or not variable practice on a ballistic open motor skill would increase transfer, as indicated by the variable of practice hypothesis, in addition to increasing retention. The second was whether or not subjective estimation would help foster error-detection capabilities upon KR removal. This developed capability would not only aid in continued success on a ballistic motor skill, but it would also promote further motor skill learning.

Participants

Forty-eight students (24 women and 24 men, M age = 18-57 years) with no prior experience at the experimental task volunteered to participate. Participants were quasi-randomly assigned to one of four experimental practice conditions with constraints that the number of participants ($n = 12$) and the female-to-male ratio (6:6) between conditions be equated. The four practice conditions were formed from two practice types, namely, the specific and the specific + variable practice groups. Each of these groups was further subdivided to include a type of error estimation (0% estimation or 100% estimation). Written informed consent was obtained prior to participation in the study.

The four experimental conditions are as follows. The specific 0% estimation condition practiced 270 acquisition trials spread out over 3 days with 90 trials each day. The speed for each trial was a constant 7 mph. Ten seconds after the completion of each acquisition trial, the participants received quantitative KR to the nearest thousandth of a second. This delay is termed the KR-delay interval. Participants in the second condition, the specific 100% estimation condition, also practiced 270 acquisition trials spread out over 3

days with 90 trials each day. The trial speed again was a constant 7 mph. Five seconds after the completion of each acquisition trial, participants in this condition gave subjective estimation (estimation of produced errors) to the thousandth of a second. Five seconds after the subjective estimation, participants received quantitative KR from the experimenter. In the third condition, the specific + variable 0% estimation, participants practiced 270 trials over 3 days with each day consisting of 90 trials. They practiced at three varying speeds: 5mph, 7 mph, and 9 mph. No more than one velocity was practiced two times in succession. Following each acquisition trial, the KR-delay interval was set at 10 s followed by quantitative KR from the experimenter. The fourth and final condition was the specific + variable 100% estimation. Participants here also practiced 270 trials over 3 days with each day of 90 trials. They practiced at same three varying speeds: 5mph, 7 mph, and 9 mph. No more than one velocity was practiced two times in succession. Five seconds following each acquisition trial, subjective estimation was given by the participants. This was in turn was followed by a KR-delay interval of 5 s and then quantitative KR.

Apparatus/Task Description

The apparatus consisted of a Bassin Anticipation Timer (model 54035, Lafayette Instrument Co., Lafayette, IN) approximately 153 cm long with a runway of lights situated equidistant along the top. The Bassin Anticipation Timer consisted of two 16-lamp runways secured on a table for height appropriateness. An amber warning light, located at the top of the runway, alerted participants 2.5 s before the progression of red lights would begin down the runway. The participant had to depress a response button when the last light illuminated. At this point, response bias (the degree to which the participant's speed was too fast or slow) was recorded to the nearest thousandth of a second (Magill, 1993). Additionally, participants

in the estimation conditions estimated errors 5 s after each acquisition trial. KR was verbalized for all four practice conditions after a 10-s KR-delay interval. The timing of all within-trial intervals was controlled by the timer, whereas the between-trial intervals and the KR-delay interval were directly controlled by the clock/counter (model 54035 Lafayette Instrument Co., Lafayette, IN. 47903), both of which were out of the participant's view.

Procedure

The 24 participants were each assigned to one of four practice conditions: a specific 0% estimation condition (S 0%), a specific 100% estimation condition (S 100%), a specific + variable 0% estimation condition (S + V 0%), or a specific + variable 100% estimation condition (S + V 100%). This order was repeated until all participants had filled the four practice conditions.

At the beginning of the investigation, participants were verbally given an overview of the experiment. Participants were informed that the goal was to perform the task as accurately as possible such as to obtain a perfect score of zero. Before performing the first trial, the participants engaged in a pretrial run to help get the idea of the movement.

There were three phases of performance, namely, acquisition which lasted for three days, followed by retention and transfer, which together lasted one day. Each of the three acquisition days consisted of 90 trial blocks for a total of 270 trials for all practice conditions. Participants in the S 0% estimation condition practiced at a constant speed of 7 mph, which was also the retention speed. These participants received quantitative KR 10 s after each trial. The participants in the S 100% estimation also practiced at a constant speed of 7 mph. However, 5 s following each trial, these participants had to provide subjective estimation of their errors. Five seconds following this, KR was provided by the experimenter. The S + V

0% practiced at variable speeds of 5, 7, and 9 mph and received KR 10 s following each trial. The S + V 100% estimation condition also practiced at variable speeds of 5, 7, and 9 mph. These participants gave subjective estimation 5 s after task completion and then after 5 s more received quantitative KR.

At the conclusion of the acquisition phase, a 24-hr, no-KR retention test took place, followed by an immediate transfer test. The retention test, phase two, consisted of 10 trials at a constant 7 mph with all four practice conditions estimating errors. There was a 10 s between-trial interval. The purpose of the no-KR retention test was to examine the predictions of the specificity of learning hypothesis. The final phase consisted of a 20-trial transfer test with 10 trials at 3 and 11 mph each. All four practice conditions again provided subjective estimation of errors. The purpose of the no-KR transfer test was to examine the predictions of the variability of practice hypothesis in addition to the specificity of learning hypothesis.

The study was conducted in 30-min blocks on M, T, W, and TH. Participants were tested on all four days consecutively. The first three days were acquisition conditions for 90 trials each day with KR. Twenty-four hours following the last acquisition trial, day 4 consisted of a 10-trial, no-KR retention test specific to practice conditions (7 mph). A no-KR variable transfer test of 20 trials (10 trials at two different speeds, 3 and 11 mph) immediately followed the retention test. The velocities for the transfer test were counterbalanced.

Statistical Analysis

A randomized-groups design was used in the investigation. The |CE| and VE for the 270 trials in the acquisition phase were calculated into trial blocks consisting of 10 trials each. The acquisition trials were analyzed in a 2 x 2 x 3 x 3 (Practice Condition x Estimation Condition x Day x Trial Block) factorial analysis of variance with repeated measures on the third and fourth factors. |CE|, mean |O-S| error, and VE for the 10 trials in the retention phase were calculated into one trial block and analyzed in a 2 x 2 (Practice Condition x Estimation Condition) factorial ANOVA. |CE|, mean |O-S| error, and VE for the 20 trials in the transfer phase were calculated into two trial blocks consisting of 10 trials each. The transfer trials were analyzed in a 2 x 2 x 2 (Practice Condition x Estimation Condition x Velocity) factorial ANOVA with repeated measures on the third factor. The alpha level was set at .05 for all statistical analyses, and the loci of significant effects were identified by the Tukey HSD post hoc procedure. When the assumption of sphericity was violated, statistical significance was determined with the use of the Greenhouse-Geisser degrees-of-freedom adjustment (Greenhouse & Geisser, 1959).

CHAPTER 4: RESULTS

The study was designed to examine two issues in motor skill learning: the question of practice variability and the efficacy of error-detection capabilities. Most studies use discrete, or closed, motor skills, which do not include the other half of the skills coaches and teachers use. To represent the types of skills that teachers and coaches primarily use, this study examined a ballistic motor skill. The dependant measures were (a) Absolute Constant Error ICEI (response accuracy), (b) Variable error VE (response consistency), and (c) Mean Absolute Objective-Subjective Difference Error $|O-S|$ (difference between actual and estimated responses).

The participants were 48 male and female students each assigned to one of two practice groups: Specific (S) or Specific + Variable (S + V). These two practice groups were further divided into two estimation conditions: 100% or 0%. The final experimental conditions were S 0%, S 100%, S + V 0%, and S + V 100%. The participants in the 100% estimation condition gave qualitative estimation of error 5 s after each trial, whereas the participants in the 0% estimation condition did not. Additionally, participants in each practice condition received KR 10 s after each trial.

The acquisition phase lasted 3 day, for a total of 270 acquisition trials. Twenty-four hours later, the no-KR retention test took place. The test consisted of 10 trials at the 7-mph retention speed, and all four practice conditions estimated errors with a 10-s between trial interval. The no-KR transfer test immediately followed the retention test with 20 trials in two 10-trial blocks. The speeds tested were 3 mph and 11 mph. Estimation after 5 s was required for all practice conditions.

Four practice conditions using specific and variable groups along with or without estimation were compared across time: (a) 3 days of acquisition, (b) a retention test 24 hours following acquisition, and (c) a transfer test immediately following the retention test. This study examined the effects of practice groups and estimation on retention and transfer tests. Specifically, it was predicted that specific practice would not only be beneficial on retention, but also on transfer, a cross testing of the specificity of learning hypothesis. Additionally, it was predicted that subjective estimation would enhance and even promote learning a ballistic motor skill when KR was removed. These hypotheses were tested through comparison of learning across time and across practice conditions, with retention and transfer tests following.

Previous research had empirical limitations for the specificity of learning hypothesis and theoretically unclear benefits for subjective estimation. The results of at least three studies, that is, Goodwin et al. (1998), Landin et al. (1993), and Shea and Kohl (1990), conflict with the specificity of learning hypothesis in that specific + variable practice resulted in better retention scores than specific alone or there were no differences found. The present study attempted to add to that finding in addition to further testing the specificity of learning hypothesis by including a transfer test in hopes of finding that specific, in addition to variable practice, will lead to enhanced transfer. Error estimation, which is supposed to qualify as variable practice and should therefore benefit transfer, was only utilized in continued acquisition or retention tests and not in any transfer tests (Hogan & Yanowitz, 1978; Liu & Wrisberg, 1997; Schmidt & White, 1972; Sherwood, 1996). Newell (1974) found that with ballistic timing tasks, those who received KR while estimating error produced less absolute difference between objective and subjective error than did those who did not receive KR. He

also found that when he used a different type of result-clarification test for the error estimation, results changed. It is hoped that this study will add some clarity to the benefits of error estimation. In addition, few studies using ballistic open motor skills (Lee, Magill, & Weeks, 1985; Newell & Shapiro, 1976; Wrisberg et al., 1987) have been done, and fewer yet have combined all three topics: variable practice, error estimation, and the cross-testing of the specificity of learning hypothesis (Hogan & Yanowitz, 1978; Schmidt & White, 1972; Sherwood, 1996; Swinnen, 1990).

The findings are presented under the following headings: (a) acquisition phase (b) retention phase, (c) transfer phase, and (d) summary of hypothesis decisions.

Acquisition Phase

The data from the 270 trials in the acquisition phase were analyzed by the experimenter, who used a 2 x 2 x 3 (Practice Condition x Estimation Condition x Time) factorial ANOVA with repeated measures on time. The significance (alpha) level was set a .05.

Absolute constant error (/CE /). Results indicated no main effect for time, $F(2, 44) = 0.38, p > .05$. There was no significant main effect for practice groups, $F(1, 44) = 0.01, p > .05$, or estimation conditions, $F(1, 44) = 0.77, p > .05$. No significant interaction effect occurred between practice groups and estimation conditions, $F(1, 44) = 0.16, p > .05$. (Table 1).

Variable error (VE). Results indicated a significant main effect occurred with the time condition, $F(2, 44) = 6.18, p < .05$. Day 3 showed significant smaller error than day 2, which in turn showed a significantly smaller error than day 1. There was no significant main

effect for practice groups, $F(1, 44) = 2.59, p > .05$, or estimation conditions, $F(1, 44) = 0.24, p > .05$. No interaction occurred between practice groups and estimation conditions, $F(1, 44) = 0.02, p > .05$ (see Table 2).

Table 1

Analysis of Variance for Absolute Constant Error (|CE |) on Acquisition

Source	df	SS	MS	F
Between subjects				
Practice condition (P)	1	0.00	0.00	0.01
Estimation condition (E)	1	0.01	0.01	0.77
P x E	1	0.00	0.00	0.16
Within subjects				
Time (T)	2	0.00	0.00	0.38
P x T	2	0.01	0.00	1.45
E x T	2	0.00	0.00	1.20

* $p < .05$

Table 2

Analysis of Variance for Variable Error (VE) on Acquisition

Source	df	SS	MS	F
Between subjects				
Practice condition (P)	1	0.01	0.01	2.59
Estimation condition (E)	1	0.00	0.00	0.24
Table 2 (cont'd.)				
P x E	1	0.00	0.00	0.02
Within subjects				
Time (T)	2	0.01	0.01	6.18*
P x T	2	0.00	0.00	0.57
E x T	2	0.00	0.00	0.95

* $p < .05$.*Retention Phase*

The data from the 10 trials in the retention phase were analyzed by the experimenter, who used a 2 x 2 (Practice Condition x Estimation Condition) factorial ANOVA. The alpha level was set at .05.

Absolute Constant Error (|CE|). Results indicated no significant main effect for practice groups, $F(1, 44) = 0.07, p > .05$. The main effect for estimation condition was also not significant, $F(1, 44) = 0.01, p > .05$. The means for |CE| are displayed in Table 3. The interaction effect for practice groups and estimation conditions was not significant, $F(1, 44)$

= 0.29, $p > .05$ (see Table 4).

Table 3

Means and Standard Deviations for Absolute Constant Error (|CE|) on Retention and Transfer

Practice group	Mean	Standard deviation
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Table 3 (cont'd.)

	Retention	
Specific 100%	0.04	0.70
Specific 0%	0.05	0.05
Specific + Variable 100%	0.04	0.06
Specific + Variable 0%	0.03	0.04
	Transfer	
Specific 100%	0.10	0.11
Specific 0%	0.01	0.08
Specific + Variable 100%	0.04	0.05
Specific + Variable 0%	0.04	0.05

Table 4

Analysis of Variance for Absolute Constant Error (|CE |) on Retention

Source	df	SS	MS	F
Between subjects				
Practice condition (P)	1	0.00	0.00	0.07
Estimation condition (E)	1	0.00	0.00	0.01
P x E	1	0.00	0.00	0.29

* $p < .05$.*Mean Absolute Objective-Subjective Difference Mean (|O-S |) Error. Results*

indicated no significant differences on the main effect for practice groups, $F(1, 44) = 1.72, p > .05$. The main effect for estimation conditions was significant, $F(1, 44) = 6.73, p < .05$.

The 100% estimation condition ($M = 0.07, SD = 0.05$) displayed a significantly smaller error than did the 0% estimation condition ($M = 0.15, SD = 0.13$). The means for $|O-S|$ are displayed in Table 5. The interaction effect between practice groups and estimation conditions was significant, $F(1, 44) = 5.09, p < .05$. The specific 100% estimation condition ($M = 0.03, SD = 0.2$) exhibited a significantly smaller error than did the specific 0% estimation condition ($M = 0.10, SD = 0.10$) (see Table 6).

Table 5

Means and Standard Deviations for Mean Objective – Subjective Error (|O-S |) on Retention and Transfer

Practice group	Mean	Standard deviation
Retention		
Specific 100%	0.03	0.02
Specific 0%	0.10	0.10
Specific + Variable 100%	0.04	0.03
Specific + Variable 0%	0.05	0.03
Transfer		
Specific 100%	0.08	0.06
Specific 0%	0.17	0.11
Specific + Variable 100%	0.04	0.03
Specific + Variable 0%	0.05	0.03

Table 6

Analysis of Variance for Mean Objective – Subjective Error (|O-S |) Error on Transfer

Source	df	SS	MS	F
Between subjects				
Practice condition (P)	1	0.15	0.15	25.02*
Estimation condition (E)	1	0.06	0.06	9.43*
P x E	1	0.04	0.04	6.71*

*p < .05.

VE. Results indicated no significant differences on the main effect for practice condition, $F(1, 44) = 0.04, p > .05$. The main effect for estimation condition was not significant, $F(1, 44) = 0.35, p > .05$. The means for VE are displayed in Table 7. The interaction effect between practice x estimation conditions was not significant, $F(1, 44) = 0.48, p > .05$ (see Table 8).

Table 7

Means and Standard Deviations for Variable Error (VE) on Retention and Transfer

Practice group	Mean	Standard deviation
		Retention
Specific 100%	0.05	0.05
Specific 0%	0.05	0.05
Specific + Variable 100%	0.06	0.05
Specific + Variable 0%	0.04	0.01
		Transfer
Specific 100%	0.14	0.15
Specific 0%	0.15	0.11
Specific + Variable 100%	0.07	0.07
Specific + Variable 0%	0.05	0.03

Table 8

Analysis of Variance for Variable Error (VE) on Retention

Source	df	SS	MS	F
Between subjects				
Practice Condition (P)	1	0.00	0.00	0.04
Estimation Condition (E)	1	0.00	0.00	0.35
P x E	1	0.00	0.00	0.48

* $p < .05$.

Transfer Phase

The data from the 20 trials in the transfer test were analyzed by the experimenter, who used a 2 x 2 (Practice Condition x Estimation Condition) factorial ANOVA.

/CE/. Results indicated a significant main effect for practice condition, $F(1, 44) = 10.71, p < .05$. The specific + variable condition ($M = 0.16, SD = 0.15$) displayed a significantly smaller error than did the specific condition ($M = 0.39, SD = 0.37$). The main effect for estimation condition was not significant, $F(1, 44) = 0.03, p > .05$. The interaction effect between practice x estimation conditions was not significant, $F(1, 44) = 0.03, p > .05$ (see Table 9).

Table 9

Analysis of Variance for Absolute Constant Error (/CE /) on Transfer

Source	df	SS	MS	F
Between subjects				
Practice condition (P)	1	0.08	0.08	10.71*
Estimation condition (E)	1	0.00	0.00	0.03
P x E	1	0.00	0.00	0.03

* $p < .05$.

Mean /O-S / Error. Results indicated a significant main effect for practice condition, $F(1, 44) = 25.02, p < .05$. The specific + variable condition ($M = 0.18, SD = 0.11$) displayed a significantly smaller error than did the specific condition ($M = 0.49, SD = 0.33$). The main effect for estimation condition was significant, $F(1, 44) = 9.43, p < .05$. The 100% estimation condition ($M = 0.24, SD = 0.17$) performed with a significantly smaller error than did the 0% estimation condition ($M = 0.43, SD = 0.27$). The interaction between practice x estimation conditions was also significant, $F(1, 44) = 6.71, p < .05$. The specific + variable with 100% estimation condition ($M = 0.08, SD = 0.05$) had a significantly smaller error than did the specific with 0% estimation condition ($M = 0.33, SD = 0.21$) (see Table 10).

Table 10

Analysis of Variance for Mean Objective – Subjective Error (|O-S |.) on Transfer

Source	df	SS	MS	F
Between subjects				
Practice condition (P)	1	0.15	0.15	25.02*
Estimation condition (E)	1	0.06	0.06	9.43*
P x E	1	0.04	0.04	6.71*

* $p < .05$.

VE. Results indicated a significant main effect for practice condition, $F(1, 44) = 11.91, p < .05$. The specific + variable condition ($M = 0.24, SD = 0.19$) demonstrated a significantly smaller error than did the specific condition ($M = 0.58, SD = 0.51$). There were no significant main effects for estimation conditions, $F(1, 44) = 0.01, p > .05$. No interaction occurred between the practice x estimation conditions, $F(1, 44) = 0.31, p > .05$ (see Table 11).

Table 11

Analysis of Variance for Variable Error (VE) on Transfer

Source	df	SS	MS	F
Between subjects				
Practice condition (P)	1	0.17	0.17	11.91*
Estimation condition (E)	1	0.00	0.00	0.01

Table 11 (cont'd.)

P x E	1	0.00	0.00	0.31
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* $p < .05$.

Summary of Hypothesis Decisions

The following hypotheses for the investigation were examined at the .05 level of significance and are labeled as either *retained* or *rejected*:

1. There were no significant differences in the acquisition phase between specific and specific + variable practice conditions for ICEI.
2. There were no significant differences in the acquisition phase between the 100% and 0% estimation conditions for ICEI.
3. There were no significant interaction effects between practice x estimation conditions in the acquisition phase for ICEI.
4. There were no significant differences in the acquisition phase over time for ICEI.
5. There were no significant differences in the acquisition phase between specific and specific + variable practice conditions for VE.
6. There were no significant differences in the acquisition phase between the 100% and 0% estimation conditions for VE.
7. There were no significant interaction effects between practice x estimation conditions in the acquisition phase for VE.
8. There were no significant differences in the acquisition phase over time for VE.
9. There were no significant differences in the retention phase between the specific

and specific + variable practice conditions for ICEI.

10. There were no significant differences in the retention phase between the 100% and 0% estimation conditions for ICEI.

11. There were no significant interaction effects between practice x estimation conditions in the retention phase for ICEI.

12. There were no significant differences in the retention phase between the specific and specific + variable practice conditions for mean $|O-S|$.

13. There were significant differences in the retention phase between the 100% and 0% estimation conditions for mean $|O-S|$.

14. There were significant interaction effects between practice x estimation conditions in the retention phase for mean $|O-S|$.

15. There were no significant differences in the retention phase between specific and specific + variable practice conditions for VE.

16. There were no significant differences in the retention phase between 100% and 0% estimation conditions for VE.

17. There were no significant interaction effects between practice x estimation conditions in the retention phase for VE.

18. There were significant differences in the transfer phase between specific and specific + variable practice conditions for ICEI.

19. There were no significant differences in the transfer phase between the 100% and 0% estimation conditions for ICEI.

20. There were no significant interaction effects between practice x estimation

conditions in the transfer phase for ICEI.

21. There were significant differences in the transfer phase between specific and specific + variable practice conditions for mean IO-SI error.

22. There were significant differences in the transfer phase between the 100% and 0% estimation conditions for mean IO-SI error.

23. There were significant interaction effects between practice x estimation conditions in the transfer phase for mean IO-SI error.

24. There were significant differences in the transfer phase between specific and specific + variable practice conditions for VE.

25. There were no significant differences in the transfer phase between the 100% and 0% estimation conditions for VE.

26. There were no significant interaction effects between practice x estimation conditions in the transfer phase for VE.

CHAPTER 5: DISCUSSION

The purpose of this study was to examine the effects of practice composition and error-detection capabilities in a ballistic open motor skill. The forty-eight male and female college students were assigned to a Specific (S) or Specific + Variable (S + V) practice group for a Bassin Anticipation timing task. The S group practiced at a speed of 7 mph, which was also the retention speed. The S + V group practiced at the 7 mph speed plus speeds of 5 and 9 mph. Both groups practiced 90 acquisition trials on three consecutive days for a total of 270 trials. Each of these practice groups was further divided into estimation and no estimation conditions for a total of four practice conditions: S 100% estimation, S 0% estimation, S + V 100% estimation, and S + V 0% estimation. After task completion, each condition would receive KR, and the estimation conditions would then estimate errors. The estimations occurred 5 s after task completion, whereas KR was given at 10 s after task completion. The 24-hr, no-KR, 10-trial retention test was held at the 7 mph speed, and both groups estimated errors at a 10 s between trial interval. The no KR transfer test of two 10 trial blocks used speeds of 3 and 11 mph for a 20-trial total immediately following the retention test. For this test, estimations were made from both practice groups after 5 s. The dependent measures of $|CE|$, VE, and $|O-S|$ were used for the experiment.

Acquisition

$|CE|$ and VE

For $|CE|$ and VE it was predicted that no interaction would be found between the two practice groups, the four estimation conditions, or practice groups x estimation conditions. In all of the above cases, the null hypotheses were not rejected.

As noted in the first experiment by Shea and Kohl (1990) and the dart throw study by

Goodwin et al. (1998), no main effect was found during acquisition. The first experiment used groups (specific and specific + variable) similar to those in the present study and found no main effect for practice conditions. In addition to the above groups, Goodwin et al. added a specific + varplus group and also found no main effect for practice conditions. The current null hypotheses concerning practice conditions were also not rejected and demonstrate that although studies testing the variability of practice hypothesis usually find that specific practice as opposed to any variation of a task is better during acquisition (Del Ray, Wughalter & Whitehurst, 1982; Lee et al., 1985; Shea & Kohl, 1990 [Experiment 2], 1991), this experiment, among others, displays that the usual findings are not consistent in all cases and often times are specific and that its task variations are similar (Landin et al., 1993; Shea & Kohl, 1990 [Experiment 1], 1991). A possible reason for the similarity of the two practice groups for |CE| and VE measures is that the speed variations had only a 2-mph difference that varied little from the specific speed. Additionally, the speeds set at 5, 7, and 9 mph may not have been drastic enough to be considered fast or slow. These speeds in general may also have been slow enough to allow the participant easy adjustments for consistent accuracy. Another reason for acquisition similarity may be that the large number of trials gave the participants the opportunity to learn the speeds. In Del Ray et al. (1982), there was a tremendous improvement in the random acquisition group after the first block (16 trials) and a slight improvement trend thereafter. Because of the present study's lack of significant differences and the possible quick learning, participants may be displaying the "after the first block effect" as in Del Ray et al. (1982).

The hypotheses' referring to error estimation stating that there is no difference between 100% and 0% estimation for |CE| and VE measures was consistent with typical

findings in the former experiments of Hogan & Yanowitz (1978), Liu & Wrisberg (1997), and Swinnen (1990). Swinnen (1990) used three groups: estimation, free or no estimation, and interpolated, all of which received KR. No significant differences were found between the estimation and free estimation groups. Verbal estimation does not augment motor skill performance in the presence of KR but can serve as an attention keeper such that when KR is removed, the verbal estimation can take the place of KR to maintain or enhance motor skill performance (Hogan & Yanowitz, 1978). In Liu and Wrisberg (1997), there again were no significant differences between estimation and no estimation groups, both of which received immediate KR. The thought is that the KR is primarily maintaining the subject's attention and that the subjective estimation will be the primary factor in sustaining the focus on the task. Perhaps the reason for the groups' similar performances in the present study was that the speeds were so close together that there was really no need for estimation.

Finding no significant interaction between practice conditions x estimation conditions could be due to each condition's having some focus of attention to additional task interference be that varying speeds, KR, or verbal estimation. No one condition stood alone, making it solely specific, which therefore made all of the conditions somewhat variable and the same. No studies were found that examined both varying practice groups and estimation groups.

Retention

|CEI|. The three null hypotheses in the |CEI| category were not rejected: no significant differences existed between S and S+ V practice groups, between 100% and 0% estimation conditions, and between practice x estimation conditions. These results are similar to those of the two studies using closed skills, Landin et al. (1993) and Goodwin et al. (1998). For

Landin et al., the study used a basketball free throw, which usually occurs in only one or two trials during a game. For this closed and discrete task, there was a first-trial significant difference with S + V's being more accurate than S, but there was no significant main effect. No thoughts were given as to why there were no significant differences between practice groups in general on retention. It may be due to the fact that only one aspect of the task was varied: distance. The variations perhaps should have been more complex; for example, the experimenter could have altered another task aspect, such as visual display (shoot from a different angle). For Goodwin et al., no significant differences between the practice conditions of S, S + V, and S + Varplus (variable plus specific) were present during the dart throw retention. However, S plus some variation did better than S only. Again, no reasons were given as to why significance was not reached for this study, although it was stated that, for the S + Varplus, more was not better and had an adverse affect. Perhaps the reasons no significant differences were found were that distances were not great enough, there weren't enough trials in succession to get a feel for a given speed, and no more than one task aspect was varied. For the present study, the reason the practice groups did not reach significance may again be that the speed differences were not varied enough. Additionally, perhaps there were too many trials (90 per day 3 days) such that participants were actually in retention mode during acquisition and therefore performed equally on the actual retention test. Also, variable practice may need to be more similar to blocked practice with two or three trials in succession in order for participants to truly recognize the difference between speeds before changing to the next speed. The results of the two studies plus the present study lean in a direction that suggests S + V practice is as good and somewhat better at times than S condition in the improvement of retention. This gives very limited support to the specificity

of learning hypothesis.

Swinnen (1990), in his reversal-slide experiment, found that estimation had no significant bearing on accuracy or consistency, although error estimation was beneficial. If no significant differences are found between practice conditions or estimation conditions, then the combination of the two condition groupings also makes no significant difference, as was found in this experiment.

|O-S|. For the |O-S| there were no significant differences between the S and S + V practice conditions. In Sherwood's study (1996), the random group outperformed the blocked group for a rapid aiming task. It was noted that one of the reasons for the random schedule's being the superior learning style was the addition of error estimation with parameter change (changing only force or amplitude rather than changing the whole motor program) by trials. The error estimation caused enough contextual interference to allow a random group, with only parameter changes, to be significant. The present study also had parameter changes by trials (the speed at which the lights illuminated down the trackway) but showed no significant differences. This can relate to the specificity of learning hypothesis that states that specific practice leads to retention, which both practice groups had. It also tends to be consistent with recent studies that state that supplementing specific practice with variable practice leads to enhanced retention. Landin et al. (1993), using a basketball-shooting task, found that the S + V practice condition initially did lead to enhanced retention. This same result was also found in Goodwin et al.'s study (1998). Although the differences were not significant, specific practice supplemented with variable practice was as good if not better than specific alone. Shea and Kohl (1990) found in their study on a force-production task that from the first trial to the completion of the first block, S + V outperformed S on retention but then leveled off to

similar performances.

There was a significant finding for estimation conditions. The 100% estimation condition displayed significantly smaller error than the 0% estimation condition. This could be due to the 100% estimation groups of S and S + V having had the advantage of acquisition error estimation as opposed to the 0% estimation groups. In Sherwood's study (1996), the random-estimation condition performed significantly better over the blocked-estimation condition in the first experiment on the immediate and delayed retention tests. The reviewed experiment focused on spatial error detection. Although the study did not have a 0% estimation condition, it demonstrated that the interference of a random condition combined with error detection during acquisition aided in the development of error-detection capabilities. These capabilities would lead to the random estimation group outperforming the blocked estimation group on a no-KR retention test. The parallel from this experiment to the one represented in this paper would be that the 100% estimation group receiving KR processed the KR in order to estimate accurately, leading to better performance. The 0% estimation group, on the other hand, did not formulate any error-detection capabilities because they were not being forced to use the KR information.

Additionally, significant differences were found across practice x estimation conditions. All other groups outperformed the S 0% estimation group. However, there were no significant differences between all the other groups (S + V 100%, S 100%, and S + V 0%). These findings are in line with that of the specificity of learning hypothesis in that practice conditions replicating the retention test will result in superior performance. Additionally, these findings suggest that the recent trend for S + V practice benefiting retention also holds true even when estimation is added in.

VE. In the retention test there was consistency across the board for all three testing conditions, that is, practice, estimation, and practice x estimation, in that there were no significant differences found between them. This follows the pattern of Landin et al.'s (1993) findings that S + V practice is better, especially on the first trial and then tends to taper down for the succeeding trial blocks. Similarly, Goodwin et al. (1998) and Shea and Kohl (1990), demonstrated no significant differences between practice conditions. These results conflict with the specificity of learning hypothesis, which states that specific practice, not variable or specific + variable practice, leads to enhanced retention. Therefore, the present results reaffirm that some variability along with the specific task is beneficial for retention.

Transfer

ICEI. For *ICEI* there was a significant difference between S and S + V practice conditions, and S + V performed better. In a study by Lee et al. (1985) (Experiment 1), the random and blocked practice conditions performed better on outside transfer than the constant practice condition, which is consistent with the variability of practice hypothesis. In addition, the transfer test had two segments. The latter segment showed the random group outperforming the constant and blocked groups to indicate that random practice over time facilitates transfer to a new skill. The Wrisberg et al. (1987) study used a closed timing task in which the dependent variable, CE, although not *ICEI*, resulted in support for the variability of practice hypothesis as well. The study demonstrated that when all three of a constant practice's components (distance, time or velocity) were similar during acquisition and transfer, no significant differences were found. When any given component was deleted, more significant differences occurred. When only one similar component was used, the most significant difference was noted. This therefore contributed to the variability of practice

hypothesis, in which varied practice leads to transfer. The null hypotheses that stated no significant differences were found in transfer between the 100% and 0% estimation conditions and between practice x estimation for |CE| were not rejected. The only study reviewed that included estimation in the transfer test was that of McCracken and Stelmach, (1977). Because all groups in the study performed self-estimation, there is nothing to use for comparison with the investigation at hand in the way of estimation versus no estimation or practice conditions versus estimation conditions. The present study showed no significant differences with either of the estimation versus no estimation or practice conditions versus estimation conditions. Estimation is supposed to facilitate learning and take the place of KR when KR is removed (Adams, 1971). Transfer is not included in that statement, and as the present transfer test did not include KR, no estimation learning took place. A possible reason for there not being any significant differences between practice x estimation conditions is that only twenty trials (2 blocks of 10 trials at different speeds) were used. This may not have been enough trials to learn the transfer speeds. Therefore, estimation was not better than no estimation for a participant to transfer to a new skill regardless of practice conditions.

|O-S|. For mean |O-S|, there was a significant difference between the S and S + V practice conditions, the 100% and 0% estimation conditions, and the practice x estimation condition. The significant main effect for practice conditions and the significant main effect for estimation conditions give support to the variability of practice hypothesis, and the S + V groups and the estimation groups performed better. The estimation would serve as contextual interference, which enhances motor skill transfer. This contextual interference effect appeared to be more influential with the S 0% estimation condition because it had less error than the S + V 0% estimation condition. The significance of the interaction would again

support the VP hypothesis; estimation made the contextual interference even greater, thus leading to a stronger transfer. The studies reviewed did not use estimation during transfer, so a reference cannot be made.

VE. The results of the present experiment are similar to those of the Del Ray et al. study (1982). This experiment, also using an anticipation-timing task, used practice groups made up of experienced softball players and participants with no prior team or open motor skill involvement. The novice group in the Del Ray et al. study was similar to the S practice condition in the present study, whereas the experienced group was similar to the S + V condition. The experienced group of softball players had a lower AE and VE at the 12-mph speed than the novice group at the 12-mph speed as opposed to the 6-mph speed. At the slower 6-mph transfer speed, accuracy (CE) was better than consistency (VE), whereas the opposite was true for the faster, 12-mph speed. The novice group in Del Ray's study that practiced under the constant condition rather than the blocked or random conditions performed better in transfer, whereas the experienced group performed better under the random conditions, supporting the theory that S practice can lead to transfer (here depending upon prior experience). The present study revealed significant differences between S and S + V practice conditions; the S + V practice condition had significantly smaller error in transfer. This finding again supports that S practice can aid in transition performance, which contradicts the variability of practice hypothesis. No significant differences showed up between the 100% and 0% estimation conditions, nor did any significant differences show up for practice x estimation conditions. It is possible that no consistency differences were found between these groups because the transfer task may have been too similar to the acquisition task. The variable practice speeds including specific were 5, 7, and 9 mph, whereas the

transfer speeds were 3 and 11 mph following a pattern of 2-mph increments. Estimation delays were the same (5 s) from acquisition to retention and transfer. Wrisberg et al. (1987) found that when they tested for transfer using variable practice, the more similar the transfer test was to the practice condition, the less likely it was that the variable group would perform significantly better than an S group.

Recommendations

In the area of acquisition, learning a ballistic motor skill would be beneficial from a varying practice schedule with error estimation for the retention and transfer benefits. With the present study, however, no significant differences were found with the practice, estimation, or practice x estimation conditions. It is recommended that a greater divergence of speeds used would result in significant differences within the abovementioned practice conditions. Additionally, studies have tended to take the pattern of varying the practice by increasing or decreasing the number of trials. The present study included a large number of trials, and perhaps the lengthy amount of learning time resulted in daydreaming and might be better spent replicating the amount of time coaches/teachers usually have participants practice a given skill. Therefore, rather than varying by trial, vary by minutes, for example, 5, 10, 15, or 20 min.

The estimation during acquisition may find significance if the groups are arranged in a 100% estimation and 0% estimation, as well as a 10-trial block estimation rotation. This last group would essentially be a S + V group and might surpass the other groups in significance.

The retention tests could be immediate, such as that of learning a skill in practice and then immediately demonstrating it. Additionally, a day sequence of 1, 3, 5, and 7 days could

reveal true retention over time.

In the present study, S + V practice was beneficial for transfer, as was error estimation. A further test may include different groups testing transfer at different elements of the variable practice, such as speeds, estimation percentages, and variable percentages, taking the studies further than all or nothing. To save time, maybe 100% estimation is not necessary and a smaller percentage would suffice, saving valuable practice time. Estimation delay intervals could also be a factor to change, simulating more real-world inconsistencies of teacher-to-student feedback timing. Teacher/coaches need to conduct practices with S + V and error estimation in which the ultimate goal of a skill is one that is open and ballistic by nature.

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